22

Some Environmental Problems of Geomedical Relevance in East and Southern Africa

T. C. Davies
School of Environmental Studies, Moi University, Eldoret, Kenya

Introduction

Medical geology studies the influence of geo-environmental factors on the geographical distribution of diseases of humans and animals. In the east and southern African subregion, there has been little attention paid to date on the extent to which these factors may be important in disease causation, even though developing countries in general can be shown to hold tremendous promise for specific research in this field. This chapter highlights some problems of geomedical relevance in the subregion and submits that interdisciplinary research among scientists can help provide practical solutions.

Iodine

The iodine deficient regions of east and southern Africa have been identified and the widespread occurrence of goiter and related conditions, collectively referred to as iodine deficiency disorders (IDD), firmly established (e.g., Davies 1994, Jooste et al. 1997).

These are serious and debilitating consequences, particularly for poor populations, as the capacity of children is severely restricted and they become a burden to the family. The reported geographical distribution of endemic goiter in East Africa is shown in Figure 22.1.

Many aid agencies and governments have attempted to solve the problem by increasing dietary intake of iodine via the introduction of iodized salt and iodized oil programs. Despite these interventions, IDD remain a major problem in the subregion. It is likely that IDD are multi-causal diseases involving factors such as trace element deficiencies, goiter-inducing substances in foodstuffs (known as goitrogens), and genetics (Fordyce 2000). However, geochemists have an important role to play in determining the environmental cycling of iodine and its uptake into the food chain if levels of dietary iodine are to be enhanced successfully.

Fluorine

It has now been established that excessive fluorine (mainly in the form of fluoride) is present in parts of the hydrological system of Kenya as well as other countries in the subregion, particularly those that are associated with rift formation (Gaciri and Davies 1993).

Fluoride in minor amounts (around 1.3 ppm) reduces dental decay and enhances the proper development of the bone. A similar level of fluoride intake may also be beneficial to animals. When the amount of fluoride consumed is either too low or much too high, undesirable physiological consequences appear, such as dental caries, mottled staining of the teeth and malformed bone structure in both humans and animals.

Fortunately for Kenya, numerous data now exist on the geochemistry of fluoride in the hydrological system of the country (e.g., Gaciri and Davies 1993,

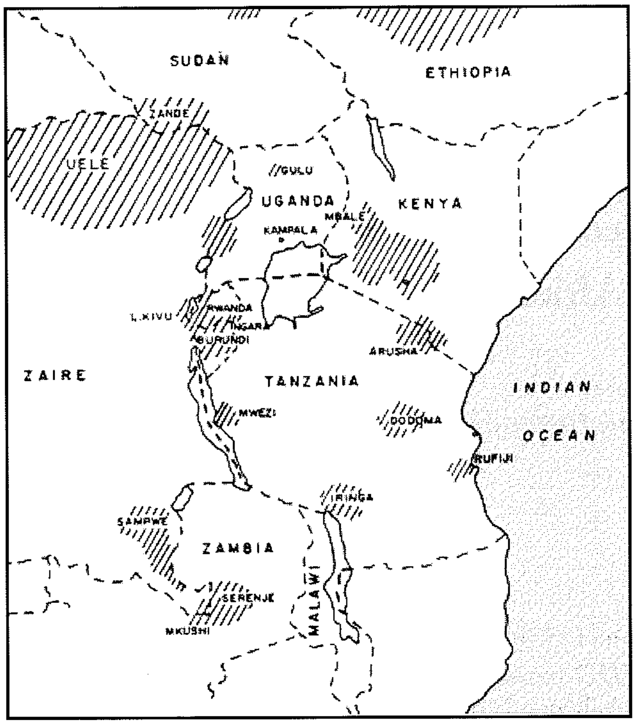

Figure 22.1: Distribution of reported goiter areas in Eastern Africa from Hanegraaf and McGill (1970) (redrawn).

