Medical Geology and its Impact on Society

Sondos Sameh Mohammed Zaki

Eman Mohammed Ibrahim

Esraa Nabil Fekry

Gannah Khaled Abd elmoez Mohammed

Reem Ahmed Ali

Reham Mohammed Abdelhakim

Supervisor : Dr./ Abdel-Samad Khafagy, Lecturer of Engineering Geology.

Ain Shams University, Faculty of Education,

Biological and Geological Sciences Department

Abstract:

Medical geology is a branch of geology that concerns with the effects of geologic materials and earth processes on the human health. It explains the relation between geology and human health through understanding the geological environment around us and its impact on the society. The geological processes and materials that exist in nature may be either beneficial or harmful and have a big impact on the living organisms. As geological materials exist everywhere and are used for many applications, raising the public awareness about medical geology becomes a crucial for mitigating geological health risks. Increasing the knowledge of community about the potential dangers, such as the risks of heavy metal poisoning or the link between radon exposure and lung cancer, can empower people to take proactive steps to protect themselves and their families. Educational campaigns, community outreach programs, and targeted communication strategies could help in recognizing and preventing many geological health hazards.

الجيولوجيا الطبية هو فرع من فروع علم الجيولوجيا يهتم بدراسة آثار المواد الجيولوجية وعمليات الأرض على صحة الإنسان ، حيث يفسر العلاقة بين الجيولوجيا وصحة الإنسان من خلال فهم البيئة الجيولوجية من حولنا وتأثيراتها على المجتمع. قد تكون العمليات الجيولوجية والمواد الموجودة في الطبيعة إما مفيدة أو ضارة ولها تأثير كبير على الكائنات الحية. ونظرا لوجود مواد جيولوجية في كل مكان تستخدم في العديد من التطبيقات ، فإن رفع الوعي العام حول الجيولوجيا الطبية بات أمراً بالغ الأهمية وذلك لتخفيف المخاطر الجيولوجية على الصحة العامة . إن زيادة معرفة المجتمع حول المخاطر المحتملة مثل مخاطر التسمم بالمعادن الثقيلة أو العلاقة بين التعرض للرادون وسرطان الرئة يمكن أن يعزز قدرة الناس على اتخاذ خطوات استباقية لحماية أنفسهم وأسرهم. كما يمكن أن تساعد الحملات التعليمية وبرامج التوعية المجتمعية واستراتيجيات الاتصال المستهدفة في التعرف على العديد من مخاطر الصحة الجيولوجية و منعها.

Keywords:

Health, environment, heavy metals, minerals, public awareness.

Preface

Medical geology is a branch of geology that concerns with the effects of geologic materials and earth processes on the human health. It's a unique arising discipline uniting the geoscience, biomedical and general health networks to settle an extensive variety of ecological health issues (Khandare, 2012). Medical geology is also the investigation of the effects of nearby or local convergences of synthetic compounds or minerals in (air, soil, water) on creature and human health. Geologic materials, for example, rocks, soils, dust and natural hazards can contain normally raised amount of elements, minerals, different mixtures or microorganisms that damage or advantage human health (cf. Selinus 2002, Finkelman et al. 2001). They can likewise contain human related substance, mineral or microorganism impurities.

The medical geology known as both deficiency and harmfulness of trace elements exposure. The Commission on geological science for Environmental planning defined medical geology as "The science dealing with the Influence of ordinary environmental factors on the geographical distribution of health problems In man and animals." (Dissanayake and Chandrasekara, 2005). More inclusive definition was proposed by Bunnell who defined medical geology as "Scientific discipline that examines the impacts that geologic materials and processes have on human and ecosystem health" and added that it "Includes both natural and anthropogenic sources of potential health problems" (Bunnell et al., 2007).

Back in old times researchers saw that a few minerals hurt human health and others were beneficial. The first to observe the connection between human health and the environment elements were Hippocrates and Aristotle. Medical geology as a field has developed over time with commitments from different researchers and scientists. It's difficult to credit its discovery to an individual as many geologists, medical experts and environmental scientists had an impact in advancing our understanding of the connection between geology and human health. Despite its basic role in human health, full definition of geological materials in biological health was not recognised till recently. Nevertheless, old researchers and specialists of medication were aware of this relationship. To be sure, as far back as, Hippocrates (~ 400 BC) in his composition, on a Airs, Waters and Places, had underlined the impact of actual climate on human health. Previously, individuals saw that specific regions had different health impacts. They understood that the rocks, minerals and soil in those spots may be assuming a part. As time went on, researchers and scientists began to dig further into this association. They tracked down links between geological elements and illnesses. Medical geology was a well-known subject that drew in popular researchers prepared as doctors from the late-18 to mid-19century. Medical Geology started to take shape in the late-20 century (Rosen, 1993). Researchers began concentrating on the impacts of geographical elements, For example, harmful minerals or radon gas on human health. From that point forward, examination and revelations in medical geology have extended, revealing insight into how geology and health are interconnected. Medical geology has taken extraordinary steps in the last 40 years. From the efforts of a group of geochemists in the mid 1960s attempting to translate potential connections between the normal geochemical climate and health of individuals in a given region to the institution of the

International Medical Geology Association (IMGA) in 2006 (Centeno, Finkelman and Selinus O, 2005).

Medical geologists work with earth, biological, physical and health scientist to assist improving general health. It analysis the impact of geological elements on the occurrence, distribution and exposure pathways of different natural elements that can influence human health. The importance of Medical geology lies in its capacity to give closure of knowledge into the connection between geological materials and human health, which can have huge implication for general health, environmental management, and risk assessment. A few key reasons for why medical geology is significant :

- Identification of health risks.
- Risk assessment and management.
- Understanding illness pattern.
- Geo-medicine and preventive medicine.
- Natural resource management.

Learning medical geology helps students to become aware of the health risks associated with geological factors like soil composition, water quality, and mineral deposits. This knowledge empowers them to identify potential health hazards in their surroundings. By understanding the geological sources of diseases such as arsenic poisoning, fluorosis, and radon exposure, students can take preventive measures to avoid these conditions. Knowing the geological origins of health issues allows individuals to make informed choices about their living environment and lifestyle. Medical geology integrates principles from geology, environmental science, public health, and medicine, providing students with an interdisciplinary learning experience. This field promotes critical thinking and problem-solving skills by fostering a holistic understanding of the connections between Earth's processes and human health. Exposure to medical geology in school can inspire students to pursue careers in geology, environmental science, public health, or medicine. Understanding the impact of geological processes on health outcomes opens up various career paths, including environmental monitoring, hazard assessment, and epidemiological research. Studying medical geology goes beyond the classroom, sparking a lifelong interest in Earth sciences and public health. Whether pursuing further education or engaging in citizen science projects, students with knowledge of medical geology continue to contribute to scientific inquiry and the well-being of society throughout their lives.

Principles of Medical Geology and its applications

The principals of medical geological include the following items:

Geological Processes and Public Health: Understanding how the influences of geological techniques, inclusive of weathering, erosion, and mineral deposition, are influencing the distribution of elements and compounds that affect human health (figure 1).

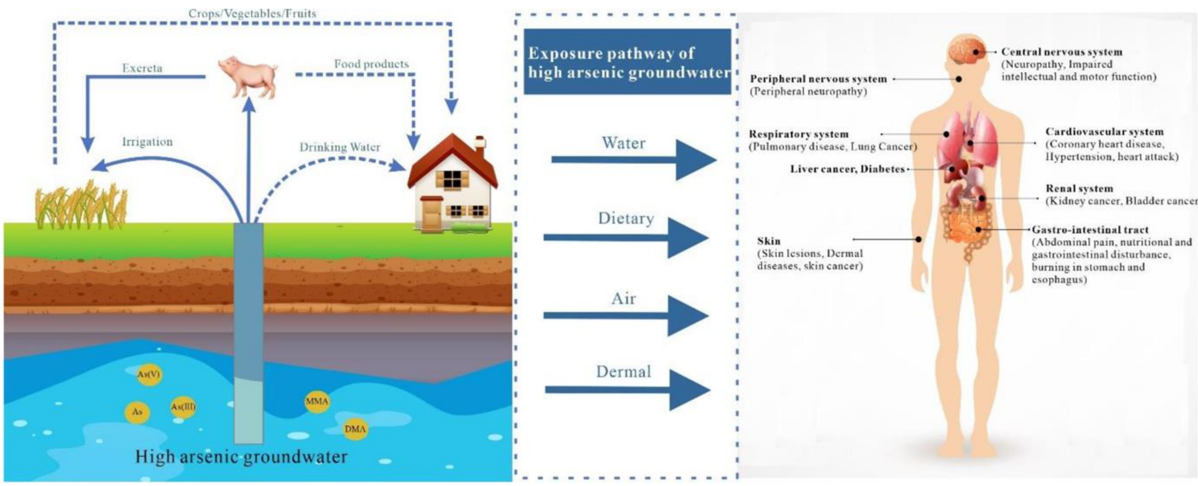

Figure 1. Different pathways of arsenic exposure in groundwater and effects on humans (after Yadav, et al 2021).

