Scientific African 6 (2019) e00131

Contents lists available at ScienceDirect

Scientific African

journal homepage: www.elsevier.com/locate/sciaf

A Medical Geology curriculum for African geoscience institutions

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ARTICLE INFO

Article history:
Received 14 March 2019
Revised 19 June 2019
Accepted 6 August 2019

Keywords:
M.Sc. curricula
Medical Geology
African geoscience institutions
Interdisciplinarity

ABSTRACT

Medical Geology is an emerging interdisciplinary study on the connection between geological materials and processes and the health of man and animals. In this science, the principal aim of a formal curriculum would be to equip students with knowledge and skills on the interpretation of the geological impact on geographical distribution of diseases in the environment, and on human and animal health. Such knowledge would no doubt contribute immensely towards better diagnoses and therapy for many environmental health related issues that continue to plague the African people. Africa's unique geoenvironmental and pedological condition gives added relevance to such studies, underlining the need for geoscience and public health students in Africa to apprise themselves with the principles and applications of this study in their pre-professional training.

In this paper, robust curricular M.Sc. programmes in *Medical Geology* are proposed for African geoscience institutions. A field based and project oriented curriculum format is advocated for each programme, with the objective of providing a vibrant learning environment that would enhance student development. But the design is also flexible, rendering the programmes adaptable to various didactic circumstances, such as the specific scientific backgrounds of candidates to be admitted into each programme, and the potential employment situation likely to be encountered upon graduation. It is recognised that to maximize the benefits of such programmes, entering students must have a background in the natural sciences, including basic knowledge of geological materials and geological processes; and if necessary, undertake at least a solid semester of elementary geochemistry (theory and laboratory work), since this discipline embodies the very foundations upon which the subject of *Medical Geology* is built. The modules provide extended enquiry-based investigations that employ real geochemical data sets, epidemiological records, public health statistics and visualisations, as well as performance assessments that provide evidence of *Medical Geology* knowledge and enquiry strategies seldom captured in traditional curriculum formats. At a time when African universities and research institutions are encouraging interdisciplinary studies, and new correlations between the geological environment and health continue to be discovered and interpreted around the Continent, the introduction of graduate programmes in *Medical Geology* seems all too appropriate and timely.

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https://doi.org/10.1016/j.sciaf.2019.e00131

Introduction

The exploration, exploitation and management of a country's mineral wealth and other georesources have always been among the principal mandates of many applied geoscience institutions in Africa, given the Continent's extraordinary endowment in these resources. However, with the rapid growth in awareness of the role played by geoenvironmental factors (many of which engender mining and processing of mineral resources) in public health issues around the Continent, these institutions are now taking up an additional responsibility: that of research in mitigating natural and man-made damage to the ecosystem, including preservation of the health of communities. Concomitant with these mandates, is the need for these institutions to formulate and teach curricula that would propel pertinent geoscientific agendas for rapid development.

Many undergraduate curricula in African tertiary geoscience institutions now commonly have a small component in Medical Geology, but the present discourse argues that maximum benefits of this study (Medical Geology) could only be realised if adequate attention is given to the design of appropriate curricula at the graduate level, taking into account the most pertinent and current constituents of a modern-day prospectus for the subject.

Medical Geology studies the role of geological materials and geological processes on the distribution of diseases in humans and (other) animals, and ways of preventing and combating these diseases [12]. Health problems arising from human interactions with the geological environment have always been observed, worldwide [49]. During the present decade, in Africa, for instance, almost every one of the top ten leading underlying natural causes of death can arguably be linked to some geoenvironmental co-factor(s), as is clearly illustrated in Tables 1 and 2.

Several studies have postulated that low selenium status exists in HIV-infected individuals [rank 1 in Table 1 and rank 5 in Table 2; (e.g., [6,8,30,43,80])]. Widespread dust plumes emanating from geogenic sources (e.g. arid soils, dust emanating from mining of silicate ores and coal) cause respiratory infections (rank 2 in Table 1 and rank 1 in Table 2; [10,59,61,86]) that include asthma [58,64,85].

Water related illnesses such as diarrhea (rank 3, Table 1 and rank 2 in Table 2) and malaria (rank 4 in Table 1; rank 7 in Table 2) are of particular concern in Africa. The causes of diarrhoea are related to water or food contamination by some water-borne pathogen (including a virus, most of the host bacteria or parasites), because many of these are found in multiple types of water resources (in the hydological cycle), including rivers, lakes, reservoirs and groundwater [65,68,88]. Medical Geology has a role in synthesising knowledge from multiple fields covering comparative aspects of pathogen contaminant hydrology, and unify them in a single place in order to present and address the problem of diarrhoeal disease [68]. Familiarity with the techniques in hydrological modelling of pathogen fate and transport (e.g., [23]) may therefore be necessary for students, in order for them to gain a better understanding of the factors that most influence the survival and transport of pathogens in different watersheds, since these are parts of the hydrological cycle. Certain geological materials, too, such as some clays, are thought to be a cure for diarrhoea.

Table 1
Leading causes of death on the African Continent. Source: [91].

Rank	Cause	Death (in thousands, 2012)
1	HIV/AIDS	1088
2	Respiratory Infections	1039
3	Diarrhoeal Infections	603
4	Malaria	554
5	Stroke	437
6	Pre-Term Birth Complications	372
7	Birth Asphyxia and Trauma	336
8	Ischeamic Heart Disease	312
9	Protein-Energy Malnutrition	284
10	Meningitis	246

Table 2
Leading causes of death in low income countries. Source: [87].

Rank	Cause of death	% of Total
1	Lower respiratory infections	9.9
2	Diarrhoeal diseases	6.7
3	Stroke	5.8
4	Ischaemic heart disease	5.7
5	HIV/AIDS	5.6
6	Tuberculosis	4.0
7	Malaria	4.0
8	Pre-term birth complications	3.8
9	Birth asphyxia and birth trauma	3.6
10	Road injury	3.3

The above arguments therefore justify the inclusion of ‘diarrhoea’ among the diseases studied within the Medical Geology compass.

Similarly, several studies have drawn the connection between habitat hydrology and geomorphology, and the distribution of malaria vector larvae in Africa [See [4,37–39,57,63]). In order to support the strategic control of malaria, Medical Geology studies that draw upon the nexus between population, morbidity and mortality data, and the influence of the hydrological milieu on malaria distribution (See e.g., [1,3,27,48,77,83]), would have to be undertaken by our students.

The construction of irrigation systems and reservoirs can also be shown to have a dramatic impact on malaria distribution and on the intensity of its transmission (See, e.g., [89]); an observation that also holds true for the epidemiology of Rift Valley Fever and West Nile Fever, since these are caused by mosquito-transmitted viruses. These topics are therefore ones that merit some consideration in any lectures on the role of the hydrological cycle on the distribution of diseases in Africa.

Water hardness has also been considered to have a role in certain forms of cardiovascular disorders and stroke [ranks 5 and 8, respectively, Table 1; ranks 3 and 4, respectively, Table 2; (e.g. [7,22,51,52,55,56,67,72,75])]; Soil dust aerosols are known predictors of seasonal meningitis incidence [rank 10 in Table 1 (e.g., [31])]; and inhalation of silica dust of tuberculosis (rank 6 Table 2; [33,40,60,70]).

Ancient and modern volcanic activity in tectonically active regions of Africa continue to impact the lives of geographically marginal populations [e.g. the Lake Nyos disaster of 1986 [50] and the Mount Nyiragongo eruption of 2003 [2]. Metals entrained in volcanic emissions are being redistributed from sources where they are fairly harmless to places where they may prove injurious to human and animal health. In regions where acid rain and the associated acidification solubilise heavy metals (such as mercury), making them more easily accessible and thus more rapidly absorbed in the nutritional chain, metal toxicity potential is even more intensified. The health effects of volcanic activities should therefore be an important topic of tuition in this curriculum.

Africa’s surface geochemistry is unique and extraordinarily complex, wrought by chemical and biochemical processes carried to extremes in the prevailing humid tropical climatic regime (See [17]). Such processes, e.g., intense tropical weathering, erosion, leaching, lateritisation, secondary mineralisation, eluviation, podsolisation and gleying are superimposed by urban and industrial activities. Adequate coverage of these processes and their impact on health are given adequate space in this curriculum.

