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Medical Geology: An Interdisciplinary Approach Intended to Unfold the Issues of Natural Environment on Public Health

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Abstract

All living organisms on the earth require elements (major, minor, and trace) for their survival, and excessive or insufficient consumption of such elements cause serious health problems. These elements usually reside in earth material of the geosphere from where they enter into biosphere through various continuously operating geological processes such as weathering, erosion, transportation, or volcanic eruptions. Medical geology is a new and emerging branch of geosciences that studies material derived from geological processes and its effects on the health of animals and plants. The relationship between elements derived from the geological processes and their impacts on human beings had been recognized from ancient times. Keeping the importance of medical geology to the society, various organizations had been working to popularize medical geology and to bring its benefits to the society by organizing various activities and offering courses in medical geology. Currently, medical geology is being developed as an interdisciplinary science with the coordination of geoscientists and health researchers to unfold the health issues associated with the use of material derived from the natural geo-environment. This paper presents a historical overview of medical geology from the very beginning to the present and highlights areas where future research attention is required.

Keywords: Earth Material, Medical Geology, Geochemical Elements, Health, Geogenic Contaminants, Geo-biosphere

Introduction

All living beings on the earth's surface need different major, minor, and trace elements derived from the earth's material for their survival. These elements are obtained directly or indirectly from a variety of geological materials (*e.g.,* rocks, minerals, or soils) provided by nature. All organisms including human beings consume or inhale these elements in the form of food, water, and air without knowing from where they are being sourced (Mehri, 2020). But, if their consumption exceeds or falls behind the desirable/prescribed limit, they cause several devastating and lethal effects on the health of the living world. The supply of these essential geochemical elements is sourced from the natural environment, which is directly controlled by various geological materials and processes, and study of their relationship constitute an independent, popular, and emerging branch of geosciences termed as medical geology (Finkelman, 2006). It is now a well-accepted fact that medical geology is not only helpful to the medical fraternity, but also to different stakeholders such as geoscientists, biologists, environmentalists, agricultural scientists, and veterinarians in assessing the risk associated with the geological processes and extraction of geo-resources. It is the study related to the geo-environmental processes and resources that affect the health and well-being of both plants and animals, in addition to humankind when exposed in excess amounts.

Ayurveda known to be ancient Indian medicine and the traditional Chinese medicine accomplished by the Chinese from the past have been practiced to uphold health and well-being and to improve the quality of life of individuals (Patwardhan *et al.,* 2005; Chen *et al*., 2020). They also reported that these notable medical systems have common similarities in the use of mineral and plant-based extracts with healing capabilities. It is noted that people in close interaction with geo-environmental processes can have a strong positive or negative enduring influence on their health (Bundschuh *et al*., 2017). The occurrence and mobility of various geogenic contaminants in different geo-environments induced by natural or anthropogenic drivers can affect the quality of food, soil, air, and drinking water (Gwenzi, 2020; Prashanth *et al.,* 2021). As a result, several health issues that are typically caused by long-term exposure to geogenic contaminants had been proved chronic.

To address the influences of geogenic material and processes on public health, medical geologists had to collaborate with public health scientists to solve the health issues associated with them. It was recorded that medical geologists had already started to collaborate with the health professionals and found that these collaborations had picked-up the pace with the initiation of several federal agencies worldwide. The International Working Group on

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Medical Geology was established in 1996 by the International Union of Geological Sciences (IUGS) as an initiative by the premier instructional work to synergize the link between medical geologists and health specialists. Later, to promote medical geology on a global scale, project 454 was launched in 2000 as an International Geological Correlation Programme (IGCP) with the participation of the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Selinus and Alloway, 2005). In the meantime, many national and international collaboration establishments took place and started popularizing the discipline of medical geology. Despite the fact that the Indian premier geoscience institute, the "Geological Survey of India (GSI)," initiated its promotion, the development of medical geology in India is still in its early stage. Keeping this in view, an attempt was made to review the progress in medical geology and identify the research gaps to suggest sustainable solutions for the promotion of the discipline.

Historical Development

The use of geological material was perceived right from the existence of life on the earth. It is noticed from historical times that several minerals and rocks sourced from various geological constituents are used for the health and well-being of humankind (Hasan, 2021). Hasan *et al.* (2013) viewed that the therapeutically application of earth materials is known from Pleistocene epoch, where clay is probably used by the *Homo sapiens* to detoxify and treat intestinal disorders. The use of various minerals and rocks for healing purposes by ancient civilizations that flourished in the past, particularly Greek, Indian, Arabic, and Chinese civilizations, had been documented in various texts. For example, the use of alum, bitumen, and other natural material for therapeutic purposes is described in the Assyrian and Babylonian written records in Mesopotamia during 3000-2400 BC (Hasan *et al*., 2013).