Nair et al. 1984), the toxicity problem (e.g., Bakshi 1974, Fendall and Grounds 1965) and some improved techniques for fluoride determination (Njenga 1982). It has therefore been possible to put forward practical guidelines for combating the fluoride toxicity problem in the country (Gaciri and Davies 1993).

Endomyocardial Fibrosis

In the late 1980s, medical workers from India noted a strong link between endomyocardial fibrosis (EMF), a fatal coronary heart condition in children throughout the tropics, and enhanced environmental levels of cerium, related to the presence of monazite sands in Kerala province (Smith 1999).

In a collaborative study, Ugandan scientists from Mulago Hospital, the Institute for Child Health, Makerere University, and colleagues from the British Geological Survey have investigated whether similar environmental exposure could account for the occurrence of endemic EMF in Uganda (Masembe et al. 1999). Case-control studies performed at Mulago Hospital, Kampala, indicate a high incidence of EMF among patients from Mukono and Luwero districts over the past 30 years. Model calculations based on the data collected in this work (Smith et al. 1998) indicate that the most important exposure route is through the ingestion of soil-bound cerium as a result of either the inadvertent oral ingestion of soil or through the habitual eating of soil (geophagy).

Geophagy

Geophagy — the involuntary or sometimes the deliberate eating of earth — is extremely common among traditional African societies and has been recognized since ancient times.

The British Geological Survey has been undertaking research to investigate the potential bioavailability of major and trace elements within soils that are commonly ingested in Uganda (Smith 2000). The objectives of this project are to (a) increase our understanding of the risks and benefits associated with soil ingestion (deliberate and/or inadvertent); and (b) to enable the bioavailability of a particular contaminative source to be accurately taken into account during site specific risk assessment.

The reasons why soils are being deliberately consumed can be difficult to establish, but known causative explanations include the use of soil during famine, as a food detoxifier, as a pharmaceutical, and for neuropsychiatric and psychological (comforting) reasons (Abrahams 2000, and **Abrahams**). It remains a matter of conjecture whether ingestion of soil actually satisfies a nutritional deficiency. Nevertheless, soils do have the potential to supply mineral nutrients, especially iron, where the ingestion of soil can account for a major proportion of the recommended daily intake.

Typical quantities of soil eaten by practicing geophagics in Kenya in the order of 20 g per day have been recorded (Smith 2000). Although the eating of such large quantities of soil increases exposure to essential trace nutrients, it also significantly increases exposure to potentially toxic trace elements and biological pathogens. The former is particularly likely in mineralized areas associated with mineral extraction, or polluted urban environments, where levels of potentially toxic trace elements are high.

Asbestos

Asbestos is a naturally occurring fibrous mineral silicate that is used in a variety of applications in Africa including insulation, pipe lagging, roofing, and brake linings. Asbestos fibers are long and thin, and their aerodynamic characteristics allow them to penetrate far into the lung. In the lungs, asbestos fibers are encased in proteinaceous materials and appear in sputum (Mashalla et al. 1998, see also **Hillerdal**).

The mining of amphibole asbestos is almost completely confined to South Africa. Crocidolite and amosite, locally abundant and mined asbestos minerals, occur in metamorphosed Precambrian sedimentary strata (banded ironstones) in the Transvaal Super-Group. About 75% of the asbestos mineral production is used in the manufacture of asbestos-containing cement pipe.

Despite all available evidence on the occupational hazards related to asbestos exposure, asbestos is still widely used in many African countries where precautionary measures are hardly applied due to high costs of maintaining health monitoring equipment and personnel.

Arsenic in Mine Waters

The exploitation of gold and base-metal deposits can result in acid mine drainage (AMD) generated through inorganic and microbially mediated sulphide oxidation. Further, arsenic contamination of surface drainage and groundwater is documented in many regions of the developing world (Williams 2000), but the overall significance of this hazard remains difficult to quantify due to a paucity of data for many African countries, often with substantial mining activity.