The sheer scale and intensity of operation of these processes account for a marked heterogeneity of Africa’s surface area (compared to other regions of the world), with the production of nearly 20 different soil groups [26], and a distinct aqueous geochemistry.

In addition, whereas the diets of most of the population of the developed countries comprise of food sources from different geographical locations, in African countries, most of the population is still rural (up to 70% in some Sub-Sahara African countries), living close to the land and relying on locally produced food and water for their daily sustenance.

The result of all this is that large tracts of cultivated land in Africa are arid, semi-arid, or lack essential micro-nutrient elements for healthy growth of food crops. Consequently, large areas of the Continent can be shown to contain element deficiencies or toxicities which are closely related to the local geology and/or geographical location. Thus, correlations between the geological environment and certain diseases are legion, making Africa a natural field laboratory for studies in Medical Geology.

However, there are also beneficial effects of geological materials and geological processes. For instance, the use of certain rocks and minerals, and tapping from certain geological processes, can have positive effects on emotional, mental and physical well-being (e.g., [28,29]). These topics are given adequate coverage in the described curricular programmes.

Finally, Medical Geology has a role in risk assessment, risk management and risk communication [76]. For instance, Teaf and Kuperberg [82] consider that the evaluation and resolution of geoenvironmental problems such as water pollution can be carried out more effectively if the process involves appropriate application of the three complimentary components, *viz*., risk assessment, risk management and risk communication.

The above considerations render credible, the recommendation that geoscience-, environmental and public health students in Africa should gain a firm understanding of the principles and applications of Medical Geology in their preprofessional training; reasons that were exquisitely illustrated at the first two workshops of the East and Southern Africa Association of Medical Geology (ESAMEG) held in Nairobi, Kenya, and Lusaka, Zambia, in 1999 and 2001, respectively [see Ceruti et al. [13]; Davies [16]; Davies and Schlüter [21]].

A multidisciplinary, applied approach to Medical Geology

In no other scientific field is multidisciplinarity, arguably, more relevant in the dissemination of knowledge and application of principles, than in Medical Geology, where marshalling of the expertise and research skills of professionals from divers disciplines and institutions has so far proven to be a *sine qua non* for success. Similarly, the development of a robust curriculum in Medical Geology would require the adoption of an approach that elicits input from a battery of professionals: geochemists, botanists, biochemists, environmental toxicologists, epidemiologists, public health specialists, nutritionists, statisticians, and so on.

Because of the interdisciplinary nature of the programmes described, students will take classes from, and interact with, faculty from a number of departments on campus and out of campus. Through such interaction, students are exposed to a range of transdisciplinary research projects, and have the opportunity to conduct independent research in allied laboratories. Exemplary models from several other institutions would be adopted, and modern quantitative geochemical and toxicological analyses integrated with biogeochemical and nutritional protocols into the programmes. The goals of such an integrative approach would be, to: (1) increase the involvement of the students in the process of modern multidisciplinary scientific investigation, taking cognisance of trends in science education towards student-centered, enquiry-based, active-participatory learning (See e.g. [15,53]), and with progressive course-based research experiences that will prepare students for independent research; (2) deepen student knowledge of fundamental relationships between mineralogical composition, and biogeochemical cycling and element uptake by plants into the food chain (3) getting students acquire a basic knowledge of human-, animal- and plant physiology, and hence, (4) develop a firm understanding of the relationship between the geological environment and health of humans, animals and plants.

Again too, owing to its multidisciplinary nature, Medical Geology is bound to develop into a very wide subject, incorporating concepts on the disparate effects of geoenvironmental variables on the health of humans and animals (See [12,17,74]). The question is: Is it possible to cover all that material in an M.Sc. programme of taught courses? Buchwald et al. [5] consider that, for the subject of geology as a whole, in a large universe of ideas, "… we should pick those which have the broadest usefulness in geology, the rest of science, and in our lives, in general, and which stand the test of time. That is, we should pick concepts that are *robustly useful*". A robustly useful idea or concept, in this context, according to Buchwald et al. [5], is one that has widespread application in geology and in life; and is a true principle which stands the test of time. Similar arguments can be advanced in making the best choice of topics to be included in a customised Medical Geology curriculum.

A Medical Geology curriculum

There are many definitions of the word *curriculum.* Marsh and Willis [54] offer a list of seven different definitions, from which, within the context of Medical Geology, definition 2 is perhaps the most apt; namely, that: "*Curriculum* is those subjects that are most useful for living in contemporary society."

Curriculum development on the other hand, as defined by Kattington [45] is: "… the systematic planning of what is taught and learnt in schools, as reflected in courses of study and school programmes." Being a relatively new field of science, we concede that Medical Geology education is less well developed than other fields of science education and as such, effective teaching methods need extensive research. This research has to be undertaken by relevant educators at all levels and from multiple disciplines working in collaboration to improve practice and pedagogy. Trying to implement interdisciplinary geoscience curriculum materials, however, could be fraught with many challenges. Hansen et al. [36] present suggestions to overcome such challenges, based on various outcomes, for a successful local enactment of these materials; and have shown the central role of modular curriculum materials for the implementation of geoscience education combined with opportunities to learn through well-structured in-service workshops.

Goals of the Medical Geology curriculum

Kelso and Brown [47] consider a major goal in a science curriculum development process to be the enhancement of students' ability to solve real-world problems by integrating concepts from several pertinent sub-disciplines. In no other discipline is this statement perhaps more valid than in Medical Geology, where, the principal aim is to imbue an improved knowledge of the ways in which geological materials and geological processes influence the geographical distribution of health problems in man and animals; and thus contribute towards better diagnoses and therapy, and improvement of the lives and livelihoods of our communities. According to Kelso [46], a central desire would be to create a curriculum that would improve student understanding of the key Medical Geology concepts. Kelso [46] went on to further observe that along with core concept acquisition, should come the need to substantially increase the programmatic emphasis on student written and oral communication skills.

Communication

In the realm of written and oral communication, Medical Geologists, just like other scientists, should, indeed, be trained not only for the purpose of acquiring knowledge, but also to be able to present that knowledge to non-scientists, including some policy makers, in a concise and intelligible manner, and without scientific jargon, such that the non-scientist can understand the information and the supporting evidence, and carve out an informed opinion.

A firm grasp of written and oral communication skills is therefore considered a crucial part of the Medical Geology programmes that students should be conversant with, and apply, especially in reporting results of the fieldwork and laboratory exercises; as well as in the defence of the ensuing dissertation/thesis (See under: "Research Methods, Dissertation/Thesis Topic Selection and Fieldwork Preparation", page 9 *et seq*.)

Finkelman et al. [29] present the following summary listing of the most apposite goals of a Medical Geology program:

- "To inform the public of environmental health risks associated with geologic materials or processes.
- To identify the environmental causes of known health problems and, in collaboration with biomedical/public health researchers, seek solutions to prevent or minimize these problems.

- To identify geochemical anomalies in air, soils, sediments, and water that may impact on health.
- To reassure the public when there are unwarranted environmental health concerns deriving from geologic materials or processes.
- To evaluate the beneficial health effects of geological materials and processes." (Sic).

An approach to curriculum design, development planning and structure

Our approach to curriculum design and development planning incudes considerations on pedagogy, faculty structure, content, instructional materials, laboratory work, fieldwork and student selection criteria. It would be based on implications of the evolutional changes that have shaped the geosciences and public health agenda in Africa, with the advent of the Earth systems paradigm and broader social impacts, the need for integration within the discipline and across traditional boundaries, and fostering of multi-investigator, multi-institution science.

Parallel to the process of curriculum development, staff members of Medical Geology programmes would receive scientific and technological courses to update their investigative skills, according to the newest insights in epidemiological, toxicological and aetiological research (See under: "Instructional Resources for Teaching Medical Geology Across the Geoscience Curricula", page 13). Staff members should be able to benefit from several short courses and field excursions organised and facilitated by international experts on specific Medical Geology topics with special emphasis on problems pertaining to the local geoenvironmental setting and disease occurrence and their prevention.

Curriculum planning and design principles

There are several ways to design a curriculum. In answering the question: How can geoscience curricula prepare our students for the future?, Savina [73] noted three principal ways to design a geoscience curriculum: "(i) By thinking in terms of course titles and their content; (ii) By making the most of local geology and geography; and (iii) By focusing on goals, skills (geoscience and otherwise), experiences, values and content." A fitting recommendation would perhaps be one that combines all three models of curricular design. One must decide how to fit research experiences, independent study opportunities and other nonstandard courses into the curriculum.