Geochemical Cycling: Analysing the movement throughout the Earth's crust, hydrosphere, environment, and biosphere and their implications for human exposure to harmful substances.

Human Environment Interactions: Exploring the relationship between human sports, environmental changes, and geological factors and their outcomes on fitness outcomes.

Identification of Geological Hazards: Evaluating the life of geological hazards like radon fuel, arsenic groundwater, or seismic interest and assessing their capability and health dangers (figure 2) (Podgorski and Berg, 2020).

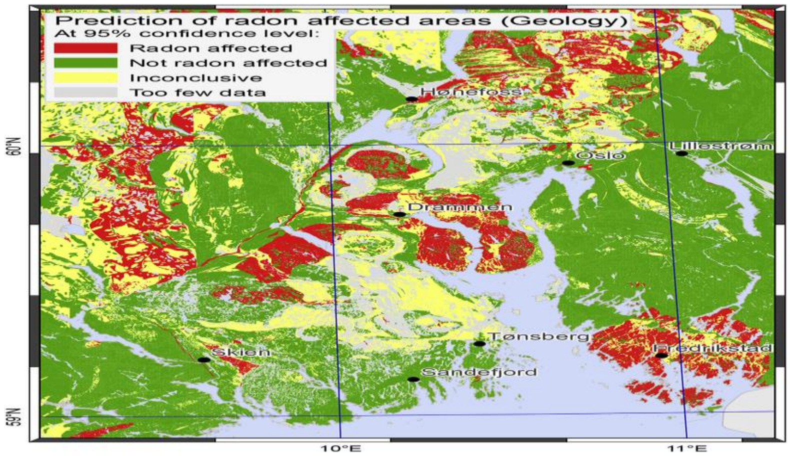

Figure 2. Map of radon affected areas and less affected areas according to the geology model (after Watson et al,2016).

Exposure Pathways: Studying routes that humans use to come into contact with geological contaminants, including ingestion, inhalation, and dermal touch.

Health Impact Assessment: Assessing the health results of exposure to geological substances like breathing sickness, cancer, neurological issues, and developmental abnormalities. Vector-Borne Diseases: Assessing the geological elements influencing the unfolding of vector-borne sicknesses such as malaria, dengue fever, and Lyme disorder and designing control measures (Finkelman, 2008).

Waterborne and Soil borne Diseases: Understanding geological sources of pathogens in water and soil and enforcing measures for the prevention of contamination and sickness transmission (Brenniman, 1999).

Nutritional Deficiencies and Excesses: Looking into how geological factors have an effect on nutrient availability and assessing their impacts on human fitness, including those related to iodine deficiency disorders or selenium toxicity.

Community health assessments are critiques undertaken on geological threat or contamination websites to understand health implications and manual, effective interventions. Geochemical remediation consists of strategies to address geological infection and, more typically, decrease human exposure to risky materials like soil and groundwater remediation techniques (figure 3) (Cibula et al,2003).

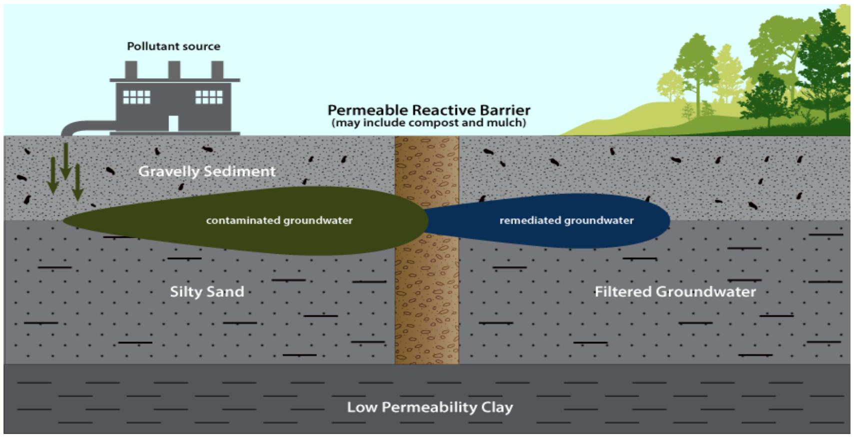

Figure 3. Bioremediation of groundwater (after Chen et al,2015).

Nutritional dietary supplements are given to fight deficiencies in critical factors because of geological factors, together with iodized salt distribution for the prevention of iodine deficiency disorders. Geologically Informed Healthcare combines geological understanding and statistics into the method of diagnosing, treating, and instructing sufferers for the development of fitness effects and the prevention of diseases associated with geological factors. Public Health Policy and Advocacy initiatives contain the improvement of a regulatory framework and guidelines that ensure the safety of public fitness from geological dangers and contaminants, including placing water quality requirements, making land use plans, and implementing pollution control measure. Public awareness and education projects are boosting the capacity of our bodies to work in conjunction with them in efforts closer to making the general public privy to the geological fitness dangers and advocating for guidelines that prioritise health rather than the rest in handling geological sources and environmental conservation.

Geospatial Analysis and GIS: Utilising geospatial analysis and GIS generation for mapping geological functions, figuring out excessive-threat regions for geological hazards or contamination, and prioritising interventions. Integrating geospatial statistics with fitness facts to discover spatial styles of disease occurrence and investigate viable family members with geological elements (Lee et al ,2003).

Climate Change and Health Impacts: Investigate the outcomes of weather trade on geological approaches consisting of sea-degree rise, coastal erosion, and precipitation patterns that have an impact on human health.

Indigenous and Traditional Knowledge Systems: Integration of indigenous and conventional understanding systems into clinical geology research and practice to enhance information on local geological risks, environmental exposures, and traditional remedies for geological-associated health issues. Collaboration with indigenous communities for the merging of conventional ecological know-how with medical techniques for managing geological resources and protecting community health.

Capacity Building and Training: Training, education, and potential building of health professionals, environmental scientists, policymakers, and community leaders with multiplied information on principles of and alertness to medical geology. Facilitating interdisciplinary getting-to-know-and-studying efforts and encouraging multidisciplinary and geological-related disciplines.

Global Health Equity and Social Justice: Promotion of fairness in accessibility of healthcare and environmental resources as factors associated with geology-related fitness disparities. Encouraging guidelines and interventions that target the fitness and welfare of terrible, marginalised communities who are susceptible to geological dangers and environmental pollutants.

Interdisciplinary Research: Medical geologists paint at an interdisciplinary level, trying to recognise the indirect relationship between geology, environment, socio-economic, and cultural factors on fitness outcomes and resilience to geological-related risks.

Disaster Preparedness and Response: Medical geologists play an important role in the components of catastrophe preparedness and reaction with the aid of presenting geological expertise to expect, determine, and mitigate the fitness impacts of geological failures like earthquakes, volcanic eruptions, and landslides. They collaborate with emergency control organisations to design evacuation plans, set up emergency shelters, and coordinate hospital treatment to treat affected populations (Zhai and Lee, 2023).

Geological Research and Innovation: In clinical geology, to investigate the correlation between geological tactics and health problems, new techniques, technology, and analytical techniques are being set up to look into health dangers related to geological factors and fitness effects.

Occupational Health and Safety: Medical geologists provide checks for occupational fitness hazards related to publicity to geological materials and methods, for instance, silica dust in mining or asbestos in creation.

Construction: Workers in the construction enterprise need to deal with tough or smooth materials like cement, concrete, wood, stones, metals, minerals, and chemicals that can be applied in the building of edifices. They lay out business safety measures, monitoring programmes, and fitness education projects to protect people from various occupational hazards.