Extreme examples with drainage acidities (below pH 1.0) are relatively rare, but acid mine drainage with a pH of 0.52 was encountered at Iron Duke Mine near Mazowe, Zimbabwe, in February 1994 during an investigation of the environmental geochemistry of mine waters in the Harare, Shamva, and Midlands Greenstone Belts of Zimbabwe. Arsenic values of up to 72 mg l^{-1}, recorded at Iron Duke, constitutes the highest dissolved arsenic concentration published to date for mine waters worldwide (Williams and Smith 2000). The site provides a valuable opportunity for studies of acutely acid mine waters, and may assist in validating and refining models for such systems. The chemical toxicity of the AMD generated at Iron Duke precludes most aquatic life immediately downstream of the waste pile, with the effect being highly localized.

Environmental arsenic exposure is a causal factor in human carcinogenesis and numerous non-cancer health disorders. Chronic exposure symptoms most commonly include hyperkeratosis, hyperpigmentation, skin malignancies, and peripheral arteriosclerosis (Blackfoot Disease), all of which are known in populations consuming water with 100–1000 $\mu g\ l^{-1}$ arsenic (**Finkelman et al.**).

Buffering methods to control AMD have, in some instances, shown considerable potential for removing arsenic from mine drainage waters (Breward and Williams 1994). Sequential extraction speciation studies and geochemical modelling methods have demonstrated that arsenic is highly prone to scavenging and precipitation with hydrous ferric oxides across a wide pH range (Breward and Williams 1994).

Mercury Exposure in Small-scale Gold Panning

Increasing health problems associated with mercury contamination, as a result of its use as an amalgam agent by small-scale alluvial gold miners, have been reported in many African countries during the past decade (Ghana, Kenya, Zimbabwe, South Africa, etc). Approximately two tons of mercury is used for each ton of gold recovered. Less efficient operations may use even more. With global gold production by small-scale miners now at a rate of thousands of tons per annum, the design and implementation of appropriate methods for monitoring mercury contamination in areas of alluvial gold mining are urgently required. The growth of independent small-scale gold mining provides employment and generates wealth, but economic gains are frequently offset by health degradation and the destruction of vital industries such as fishing.

In Africa, problems due to mercury and arsenic contamination associated with gold mining are a result of lack of environmental concern (or lack of enforcement of regulations) and, in some cases, inappropriate mining and operating practices. Geochemical

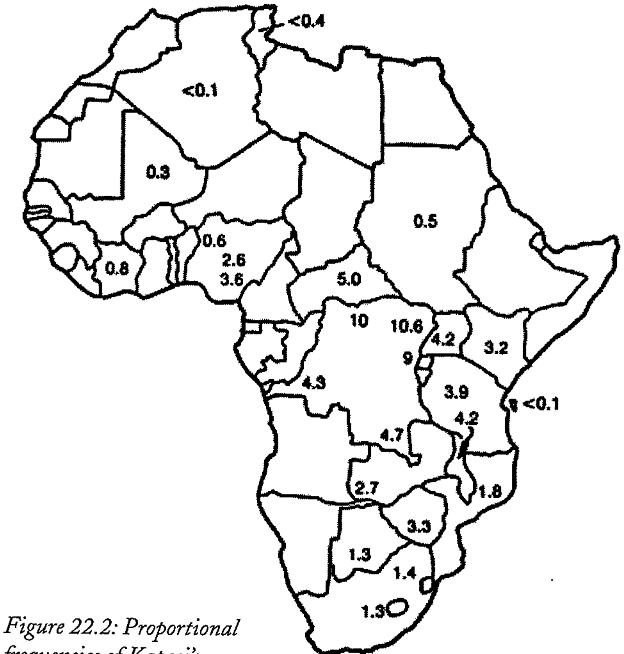

Figure 22.2: Proportional frequencies of Kaposi's sarcoma (percentage of all malignancies) in Africa.

surveys prior to operation and close monitoring during mining, coupled with good planning and working procedures can minimize contamination, while remediation schemes can also be devised and monitored by the application of sound geochemical science (Breward and Williams 1994).