Savina [73] further noted that "… if current trends continue, future geoscientists will engage in more applied geoscience work, in collaboration with others, studying a broader spectrum of issues. These issues will, in general, have greater societal relevance, and will involve managing more complex data sets."

In addition, Cawelti [11] of the Association for Supervision and Curriculum Development (ASCD) recommended the following principles to guide course planning:

- "Offer a balanced core of learning in each course.
- Adopt the belief that in-depth study of a limited number of important topics will have a more lasting effect than a course that tries to cover too many disconnected bits and pieces of information.
- Design course outcomes to focus on results, with multiple indicators (assessments) of performance.
- Design authentic assessments that will encourage originality, insightfulness, and problem-solving, along with mastery of important information.
- Design courses to encourage active involvement.
- Get students 'doing' early in the course rather than studying all the principles and basics prior to performing."

Curriculum development

We propose the establishment of robust M.Sc curricular programmes in Medical Geology and later on, Diploma programmes (essentially sub-sets of the Masters' programmes), for African geoscience institutions. We are however aware that there is currently a dearth of needed expertise to teach Medical Geology across the geoscience and public health spectrum; so, we need to not only urgently introduce appropriate curricula, but also train would-be teachers (See under: "Instructional Resources for Teaching Medical Geology Across the Geoscience Curricula", page 13). A process-oriented approach to curriculum development is therefore recommended. The term "process-oriented" according to Gosselin et al. [32], refers both to the process of scientific enquiry and to enquiry-based education, whereby students are encouraged to learn by doing.

By establishing these formal curricula, we wish to work towards the training and attainment of a critical mass of expertise in the field, capable of sustainably propagating innovative contributions to geoenvironmental medical science education and research in Africa.

A participatory Curriculum Development and Learner-Centered Education in Medical Geology

It is noted that a wide range of stakeholders is emerging with different interests in what Medical Geology education can, and should, achieve. This emerging situation is creating a growing need for well-trained people to fulfil the new institutional requirements of the public health sector. Graduate training programmes in Medical Geology therefore need to become more relevant and flexible, diverse, and yet well integrated - attributes that help foster a participatory approach.

The participation of different stakeholders in meaningful ways in Medical Geology and in Medical Geology education would also become vital as the discipline continues to evolve. Hence, a framework is required through which participation can be facilitated; and this can be provided by participatory curriculum development, following a learner-centered education approach.

Curriculum structure

Each of the proposed M.Sc. curricular programmes comprises five modules. Each module consists of a number of blocks connected to each other by a common theme. Each topic begins by asking questions about how various geoenvironmental phenomena affect public health and other aspects of the community's well-being. Students develop answers to those questions, learning key ideas and understandings in the block's activities. It is intended that the modules and blocks can be taught in any sequence. Teachers would need to consider the best sequence for their own students.

Curriculum components

In the proposed M.Sc. curricular programmes, students first study the essentials of Earth materials and processes (Module I, Block 1), basic geochemistry, including pathways of elemental uptake into the human body (Module I, Block 2) and basic physiology of living organisms (Module II). They then go on to Module III, which features research methods and fieldwork orientation, to enable them identify, at an early enough stage, from the subsequent modules, topics that (from their own perspective) are customised and feasible, for their imminent field investigations and dissertation/thesis write-up. The early introduction of this module also helps to promote the enquiry based-, investigative approach (research) to the learning process; especially for topics in the ensuing Module IV, "Principles of Medical Geology", which presents an overview of the main concepts in Medical Geology, with descriptions of the different diseases covered in this field in Africa. Next, students review and practice a variety of sampling and analytical techniques (Module V).

The M.Sc. programmes are designed for candidates with science backgrounds, with or without fundamental geology and geochemistry. A "bridging" course (Module I, Blocks 1 and 2, of 1- or 2-semester duration) (See Table 3), comprised of a number of fundamental Earth science, geochemistry and environmental health topics are then given as a mandatory prerequisite for candidates without fundamental geology and geochemistry. The applied geochemistry blocks (Blocks 3 and 4, Module I) may involve the analyses and interpretation of some experimental data using mathematical tools. It would therefore be necessary, in such cases, to teach students who are taking these blocks some elementary quantitative skills as well.

Table 3
Course structure and duration for different enrolment categories.

Enrolment category	Medical Geology qualification sought	Modules/Blocks required	Duration	Examinable
Science Graduates With Fundamental Geology and Geochemistry Background	M.Sc.	Module I, Blocks 3 and 4; Modules II, III, IV and V	18 Months	Yes (All)
Science Graduates Without Fundamental Geology and Geochemistry Background	M.Sc.	Modules I, II, III, IV and V	24 Months	All Examinable; Except Module I, Blocks 3 and 4 (To be Audited)

M.Sc. programme duration

For candidates who join the M.Sc. programme with a strong background in geology and geochemistry, the programme would extend over a period of eighteen months; which means that these students do not require Module 1, Blocks 1 and 2 (Table 3). This translates to a period of nine months for this category of students to complete Modules I (Blocks 3 and 4), II, III, IV and V, including examinations; and an additional nine months to complete their dissertation/thesis, making a total of eighteen months of coursework and dissertation/thesis before graduation (Table 3). Candidates with little or no background in geology and geochemistry would need to start their M.Sc. programme with Blocks 1 and 2 of Module 1, which run over one or two semesters (maximum six months). This group of students could opt to audit Modude I, Blocks 3 and 4. Students who begin the programme with Module I, Blocks 1 and 2 would need a minimum of twenty four months to complete their M.Sc. programme.

Specifications on duration of a module as well as suitable allocation of course credits and weighting would remain the prerogative of course directors and tutors. Such stipulations are normally made at regularly held 'curriculum review meetings'.

Modes of articulating the curriculum

Several methods exist for teaching Medical Geology across the geoscience and public health spectrum, including methods such as: application of the scientific method, critical reasoning, observation of natural geological phenomena and processes, hypothesis testing, designing of experiments, synthesis of multiple ideas, and communicating Medical Geology information. Designing experiments, however, requires the establishment of strict controls, and a few variables. But there are few controls we could use in studying the impact of geological materials and geological processes on the distribution of diseases in humans and animals. And although some tangible conclusions can be reached through approximations in the laboratory and by using computer models, most Medical Geology data are captured through field observations and careful analyses and interpretation of the data collected (See under: "Module III. Research Methods, Dissertation/Thesis Topic Selection and Fieldwork Preparation", page 9 *et seq.*).

Role of technology in such a programme

According to Drummond [24], programmes that offer the students opportunities to use advanced technology are considered to be the ones most likely to attract the best people to their professions. Geographical information systems (GIS) and Global Positioning Satellites (GPS) techniques must be integrated throughout the curriculum [24]. Advanced digital field techniques, including simulation, imaging, and analysis are essential. But whatever design approach is adopted in designing a suitable curriculum to meet the stated goals, the curriculum should at all times be relevant and current.

Computer aided learning

Edelson et al. [25] have noted the tremendous new opportunities that are opening up through the availability of computing and networking technologies in supporting enquiry-based learning; stating inter alia, that "… All of the fundamental properties of computing technologies offer benefits for enquiry-based learning - the ability to store and manipulate large quantities of information in a variety of visual and audio formats, the ability to perform complex computations, the support for communication and expression, and the ability to respond rapidly and individually to users."

The virtual exploratorium

The "Virtual Exploratorium (VE)" is a web-based geoscience learning environment in which learners use authentic data sets and scientific tools to build their own high-end visualisation, modelling and data in the support of education. According to Pandya et al. [69], the VE supports enquiry-based learning in geoscience courses by exploiting recent advances in information and promoting deeper understanding through scientific exploration. Learner-constructed visualisations have the advantage of not only giving the learner a more robust conception than passive visualisation, but also guiding enquiry toward fundamental physical principles.

A 3-sided pyramid (Fig. 1) is used to represent the structure of the learning model, the curricular elements and the anticipated understanding students will construct in the VE.