Long-Term Monitoring and Surveillance: Developing a gadget to monitor and survey for the continuation of trends in geological hazards, environmental contamination, and fitness final results adjustments through the years to ensure early identification of rising health risks and evaluation of intervention effectiveness (figure 4).

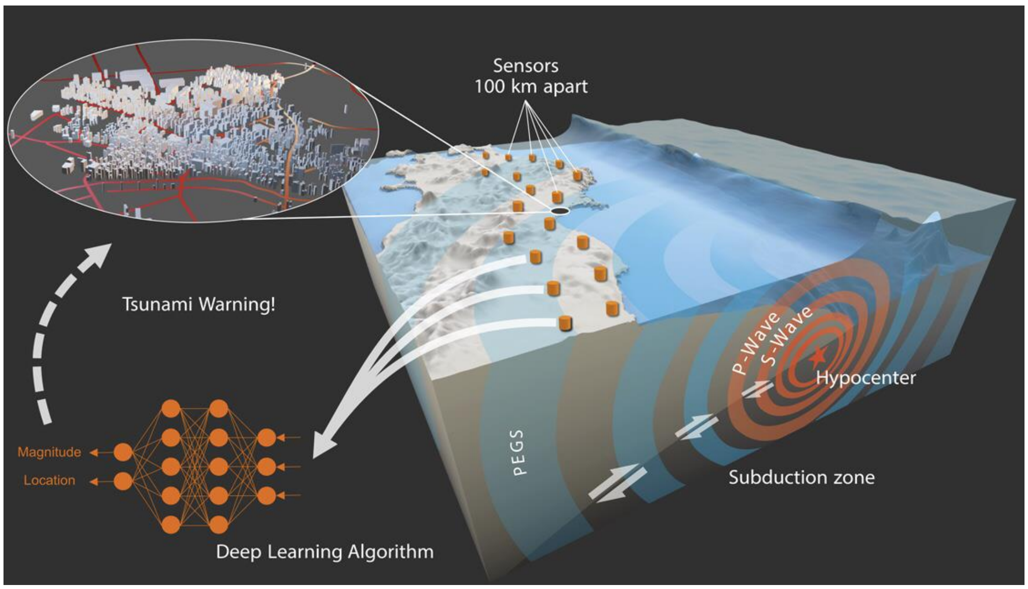

Figure 4. showing that scientists use sensors for monitoring the earthquake and tsunami (after Lori Dengler, 2024).

Application of Medical Geology in Medicine: Medical geology could be very vital in almost each discipline of drugs, starting with dental care, bone health, and eye remedies. It is applied in producing porcelain teeth through the use of substances like gold and platinum for dental approaches and orthodontics with braces. Medical geology also contributes to toothpaste composition. Further, gypsum treats fractures in bone health, even as hot sulphur water, clay paste, sand baths, and sauna baths have therapeutic blessings. Calcium carbonate and phosphate are utilised in bone remedies at the side of platinum nails for fractures.

Medical geology influences eye care through an eyeliner containing galena and antimony, zinc drops, and prescription lenses. Laser rays from agate are utilized in eye treatments, displaying the diverse applications of medical geology in remedy.

Effects of geological environment on human health

Heavy metals are metallic chemical elements with high density and toxicity in low concentrations. Some examples are mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Ti), and lead (Pb). These metals have densities five times higher than water, while light metals have lower densities. Humans are exposed to heavy metals through consumption of water and food. Various environmental compartments such as soil, water, air and food can serve as reservoirs for heavy metals. Although these elements occur naturally in the Earth's crust, they can also enter the environment through human activities such as mining, industrial processes and agriculture. Additionally, untreated sewage sludge, metal pipes, traffic, and combustion by products from coal-fired power plants are sources of heavy metals. E-waste disposal is becoming an increasingly serious problem worldwide, particularly with regard to the disposal of used computers and cell phones. These electronic devices contain a variety of materials, many of which are harmful to health (figure 5) (Fergusson, 1990) (Duffus, 2002).

Figure 5. Showing existence of heavy metals in nature due to pollution (after Tuayai, 2014)

Heavy metals, such as cadmium, lead, and mercury, are commonly found in soil and water as a result of geological processes. Exposure to these heavy metals can result in severe health issues, including neurological damage, kidney damage, developmental disorders, and cancer. The harmful effects of heavy metals on human health are exacerbated by industrial activities and modernization. There is a global concern regarding the contamination of water, air, and food with heavy metals, with variations in toxicity based on gender. These metals interact with biological systems, forming metal cations that impact essential macromolecules. Both acute and chronic toxic effects of heavy metal exposure can lead to gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, immune system dysfunction, birth defects, and cancer. High-dose exposure to metals like mercury and lead can result in severe complications, while low-dose exposure may lead to neuropsychiatric disorders. Carcinogenic metals such as arsenic, cadmium, and chromium interfere with DNA synthesis and repair processes.

Cadmium poisoning has been reported in many parts of the world. It is one of the global health problems that affects many organs and, in some cases, can cause death every year. Long-term exposure to cadmium through air, water, soil and food leads to cancer and toxicity of organ systems such as the skeletal, urinary, reproductive, cardiovascular, central and peripheral nervous and respiratory systems. Cadmium levels can be measured in blood, urine, hair, nail and saliva samples. Cadmium occurs extensively in the environment due to human activities such as fossil fuel use, metal ore burning, and waste incineration. When sewage sludge enters agricultural soils, there may be transfer of cadmium compounds that are adsorbed by plants, which may play an important role in the food chain and accumulate in various human organs. Another major source of cadmium exposure is cigarette smoke. When cadmium was measured in blood samples from smokers, CD levels in the blood of these smokers were found to be four to five times higher than those of non-smokers (Munisamy et al, 2013).

Mechanism of toxicity: Cadmium affects cell proliferation, differentiation and apoptosis. These activities interact with the DNA repair mechanism, generation of reactive oxygen species (ROS), and induction of apoptosis (Rani et al, 2014). Cadmium binds to mitochondria and, at low concentrations, can inhibit both cellular respiration and oxidative phosphorylation (Patrick, 2003).

Several studies have mentioned that cadmium can affect the skeletal system. Exposure to cadmium caused demineralization of the skeleton, allowing it to interact directly with bone cells, reducing mineralization, and also inhibiting procollagen C proteinases and collagen production (Staessen et al, 1999). Clinical findings associated with osteoporosis include pain, physical impairment, and decreased quality of life. Additionally, reduced bone density increases the risk of bone fractures. Osteoporotic fractures are most common in postmenopausal women and can result in disability. Pseudo fractures secondary to osteomalacia and severe skeletal decalcification may also be observed (figure 6) (Nawrot et al, 2010).

Figure 6. Showing the Itai-Itai disease is the most severe form of chronic cadmium poisoning. The first detection was at Jinzu River, Toyama Prefecture, Japan (after Umemura. et al,2006) (after Ayşe Handan and Dökmeci jan, 2009)

Kidney damage due to cadmium toxicity: Cadmium accumulates primarily in the kidney and liver, but can also be found in other tissues such as bone and placenta. Occupational and environmental exposure to cadmium has been reported to result in renal dysfunction (Jarup, 2002).Cadmium exposure may show early signs of kidney damage, proteinuria, calcium loss, and tubular lesions.

Cadmium and Reproductive System: Cadmium in the male reproductive system is claimed to decrease sperm density, volume, and number and increase immature sperm forms (Pizent et al,2012). These problems are followed by a defect in spermatogenesis, sperm quality and the secretory functions of the accessory glands. It also reduces libido, fertility, and serum testosterone levels (Chandel and Chand Jain, 2014). In the female reproductive system, ovarian function and egg development may be inhibited. Steroidogenesis is reduced by Cd toxicity and ovarian haemorrhage and necrosis can co-occur (Thompson and Bannigan, 2008). Spontaneous abortion rates and duration of pregnancy were reported to increase and live birth rates decreased.

Cadmium and cardiovascular system: In vitro studies have suggested the involvement of cadmium in endothelial dysfunction and carotid artery intima media thickness (IMT). Furthermore, atherosclerotic plaque formation was promoted in vivo (Fagerberg et al, 2012). Following cadmium poisoning, endothelial dysfunction at the onset of cardiovascular disease (CVD), loss of endothelial cell structure leading to cell death, and chromogenic events may occur. These results support the hypothesis that cadmium is involved in cardiovascular disease and myocardial infarction (Everett and Frithsen, 2008).