The use of mineral matter in traditional Chinese medicines to treat various diseases dates back to more than 2000 years. As described in the Compendium of Materia Medica in the Ming Dynasty (1368–1644), out of the 1892 kinds of medicinal material recorded, 265 mineral medicines are used and accounted for 14% of total documented medicines(Chen *et al*., 2020). According to Dharmananda (2012), Tibetan medicine has its origin far back about 300 BC and the modern Tibetian Materia Medica recognized from the volumes of *Jingzhu Bencao* described nearly 2,294 materials, out of which 1,006 are sourced from plants, 448 from animals and 840 are of inorganic origin. The Ayurveda, an ancient Indian medicinal system, thought to be evolved during the Vedic period used the natural material derived from the plants and minerals, which are found to be slow in action but with remarkable curative properties and fewer side effects (Radhakrishna, 2005). Unani medicine, the older system of medicine that is similar to Ayurveda in its use of metals and minerals originated in Greece and is based on the philosophies advocated by Hippocrates and Galen (https://www.who.int).

The practice of consuming earthy materials (soils, clays, or minerals) by human-beings and animals is known as geophagy. It is usually practised in tropical regions and is more commonly seen in pregnant and breastfeeding women in the sub-Sahara region of Africa (Kutalek *et al*., 2010). Alexander von Humboldt noticed that people practised geophagy when he explored Venezuela, South America from 1799 to 1804 (Dissanayake, 2005). Other than the rocks, soils, and minerals, the natural thermal waters had been used as natural constituents for healing purposes. For example, people of northern India have been using hot sulphur-rich spring water of Tattapani (Rajouri District), Jammu and Kashmir for curing various body ailments (Vardhan *et al*., 2015). The study of healing diseases and physical ailments through bath and bathing, particularly in naturally occurring mineral waters like natural springs is known as “Balneotherapy”. Altman (2000) recorded that “using spring water for the prevention and cure of disease can be traced back about 5,000 years to the Bronze Age, although there are pieces of evidence that human beings have been using hot springs for more than 600,000 years.”

The discipline of medical geology may be an emerging discipline, but the impact of geological materials such as dust particles on the human race derived from various geological processes is quite ancient. It is reported that the dust particles inhaled by the early Tyrolean Iceman are preserved in the lungs, who lived nearly 5,000 years ago (Finkelman *et al*., 2001). Trace elements and minerals derived from various geological environments are required for life's survival, particularly for the metabolic and physiological functioning of various organs of human beings and animals. Nevertheless, they are proved to be fatal, if exposed in excess or trace. Of late, it is accepted that the main cause of iodine deficiency disorders is the lack of iodine in the diet, which is garnered from food grains produced from iodine-deficient soils (Fuge, 2005).

Over time, people started to know the interconnected system of a natural environment with the involvement of geological processes and their impact on health. With this factor, the discipline of medical geology emerged from the past and is continuing to be emerging as numerous researchers are striding to decipher the relationship between the natural geochemical environment with health and well-being of the global communities.

Geosciences, Natural Environment and Public Health

The global environmental setting is an interface of biological and geological features that illustrate the relationship between life and the earth systems. Though, geochemical elements are involved in the evolutionary process of the environment, their geochemical behavior causes a potential threat to the natural environment and human health (Plumlee and Ziegler, 2007). These elements may be harmful when consumed insufficiently or in excess (Selinus, 2007). Almost all the elements are sourced from natural processes where certain elements are required for maintaining good health, and some cause a threat to survival. The weathering of earth material releases chemical elements into soil, air, and water. The elements discharged through the geochemical pathways enter into food chains may be deleterious with excess, imbalances, and deficiencies of consumption by human beings and other organisms. The advances in science and technology at the end of the 20th century witnessed an unprecedented digital revolution that led to the probe, identify and analyze any geological material with precision. Different elements are categorized as essential (major and minor) and trace based on the human body requirements (Table 1). The essential elements are required for human survival while trace elements for body functioning. Animal health, like human health, is dependent on the intake of minerals and trace elements. It had been reported that intake of various elements (Zn, Cu, Se, Mo, Mn, Ca, Co, I, F) are required for maintaining good metabolic activity and their deficiency may be fatal in animals.