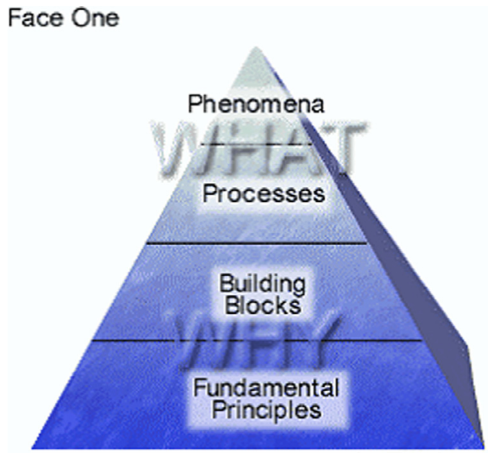


Fig. 1. Face one of a 3-sided pyramid representing a virtual exploratorium. Source: Adapted from Pandya et al. [69].

Benefits of an enquiry-based learning

Some perceived benefits of an enquiry-based learning according to Edelson et al. [25], are:

- Enhancement in the development of an integrated understanding of scientific (*cf.*, Medical Geology) concepts, tools and media, which are inextricably intertwined with enquiry skills.

- Providing students with the opportunity to achieve three interrelated learning objectives: (i) the development of general enquiry abilities, (ii) the acquisition of specific investigative skills, and (iii) the understanding of science concepts and principles. For example, central questions in Medical Geology investigations could be: Why is this particular disease outbreak confined to localities with identical geoenvironmental conditions? What are the specific epidemiological and aetiological characteristics of this outbreak?

Detailed course content

Module I. Fundamentals of Geology and Geochemistry

This Module is divided into 4 Blocks, and covers the basic concepts and principles of geology and geochemistry. The Module is meant to expose candidates to the language used in communicating these concepts and principles, and introduce them to a study of the dynamics of element circulation in the body of living organisms. The language of instruction is one that could easily be understood by any trans-disciplinary cohort of students with little or no prior geology and geochemistry knowledge.

Block 1. Basic mineralogy and petrology. Students learn to recognise common rock-forming minerals and rocks in laboratory hand specimens.

- Physical properties of minerals. Chemical properties of minerals. Identification and classification of minerals. Environmental mineralogy. Different conditions of origin of minerals.
- The origin, composition, occurrence/formation and distribution of igneous, metamorphic and sedimentary rocks; their identification, classification and evolution. The rock cycle.
- Brief accounts on mineral exploration and exploitation, and environmental effects, with emphasis on the release of potentially harmful elements (PHEs) into the environment, due to mining. Mitigating environmental problems (pollution) due to mineral development.

Block 2. Basic geochemistry: Students learn to classify elements according to similar properties (e.g., metals, non-metals, solids, liquids, gases). Classify changes in matter as physical or chemical. Construct a model of an atom (e.g., protons, neutrons, electrons, nucleus, electron cloud). Identify the reactants and products in a chemical reaction. Distinguish between balanced and unbalanced chemical reaction. Cations and valency; processes of sorption; importance of pH, Eh and chemical speciation. Geochemical classification of the elements. Crustal chemistry. Geochemical composition and the distribution of minor and trace elements in igneous, metamorphic and sedimentary rocks. Partitioning of trace elements during magmatic processes. Energy and mineral resources. The geochemical cycle. Pathways of chemical elements into the human body.

Block 3. This Block focuses mainly upon inorganic geochemistry (notably, trace elements), with particular reference to the surface environment.

Weathering, soil formation and classification. Erosion, transportation, podsolisation, gleying, etc. The geochemical circulation of nutritional and toxic elements (I, F, Se, Zn, Cd, As, Pb, Hg, etc.) in different environmental media - soils, natural waters, vegetation and food crops. Understanding element partitioning between minerals and their environment; numerical analysis of soil trace element data. Applications to Medical Geology and environmental geochemistry.

Block 4. This Block is concerned with aqueous environmental geochemistry and atmospheric chemistry: Introduction to hydrogeochemistry and the hydrological cycle. Surface water. Contamination of groundwater. Sampling and monitoring of natural waters. Acid mine drainage (AMD). Eutrophication of water bodies. Salinisation and saline environments. Atmospheric structure and dynamics. Evolution and physics of the atmosphere. Sources, transformation and sinks of pollutants in the atmosphere.

Numerical models that simulate transport, chemistry, emissions, and deposition of chemical species in the atmosphere. Air quality and health.

Expected outcome for Module I

On successful completion of Module 1, students should be able to demonstrate:

Knowledge of the fundamental principles of geology and geochemistry and the role of trace elements in shaping environmental systems; and how to apply these principles to decipher natural and anthropogenic processes that modify our environment.

Module II. basic physiology of humans, animals and plants; nutrition and diseases

A thorough understanding of the principles of Medical Geology requires a basic knowledge of human-, animal- and plant physiology. Module II covers these topics in 4 Blocks.

Block 1. Basic physiology of humans

- Fundamental physiology of humans presented in a simple and easy language.
- Nature of mechanical, physical, and biochemical functions of the systems (organs, cells and biomolecules) forming the human body; relationships between the systems.
- Key homeostatic processes: thermal adaptation, blood flow and hormones, gas exchange, osmoregulation, respiration, circulation, digestive system, and integrative neuromuscular, endocrine and sensory physiology.
- Biotransformation, biomagnification and bioaccumulation. Membrane transport mechanisms, metabolism and bioenergetics, fundamental principles of muscle and nervous system physiology, evolution and plasticity.
- Impact of changes in physiology on the mental functions of individuals. Diseases, defects and abnormalities. Diseases and the environment. Effects of certain medications or toxic levels of substances.

Block 2. Basic physiology of animals

- Fundamental biology of animals. The life-supporting properties and processes of animals. Ways by which animals function, with an emphasis on physiological adaptations to the environment.
- Respiration and circulation.
- Metabolism and bioenergetics.
- Thermoregulation and hormones.

Block 3. Fundamentals of plant physiology

- Basic physiology of plants: chemical and physical processes associated with life as they occur in plants; importance of photosynthesis; photorespiration and its implications; osmosis; imbibition; diffusion; mechanisms of absorption, and ascent of sap. Stomata: structure, distribution and guttation. Structure and function of chloroplast; dark and light reactions; CO_2 fixation; tropisms; nastic movements; photoperiodism; photomorphogenesis; circadian rhythms; seed germination; dormancy, and stomata function and transpiration. Absorption of water by roots; production of food in the leaves; and growth of shoots towards light. Environmental physiology.
- Plant nutrition: biochemistry of trace elements in soils and plants; bioavailability and bioaccessibility; implications for human and wildlife nutrition and health. Soil borne plant pathogens and soil borne diseases in crop plants and their management.

Block 4. Essential link between geosphere and biosphere

- The relationship between humans, the Earth, and food sources.
- Food chain dynamics and diet; metabolism pathways.
- Transfer of nutrients and PHEs from soil through crop plants and water to body tissues and storage pools of humans and animals.
- Regulation of nutrient transport; nutrient utilisation in humans and animals.
- The composition of African diets; the nutritional value of locally produced food crops.
- Factors affecting meal preparation and eating patterns.
- Health effects of genetically produced food crops.

Metabolism pathways: Transfer of nutrients and PHEs from soil through crop plants and water to body tissues and storage pools of humans and animals.

- Regulation of nutrient transport.
- Nutrient utilization in humans and animals.
- The composition of African diets. The nutritional value of locally produced food crops.
- Factors affecting meal preparation and eating patterns.
- Health effects of genetically produced food crops.

Expected outcome, Module II

On successful completion of Module II, participants will have:

- The ability to explain the basis of how animal physiology and plant physiology are influenced by changes in geoenvironmental factors, and assess how animals deal with environmental stress, particularly temperature, water, osmotic pressure and oxygen limitations.
- An understanding of the interactions in the 'water-soil-food crop-food chain' continuum.
- The ability to explain the relationship between nutrition and health.

Module III. Research Methods, Dissertation/Thesis Topic selection and Fieldwork Preparation

This Module will prepare students for undertaking an independent field investigation of a specific problem in Medical Geology. Owing to the strong field based- and project oriented nature of the curriculum (40% of the entire programme), it is recommended that this Module be presented early in the curriculum. This would enable participants identify potential titles for their dissertation/thesis as they muse over the ensuing topics in the subsequent modules, basing their choice on feasibility of project execution, which among others (accessibility of study area, security issues, availability of resources, etc.), they could determine from their already acquired skills in research methodology, including data handling and data analysis.