Epidemiological studies had shown an association between cadmium exposure and the risk of hypertension (systolic and diastolic blood pressure). People can be exposed to lead through occupational and environmental sources. This results primarily from: inhalation of lead particles produced by the burning of lead-containing materials, such as melting, recycling, removal of lead-based paint and lead-containing plastic wiring, and the use of lead-containing aviation fuel; and ingestion of lead-contaminated dust, water (from lead-containing pipes), and food (from lead-glazed or lead-soldered containers), as well as through hand-to-mouth behaviour. Young children are particularly vulnerable to lead poisoning because they ingest 4-5 times as much lead from a given source as adults. Additionally, children's innate curiosity and age-appropriate hand-to-mouth behaviour cause them to put leaded or lead-containing materials in their mouths and swallow them.

Lead exposure can have serious consequences on children's health. High levels of lead exposure can cause severe damage to the brain and central nervous system, leading to coma, convulsions and even death. Children who survive severe lead poisoning can be left with permanent mental and behavioural disabilities. Lead is now known to cause a spectrum of injuries in multiple body systems at lower levels of exposure that do not produce obvious symptoms. In particular, lead can affect children's brain development, resulting in reduced intelligence quotient (IQ), behavioural changes such as reduced attention span and increased antisocial behaviour, and reduced educational attainment. Lead exposure also causes anaemia, hypertension, renal dysfunction, immune toxicity, and reproductive organ toxicity.

Mercury, a powerful neurotoxin, can accumulate in the food chain, with fish and seafood particularly susceptible to accumulation. Methylmercury, an organic form of mercury, poses a significant threat because it can penetrate the blood-brain barrier and cause neurological damage. The main source of exposure is consumption of contaminated fish, but inhalation of mercury vapours or contact with certain products can also lead to contamination. Symptoms of mercury poisoning can include sensory disturbances, difficulty with coordination, and problems with speech, vision, and hearing.

Workers in various industries such as manufacturing, construction, and waste management face potential risks of occupational exposure. This exposure can come from a number of sources, including industrial activities such as factories, mining, smelting and burning fossil fuels. Additionally, natural sources such as volcanic activity, mineral weathering, and erosion can contribute to occupational exposure. In addition, consumer products such as electronics, batteries and certain cookware can also pose a risk. Finally, contaminated food and water, which may contain heavy metals from crops, livestock, and groundwater, may be another cause for concern for occupational exposure. Exposure to excessive amounts of trace elements can result in toxic effects, some of which are attributed to natural geological sources. Among the trace elements studied, fluorine has received considerable attention. Fluoride (F^-), the ionic form of fluorine, has been shown to promote bone formation and has been shown to be effective in reducing dental caries at concentrations of at least 0.7 mg/L in drinking water. However, excessive fluoride exposure can lead to fluorosis of the tooth enamel (tooth discoloration) and bones (skeletal fluorosis). Chronic exposure to non-essential metals and metalloids such as arsenic is also the subject of investigations in medical geology. Arsenic, a toxic and carcinogenic element, is commonly found in various rock-forming minerals, including iron oxides, clay and sulphide minerals. If arsenic enters groundwater through oxidation and then enters the human body through drinking water, serious health risks can arise. Well-documented cases of chronic arsenic poisoning have been reported in regions such as southern Bangladesh, West Bengal (India), Vietnam, China, Taiwan, Chile, Argentina and Mexico. Skin diseases, including pigment disorders, hyperkeratosis and skin cancer, are typical symptoms of chronic arsenic exposure through drinking water. In addition, other symptoms affecting the renal, gastrointestinal, neurological, haematological, cardiovascular and respiratory systems may also occur. The study of medical geochemistry related to arsenic is now recognized as a priority area of research by various governments.

Arsenic pollution occurs as a result of natural phenomena such as volcanic eruptions and soil erosion, as well as anthropogenic activities. Several arsenic-containing compounds are produced industrially and used to produce products for agricultural purposes such as insecticides, herbicides, fungicides, algaecides, sheep remedies, wood preservatives and dyes. They have also been used in veterinary medicine to eradicate tapeworms in sheep and cattle (Tchounwou et al ,1999). Arsenic compounds have also been used in the medical field for at least a century to treat syphilis, yaws, amoebic dysentery and trypanosomiasis. Arsenic based drugs are still used to treat certain tropical diseases such as African sleeping sickness and amoebic dysentery, as well as in veterinary medicine to treat parasitic diseases such as filariasis in dogs and blackheads in turkeys and chickens (Centeno et al,2005). Recently, arsenic trioxide was approved by the Food and Drug Administration as an anticancer agent for the treatment of acute promeylocytic leukemia (Rousselot et al,1999). Its therapeutic effect is attributed to the triggering of programmed cell death (apoptosis) in leukemia cells (Yedjou and Tchounwou, 2007).

Human exposure at these sites can occur in a variety of ways, including inhalation of airborne dusts, ingestion of contaminated water or soil, or through the food chain. Contamination with high concentrations of arsenic is a concern because arsenic can cause a number of human health effects. Several epidemiological studies have found a strong association between arsenic exposure and an increased risk of both carcinogenic and systemic health effects (Tchounwou et al,2003). Interest in the toxicity of arsenic has been increased by recent reports of large populations in West Bengal, Bangladesh, Thailand, Inner Mongolia, Taiwan, China, Mexico, Argentina, Chile, Finland and Hungary exposed to high concentrations of arsenic in their residential drinking water and exhibit various clinical pathological conditions, including cardiovascular and peripheral vascular diseases, developmental anomalies, neurological and neurobehavioral disorders, diabetes, hearing loss, portal fibrosis, haematological disorders (anaemia, leukopenia, and eosinophilia), and carcinoma Exposure to arsenic affects virtually all organ systems, including the cardiovascular, cutaneous, nervous, hepatobiliary, renal, gastrointestinal, and respiratory systems (Tchounwou et al, 2003). Research has also indicated significantly higher standardized mortality rates for cancers of the bladder, kidney and skin. and liver in many areas of arsenic exposure. The severity of adverse health effects is related to the chemical form of arsenic and is also time and dose dependent. Although there appears to be strong evidence for the carcinogenicity of arsenic in humans, the mechanism by which it produces tumours in humans is not fully understood (figure 7) (Chappell et al, 1997).

Figure 7. Showing the effect of arsenic (after Rakesh Kumar, 2022).

Elephantiasis occurred in some countries, and on observation of the areas where the disease was widespread, it was found that they all had red clay soil, and on analysis of the lymph nodes of the infected tissue, fine particles containing aluminium, Contained silicon and titanium. Then the mineral akermanite from the group of amphibole minerals, which occurs in volcanic bedrock, was identified as the responsible trigger for elephantiasis. The importance of geo-medical research is also obvious (figure 8).

Figure 8. Showing elephantiasis (after Agencies, 2022).

Fluoride occurs naturally in various sources such as soil, water, and certain foods, although it is not directly derived from heavy metals. However, The severity of fluorosis is related to the concentration of fluoride in drinking water, daily intake, duration of exposure, and climatic conditions. Exposure to high levels of fluoride over a long period of time results in dental fluorosis, skeletal fluorosis, and non-skeletal fluorosis, manifested by muscle weakness, fatigue, anaemia, dyspepsia, male infertility, decreased IQ, and other symptoms(Everett, 2011). Epidemiological research has shown that fluorosis can severely affect any age group and can range from mild dental fluorosis to debilitating skeletal fluorosis. Its effects are particularly harmful to developing children and its deleterious effects are irreversible. In 1937, Murray first reported the manifestation of nervous system dysfunction in patients with endemic fluorosis. Since then, other studies have found that long-term excessive ingestion of fluoride can cause demyelinating changes in the cerebral cortex and subcortical areas and lead to hypothyroidism; This could explain the decline in children's intelligence levels in areas with high fluoride levels. Based on these findings and the fact that fluoride threats currently affect approximately 100 million people in 1115 counties in China (Wang et al, 2020).

