MEDICAL GEOLOGY
A CASE STUDY OF KASHMIR

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Abstract
Medical Geology, the study of the impacts of geological materials and processes on animal and human health, is a dynamic emerging discipline bringing together the geological, biomedical and public health communities to address a wide range of geo-environmental health issue. In the present review, an attempt has been made to present the toxicity posed by various trace metal exposures, radionuclides, atmospheric dust and smoke, geo-disasters, geo-circulation of pesticides, microbes and pathogens along with their implications on the heath of flora and fauna. Depending on the concentration and association of any element with other elements, the same element can induce quite different effects. Kashmir Valley, located in western Himalayas, is characterized by a unique geological history as it bears a complete geological stratigraphic succession of rock formations ranging in age from Meso-Proterozoic (~1600-1000 Ma) to Holocene. Like other regions, the geological rock formations of the valley are continually interacting with the intimate ambient environment and populace. In this review, the possible medical geological issues associated with diverse geological materials are highlighted to undertake further structured and comprehensive studies in the field. Furthermore, an account to understand the sources, distribution, pathways and health effects associated with potentially harmful chemical substances in terms of exposure, mixtures of different substances and dose-response relationships in the immediate geological environment of Kashmir Valley, is also analyzed. Therefore, the geo-scientific data generated can be effectively used by the medical/ other experts for conducting further epidemiological studies on various anticipating health troubles. In this way, the risks and contaminations once identified in the geological environment of the valley can be minimized to safer levels following the established remedial strategies.

Keywords
Geo-scientific Data, Medical Geology, Trace Elements, Toxicity, Geo-circulation, Kashmir Himalayas, Epidemiology, Land Degradation, Water Borne Diseases, Geology-Health Interrelationship, Air Pollution, Region-Specific Health Hazards, Geological Formations, Rocks and Minerals, Natural Disasters, Geo-Environmental Medicine.

Introduction
Most of the people are well aware and conscious of a range of health effects of geo-hazards irrespective of their occurrence. In order to moderate and mitigate the apparent effects of natural disasters, early warning systems have been developed. These warning systems are used to understand the effects of

emerging natural disasters provided the detection systems are appropriately situated and monitored and the population at risk timely alerted. However, this development and public awareness has further enhanced the realization that we need a better understanding of links between the dynamics of Earth and its inhabitants. The health of billions of people around the globe is affected to varying degrees by our natural environment, a major component of which is the geology of the earth. Geological materials, such as, rocks, minerals, and water alongwith geological processes, such as, volcanic eruptions, earthquakes and dust play a key role in a domain of environmental health issues that impact the health and wellbeing of people around. As a response to this global concern depicting the importance of geological factors on health, coupled with general lack of appreciation in understanding the geology, International Commission on Geological Sciences for Environmental Planning framed in 1996, an International Working Group on Medical Geology,[1] which subsequently led to the establishment of International Medical Geology Association (IMGA) in 2006. Medical geology was included as one of the ten main themes of the International Year of Planet Earth (2007-2009) under the title "Earth and Health" – for a safer environment under the coordination of IUGS and UNESCO.[2]

During recent years, a lot of studies have been carried out in the field of medical geology in different parts of earth like America, Europe, Africa, Middle East, Australia, China, Japan and Indian Subcontinent, to know the pattern of various diseases associated with geological environment with significant successes and strides. Medical Geology, thus, is emerging as a promising interdisciplinary scientific field focusing on the relationship between natural geological environments and their health effects on human beings, livestock and plant kingdom including understanding the influence of environmental factors on the geographical distribution of health problems which involves geoscientists, medical professionals, veterinary people, agricultural experts, environmental and biological scientists etc. Hence the field of Medical Geology demanding collaboration between the geo-scientists and biomedical/other researchers, offers promise of developing innovative solutions to minimize or prevent exposure to potentially deleterious natural materials and geological processes.

The fast growing human populations; increasing pressure on land, water and air resources; excessive use of fertilizers and pesticides; growing rural to urban migrations; unsustainable developmental initiatives and a host of other related issues – all have contributed to shape the Kashmir Valley as it exists today. The resultant relationship between medical geology and our daily lives, while focusing on the interactions between chemically harmful elements and biological systems alongwith the presence or absence of chemical harmful substances/trace elements and their implications on the human and ecosystem health in the valley, will be analyzed in the following sub-sections.