In this Module, students acquire intellectual and practical skills in synthesising information/data from a variety of sources, including medical data sources, epidemiological records and public health surveys and statistics. It also provides students with the requisite tools for investigating Medical Geology problems involving both field and laboratory based research; and improve their scientific writing skills, particularly scientific proposal preparation, public presentations, and communicating professional ethics principles and public policy issues. The Module also covers literature search techniques and the critical appraisal of published research, the organisation of a research project, research ethics, measurement techniques, the analysis of qualitative and quantitative data, the presentation of results, and dissemination.

Detailed course content:

1. Introduction: Philosophy of Science. Nature of scientific enquiry, consensus in science, certainty in science and "proof" in science, and research ethics in Medical Geology. Questions about: "How does one formulate an investigative question in Medical Geology?" and "What standards are implied by an investigative Medical Geology research question?", would constitute focal points of discussion in this section.
2. Research design: Designing a sampling frame; methods of sample collection and analyses (See also Module V, Block 2); data portrayal and interpretation.
3. Qualitative, quantitative and mixed research methods of data analysis:
   - Statistical methods featuring: Elementary descriptive statistics and inferential statistics; central tendency (or location) dispersion (or variability) test of the relationship between two statistical data sets, or a data set and synthetic data drawn from an idealised model. Data analysis using Pearson's correlation; stepwise multiple regression. Hypothesis testing. Estimation, orders of magnitude and probability.
   - Visualising data: Analysis of sequence data; geospatial analysis and analysis of uni- and multivariate data; selected parametric statistics (t-tests, general linear models), selected non-parametric methods, statistical inference.
   - Dimensional analysis, signal processing, spatial extrapolation, and numerical modelling.
4. Computer applications. Computational skills including introductory programming.
5. Project management. Library use. Quality assurance.
6. Health and safety protocols in mapping disease distribution and their geoenvironmental correlates.
7. Risk assessment, risk management and risk communication in Medical Geology
8. Field case studies.
9. Report writing: The importance of inculcating good oral and communication skills for project write-up and publishing of scientific papers in high impact journals, has already been emphasized in the Section: "Goals of the Medical Geology Curriculum" on page 4. Course participants will learn to write and present their research projects, the content of which will reflect the individual goals and preferences of the students, but guided by the project selection principles given in the next Section.

Fieldwork/Choice of dissertation/thesis topic

A number of authors, e.g., [79]; Ireton et al. [42]; Trop et al. [84], have subscribed to the recommendation that field activities be integrated with classroom activities, as this would serve to enhance development of student's abilities to solve multidisciplinary, real-world Medical Geology problems.

Several pathways can be followed for appropriate field project selection; and numerous authors have described procedures for discussing types of risk perception and assessment in field situations, that are customised and adaptable to different didactic circumstances. These include the works of Gunter [35], and Norton and Gunter [62]. Cogent information for the first four steps of such a procedure, according to Gunter [35], Clarke et al. [14], Ross and Nolan [71] and Skinner and Berger [78], would be: 1. An overview of the problem; 2. Definition of material, properties and analytical techniques; 3. A description of diseases and exposures, and 4. Discussion of case studies. With this kind of information in hand, Tauton and Gunter [81] and Whitmeyer et al. [90] consider that the research project will provide data for a fifth step, namely, the contextual/societal impact discussion. After this exercise, students should be able to evaluate the "real problem" based on data they, themselves, collected.

Students should be encouraged to critically think about the information given to them and to develop a passion for field observations, during which they can have the opportunity to confront real life situations and assess the risk posed to them in investigating disease occurrences. Field experiences, including planning, data acquisition, analyses and interpretation, are integrated into all aspects of the coursework; so also is the incorporation of background and supplementary data, and completion of oral and written reports of fieldwork data. According to Whitmeyer et al. [90], the field projects stimulate interest, provide motivation for learning new concepts, and are structured to develop teamwork and communication skills.

An Example of Project Selection in Medical Geology: Volcanoes and Human Populations

Volcanism is an integral and inevitable part of the global tectonic cycle, ensuring that Earth remains a habitable planet [44]. Volcanoes and volcanic eruptions in Africa such as Nyiragongo in the Democratic Republic of the Congo (DRC) are devastating to human populations and adversely affect social and cultural structures. In a project on 'Volcanoes and Human Populations', a student will explore the scientific knowledge and human dimensions of volcanism through readings, writing assignments, and discussions drawn from varied literature, visual media, and where possible, actual visits. The students would be required to assess the volcanic hazards for populations living near major volcanoes in Africa.

Expected learning outcomes, Module III (Research methods, dissertation/thesis topic selection and fieldwork preparation)

Students who successfully complete this course would:

- Be able to discuss the scientific method, including hypothesis testing, as applied in Medical Geology research.
- Be able to demonstrate a thorough grasp of statistical techniques needed for accurately interpreting multiple data sets from Medical Geology field surveys.
- Have acquired the generic skills required to communicate effectively, geochemistry and health data, using written reports and oral presentations.
- Be able to use the internet critically as a means of communication and as a source of information (literature searches).
- Be able to use a wide range of information sources (notably, geochemical data) with an understanding of the relative merits of these sources.
- Be able to prepare a research proposal of a quality capable of eliciting external funding; and deliver a professional oral presentation of the proposal. Such a research proposal should come with an appropriate research design, measurement techniques, sampling frame, and consideration of ethical issues sufficient to be approved by an ethical committee. The research projects should be feasible to undertake, and of potentially high impact with regard to national and regional development agendas.
- Be able to describe the process of peer-reviewed publication of scientific research and critically appraise a recently published research paper.
- Be able to discuss professional ethics in Medical Geology, the Earth sciences and in academia.
- Be able to discuss the role of Medical Geologists in public policy.

Given the great importance of acquiring credible and precise investigative techniques and the sound knowledge of field and laboratory data analyses needed in Medical Geology, this course will attract substantial credit weighting and assessment score (40% of the entire program).

Module IV: Principles of Medical Geology

Block 1. Natural, Geological Effects

In this Block, an introduction to the concept, terminology and scope of Medical Geology is followed by a study of how the circulation of chemical elements in the geosphere may influence the geographical distribution of environmental diseases, and people's physical well-being.

- Definitions, concepts, history and scope of Medical Geology.
- The health field concept; disease ecology; geography and disease; the changing nature of disease.
- Principal chemical constituents of the human body; essential trace elements in life systems; PHEs; functioning of the human body; the food chain (*cf*., Module II, Block 4).
- Controls on elemental intake and health risk exposure pathways.
- Health effects of excess/deficiency of trace elements; simple dose–response curves; antagonistic and synergistic effects. Determination of 'background' metal concentrations.
- Iodine deficiency disorders (IDD); role of goitrogens in I activity, and elimination of IDD.
- Public health conditions attributed to fluoride deficiency/excess; prolapsed intervertebral disk (PID); spiral stenosis and Paget's disease of bone; defluoridation techniques.
- Arsenic and dermatoses; Black Foot Disease; (case studies: Bangladesh, West Bengal).
- Molybdenosis.
- Psoriasis.
- The role of Se as a possible co-factor in HIV-AIDS diffusion. Keshan disease and Kashin–Beck disease.
- Organic compounds and Balkan's nephropathy;
- Mseleni joint disease (MJD).
- Geophagia, Kaposi's sarcoma and podoconiosis.
- Endomyocardial fibrosis.
- Cardiovascular disease; regional variation in heart disease.
- Stroke, hypertension and the geochemical environment.
- Diabetes; mental health conditions; neurological, endocrinal, gastrointestinal, renal, allergic, and autoimmune disorders.
- Cancer, mutagens and the geochemical environment.
- Communicable and non-communicable diseases and the geological environment.

- Interspecific interaction - symbiosis, mutualism, commensalism and parasitism.
- Protozoan and helminth parasites - life cycle, pathogenicity and control.
- Vector organisms and their environment.
- Mosquitoes, sand flies, ticks and mites as vectors.
- Volcanic gas chemistry; health effects of volcanic emissions.
- Case studies.