The functional and organic effects of fluorosis on the central nervous system, particularly on children’s intellectual development and learning, are unclear, and increasing attention is being paid to memory. Skeletal fluorosis usually occurs in young adults. It is a chronic invasive systemic bone disease caused by long-term excessive intake of fluoride and is an important indicator of the effect of water improvement and de-fluoridation strategies (Idowu et al, 2019). The present results showed that the prevalence of skeletal fluorosis and urinary fluoride levels in adults and children decreased significantly after the implementation of the water improvement projects in China. The results of this study suggest that fluoride levels in the human body can be effectively reduced through water improvement and de-fluoridation strategies. The results showed that the incidence rate of dental fluorosis in children was higher in the south than in the north, and this is consistent with the trend of fluoride levels in water. This implies that the incidence rate of dental fluorosis in children is positively correlated with the fluoride content in water. The decline in the incidence of dental fluorosis in children was most pronounced in northeast China. According to Dean's Fluorosis Index, the results of the current analysis indicate that the severity of dental fluorosis was significantly lower in children (figure 9).

Figure 9. Showing the effect of fluoride on teeth. (After Michael Connett, 2012)

Absorption and Accumulation of heavy metals in the Body such as cadmium, lead, and mercury have the potential to enter the human body through multiple pathways, including inhalation, ingestion, and dermal absorption. Once inside the body, these metals can accumulate in various tissues and organs, resulting in detrimental health consequences. Cadmium, for instance, is predominantly absorbed through the gastrointestinal tract and can build up in the kidneys, liver, and bones. Similarly, lead is primarily absorbed through the lungs and gastrointestinal tract, leading to accumulation in the bones, blood, and soft tissues. Mercury, on the other hand, can be absorbed through the lungs, gastrointestinal tract, and skin, accumulating in the brain, kidneys, and other tissues. The absorption rate and bioaccumulation of heavy metals in the body are influenced by several factors, including the chemical form of the metal, the exposure route, the duration and frequency of exposure, and individual characteristics like age, nutritional status, and genetic makeup (Mondal et al ,2018). For example, organic forms of mercury, such as methylmercury, are more easily absorbed and can penetrate the blood-brain barrier, causing neurological effects. In contrast, inorganic mercury is mainly absorbed through the gastrointestinal tract and can accumulate in the kidneys. The body's ability to eliminate heavy metals is also crucial in determining their accumulation levels. Some metals, like lead and cadmium, have extended biological half-lives and can persist in the body for years, resulting in chronic exposure and long-lasting health impacts. Additionally, the presence of other minerals and nutrients in the body can affect the absorption and toxicity of heavy metals. For instance, calcium and iron can compete with lead for absorption, potentially reducing its harmful effects.

The accumulation of toxic substances in various parts of the body such as organs, tissues, and bodily fluids can result in a variety of debilitating and potentially life-threatening conditions. Exposure to cadmium has been linked to kidney damage, lung disease, and an increased risk of specific types of cancer (Patrick, 2003). Lead exposure, especially in children, can hinder cognitive development, cause neurological issues, and contribute to hypertension and reproductive problems (Wadhwa et al, 2012) (Flora et al, 2012).

Mercury poisoning can lead to sensory disturbances, lack of coordination, changes in vision, and damage to the nervous system, including the brain (Patrick, 2002).The severity of the health effects caused by these toxic substances is influenced by factors such as the amount of exposure, the duration of exposure, and the route of exposure. Chronic, low-level exposure over an extended period can be equally harmful as acute, high-level exposure. It is essential to accurately identify and address sources of heavy metals in the environment to safeguard public health and prevent the devastating consequences associated with exposure to these substances.

Natural radiation is a form of ionizing radiation that originates from various natural sources within the Earth's environment. These sources can be classified into two categories: terrestrial radiation and cosmic radiation. Terrestrial radiation arises from radioactive minerals and elements present naturally in the Earth's crust, such as uranium, thorium, and their decay products. As these elements undergo radioactive decay, they emit alpha, beta, and gamma rays, which can be found in soil, rocks, and groundwater. Consequently, individuals residing in specific geological regions may be exposed to this type of radiation. On the other hand, cosmic radiation is composed of high-energy particles that constantly bombard the Earth's atmosphere from outer space. These particles, including protons, electrons, and heavy ions, interact with the atoms in the atmosphere, resulting in the creation of secondary radiation. This secondary radiation encompasses neutrons, muons, and other subatomic particles. The exposure to cosmic radiation is more pronounced at higher altitudes and can pose a concern for individuals who spend significant amounts of time at elevated locations or in aircraft (U.S.NRC 20March, 2020) Additionally, radon gas represents a significant natural radiation source. It is a radioactive gas generated through the decay of uranium in the Earth's crust. Radon has the potential to accumulate in homes and buildings, particularly in areas with elevated levels of uranium in the soil or underlying bedrock. Exposure to radon gas is a leading cause of lung cancer, particularly among individuals who smoke. Therefore, it is crucial to address and mitigate the risks associated with radon exposure to ensure public health and safety.

Ionizing radiation is a form of energy that is released by atoms in the form of either electromagnetic waves (such as gamma or X-rays) or particles (like neutrons, beta, or alpha particles). The process of atoms spontaneously breaking down is known as radioactivity, with the excess energy emitted being in the form of ionizing radiation. Radionuclides are unstable elements that disintegrate and emit ionizing radiation. Each radionuclide is distinguished by the type of radiation it emits, the energy of the radiation, and its half-life, which is the time taken for the activity of a radionuclide to decrease by decay to half of its initial value. The activity of a radionuclide, which is a measure of the amount present, is quantified using the unit known as the becquerel (Bq), where one becquerel is equivalent to one disintegration per second. The half-life of a radioactive element indicates the duration required for half of its atoms to disintegrate, with this timeframe varying significantly from a fraction of a second to millions of years, as seen in examples like iodine-131 with a half-life of 8 days and carbon-14 with a half-life of 5730 years. (World Health Organization, 2023)

Individuals are regularly subjected to ionizing radiation from both natural sources like soil, water, and vegetation, and artificial sources like x-rays from medical equipment. The utilization of ionizing radiation spans across various fields, including medicine, industry, agriculture, and scientific research, showcasing its diverse beneficial applications. With the rising prevalence of ionizing radiation usage, there is a corresponding increase in the potential health risks if not managed or utilized correctly. Exposure to high levels of radiation can lead to immediate health issues like skin burns or acute radiation syndrome. Even low doses of ionizing radiation have the potential to elevate the risk of developing long-term health effects, such as cancer.

Exposure to ionizing radiation can be encountered in various settings, including homes, public places, workplaces, and medical facilities. Exposure to radiation can occur through internal or external pathways. Internal exposure happens when a radionuclide enters the bloodstream through inhalation, ingestion, injection, or wounds. This type of exposure ceases when the radionuclide is eliminated from the body naturally or through treatment. On the other hand, external exposure can occur when radioactive materials, like dust or aerosols, come into contact with the skin or clothes. These materials can often be removed by washing. Additionally, external exposure can result from irradiation by an external source, such as medical radiation from x-rays. This exposure stops when the radiation source is shielded or when the individual moves outside the radiation field. For radiation protection purposes, exposure to ionizing radiation is classified into three situations: planned, existing, and emergency. Planned exposure arises from the intentional use of radiation sources for specific purposes, such as medical diagnosis or industrial applications. Existing exposure occurs when radiation already exists, and measures must be taken to control it, such as exposure to radon or natural background radiation. Emergency exposure situations arise from unexpected events, like nuclear accidents or deliberate acts, requiring immediate response. It is worth noting that medical use of radiation contributes significantly to the population's dose, accounting for 98% of the dose from human-made sources and representing 20% of the total population dose. (U.S.NRC, 2020) (World Health Organization, 2023)