Table 1: Classification of chemical elements required for survival and functioning of various organs of the human body (*after* Hasan, 2021)

S. No.	Category		Elements	Concentration
1.	Essential		C, H, O, N, Ca, Mg, Na, K, P, S	comprises 99.9% of the human body
2.	Essential	Major	O, C, H, N	> 1% (comprises 3-65% of the human body)
3.		Minor	Ca, Mg, Na, Cl, K, P, S	0.1-1% (1000-10,000 ppm)
4.	Trace		As, Br, Zn, Co, Cr, Cu, F, Fe, Se, I, Li, Mn, Mo, Ni, V, W	< 0.1%

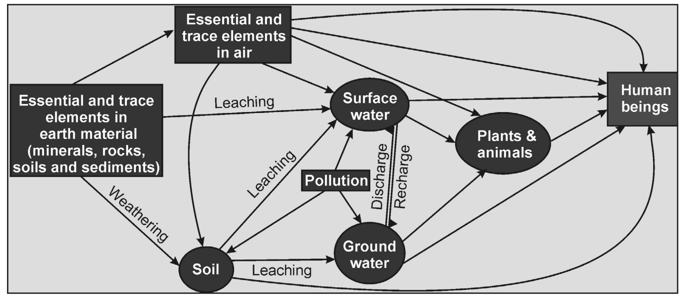

Fig. 1. Schematic showing essential and trace elements that enter the human body from various components of the geosphere (*modified after* Selinus, 2004).

The profound intake of essential and trace elements through soil, air, water, and food is intimately linked to the surrounding geological environment around us (Fig. 1). The regional geological settings that host the geochemical provinces enriched in trace elements have a global spatial distribution and are closely linked to the occurrences of regionally prevalent endemic diseases with a long-term exposure (Dissanayake *et al*., 2010). For example, intake of groundwater with excessive fluoride and arsenic has caused severe impairment and deaths in several regions of the world (Edmunds and Smedley, 2013; Hashim *et al*., 2019; Kashyap *et al*., 2021; Shaji *et al*., 2021; Kouser *et al.,* 2022). In contrast, almost 30% of the global population has been suffering from iodine deficiency disorder that causes brain disorders and mental retardation (Dissanayake, 2005).

Aerosols and other particulate substances derived from geogenic dust are produced as a result of various geological processes that endanger human health (Pepper, 2013). The wind, which carries dust particles from volcanoes, arid regions (deserts, marine aerosols, and forest fires) has a negative impact on health and environment (Table 2). Soils with their derived chemical constituents from the rocks may be dangerous in some instances though they are necessary for the life to exist. Podoconiosis (non-filarial elephantiasis), for example, is a disease caused in many African countries when people are exposed to red clay soils, which are rich in geogenic elements (Al, SiO_2 and Ti) (Dissanayake and Chandrajith, 1999). Consequently, it is critical to emphasise the role of earth scientists in elucidating earth materials in linking the geochemical processes and their impact on the human body.

Interdisciplinary Approach

From ancient times, philosophers and scientists noticed the positive and negative impacts of the rocks, minerals, and soils on the health and well-being of mankind. With the progress of science through the centuries, the complex nature of the geological constituents and their influences on human health became more significant. These advancements initiated the interdisciplinary outlook between the geoscientists, and the medical and public health experts. Lack of sufficient data and collaborative approach between the earth scientists and the various scientists associated with public health has victimized the innocent people around the world to the geogenic pollutants (Bundschuh *et al*., 2017).

Of late, medical geologists are working with biomedical and health researchers on various geo-environmental health problems focusing on toxic effects caused mainly because of exposure to trace, essential and non-essential elements; diseases caused due to nutritional deficiencies of trace elements; effects caused by the naturally occurring constituents in drinking water enriched in organic compounds; health hazards associated with exposure to volcanic and other natural dust, vector-borne diseases, etc. (Finkelman *et al*., 2005; Hasan, 2021). In course of time, earth scientists in collaboration with an array of researchers have developed various models to know the interface between the geogenic contaminants, health, and well-being (Bundschuh *et al*., 2017). However, the pressing need for enriched collaboration between earth scientists and other researchers involved in the studies of geogenic contaminants and their impact on human health is crucial for better understanding from a wider global perspective. Recently, the funding agencies are encouraging multidisciplinary research to establish the importance of collaborative approaches that fill the knowledge gaps and provide help to assess the wide range of issues that are difficult to be addressed by individual disciplines. Medical geology is undeniably, not an exception, and many international and national organizations are actively involved