Kaposi's Sarcoma and Podoconiosis

Kaposi's sarcoma (pronounced *Kawposhi*) is characterized by the growth of multiple vascular nodules on the skin of one or more extremities with occasional involvement of internal organs.

Podoconiosis (non-filarial elephantiasis) is characterized microscopically by neo-volcanic submicron mineral particles (mainly composed of aluminium, silicon, titanium, and iron) stored in the phagolysosomes of macrophages within lymphoid tissues of the lower limbs.

In 1961, at an international conference held at Makerere Medical School in Kampala, Uganda, the high incidence of Kaposi's sarcoma (KS) in the black male population of sub-Saharan Africa was noted. At a second conference in Kampala in 1980, particularly high rates were noted from central, east, and southern African countries, especially the former Zaire (now the Democratic Republic of Congo), Rwanda, Burundi, Uganda, Malawi, Tanzania, Zambia, Zimbabwe, and Kenya (Fig. 22.2). Incidences decreased toward west and southern Africa (Hutt 1981). Time-space clustering had been observed in the West Nile district of Uganda. The observation that 25 to 30% of individuals with AIDS have KS has given considerable prominence to KS. Thus, KS occurs in sporadic form [as originally described by Kaposi in southern Europeans (cited by England 1961)], in endemic form (as was seen in central African countries prior to the AIDS epidemic), and more recently in epidemic form in association with AIDS. In Africa, all three epidemiological varieties occur. Recent observations indicate that the epidemic form is on the increase in countries such as Uganda and Zambia (Bayley 1984, Lindsay and Thomas 2000).

Many theories of the etiology of KS have been postulated, among which is a geographically linked environmental factor. This nodular condition is believed to arise in the lymphatic endothelium and is associated with chronic lymphoedema. As such, KS bears a superficial resemblance to podoconiosis. The geographical prevalence of both conditions in highland areas of moderate rainfall in proximity to volcanoes suggests a pathogenetic relationship to exposure to volcanic soils. The geographical endemicity of KS in the Congo-Nile watershed (western branch of the East African Rift System) and Nigeria-Cameroon border (Benue Trough and Cameroon Volcanic Line) is particularly striking (Ziegler 1993).

Podoconiosis is also largely endemic in Africa, especially among populations living in areas of heavy exposure to volcanic clay minerals (Price 1990). These iron-oxide-rich kaolinitic soils overlie regions of alkaline basalt associated with volcanism of the major African intercontinental rift systems. The pathogenesis of podoconiosis is consistent with the theory that ultrafine clay minerals from the soil are absorbed through the feet. The resulting chronic lymphatic irritation, inflammation, and collagenesis cause obstruction and lymphoedema of the affected limb. The geographical proximity of endemic KS to areas containing volcanic clay minerals, its lympho-endothelial origin, predilection for the feet and legs, and its prevalence among rural dwelling peasants and cultivators, suggest a common etiology, namely chronic dermal exposure to volcanic clay minerals.

Radiation and Radon Gas

Radon is a colorless, odorless, radioactive gas formed naturally by the radioactive decay of uranium that occurs in all rocks and soils. There is a direct link between the levels of radon generated at the surface and the underlying rocks and soils. Radon generated in shales and granite can reach the surface via faults and fractures.

Variations in radon levels are evident between different parts of the African continent. The principal basis for present concern about radon and its decay products focuses on exposures resulting from industrial processes — primarily the mining and milling of uranium — that increases the accessibility of radon to the outdoor atmosphere or to indoor environments, leading to the incidence of lung cancer. Uranium occurs in a variety of ores, often in association with other minerals such as gold, phosphate, and copper, and may be mined by open-cast, underground, or *in situ* leach methods, depending on the circumstances.

South Africa has Africa's largest identified uranium resources (currently estimated at over 241,000 metric tons), followed by Niger, Namibia, and Gabon. Uranium has also been found in Algeria, Botswana, the Central African Republic, Chad, Egypt, Guinea, Madagascar, Mali, Mauritania, Morocco, Nigeria, Somalia, Tanzania, Togo, Zaire, and Zambia. However, under current economic conditions, it is unlikely that any of these deposits will be exploited in the immediate future.