The health effects of ionizing radiation are dependent on the dose of radiation received, which is measured in gray (Gy). The potential damage caused by this absorbed dose is influenced by the type of radiation and the sensitivity of different tissues and organs to radiation. to assess the potential harm caused by ionizing radiation, an effective dose is used. This dose is measured in Sievert (Sv) and takes into account the type of radiation and the sensitivity of tissues and organs. It provides a way to quantify the potential harm caused by ionizing radiation. In addition to the amount of radiation received, the rate at which the dose is delivered, known as the dose rate, is an important factor. This dose rate is described in micro Sieverts per hour (μSv/hour) or milli Sieverts per year (mSv/year). The dose rate determines how quickly the radiation is delivered to the body and can impact the severity of the effects. When radiation exceeds certain thresholds, it can lead to impairment of tissues and organs, resulting in acute effects such as skin redness, hair loss, radiation burns, or acute radiation syndrome. These effects are more severe at higher doses and higher dose rates. For example, the threshold for acute radiation syndrome is approximately 1 Sv (1000 mSv). If the radiation dose is low and delivered over a long period of time (low dose rate), the risk of harm is significantly reduced because there is a greater chance for the body to repair the damage. However, there is still a risk of long-term effects such as cataracts or cancer, which may manifest years or even decades later. The likelihood of these effects is proportional to the radiation dose, with children and adolescents being more sensitive to radiation exposure than adults. Epidemiological studies conducted on populations exposed to radiation, such as survivors of atomic bombings or radiotherapy patients, have shown a significant increase in cancer risk at doses above 100 mSv. More recent studies have also examined individuals exposed to medical radiation and have provided valuable insights into the risks associated with different levels of exposure. (World Health Organization, 2023)

Mitigating Geological Health Risks a d Identifying Exposure Risks is the first step in mitigating geological health risks is to identify potential sources of exposure. This involves conducting environmental assessments to detect the presence of heavy metals, natural radiation, or other harmful substances in the local geology. Soil, water, and air samples can be analysed to determine the levels of contaminants and pinpoint areas of concern. Once high-risk locations are identified, steps can be taken to limit or prevent exposure.

Implementing Protective Measures For areas with elevated heavy metal levels, protective measures may include using specialized water filters, covering contaminated soil, or implementing agricultural practices that reduce the uptake of metals by crops. In regions with high natural radiation, steps can be taken to mitigate radon exposure, such as sealing cracks and gaps in building foundations or using ventilation systems to increase air flow. Personal protective equipment like respirators may also be necessary in certain high-risk occupational settings.

Mineralogy and Medical Geology

Mineralogy is the medical observe of minerals, which can be glaringly occurring inorganic substances with a genuine chemical composition and crystalline shape. Mineralogy entails the identity, magnificence, and characterization of minerals based totally mostly on their bodily and chemical homes. Medical geology and mineralogy are carefully related due to the fact positive minerals and geological materials could have significant implications for human health (The American Heritage Dictionary of the English language, 2017) (Collins Dictionary, 2017). Here are some examples:

1.Toxic minerals: Some minerals, which includes asbestos, arsenic, lead, mercury, and radon, may be dangerous to human health while they will be gift within the environment. Inhalation or ingestion of these minerals can reason diverse illnesses, which includes lung cancer, respiratory problems, neurological problems, and organ harm.

2.Essential minerals: On the alternative hand, certain minerals are vital for human fitness and are required for the proper functioning of the frame. For instance, minerals like calcium, magnesium, potassium, and sodium play critical roles in maintaining bone health, regulating physical functions, and helping numerous metabolic strategies.

3.Geochemical anomalies: Geological approaches can result in the accumulation of sure elements or minerals inside the environment, resulting in geochemical anomalies. These anomalies can impact human health in particular approaches. For example, regions with excessive degrees of truly occurring fluoride in water assets can bring about dental and skeletal fluorosis, even as regions with immoderate degrees of selenium can motive selenosis.

4.Medical remedies: Minerals and geological substances were used for medicinal functions for the duration of history. For example, diverse mineral-based totally substances, along with clays, were utilized in traditional medication for their recuperation homes. Additionally, some minerals and hint elements are covered into prescription drugs and dietary supplements to address precise fitness conditions or nutrient deficiencies.

The vicinity of medical geology and mineralogy targets to understand these interactions between geologic substances and human health to evaluate and manage capability dangers, pick out beneficial sources, and increase preventive measures and remedies. It includes collaboration among geologists, mineralogists, environmental scientists, public fitness specialists, and medical practitioners.

Rocks Geologic materials, specially minerals have been used for recuperation functions for several millennia in several cultures. Lithotherapy turned into practiced till the sixteenth century, but was phased out whilst a extra empirical approach, following the Paracelsian revolution, emerge as embraced in pharmacology. Paracelsus (1493–1541), in comparison to Galen, believed that 3 humours salt, sulfur, and mercury, in proper proportions, had been crucial for health, and separation of 1 humour from the opposite two prompted disorder. By assessment, Galen believed that correct health resulted as long as the four humours inside the frame blood, phlegm, black, and yellow bile remained in balance, and the preponderance of 1 over the others ended in contamination.

Among the metals, arsenic, copper, gold, mercury, and sliver have been generally used for remedy of several illnesses (figure 10).

Figure 10. Showing some kinds of toxic heavy metals (after Electronics Recycling, IT Equipment Disposal & Data Destruction Blog, 2023).

Despite their toxic nature arsenic, copper, and mercury, inside the proper mixture with herbs and distinct materials positioned many applications in ancient medicinal practices. Gold especially was extensively utilized in Arabic medicine and Avicenna used gold filings for remedy of horrible breath, hair loss, melancholy, heart fitness, and as a cauterizing agent for wounds. In Europe, it have become used for treatment of syncope, lassitude, and special troubles. One of the famous formulations, Aurum potabile a pleasing suspension of gold, mixed with unique factors in a suitable consuming fluid, grow to be used to deal with paralysis and cardiac conditions. Pumice, as a geo pharmaceutical material, has been applied in ancient Arabic, Chinese, Greek, and Western medicinal drug as a scientific abrasive, dentifrice, depilatory agent and for cauterization. Some minerals, at the side of alum [$KAl(SO_4)_2 \cdot 12H_2O$], clay, borax ($Na_2B_4O_7 \cdot 10H_2O$), marble ($CaCO_3$), nacre (mother of pearl, aragonite, $CaCO_3$), lapis lazuli [$Na_3Ca(Si_3Al_3)O_{12}S$], lime (CaO), marcasite (FeS_2), orpiment (As_2S_3), not unusual salt ($NaCl$), sulfur, and vitriol (diverse sulfates, e.G., red vitriol, $CoSO_4$; white vitriol, $ZnSO_4$; blue vitriol, $CuSO_4$) endured for use in medicinal components with lots achievement. Some natural geologic substances are used even now in lots of fitness care merchandise. Recently a dehydrated Cuban zeolite paste, referred to as Detox, has been efficaciously used for remedy of pores and pores and skin diseases such as mycosis and intertrigo.

Clays have been utilized in recuperation for over 2000 years, and are applied in healthcare merchandise even these days. Terra sigillata, or "sealed earths," from Greek islands, Malta, Palestine, Armenia, Turkey, and precious Europe were used to therapy numerous maladies, extensively poisoning. It became used appreciably from the 13th to sixteenth centuries and become referred to in all scientific books until the 18th century. Its claimed scientific blessings had been taken into consideration to be related to faith and superstition. However, modern studies have validated that the excessive cation alternate capability of nice clay minerals, which incorporates montmorillonite, that is recognized to soak up risky poisonous heavy metal ions (e.G., As, Hg), might also account to be used of montmorillonite rich samples of terra sigillata as an antidote for poisoning. High absorbency of toxic molecules via kaolin and distinctive clay minerals may provide an explanation for use of sure terra sigillata for effective treatment of gastrointestinal troubles, in particular gastroenteritis.

Minerals are considered as materials that produce poor effects or benefits on fitness. Research on minerals is essential to carry out for you to set up not most effective their programs within the scientific subject however also their consequences on health. In this way, it's miles viable to decide perform the characterization of minerals to set up their bodily and chemical homes with the intention to decide which can have poor outcomes as the case of asbestos or high quality because the case of clays and zeolites . Minerals can exert a strong effect on health and have an effect on this in numerous methods. The precise and high-quality physicochemical homes of a few minerals prefer their useful use within the supply of vital vitamins to produce nutritious food products, environmental remediation and distinct pills. There are numerous programs in medicine, inclusive of the system of pharmaceutical pills in the pharmaceutical industry, the manufacture of dental cements and molds in dentistry, the immobilization by fractures or surgical tactics in traumatology or bone grafts or construction of implants in maxillofacial surgical treatment. The porosity, adsorption capacity and ion trade right-ties of natural zeolites lead them to extraordinarily beneficial in a variety of applications in health sciences as promising automobile to encapsulate and to release capsules. On the opposite hand, some minerals can produce a bad have an impact on due to exposure to risky substances, which includes metallic(loid)s, radioactive metals and isotopes going on naturally in geo resources, which can be launched from their source into the environment as a result of mobilization thru biogeochemical hobby promoted through one-of-a-kind natural and anthropogenic methods. Therefore, substances, which includes As, Pb, Cd, Hg, U and asbestos or their additives may be poisonous, and, in keeping with Fergusson , their consumption by using food, water, soil or air contains out by ingestion, inhalation or dermal absorption. In this manner, considering the physical and chemical residences of the minerals, they may be vital to preserve human health in good situation, but beneath negative situations, deficiency or excess of minerals can affect the technology of sicknesses (Bundschuh .et al, 2016). It is well known that people take benefit of natural sources to fulfil their wishes regardless of what occurs to the surroundings and its impacts (publicity to poisonous stages of trace elements, deficiency of critical trace factors, exposure to mineral dusts or radioactivity) on public fitness, which is the object of look at of relation between Mineralogy and clinical geology.