Table 2: Sources of earth material and their health implications (*after* Plumlee and Ziegler, 2003)

Material	Possible source	Exposure pathways	Health impacts
Silica	Dust produced from erosion of silica-rich material and other man-made activities	Inhalation	Silicosis, bronchitis, fibrosis, lung cancer, and silica nephropathy
Asbestos	Dust from natural sources, industries, and mining	Inhalation	Asbestosis, asthma, mesothelioma, and lung cancer
Coal dust, fly ash	Dust produced from coal mining, processing and coal-burning	Inhalation	Black lung disease, bronchitis, pneumoconiosis, fibrosis, likely silicosis
Volcanic ash	Ash and particulate matter are released from volcanic eruptions. Anthropogenic interference of volcanic ash deposits	Inhalation	Respiratory tract infection, asthma
Volcanic gases and related material	Poisonous gases arising from volcanoes. Acidic aerosols released when hot lava encounters the seawater	Inhalation, exposure of mucous membranes and moist skin	Eye, throat and respiratory tract irritation, ulceration of mucous surfaces. High concentration of gases may cause lethal effects
Other mineral dusts	Dusts released from industrial, mining and other allied activities	Inhalation	Talcosis, silicosis, asbestosis

in popularizing multidisciplinary research. The institutes with biomedical and public health departments, universities, medical institutions, hospitals, and individuals of interest from various disciplines and backgrounds, such as engineers, geographers, chemists, environmentalists, and so on, are participating with interest to attend the health issues related to geo-environmental processes and earth material.

Promoting Sustainability and Enhancing Support in Practicing Medical Geology

Medical Geology had started to emerge more rapidly in the beginning of the 21st century to assist the public and medical health experts to know the various health problems associated with geo-environmental processes and earth material. The field of medical geology with its organizational structure and development activities had been established in almost all parts of the world. The initiation for setting up a global network of medical geologists was started in 1996 in Sweden with the assistance of UNESCO, and the International Council of Science (ICSU). Besides, short courses on various aspects of medical geology were developed in 2001 and are being followed by many countries (Buck *et al*., 2016). In course of time, the International Medical Geology Association (IMGA) was formed in 2006 and several nations became members simultaneously, encouraging the formation of committees at the national level (Selinus, 2007; Fig. 2). In addition to the maintaining website, the association is enriched in supporting various activities-publishing newsletters, books, and articles in different languages (https://www.medicalgeology.org/publications). Furthermore, the IMGA organizes and supports conferences and scientific consultations at local, national, and international levels, as well as funding young researchers to attend conferences and short courses. The association also aims to encourage and strengthen the relationship between earth scientists and health specialists to depict the link between the causative factors of various diseases associated with geo-environmental processes. Altogether, the association is committed to the global promotion of medical geology with special emphasis on developing and underdeveloped countries. Considering its importance, the medical geology is declared as one of the significant ten themes in the International Year of Planet Earth in 2008 with the title "Earth and Health – for a safer environment", in response to the effort made by the IMGA (Selinus *et al*., 2010).

Though the popularization of the discipline had increased manifold in the developed world, it is still striding forward particularly in developing and underdeveloped regions of the world. In Africa, the importance of the relation between the geo-environmental processes and health was noticed since 1960, but, actual efforts to promote the discipline started in Nairobi with the conduct of a regional workshop on geomedicine in 1999 (Davies and Schlüter, 2002; Davies, 2010). The International Council for Science (ICSU) became involved in the development of short courses at the international level began in 2000, with the cooperation of some international premier institutions such as the Geological Survey of Sweden, US Geological Survey, and the US Armed Forces Institute of Pathology (Selinus and Alloway, 2005). The main aim of collaborating institutions was to disseminate information about the geo-environmental issues affecting public health. In South America, a short-term course in medical geology was scheduled to begin in Chile in 2002 (Selinus *et al*., 2010). The nascent stage of the emerging discipline had not yet overcome in the Indian subcontinent, despite the fact that the subject had been introduced in many of the countries. For example, Sri Lanka has been bestowed in encouraging the discipline and providing support for understanding diseases associated with geological processes (Dissanayake and Chandrajith, 2007).