Geology-health Interrelationship

There are direct links between geochemistry of rocks/soil and health e,g, via food chain alongwith inhalation of atmospheric dust and gases. As we know

the rocks are the fundamental building blocks of our planet's surface and different rock-mineral assemblages contain 92 naturally occurring chemical elements found on the Earth. Many of these elements are essential to plant, animal and human health in small doses.[3] The essential elements are generally grouped as under:

- Macro elements – (with daily requirements more than 100 mg e.g. Ca, P, Na, K, Cl, Mg & S);
- Micro elements – (with daily requirement from less than 1 mg up to 100 mg e.g. Fe, Cu, Zn, Mn, I, Mo, Se ,F, Br, Cr, Co & Si) and
- Trace elements – (with requirements not as yet adequately determined, but whose presence in microgram quantities is thought to be necessary e.g. B, Sn, Ni, Ge, V & W).

The trace elements occur naturally in rocks, soils, gases and water in both harmless and harmful forms and concentrations. The geochemical pathways of the essential trace nutrients that enter the food chain are clear and being intimately linked to the immediate geological environment.[4] Every day we eat, drink and breathe minerals and trace elements, never giving a thought to what moves from the environment into our bodies. For most of us this interaction with natural materials is harmless, perhaps even beneficial, supplying us with essential nutrients. These elements are important in environmental health because they perform several vital functions e.g. calcification of bone, blood coagulation, neuromuscular irritability, acid-base-equilibrium, fluid balance, osmotic regulation etc. Certain elements are integral components of biologically important compounds such as hemoglobin (Fe), thyroxin (I), insulin (Zn) and vitamin B_{12} (Co). Several metals also participate as cofactors for enzymes in metabolism (e.g. Mg, Mn, Cu, Zn, K) and some are essential constituents of certain enzymes (e.g. Co, Mo, Se). However, the 92 naturally occurring elements are not distributed evenly on the surface of the earth and problems can arise, when the elemental concentrations are too low (deficiency) or too high (toxicity). For example, low concentrations of iodine characterize the soils and rocks at high elevations and in limestone terrains. The inability of the environment to provide the correct mineral balance can lead to serious health problems (table 1).

The above-mentioned mineral imbalance in the natural environment can be underlined by geochemical provinces. The clear demarcation of geochemical provinces are also closely linked to the incidence of several regionally distributed diseases. For example, an occurrence of endemic goiter and cretinism has been associated with iodine deficiency in several parts of the globe including India, Sri Lanka, China, South America and Africa. Selenium deficiency in some parts of China has been related with cases of muscular dystrophy as well as induction of endemic cardiomyopathy. Excess of fluorine in drinking water has been associated with endemic dental and skeletal fluorosis in several geographical areas including India, China, Africa, Mexico and Chile. Well documented cases of chronic arsenic poisoning from consumption of contaminated drinking water are known in Taiwan, Chile, Argentina, Mexico, China and recently in West Bengal and Bangladesh.

Table 1
Diseases Associated with Deficiency and Toxicity of a Given Element

Element	Deficiency	Toxicity
Iron	Anaemia	Haemochromatosis
Molybdenum	Mouth and Esophageal cancer	Bony deformities
Copper	Anaemia Skeletal defects	Chronic copper poisoning Wilson, Bedlington disease
Zinc	Dwarf growth, Retarded development of gonads, Akrodermatitis enteropathica	Metallic fever Diarrhoea
Cobalt	Anaemia White liver disease	Heart failure Polycythaemia
Cadmium		Renal and heart diseases
Lead		Neurological disorders
Mercury		Neurological disorders
Iodine	Endemic goitre Endemic cretinism Mental retardation	
Fluoride	Dental caries	Dental or skeletal fluorosis
Radon		Lung cancer
Arsenic		Cancer, skin disease
Magnesium	Dysfunction of gonads, Convulsions, Malformations of the skeleton, Urolithiasis	Ataxia
Chromium	Disturbances in the glucose metabolism	Kidney damage (Nephritis)
Selenium	Liver necrosis, Kaschi-Beck disease, Cardiomyopathy	Alkali disease, Blindstaggers Selenosis

The geology is the most important factor controlling the source and distribution of radionuclides, such as, radon, radium, uranium etc. associated with particular types of bedrock and unconsolidated deposits. Inhalation of radon is a severe occupational hazard for uranium miners, commonly resulting in fatal lung cancer. In addition to it, the low level of awareness about health hazards due to geological environmental toxins, general poverty leading to poor nutrition and health status, consumption of food grown in contaminated areas, serious lacking of proper sanitation, pipe-borne clean water and poor implementation of pollution control laws etc. clearly intensify and enhance the spread of many geogenic diseases and, therefore, complex the risks involved.