It is apparent that minerals can without delay have an effect on the nicely-being of billions of humans global, however, this interaction isn't always yet truly understood due in huge element to its complexity, since it relies upon on several factors. On the other hand, there may be a fashionable lack of knowledge of this fact, no longer handiest of the population, in preferred, but also of the clinical network. The principal manner that have interaction directly with human beings and might condition their health through being a vehicle of elements that may be harmful or useful are soil, dust, air and water. In this manner, plenty of the chemical elements that the organism requires are in its surroundings and its deficit or excess can generate a bad or advantageous reaction in human health. Therefore, it's miles a social task to establish the surroundings-fitness link and to recognize the laws that govern this relationship to enhance the pleasant of lifestyles of the populace, improving as a ways as possible the connection with their surroundings. In the sector of Medical Geology, experts and scientists connected to specific branches of technology (geologists, docs, pharmacists, chemists, toxicologists, epidemiologists, hydro geologists, geographers, etc.) seek a purpose-effect relationship in environmental health patterns. Among the troubles that may be addressed are the affects of the factors which might be certainly present in natural dust, in floor and floor waters, or soils, now not forgetting natural radiation or exposure to natural substances within the administrative centre or maybe in city regions. It is also essential to consist of in this context the most surprising geological tactics consisting of volcanic eruptions, earthquakes or tsunamis, whose consequences at the population's health are obtrusive. Medical geology studies the assets, presence, distribution, attention and chemistry of elements that could purpose troubles in human health, trying to set up the exposure channels to, in brief, produce maps that illustrate nearby geological and geochemical factors, regional or international, as well as their relationships with current or ability health troubles.

The sources and consumption pathways of minerals and their derivate chemical factors in addition to the outcomes of pollutants on human health Hazardous substances present in the surroundings due to natural phenomena or anthropogenic sports may additionally reason damaging outcomes on human health. In human fitness, most of the problems are related to the dietary deficiencies and excesses of sure important chemical elements characterised via particular functions I, Ca, Mg, K, Na, Fe, Zn, Cu, F, and Se . It could be very critical to understand the role of minerals in environmental sciences, and, therefore, in human fitness. They are vital to every dwelling being that inhabits the Earth planet. Minerals found in soil, surface and underground water and inside the environment (mineral dust, emissions from volcanic and anthropogenic sports and radon) play a critical function in promoting an untold quantity of gastro-intestinal, muscular–skeletal, breathing and dermatological illnesses (Centeno. et al, 2005) (Combs. et al, 2005) (Nieboer and Sanford , 1984) (Lindh, et al, 2005) (Hochella and Madden, 2005) (Harada, et al, 1999) (Jason, et al, 2002) (Herman and Keri, 2014) (Rice, et al, 2014) (Laffon , et al, 2016) Natural waters play a fundamental role within the transfer of potentially poisonous substances from the physical surroundings to the biosphere, which constitutes a complex dynamic interrelation among the surroundings and human fitness. The geological surroundings is the only that conditions the presence of certain chemical elements in surface and groundwater to a more volume and, even though rocks and minerals generally do now not have high concentrations of heavy metals, it is relatively clean to locate waters with concentrations that exceed those allowed for ingesting water by using the World Health Organization (WHO). Society will need to face the future of water sources on a globalized planet. The floor and underground hydric assets represents a supply of water supply, even though anthropogenic assets of contaminants from mining, agriculture, home and business wastes were affecting its water high-quality. The contamination of water promotes the lack of fauna and flowers as shielding elements and pleasant of existence and deteriorates the environment and, consequently, the first-class of lifestyles of humans. In business processes, mainly in mining operations, electroplating flowers, energy plants, equipment factories, and tanneries, liquid effluents are generated with high concentrations of exceptionally poisonous, non-biodegradable and carcinogenic substances

Metals occur evidently within the Earth's crust as a blended country or as a free country. The geographical distribution of metals can vary between extraordinary areas resulting in spatial variations of heritage concentrations, that is ruled with the aid of the bodily and chemical houses of metals and several environmental elements (figure 11).

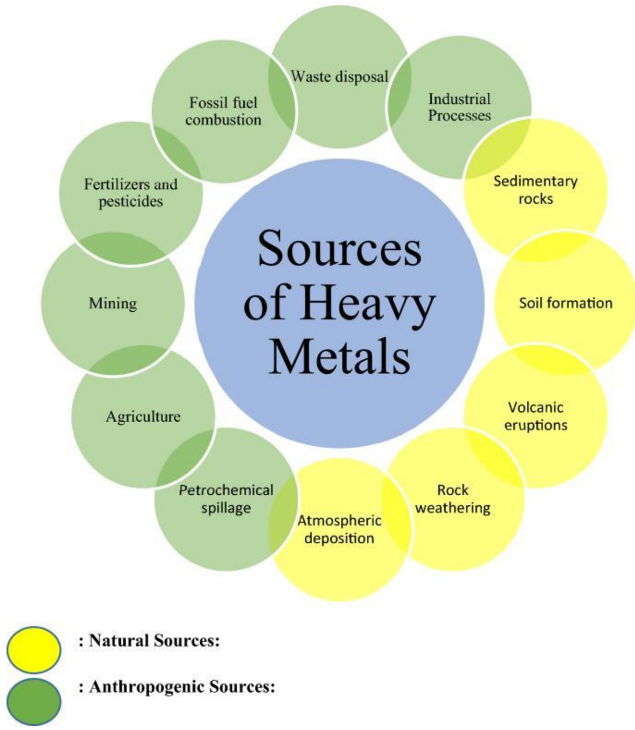

Figure 11. A graphic showing sources of heavy metals (after Nnabueze Darlington Nnaji, 2023).

Approximately 30 metals and metalloids are doubtlessly poisonous. Heavy metals are the common term for metal factors having an atomic weight better than 40.04. However, those are acknowledged each for their excessive density and for their negative effects on ecosystems and residing beings Heavy metals are dispensed inside the surroundings via numerous natural techniques consisting of volcanic eruptions, spring waters, erosion, and bacterial interest, and via anthropogenic activities including fossil gas combustion, mining, industrial discharges, urban runoff, sewage effluents, pest or ailment manipulate retailers implemented to vegetation, air pollutants fallout, feeding and some of others. (Khlifi and Hamza-Chaffai , 2010) (Morais, et al, 2012) (Ming, et al, 2011) (Bradl, 2002) (Najar, et al, 2015) Although heavy metals are found in several ecosystems, their publicity to living beings is thru various anthropogenic activities. Heavy metals occur in ore minerals, which might be exploited thru open pit or underground mining. They can exist both as sulfides (argentite, Ag_2S; sphalerite, ZnS; cinnabar, HgS; stibine, Sb_2S_3; galena, PbS; oropiment, As_2S_3; rejalgar, AsS; pyrite, FeS_2) or oxides (magnetite, Fe_3O_4; hematite, Fe_2O_3; cuprite, Cu_2O; casiterite, SnO_2; pyrolusite, MnO_2; uraninite, U_2O). Some heavy metals can exist both as sulfides and oxides and in some minerals together with chalcopyrite ($CuFeS_2$) as a minimum two heavy metals can occur collectively. As mentioned earlier that heavy metals occur in mineral ores as a close machine (figure 12).

Figure 12. Showing pictures of pure toxic heavy metals (after Homedoc.tech, 2022).