Block 2. Anthropogenic effects

- NORM (naturally occurring radioactive material); TENORM (technologically-enhanced naturally occurring radioactive material); distribution and mining of uranium in Africa; sources and health effects of ionising radiation and radon gas; case studies: South Africa, Namibia, Niger, Gabon.
- Geological aspects of waste disposal, including radioactive waste.
- Mercury and lead emission in small-scale gold panning and health effects.
- Health and the geology of energy.
- The African dust plume: sources, composition, propagation and health effects; modelling potential changes in dust associated with increasing future aridity as a means of predicting climate change in Africa.
- The health impact of mining and mineral processing. Lungs and breathing; skin and adsorption; ingestion and absorption. Geogenic dust and the fate of inhaled particles. Chronic respiratory diseases; silicosis; tuberculosis; allergic lung disease; chronic bronchitis; berylliosis; talcosis, coal workers' pneumoconiosis (CWP) and asbestosis.
- Health effects of leachates, emissions and other waste from mining and mineral processing; acid mine drainage (AMD); acid rain.
- Health effects of geo-construction activities: large dams; reservoirs and irrigation tunnels. Malaria, West Nile fever and Rift Valley fever.
- Implications for environmental legislation and human health; water law; environmental protection; Clean Water Act; Solid Waste Disposal Act.
- Case studies.

Block 3. Health benefits of geological materials and geological processes

- Use of geomaterials in indigenous medicines and remedies: use of trace elements, metals, rocks (clays) and minerals in pharmaceuticals and health care products: dermatological protectors and bactericides.
- Emotional, mental, and physical health benefits of geomaterials; belief in the curative and preventative properties of crystals (talismans and amulets); coal combustion and IDD prevention.
- Thermal (hot) springs and mineral waters: their chemical classification and associated curative properties; alkaline water production and use.
- Balneology of peat deposits; peat formation and classification; exploitation of the health benefits of peat baths.
- Naturopathic medicine and Medical Geology.
- Case studies.

Expected outcome, Module IV

On successful completion of Module IV, students should be able to demonstrate:

- A thorough knowledge of the principles of Medical Geology, and in particularly the role of trace elements on human and animal health.

Module V. Applications of Medical Geology

Block 1.

- Use of stable isotopes in environmental geochemistry.
- Environmental epidemiology: the incidence, distribution and control of environmental diseases.
- Epidemio-ecology: identification of the environmental factors that cause or control the presence or absence of disease or pathogens in living organisms.
- Use of GIS techniques in environmental medicine: new geospacial technologies for health; advances in environmental monitoring; data integration and modeling; real-time early warning systems; emerging and re-emerging diseases; international monitoring programmes.
- Environmental and medical data sources.
- Cost-benefit analysis; cause and effect; implications for prevention and treatment; aetiological attribution.
- Geochemical maps in Medical Geology; Africa geochemical database.
- Case studies, Current status of Medical Geology research in Africa.
- Future perspectives and prospects.

Block 2. Geochemical Instrumentation and Analysis

This block provides a tutorial on geochemical sampling and analytical techniques. The goal is to get participants (especially those with little or no prior knowledge of fundamental geochemical techniques), gain familiarity with the methods commonly used in sampling and measurement of the content of chemical elements in geological materials and environmental samples (soil, sediments, natural waters, tissue samples, atmospheric particulates, and so on):

Analytical techniques in environmental geochemistry:

- Analysis of minerals and rocks: X-ray diffraction spectrometry (XRD); scanning electron microscopy (SEM); transmission electron microscopy (TEM).
- Elemental analysis: Mass spectrometry; X-ray fluorescence spectrometry (XRF); atomic absorption spectrometry (AAS); inductively coupled plasma/mass spectrometry (ICP-MS); inductively coupled plasma/optical emission spectrometry (ICP-OES); liquid chromatography; gas chromatography; neutron activation analysis (NAA).
- Sampling and analytical techniques for measurement of trace element content of human and animal tissues: Analysis of serum, urine, hair and toenails for monitoring exposure levels of toxic elements over time.
- Quality assurance testing; detection limits; instrument sensitivity.

Expected outcome, Module V

On successful completion of Module V, participants will be equipped with sufficient knowledge to enable the practice of appropriate sampling, analytical and monitoring techniques that are required for assessing environmental processes; in particular, the circulation of nutritional and PHEs in the geosphere, hydrosphere and atmosphere.

The selection criteria

The highly interdisciplinary nature of Medical Geology makes it inevitable that the potential pool for candidate selection would comprise students from widely different backgrounds and faculties. This fact presents us with the biggest curriculum dilemma; that is, how to decide on selection criteria and stipulate prerequisites for student enrolment. Should we require two or more courses in geology and chemistry? What can be done to instill some knowledge of basic geochemistry on students enrolling from the life sciences, for example?

It is important that prospective candidates who are graduates from any of the other natural sciences (besides geology), or who are from public health disciplines, acquire background knowledge of geological materials, geological processes and fundamental geochemistry, upon admission. Candidates who join the programme without a geology and geochemistry background therefore, would of necessity, be required to start their M.Sc. programme from Module I, Block 1 (See under 'Curriculum Structure' on page 6). This is so, because thorough knowledge of the role of geochemicals and element migration dynamics in the *soil–water–food chain continuum*, and disease causation, is our principal engagement in this curriculum formulation, a fact that must be taken into account in candidate selection; and appropriate adjustments made to the curriculum structure for concept assimilation to be a smooth process.

Instructional resources for teaching Medical Geology across the geoscience curricula

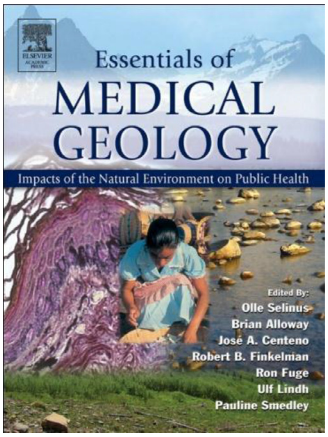
A wide variety of online teaching and learning resources are now available to support teaching and learning about Medical Geology. These include class-ready teaching materials, laboratory exercises, visualisations and links to related websites. All the instructional activities in these collections employ active, experiential learning approaches using a variety of teaching methods, and a bibliography of teaching techniques.

The digital teaching materials are designed for faculty to use while designing new courses, or, simply looking for new ideas in teaching Medical Geology. Students will also find these collections helpful for finding supplementary study materials and for doing research projects in Medical Geology.

The availability of qualified teachers to teach Medical Geology is a crucial issue, since this is an emerging, highly multidisciplinary, subject. Would-be teachers are specialists in their respective fields (geochemists, toxicologists, nutritionists, dieticians, biochemists, epidemiologists, and so on), who are able to see beyond the future the students envisage. However, no one specialist is expected to teach across the entire spectrum of the Medical Geology curriculum. Appropriate personnel would therefore be drawn from suitably qualified academic staff in the respective disciplines both from relevant departments and faculties at African geoscience and public health institutions, as well as from institutions outside the Continent, through academic staff exchange arrangements.

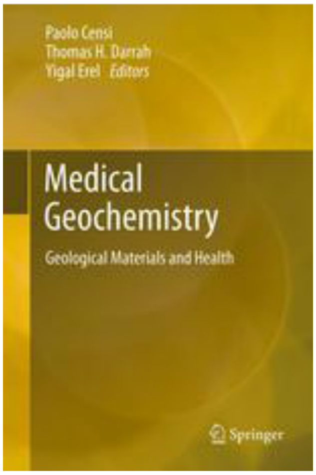
Two UNESCO-sponsored pedagogy workshops for training of trainers for the programmes are scheduled for February 2020 and June 2020, respectively (See [19]). The purpose of these workshops is not to create expertise (for selected participants would already be venerable experts in their own fields), but to evolve ways by which integration of pertinent concepts from our various fields would clearly bring out the nexus between geology and health in Africa.

A number of books on Medical Geology (some of the more important ones are illustrated below) have appeared since 2005, giving worldwide examples of the relationship between geological materials and geological processes and the occurrence and distribution of diseases in man and animals. These books are however akin to reference works, useful largely to researchers in various aspects of the subject. There is still the lack of textbooks with African examples and case studies suitable for use in the described curricula, albeit a situation that is currently being addressed [see Davies [20]; In preparation].