Infectious diseases in humans are also dramatically affected by the geological environment, albeit, indirectly. Geological forces shape the environments in which microbes thrive, sometimes creating opportunities for the emergence of infections. Atmosphere is a daily host to a variety of particles

or aerosols originating from the surface of earth through several geological and anthropogenic processes. Many of these particles are smaller than 2.5 mm making them easy to inhale e.g., alluvial dust, cigarette smoke, coal dust or asbestos, affecting our respiratory systems. The trade winds are able to lift fine mineral particles from soils sometimes laden with bacteria and toxic elements and then carry those particles to great distances around the planet which can impact the health and sustainability of living species. Satellites today track and provide an excellent picture of the transport of these dust and other aerosols on a global scale.

In addition to it, the roles of different organic compounds on health is presented by polycyclic aromatic hydrocarbons (PAHs) and pesticides and are quite toxic, especially when present in drinking water (table 2). One classical example is the case of Balkan Endemic Nephropathy (BEN) due to the presence of PAHs in water derived from coal fields which affects the people living in areas of the former Yugoslavia, Romania and Bulgaria. The pesticides are by nature toxic to one or more life forms. Generally pesticides damage the liver and nervous system. Also various microbes and pathogens released during different geological processes have an impact on health. For example, the landslides and the resulting dust clouds generated by the 1994 Northridge earthquake triggered an outbreak of coccidioidomycosis, or valley fever, among residents of the nearby Simi valley in southern California. The landslide released the soil fungus *(coccidioides immitis)* into dust clouds, exposing people to the fungus which caused valley fever.

Table 2
Some Commonly Used Pesticides and Their Adverse Effects

Pesticide	Disease/Adverse Effect
Aldrine	Attacks the nervous system, Convulsions, Carcinogenic
HCH	Liver tumor
Chlordane	Carcinogenic
DDT	Liver damage, Carcinogenic
Dieldrine	Carcinogenic, Destroys enzymatic activities
Heptachlor	Liver damage, Carcinogenic
HCB	Highly toxic, Bone marrow damage

Medical Geology Issues in Kashmir Valley

Kashmir Valley is characterized by a varied topography with bounding high, rugged structural hills, small mounds of *karewas*, colluvial fans and alluvial filled valleys, as the main geomorphological features. Geologically speaking, Kashmir Valley bears a unique identity as it hosts a complete geological succession of rocks ranging in age from Meso- Proterozoic (~1600-1000 Ma) to Holocene. The main geological formations of the basement of valley and surrounding mountains include the Panjal Volcanics (~298-252 Ma) and Triassic Limestones (~252-200 Ma) overlying the Archean metasedimentary rocks followed by the Karewas (~23-0.01 Ma) and Alluvium (<0.011 Ma). The Archean metasedimentary rocks comprise carbonaceous slates, pyritous graphitic phyllites, carbonaceous grey or white limestone and marble,

calcareous slates and mica schist. The Panjal volcanic rocks predominantly include andesite and basalt with shale, silt stone and quartzites. The Triassic Limestone constitutes a thick series of compact blue limestone, slates and dolomites. Karewas are the glacio-fluvio-lacustrine deposits and contain blue, grey and buff silts, sands, partly compacted conglomerates, lignite and embedded moraines. The recent alluvial deposits include boulders, pebbles sands and clay spreading over the flood plains of river Jhelum and its tributaries.[5] These different types of rocks supply most of the raw materials from which soils are formed and from which water derives its inorganic constituents. The compositions of what we eat and drink, thus, depend partly on the composition of these source rocks. The contents of individual elements also vary widely with rock types. Rocks like igneous, sedimentary and metamorphics contain trace elements and also contribute them to the water bodies like fluoride, arsenic, lead, copper, mercury, zinc, etc. Granites are known to contain minerals that emit radon, radium, potassium and uranium. Chromium, titanium, nickel and cobalt are conspicuously concentrated in low-silica igneous rocks. Arsenic, iodine, molybdenum and selenium are conspicuously concentrated in shale and clay.