As may be lethal to livings beings while being uncovered to this element via several approach, which encompass resources as smelting and microelectronic industries, and its toxic results rely specifically on oxidation kingdom and chemical species, among others. Drinking water may be contaminated with As that is present in wood preservatives, herbicides, insecticides, fungicides and paints. As is taken into consideration carcinogenic and is associated mainly to lung, kidney, bladder, and pores and skin disorders.

The foremost sources of Pb exposure consist of drinking water, food, cigarette, industrial processes and domestic sources. The industrial resources of Pb include gas, residence paint, plumbing pipes, lead bullets, garage batteries, sheets for roofing to screens for X-rays and radioactive emissions, pewter pitchers, toys and faucets. Pb as a toxicologically relevant detail has been brought into the environment by way of man in extreme amounts, notwithstanding its low geochemical mobility and has been distributed worldwide. Pb is released into the ecosystem from business approaches as well as from vehicle exhausts. Therefore, it may enter the soil and circulate the aquifers, and human Pb exposure can also be thru food or ingesting water (Oehlenschläger, 2002) (Thurmer, 2002) (Wani, et al, 2015). The tannery industry no longer handiest generates a large quantity of toxic waste however additionally has poor results on the environment and human fitness. In those effluents, Cr may be found as Cr6 or Cr3 ; however, Cr6 form may be very poisonous, mutagenic, and carcinogenic. Exposure to Cr may additionally purpose many persistent illnesses inclusive of dermatitis, perforation of the nasal septum, respiratory illness, and lung and nasal cancer (Bulut and Tez, 2007) (Pandey, et al, 2010).

Cd is generally used in the manufacturing of paints, pigment alloys, coatings, batteries, and plastics, but, most of the Cd is fed on in the production of alkaline batteries. Significant human exposure to

Cd may be due to ingestion of contaminated meals and drinks or by way of inhalation thru incineration of municipal waste (Engwa, et al, 2015) (Unaegbu, et al, 2016). Cu is used within the manufacturing of tubes, cables, wires, kitchen utensils, intrauterine devices, and beginning manage capsules or in water treatment. This detail can accumulate within the soil and be absorbed by flora (Agency for Toxic Substances and Disease Registry, 2004). Gasoline vapours include VOCs that make contributions to the formation of ground-stage ozone. In addition, they incorporate many other poisonous materials, consisting of Mn, like different elements, can't be degraded in the environment but can change shape or adhere or detach itself from debris. The Mn-containing agent brought to gas can hastily degrade within the surroundings whilst uncovered to natural light, thereby releasing Mn. However, there are factors that determine whether or not publicity to Mn may be harmful or not (Ferner, 2001).

Ni is used inside the manufacturing of batteries, nickel-plated jewellery, device components, nickel plating on metallic objects, steel fabrication, cigarette smoking, cables, electrical parts, etc. This element can also be located in contaminated meals and alcoholic liquids (Ferner, 2001).

Discussion

Medical geology research can help identify and quantify the levels of potentially harmful substances in the environment, providing a foundation for evidence-based public health policies and regulations. By understanding the geological factors that contribute to environmental health risks, policymakers can develop targeted interventions, such as water treatment systems, soil remediation strategies, and air quality monitoring programs, to mitigate these risks. Medical geology findings can inform the development of public health programs and initiatives that address the specific needs of communities affected by environmental health issues, ensuring that interventions are tailored and effective. Geologists provide expertise in understanding the Earth's geological processes and the distribution of naturally occurring substances, which is crucial for identifying potential health risks.

Epidemiologists contribute their knowledge of disease patterns, risk factors, and population-level health outcomes, helping to connect geological factors to their impacts on human and environmental health. Toxicologists bring their expertise in understanding the mechanisms by which exposure to harmful substances can affect biological systems, informing the assessment of health risks and the development of appropriate interventions. Public health professionals play a crucial role in translating medical geology findings into actionable policies, programs, and community engagement strategies to improve health outcomes. Medical geologists can help identify and monitor the presence of naturally occurring contaminants, such as arsenic or fluoride, in water sources, informing efforts to ensure safe and accessible drinking water.

By understanding the geological composition and nutrient availability of soils, medical geologists can support the development of sustainable agricultural practices and the production of nutrient-rich food supplies. Medical geology research can contribute to the understanding of how geological factors, such as mineral dust or volcanic emissions, can influence air quality and respiratory health, guiding the implementation of effective air quality monitoring and mitigation strategies. Insights from medical geology can help identify the geological factors that contribute to the prevalence of certain diseases, informing the development of targeted prevention and control measures, such as nutritional supplementation programs or environmental remediation efforts.

Continued advancements in analytical tools and technologies, such as remote sensing, geospatial analysis, and high-resolution spectroscopy, can enhance the ability of medical geologists to accurately identify and quantify environmental health risks. The integration of large, diverse datasets from various sources, including environmental monitoring, epidemiological studies, and socioeconomic information, can provide a more comprehensive understanding of the complex interactions between geological factors and health outcomes. Continued efforts to strengthen interdisciplinary collaboration between medical geologists, public health professionals, policymakers, and community stakeholders can ensure that research findings are effectively translated into practical solutions and interventions.

Learning medical geology helps students to become aware of the health risks associated with geological factors like soil composition, water quality, and mineral deposits. This knowledge empowers them to identify potential health hazards in their surroundings. By understanding the geological sources of diseases such as arsenic poisoning, fluorosis, and radon exposure, students can take preventive measures to avoid these conditions. Knowing the geological origins of health issues allows individuals to make informed choices about their living environment and lifestyle. Medical geology integrates principles from geology, environmental science, public health, and medicine, providing students with an interdisciplinary learning experience. This field promotes critical thinking and problem-solving skills by fostering a holistic understanding of the connections between Earth's processes and human health. Exposure to medical geology in school can inspire students to pursue careers in geology, environmental science, public health, or medicine.

Understanding the impact of geological processes on health outcomes opens up various career paths, including environmental monitoring, hazard assessment, and epidemiological research. Studying medical geology goes beyond the classroom, sparking a lifelong interest in Earth sciences and public health. Whether pursuing further education or engaging in citizen science projects, students with knowledge of medical geology continue to contribute to scientific inquiry and the well-being of society throughout their lives.

Applying medical geology in schools can be systemized by deciding what each educational level need by using potential applications. in elementary school; introducing the concept of the Earth's geological processes and their connection to human and environmental health through hands-on activities and field trips. In middle school; exploring the role of essential nutrients and toxic substances in the environment, and how they can impact health and development. In high school; integrating medical geology principles into science curricula, such as by analysing water quality data or investigating the effects of mining activities on local communities.

Conclusion and Recommendations

The geological environment has a profound impact on human health, both through the presence of heavy metals and the exposure to natural radiation. The toxic effects of substances like cadmium, lead, and mercury can lead to a range of serious health issues, including neurological damage, organ failure, and increased cancer risk. Similarly, exposure to ionizing radiation from sources like radon gas can significantly elevate the chances of developing various forms of cancer. To mitigate these geological health risks, a multifaceted approach is necessary. This includes reducing environmental pollution, improving water and soil quality, and implementing strict regulations on the use and disposal of hazardous materials. Individuals can also take steps to limit their exposure, such as testing their homes for radon, using water filters, and being mindful of potential sources of heavy metal contamination in food and consumer products. Ultimately, by understanding the complex interplay between the geological environment and human health, we can develop more effective strategies for protecting public well-being and ensuring a sustainable future. Continued research, education, and collaboration between scientists, policymakers, and communities will be essential in addressing these critical challenges. Only through a comprehensive, proactive approach can we hope to safeguard the health and well-being of present and future generations.

Learning medical geology helps students to become aware of the health risks associated with geological factors like soil composition, water quality, and mineral deposits. This knowledge empowers them to identify potential health hazards in their surroundings. Exposure to medical geology in school can inspire students to pursue careers in geology, environmental science, public health, or medicine. Applying medical geology in schools can be systemized by deciding what each educational level need by using potential applications. In elementary school; introducing the concept of the Earth's geological processes and their connection to human and environmental health through hands-on activities and field trips. In middle school; exploring the role of essential nutrients and toxic substances in the environment, and how they can impact health and development. In high school; integrating medical geology principles into science curricula, such as by analysing water quality data or investigating the effects of mining activities on local communities.

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