South Africa produces uranium concentrates as a by-product of gold mining and copper mining, and possesses uranium conversion and enrichment facilities. Uranium is chiefly used as a fuel in nuclear reactors for the production of electricity.

The processes involved in radon gas generation and its movement to the surface and into buildings are complex. These include interactions between rocks, soils, and underground waters. It is important to determine the natural levels of radon produced from rocks and soils as these will provide essential data indicating the potential for high levels of radon entering buildings.

Trace Elements in Soils and Plants — Implications for Wildlife Nutrition

The following case study is an excerpt largely from the conclusions of a paper by Maskall and Thornton (1991) on the Kenyan situation.

Broad variations in the concentrations of some trace and major elements are attributable to differences in soil parent material, but pedogenic and hydrological processes also influence the distribution in soil profiles of trace and major elements, of which the latter (hydrological processes) can affect soil pH and trace and major element uptake into plants and animals, with consequent imbalances in the food chain.

In Lake Nakuru National Park, trace element concentrations in plants varied with the species. Solonetz soils develop on old lake sediments in the presence of sodium cations and carbonate and bicarbonate anions. The geochemistry of these soils nearer to Lake Nakuru appears to greatly increase the availability of molybdenum to the grass *Sporobulus spicatus*.

In general, higher concentrations of copper and cobalt were found in soils developed on basalts than in soils developed on phonolites, trachytes, and volcanic ash. Both impala at Lake Nakuru National Park and black rhino at Solio Wildlife Reserve have a lower blood copper status than animals from other areas. At Lake Nakuru National Park, the low soil copper content and high molybdenum content of some plants probably contribute to the low copper status of impala and may pose a problem for other grazing species.

Application of critical values determined by Maskall (1991) used for domestic ruminants indicates trace element deficiencies in impala at Lake Nakuru National Park and in black rhinoceros at Solio Wildlife Reserve.

Conclusions

Disease seldom has a one-cause, one-effect relationship. The geologist's contribution is to help isolate aspects of the geological environment that may influence the incidence of disease. A unique combination of geochemical factors, traditional practices, cultural norms, and genetics provides an ideal setting for these kinds of study in Africa. But the task is tremendously complex and requires sound scientific inquiry coupled with interdisciplinary research with physicians and other scientists. Although most of the picture is still rather unclear, the possible rewards of this emerging field of medical geology are exciting and may eventually play a significant role in environmental health.

References

Abraham, P.W., 2000. Geophagy by human societies. 'Health and the Geochemical Environment', Abstract Volume, International Working Group on Medical Geology, Uppsala Meeting, 4–6 September, 2000.

Bahshi, A.K., 1974. Dental conditions and dental health. In : L.C. Vogel, A.S. Muller, R.S. Odingo, Z. Onyango and A. de Geus (Eds) : Health and Disease in Kenya, p. 519–522. East African Literature Bureau, Nairobi, Kenya.

Bayley, A.C., 1984. Aggressive Kaposi's sarcoma in Zambia. Lancet, p. 1318.

Breward, N. and Williams, M., 1994. Arsenic and mercury pollution in gold mining. Mining Environmental Management, p. 25–27.

Davies, T.C., 1994. Combating iodine deficiency disorders in Kenya : the need for a multi-disciplinary approach. International Journal of Environmental Health Research, V. 4, p. 236–243.

England, N.W.J., 1961. Histopathological determination of three cases of Kaposi's sarcoma in West Africans; one showing metastasis in an inguinal node. Transactions of the Royal Society of Tropical Medicine and Hygiene, V. 55, p. 301.

Fendall, N.R.E. and Grounds, T.G., 1965. The incidence and epidemiology of disease in Kenya. Part 1. Some diseases of social significance. Journal of Tropical Medicine and Hygiene, Vol. 68, p. 77–84.