Essentials of Medical Geology - Impacts of the Natural Environment on Public Health, 2005. Editors: O. Selinus, B. Alloway, J. A. Centeno, R. B. Finkelman, R. Fuge, U. Lindh, P. Smedley. Elsevier

"This is a fascinating reference work that will inevitably find its way into earth sciences classrooms, but also will appeal to a wider readership, including public health scientists and decision makers. Anyone looking to explore the field of Medical Geology will be captivated by the contents of this publication …The volume emphasises the importance and interrelationships of geological processes to the health and diseases of humans and animals. Numerous examples of the environmental influences on human health from across the globe are also presented and discussed. A revised Springer version appeared in 2013." **Excerpted from book review.** Available at: https://www.medicalgeology.org/pages/public/publications/Publications_INT%20BOOKS.html (accessed 23.02.2019).

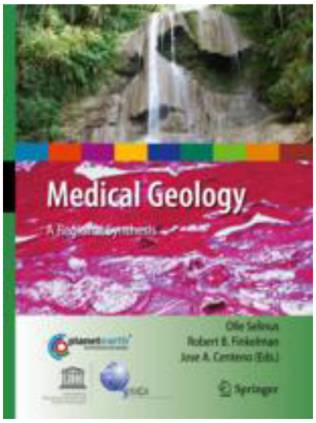


Medical Geochemistry: Geological Materials and Health, 2013.

Censi, Paolo; Darrah, Thomas; Erel, Yigal (Eds.)

2013, VIII, 194 p. 58 illus., 27 illus. in color.

"This book includes a collection of chapters illustrating the application of geochemical methods to investigate the interactions between geological materials and fluids with humans. Examples include the incorporation and human health effects of inhaling lithogenic materials, the reactivity of biological fluids with geological materials, and the impact on nascent biomineral formation. Biomineralisation is investigated in terms of mineralogy, morphology, bone chemistry, and pathological significance with a focus on the health impacts of "foreign" geological/environmental trace element incorporation." **Excerpted from book review**. Available at: https://www.springer.com/gp/book/9789400743717 (accessed 23.02.2019).

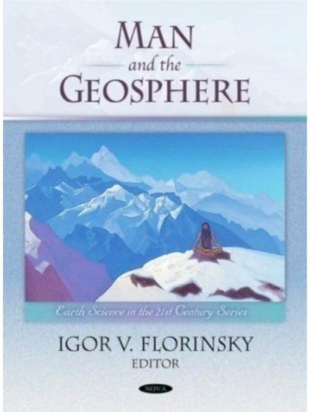


Medical Geology - A Regional Synthesis, 2010.

Editors: O. Selinus, R.B. Finkelman,

J.A. Centeno; Springer Science+Business Media; Series: International Year of Planet Earth

"Medical Geology: A Regional Synthesis brings together the work of geoscientists and medical/public health researchers, and addresses the health problems caused, or exacerbated, by geological materials (rocks, minerals, atmospheric dust and water) and processes (including volcanic eruptions and earthquakes). This wide-ranging volume also covers other issues in Medical Geology all over the world, with each author covering their respective region." **Excerpted from book review.** Available at: https://www.springer.com/gp/book/9789048134298 (23.02.2019).

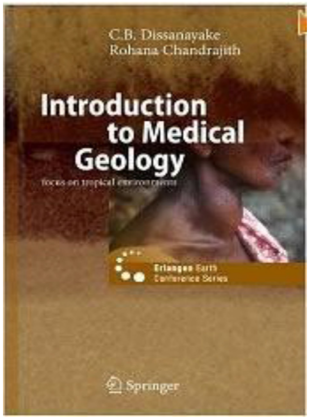


Man and the Geosphere, 2010.

Editor: I.V. Florinsky. Nova Science Publishers, New York.

Series: Earth Science in the 21st Century

"Humankind is under the permanent influence of the geological environment. Roles of some geological biotropic factors, such as volcanic explosions, strong earthquakes, and geochemical anomalies, have been well studied. Little is known about biotropic effects of the Earth's fluid degassing, geomagnetic activity, natural background radiation, fluid migration and gas emission within fault zones, mild seismicity, cyclicity of tectonic and climatic processes, etc. This book is the first attempt to synthesize the interdisciplinary knowledge on all geogenic factors influencing humans, society, and civilisation." **Excerpted from book review.** Available at: https://www.amazon.co.uk/Geosphere-Earth-Sciences-21st-Century/dp/1608763870 (accessed 23.02.2019).



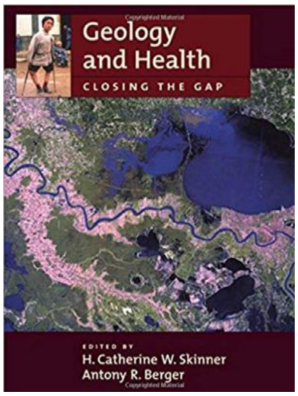
Introduction to Medical Geology, 2009.

Editors: C.B. Dissanayake and R. Chandrajith

Springer Science+Business Media

Series: Erlangen Earth Conference Series

"Over two billion people live in tropical lands. Most of them live in intimate contact with the immediate geological environment, obtaining their food and water directly from it. The unique geochemistry of these tropical environments have a marked influence on their health, giving rise to diseases that affect millions of people. The origin of these diseases is geologic as exemplified by dental and skeletal fluorosis, iodine deficiency disorders, trace element imbalances to name a few. This book, one of the first of its kind, serves as an excellent introduction to the emerging discipline of Medical Geology." **Excerpted from book review.** Available at: https://www.springer.com/gp/book/9783642004841 (accessed 23.02.2019).



Geology and Health - Closing the Gap, 2003.

Editors: H.C. W. Skinner, A. R. Berger

Oxford University Press

"Geology and Health is an integration of papers from geo-bio-chemical scientists on health issues of concern to humankind worldwide, demonstrating how the health and well-being of populations now and in the future can benefit through coordinated scientific efforts. International examples on dusts, coal, arsenic, fluorine, lead, mercury, and water borne chemicals, that lead to health effects are documented and explored. They were selected to illustrate how hazards and potential hazards may be from natural materials and processes and how anthropomorphic changes may have contributed to disease and debilitation instead of solutions." **Excerpted from book review.** Available at:https://www.amazon.ca/Geology-Health-H-Catherine-Skinner/dp/0195162048 (accessed 23.02.2019).

Assessment aids aligned to modes of instruction

Assessment is one of the key areas of classroom teaching that participants ask about when trying to envision implementing a new curriculum. Multiple assessment formats are used in this curriculum formulation. Some are non-traditional and are consistent with reform movements in modern science education. According to Kelso, [46], along with core concept acquisition, is the need to substantially increase our programmatic emphasis on student written and oral communication skills (See under; "Communication", page 4). Substantial weighting is therefore given to written and oral presentations, as the breakdown below clearly indicates.

The assessment model used for allocating credits to course units is one based on the student's ability to demonstrate greater understanding of the conventions and constraints of enquiry about Medical Geology phenomena. According to Zalles et al. [92], such models inform "… the interpretation and analysis of geoscientific data sets that can be scaffolded through age-appropriate tasks that facilitate high-quality student enquiry."

All the courses are assessed by written examination, practical exercises, oral examination or a combination of these, and a comprehensive field research project/dissertation/thesis, as follows:

(ii) Written examinations: 40%.
(iv) Project/Dissertation/Thesis (incorporating fieldwork, laboratory activities and experiments, and preparation of thesis/dissertation): 40%.
(iii) Readings, assignments, seminar presentations and participation in class and online discussions: 20%.

Curriculum evaluation and review

Curriculum evaluation, according to Hussain et al. [41] refers to the gathering of information on which judgment might be made about the worth and the effectiveness of a particular programme. In a very general sense, these activities (evaluation and review) are designed to serve as quality assurance programmes. A holistic evaluation process includes, of course, actually making those judgments so that decision might be made about the future of the programme, whether to retain the programme as it stands, modify it, or throw it out altogether.

Drummond [24] points out that two of the most pervasive reform movements in higher education are: (i) the establishment of formal programme review processes, and (ii) regular reporting of metrics assessing student learning. The need for existing curricula to be continuously studied and *evaluated* can never be overstated.

Faculties undertake revisions of the curriculum for a variety of reasons, reflecting: shifts in disciplinary approaches and emphases, trends in societal evolution, environmental changes (e.g., climate) and changes in student demographics and interests. Consideration has to be given to questions such as: Which elements are essential? Which are optional? What are the goals of the programme's curriculum?