Most of the people in the valley live in intimate contact with the immediate geological environment obtaining their basic requirements such as food and water directly from it. Therefore, the unique geochemistry of this geo-environment has a marked influence on their living and health. The Panjal Volcanic and Triassic Limestone provide building stones, besides, constituting the hard rock aquifers. The horticultural activities are carried out on the *karewas* where as the other major agricultural practices are dominantly carried out on the alluvium plains. The *karewas* and Alluvium also comprise the soft rock aquifers or groundwater resources of the valley satiating the irrigation and drinking water requirements of large chunk of population of the region. The chemistry and suitability of these water resources is defined in terms of dissolved inorganic and organic constituents obtained dominantly through rock-water interactions. Similarly the composition of the soil is also dependent and influenced by the raw material supplied by weathering of the different underlying litho-units in the area. Like other regions, the soil is an essential resource for the cultivation and plantation of diverse crops in the valley. Therefore, what we eat and drink largely depends on the composition of the source rocks from which soil is formed. The geological rock formations of diverse geochemical nature revealing their presence in the ambient geo-environment of Kashmir Valley continuously may have a profound effect on the health of the flora and fauna in the region. In order to study and understand the influence of geochemical factors on the distribution of diseases in man and animals, the geological setting of the valley provides a striking opportunity. Thus, in this perspective, we are providing a brief insight into a few major medical geology issues observed in the valley.

Fluorine and Iron

Fluorine is ubiquitous in the natural environment and 14th most abundant element in the Earth's crust, supremely reactive and oxidative. Fluorine is an

essential element in the human diet but chronic ingestion of high doses has been linked to the development of dental fluorosis and in extreme cases with skeletal fluorosis including osteosclerosis, limited movement of the joints, and outward manifestations such as knock-knees, bow legs, and spinal curvature. Fluorosis combined with nutritional deficiencies in children may produce severe bone deformations. Earth materials that are characteristically rich in fluorine are organic clays and shales, carbonates, phosphates, hydrothermal ores, and silicic igneous rocks like rhyolites, dacites, and granites. Fluorosis is a countrywide problem in India and it has reached alarming proportions in 17 states including Jammu & Kashmir wherein the concentration of fluoride beyond permissible limits is commonly observed in ground water resources of many parts of the valley.[6] It is very pertinent to mention here that recently, the Union Ministry of Drinking Water and Sanitation (UMDWS) has also warned about the incident of fluorosis in the valley. Besides fluoride, Iron is also one of the main contaminants of water and is widely reported from the valley. Panjal volcanics, carbonate rocks and ferruginous boulder beds in *karewas* are the main sources of Iron in the water resources of the valley. The water with high iron content causes staining of clothes while washing and imparts a bitter stringent taste to it. Trace inorganic chemicals that pose a potential health concern, such as arsenic, boron and lead, have high probability to be associated with iron in ground water.

Heavy Metals

The Kashmir Himalayas, particularly, in Anantnag, Ganderbal, Baramulla and Kupwara districts, is impregnated by sulphide mineralization wherein bioavailability of deleterious heavy metals like lead, mercury, cadmium, arsenic, zinc, cobalt, copper etc. can't be ruled out. Thus, the soil which covers these underlying sulphide mineralization rocks while in the process of weathering may concentrate some of the trace elements and even transfer some to plants

Table 3
Concentration of F, Fe and Pb in Groundwater Resources of Kashmir Valley

Parameter	Range in Kashmir Valley	Max. Permissible Limits		Health Effects
		BIS (10500)	WHO (2010)	
Fluoride	0-3 mg/l	1.5 mg/l	1.5 mg/l	Dental fluorosis, Skeletal fluorosis including osteosclerosis
Iron	1-10 mg/l	1 mg/l	--	Haemochromatosis
Lead	0.500 – 2.044 ppm	0.05 ppm	0.01 ppm	Reduced neuro physiological functioning, Peripheral neurological effects, Kidney dysfunction

Source: DGM, CGWB

grown on such soil. In addition, the groundwater which filters through this soil profile may also dissolve certain other elements. During our study, the concentration of geogenic Lead (Pb) in surface and sub-surface waters of Hapatkhai watershed, in district Baramulla has been found to be exceeding the safe drinking water limits of WHO[7] and BIS[8] Standards. This is also argued in the reliable report as well.[9] Chronic or acute exposure to lead affects human central nervous system and may cause several adverse effects on human health, e.g., anemia, gastric irritation, kidney, liver, and heart dysfunctions, brain damage and mental retardation especially among children.

Geo-circulation of Pesticides

Kashmir Valley is an agrarian region with agriculture as a dominant constituent of its economy and Rice, Maize and Wheat being major crops. Kashmir is known for its mono-cropped and rain-fed economy with 60 percent area in valley. Production of fruits like apples, pears, cherries, plums, mulberry peaches, apricots, walnuts and almonds, is common in the territory. About 20 percent of the total cultivated area is under horticulture with a the rapid conversion of agricultural land to horticulture. The people in valley, in order to coax more from the soil, add different kinds of fertilizers pesticides, insecticides and fungicides for destroying pests which affect their crop growth and crop productivity. These pesticides consisting of various cancer causing chemicals contaminate the drinking water and eatables. In the process, the agricultural return flow becomes potential source of pollution for the surface and groundwater resources which when ingested by the local populace, becomes a health concern. In a recent most study conducted by SMHS Hospital, Srinagar, the extensive use of pesticides during last two decades has been linked with an increase in the cancer incidents, particularly, in rural areas especially in the cereal and horticultural hotbed of the valley. Development of shallow aquifers is a common phenomenon in these rural areas which are highly susceptible for such contaminants. The cancer triggering elements in these areas may also associate with the several rock types such as clay and silt which forms the predominant litho-units of the valley. The USGS has found that low level of pesticides and their derivatives, which can disrupt hormone systems, are common in surface and ground water in both rural and urban areas.