Fordyce, F., 2000. Geochemistry and health — why geoscience information is necessary. Geoscience and Development, No. 6, p. 6–8.

Gaciri, S.J. and Davies, T.C., 1993. Occurrence and geochemistry of fluoride in some natural waters of Kenya. Journal of Hydrology, V. 143, p. 395–412.

Hanegraaf, T.A.C. and McGill, P.E., 1970. Prevalence and geographic distribution of endemic goitre in East Africa. East African Medical Journal, V. 47. p. 61.

Hutt, M.S.R., 1981. The epidemiology of Kaposi's sarcoma. In : Olweny, C.L.M., Hutt, M.S.R., Owor, R. (Eds) : Kaposi's Sarcoma, p. 3–8. Basel, Karger.

Jooste, P.L., Weight, M.J. and Kriek, J.A., 1997. Iodine deficiency and endemic goitre in the Langkloof area of South Africa. South African Medical Journal, V. 87, p. 1374–1379.

Lindsay, S.W. and Thomas, C.J., 2000. Mapping and estimating the population at risk from lymphatic filariasis in Africa. Transactions of the Royal Society of Tropical Medicine and Hygiene, V. 94, p. 37–45.

Masembe, V., Mayanya-Kizza, H., Freers, J., Smith, B., Hampton, C., Tiberindwa, J.V., Rutakingirwa, M., Chenery, S., Cook, J., Styles, M., Tomkins, A. and Brown, C., 1999. Low environmental cerium and high magnesium : Are they risk factors for endomyocardial fibrosis in Uganda? Abstract Volume, East and Southern Africa Regional Workshop on Geomedicine, Nairobi, Kenya, p. 13.

Mashalla, Y.J.S., Ntogwisangu, J.H. and Mtinangi, B.L., 1998. Pulmonary function tests in asbestos factory workers in Dar es Salaam. MEDICOM, The African Journal of Hospital Medicine, V. 13, p. 11–14.

Maskall, J. and Thornton, I., 1991. Trace element geochemistry of soils and plants in Kenyan conservation areas and implications for wildlife nutrition. Environmental Geochemistry and Health, V. 13, p. 93–107.

Nair, K.R., Manji, F. and Gitonga, J.N., 1984. The occurrence and distribution of fluoride in groundwaters of Kenya. Challenges in African Hydrology and Water Resources (Proceedings of the Harare Symposium). IAHS Publication, v.144, p. 75–86.

Njenga, L.W., 1982. Determination of fluoride in water and tea using ion selective electrode and colorimetric methods. M. Sc. dissertation, 113 p. University of Nairobi, Nairobi, Kenya.

Price, E.W., 1990. Podoconiosis / non-filarial elephantiasis. Oxford University Press, New York, 131 p.

Smith, B., 1999. Cerium and infantile heart disease. EARTHWORKS, Issue 9, p. 8. DFID Newsletter, Nottingham, U.K.

Smith, B., 2000. Exposure to soil. Geoscience and Development, No. 6, p. 12.

Smith, B., Chenery, S.R.N., Cook, J.M., Styles, M.T., Tiberindwa, J.V., Hampton, C., Freers, J., Rutkinggirwa, M., Sserunjogi, L., Tomkins, A.M. and Brown, C.J., 1998. Geochemical and environmental factors controlling exposure to cerium and magnesium in Uganda. Journal of Geochemical Exploration, Vol. 65, p. 1–15.

Williams, M., 2000. Arsenic in mine waters : an empirical database for the tropics. Geoscience and Development, No. 6, p. 9–12.

Williams, T.M. and Smith, B., 2000. Hydrochemical characterization of acute acid mine drainage at Iron Duke Mine, Mazowe, Zimbabwe. Environmental Geology, Vol. 39, p. 272–278.

Ziegler, J.L., 1993. Endemic Kaposi's sarcoma in Africa is associated with exposure to volcanic clay soils. Abstract Volume, International Conference on Environmental Geochemistry and Health in Developing Countries. The Geological Society, London, 72 p.