According to Hussain et al. [41], a curriculum evaluation process should include discussion, experiments, interviews (group and personal), opinion of various stakeholders, questionnaires, practical performance and official record. Among the programme assessment resources considered essential for the evaluation process, Ormand et al. [66] included: "… a collection of assessment instruments, ranging from alumni surveys and student exit interviews to course evaluations and rubrics for assessing student work, and a collection of assessment planning documents, ranging from mission and vision statements through student learning goals and outcomes statements, to departmental assessment plans and guidelines for external reviews."

According to Guba and Stufflebeam [34], there are four types of decision that are crucial in a curriculum evaluation process. These authors [Guba and Stufflebeam [34]] also present features that are useful in organising a framework for examining curriculum evaluation, including decisions about:

1. Planning intention, e.g., which objectives to select.
2. Planning procedures, e.g., which personnel, methods and materials to employ.
3. Implementing procedure, e.g., whether to continue, modify or abandon a procedural plan.
4. Outcomes, e.g., which intentions are realised, to which extent, and by whom.

Being the centrepiece of a geoscience programme, a curriculum should be built or revised by incorporation of the most essential elements (*cf*., [9]). This is best done through a participatory approach, including all stakeholders, to take into account all the needs of the curriculum in terms of the evolutionary directions of the subject and best output of, in this case, Medical geology students.

Graduate employability

Medical Geologists are concerned with important societal issues including water purification, water pollution, storage of nuclear waste, analysis of groundwater and soil for determining nutrient cycling, contaminated land remediation, the emission of geogenic particulates, and health effects of climate change. Graduates with a degree in Medical Geology are qualified for employment with government agencies, private consulting firms and universities.

The primary applications of Medical Geology are in research, public health and environmental pollution. Our vocationally focussed M.Sc. degree (and later, Diploma programmes) in Medical Geology will provide the requisite skills for employment in professional geoenvironmental and public health consultancies and government environmental agencies. Our graduates will have knowledge and practical skills to ensure an interesting and rewarding career in the specialist areas of contaminated land consultancy, regulation and remediation, both in Africa and overseas.

In the local government sector, Medical Geologists find opportunities in departments such as the Department of Environmental Affairs, Water Affairs and Agriculture and Forestry, but also in industry and consulting companies. In the Water Affairs Ministry, for example, a Medical Geologist would be expected to plan, coordinate and implement the enforcement of state and local laws and regulations regarding the compliance, monitoring, and prevention of contamination and pollution of the public water supply. She/He would determine contractor compliance with local irrigation and backflow ordinances at sites under construction.

Regulatory authorities and government environmental agencies are required to apply a wide range of transferrable skills to their jobs. The skills of Medical Geologists are also sought in areas of public engagement, communication, professional research and report writing, in addition to academic knowledge and field skills. Career paths in environmental quality control, water resources, and water quality can be pursued from the platform of courses provided by our Medical Geology postgraduate programmes.

Professional Medical Geologists can also work in public health consultancies, and health spar resorts. Others become professors or research staff at universities and colleges, engaged in curricula such as public health, toxicology, environmental pollution and forensic geology.

The job search

Graduates from the proposed M.Sc. curricular programmes would have to define the job search and learn about the job search process, including applying, undergoing interviews and negotiating. If there are factors that make the job search unusual (e.g., if graduates are part of a "dual career couple", or have a disability), they should learn how other people like them have addressed that situation (See e.g., [18]).

For prospective teachers and lecturers, possible ways of getting teaching experience should be explored. They should seek out effective ways of designing the courses they will teach, planning their day-to-day teaching, and documenting their teaching strengths and accomplishments.

Conclusion

An attempt is made at constructing M.Sc. (Medical Geology) curricular programmes that will provide excitement, stimulate interest and improve student problem-solving abilities. It is considered that the design of a Medical Geology curriculum with focus on project-centered activities which incorporate a variety of field-based exercises, could create an active learning environment that enhances student development of a meaningful geoscience knowledge base and of complex reasoning skills in authentic contexts. As science education becomes more enquiry-based, this curriculum discourse submits that we would continue to see a growing trend towards the use of VE in geoscience programmes, taking advantage of the significant advances in computer technology to adapt scientific tools in the learning environment.

Effective implementation of integrated Medical Geology curricula as proposed, can only be realised by faculty doing work that is multidisciplinary and collaborative, using cutting-edge technology and large data sets, utilising a systems approach, or studying the applications of Medical Geology at the interface with societally relevant issues. Cultivating a passion for learning by students as well as staff should remain a first priority at all levels of Medical Geology education.

Meticulous field-based observations are fundamental to the science of Medical Geology. Perhaps of equal importance to a more complete understanding of geoenvironmental processes and disease is the adoption of a multidisciplinary approach to the collection, interpretation and application of quantitative geochemistry and health data. Such an approach, however, also dictates a sufficiently flexible architectural design to the curriculum, enabling the ready accommodation of students from varied scientific backgrounds other than the Earth sciences and geochemistry.

Owing to the interdisciplinary nature of Medical Geology, it is evident that the most tangible solutions to geology and health problems would be struck only by an assembly of experts from diverse disciplines, from which group the course directors and tutors would also come.

The principles of curriculum development should be based on providing the best possible education and training in Medical Geology within available resources, but also taking into consideration transformations in the field of education through major insights in the areas of cognition, learning theory and educational technology.

Regular curriculum revision is emphasised, and must be viewed as a systemic change. Backwards design based on desired outcomes is crucial. New curricula should be implemented and subsequently monitored and evaluated. However, in modernising our curricula, cognisance must always be taken of the need to ensure that our students are exposed to the methodologies and paradigms of elementary geochemistry, a subject that underlines most of the applications of Medical Geology. Central to the success of any curriculum development process is the learning outcome when the revised curriculum is applied. And, generally, the best or most efficient route to that outcome is the one that must always be chosen.

Medical Geology is an interdisciplinary curriculum, integrating physical, chemical and biological aspects of the environment and health systems. A huge demand is developing for Medical Geologists with quantitative, interdisciplinary training in geology and health, to address, mitigate and manage a multitude of complex environmental health problems facing the African society.

Future initiatives

In spite of the many advances that have been made in African Medical Geology during the past three decades or so, much more needs to be done to maintain the momentum. The important short-term goals include:

- Degree programmes - This Document has emphasised the need for M.Sc. degree (and later diploma programmes) in Medical Geology at universities, colleges and other tertiary geoscience institutions around Africa.
- Multidisciplinary journals and regular conferences should be launched, as was resolved at the Nairobi - 1999 [21] and Lusaka - 2001 [13] meetings, respectively. The biennial conferences of IMGA are continuing in a remarkable way. Similar meetings at the regional level now need to be formalised.

- Success stories - It is important for African Medical Geologists to show clearly the value of their input to the biomedical and public health communities, especially in the areas of disease diagnosis and therapy.
- Greater interaction and communication are essential between the geoscience, biomedical and public health communities to protect human health from the damaging effects of physical, chemical and biological agents in the environment.
- Jobs - Employers need to be more aware of the benefits of Medical Geology; recognition and acceptance by politicians, decision makers and the public is vital for the continued success of this emerging science.
- Generous sources of funding for researchers and internships, and pre- and post-doctoral training opportunities should be made available.

It is hoped that this paper would be useful in guiding African geoscience institutions towards achieving the three objectives of formulating robust and customised M.Sc. (Medical Geology) curricular programmes, *viz.*: (a) describing an appropriate curriculum content, instructional methods and materials, (b) illustrating an approach to the transfer of scientific and statistical skills to solving geoenvironment and health problems, and (c) examining the general impact of the course on the students and on the lives and livelihoods of their communities.

Acknowledgments

My thanks go to the colleagues and students whose discussions at the biennial International Medical Geology Association (IMGA) conferences and other relevant for a over the last twenty five years, have served to galvanize my interest in Medical Geology curriculum development. I am grateful to the editors of the Journal, Scientific African, and their (anonymous) reviewers for providing insightful comments and suggestions that have helped in producing a much improved manuscript.

Funding

"This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors."

Appendix A. Some useful web resources

- Building Interdisciplinary Connections. https://serc.carleton.edu/integrate/teaching_materials/themes/interdisciplinary/index.html (accessed 26.02.2019).
- Carleton College, Science, Education Research Center: Geology and Human Health - Topical Resources. https://serc.carleton.edu/NAGTWorkshops/health/index.html (accessed 27.05.2019).
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