In India, the start of the discipline is initiated by recognizing GSI as the nodal organization by IUGS for promoting medical geology and monitoring the activities at the national level (GSI, 2004). In the early days of its recognition, a national workshop on medical geology was conducted in the year 2004 by the GSI, and simultaneously, proceedings were published. Though there is some appreciation in introducing the subject in curricula by some institutions and sporadically conducting promotional activities, still requires much attention in upholding the subject (Mondal, 2006).

Future Scope and Development

Future medical geology research should focus on the various evolving areas of research in geo-environmental health. Concerns include environmental pollution, climate change impacts, plastics, heavy metal contamination, pandemics/epidemics, and so on. It was observed that there had been a drastic increase in human exposure to geo-environmental contamination as a result of an increase in the

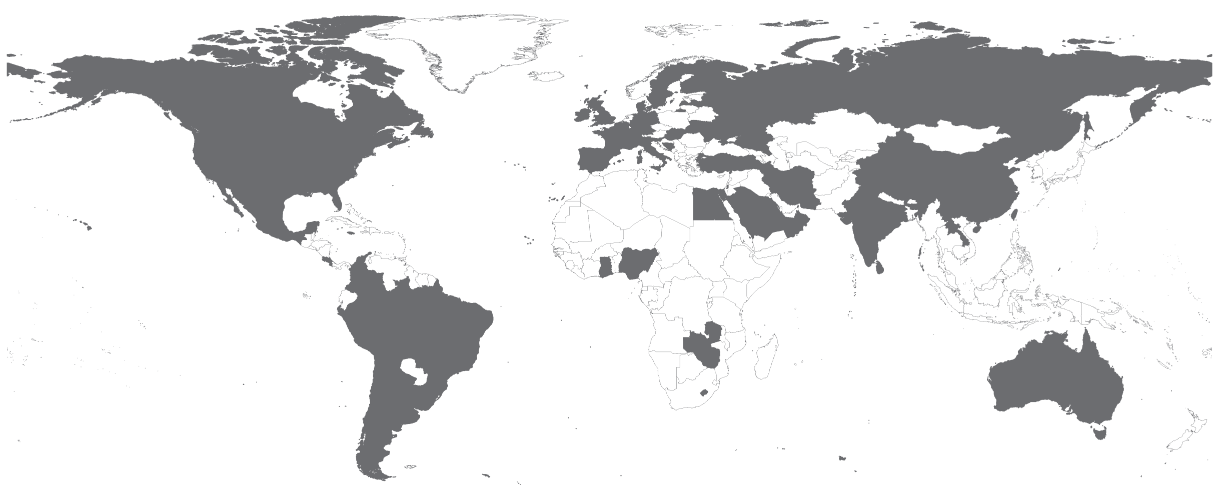

Fig. 2. World map showing countries associated with IMGA (*after* http://www.medicalgeology.org).

practice of geo-resources exploitation sourced through a natural environment rich in heavy metals. According to several researchers, climate change has exacerbated environmental pollution by increasing the frequency of extreme events and amplifying the occurrence of pollution-related diseases (Verma, 2021).

The pollution caused by plastic waste disposal including micro-plastics is of major concern and it negatively impacts the environment as it is non-biodegradable. The animals exposed to micro-plastics, primarily in aquatic environment, will develop impotency and other physical ailments (Lim, 2021). In the current scenario, studies related to micro-plastics are limited, medical geologists can explore the new avenues of research in plastic contamination.

Advancement in the use of geospatial technologies is playing an important role in the spatial mapping of diseases. The use of GIS as a geospatial tool with its inbuilt capabilities plays a dynamic role in critically analyzing and presenting the information relating to spatial distribution and associated environments of diseases (Prashanth and Verma, 2019; Saran *et al*., 2020). Furthermore, with the enhanced application of geospatial tools, it can be combined with artificial intelligence, and taking advantage of the wider use of mobile technologies can provide advanced solutions to comprehensive health problems. Hence, medical geologists can enrich their possibilities for future research by utilizing these spatial technologies.

A major task for medical geologists is to collaborate intensively with health scientists, despite their efforts to collaborate and broaden the scope of future studies in disease control caused by geogenic contaminants. Moreover, medical geologists should plan to collaborate with scientists from different disciplines including scientists from behavioural sciences, humanities, and social sciences to potentially eradicate or reduce the effects of diseases and establish successful pathways for finding long-term solutions.

Authors' Contributions

Manthena Prashanth: Conceptualization, Investigation, Writing, Reviewing and Editing. **Omkar Verma:** Conceptualization, Investigation, Writing, Reviewing and Editing.

Conflict of Interest

The authors declare no conflict of interest.

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