***Atmospheric Particulate*s**

The atmosphere is a daily host to a variety of particles e.g. smokes particles, aerosols etc. in thick hazes of pollution that can affect our health. Many of these particles are smaller than 2.5 micrometers, making them easy to inhale. The presence of high concentrations of mineral dust in the atmosphere has implications not only for human health, but also for meteorology, climate, geology and bio-geochemical processes. These processes are all strongly linked. In the Kashmir Valley, the atmospheric dust and smoke generated from mining activities, vehicular traffic and combustion of fossil fuels are acting great challenges for the public health of the region. The mineral based industries are generating huge amounts of dust and smoke which is casting harmful impressions on the surrounding environment and population.

Higher concentration of black carbon (BC) and particulate matter (PM) in the atmosphere of the valley, particularly, around Srinagar city as compared to the other cities of India, is again a matter of concern as it causes severe health problems in masses besides the drastic variations in climatic regime of the valley. The fast growth in respiratory problems and the emission-crop interference, mostly, around industrial areas of the region, are also issues of great concern.

Natural Disasters

Kashmir Valley has a devastating history of extreme natural disasters like earthquakes, landslide, floods etc. the October-2005 earthquake and September-2014 floods can be cited as two examples of the recent most natural catastrophes. Such geo-hazards have the potential to produce copious solid, gaseous, or liquid materials of potential environmental and public health concern. For example, a huge quantity of contaminated and/or pathogen-bearing waters, dusts, soils, and sediments; liquids; gases; smoke; ash; and debris are produced during these disasters. Most of these materials are derived from the earth's surface, followed by the influence of geochemical processes during the evolution in the environment. The geochemical characteristics of these materials can strongly influence their potential impacts on the environment and health. In addition of analyzing the root causes of such disasters followed by the relevant mitigation measures, particularly, in case of man induced causes, we need to develop the proper disaster management infrastructure so as to overcome any such eventuality in future. Furthermore, it is collective responsibility of government, civil society, NGOs and other relevant agencies to pool their resources and cooperate in each other's efforts. Here it is worthmentioning that most people may not be aware regarding the future consequences of such disasters whose far-reaching negative impacts are much more dangerous than the immediate devastations.

In view of the above facts and figures, some doables are to be prioritized. Today Geo-scientists in association with public health professionals are seriously engaged to understand and address the health problems caused or exacerbated by geological materials and processes. The analytical characterization of naturally occurring trace elements and toxic organic compounds in soil and water is helping them to explain patterns of various diseases. Therefore, like other regions, in Kashmir Valley, there is a dire need for collaboration between geoscientists and public health professionals for the collection of more information on the sources, distribution, pathways and health effects of potentially harmful substances in the environment in terms of exposure, mixtures of different substances, and dose-response relationships.

A thorough assessment of the toxicity posed by bioavailability of geogenic sources, such as, Fluorine, Iron, Lead and Arsenic is highly warranted and the real risk to the population needs to be systematically quantified at higher priority levels. The main work in this direction will be to generate the Geoscientific data which, later on can be effectively utilized by medical/other experts for conducting further epidemiological studies on various health problems. Furthermore, the merging of physical science and bio-medical

databases, development of risk assessment maps, cross training of scientists and application of geo-science tools to other health problems, need attention. In this way, the risks and contaminations once identified can be minimized to safer levels by the established remediation strategies. Medical geologists can also help in identifying and ideally controlling various anthropogenic sources of contamination, such as extensive use of pesticides and insecticides. As a result, there is a growing role for process-focused earth science expertise and methods applied to environmental disaster response and planning in the valley. The aim of research in geo-environmental medicine is not to cure the disease but rather to prevent it. Hence, the field of Medical Geology demanding collaboration between the geo-scientists and biomedical/other researchers offers promise of developing innovative solutions to minimize or prevent exposure to potentially deleterious natural materials and geological processes which can subsequently pave way for a healthy society.

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