iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** IX **Month of publication:** September 2023

DOI: https://doi.org/10.22214/ijraset.2023.55616

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue IX Sep 2023- Available at www.ijraset.com

Medical Geology Related to Different Trace Elements Deficiency and Toxicity Diseases

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Abstract: Medical geology is an emerging discipline that, broadly defined, examines the public health impacts of geologic materials and geologic processes. Medical Geology, the study of the impacts of geologic materials and processes on animal and human health, is a dynamic emerging discipline bringing together the geosciences, biomedical, and public health communities to solve a wide range of environmental health problems. Among the Medical Geology described in this review are examples of both deficiency and toxicity of trace element exposure. Goiter is a widespread and potentially serious health problem caused by deficiency of iodine. In many locations the deficiency is attributable to low concentrations of iodine in the bedrock. Similarly, deficiency of selenium in the soil has been cited as the principal cause of juvenile cardiomyopathy and muscular abnormalities. Overexposure to arsenic is one of the most widespread Medical Geology problems affecting more than one hundred million people in Bangladesh, India, China, Europe, Africa and North and South America. The arsenic exposure is primarily due to naturally high levels in groundwater but combustion of mineralized coal has also caused arsenic poisoning. Dental and skeletal fluorosis also impacts the health of millions of people around the world and, like arsenic, is due to naturally high concentrations in drinking water and, to a lesser extent, coal combustion. Other Medical Geology issues described include geophagia, the deliberate ingestion of soil, exposure to radon, and ingestion of high concentrations of organic compounds in drinking water. Geosciences and biomedical/public health researchers are teaming to help mitigate these health problems.

I. INTRODUCTION

Medical geology is a developing field that mainly define how geological process and materials affect the health of human being and other animals.

It helps to bring the geological science, biomedical, and public health communities together to solve a wide range of environmental health problems. Geologic materials such as rocks, soils, dusts and volcanic materials can contain naturally elevated levels of elements, minerals, other compounds or microbes that harm or benefit human health. Medical geologists work with health scientists to help in improving public health.

The scope and range of medical geology include:

1) Identifying and characterizing natural and anthropogenic sources of harmful materials in the environment
2) Learning how to predict the movement and alteration of chemical, infectious, and other disease-causing agents over time and space
3) Understanding how people are exposed to such materials and what can be done to minimize or prevent such exposure.

Emerging diseases can present the medical community with many difficult problems. However, emerging disciplines may offer the medical community new opportunities to address a range of health problems including emerging diseases. One such emerging discipline is Medical Geology. Medical Geology is a rapidly growing discipline that has the potential of helping the medical community in the Asia Pacific Region and elsewhere to pursue a wide range of environmental health issues.

Among the environmental health problems that geologists and the medical community need to collaborate on include: exposure to natural dust and to radioactivity; exposure to toxic levels of trace essential and non-essential elements such as arsenic and mercury; nutrient trace element deficiencies; naturally occurring toxic organic and inorganic compounds in drinking water; identification and effects of volcanic emissions, etc. Geoscientists have also developed an array of tools and databases that can be used by the environmental health community to study vector-borne diseases, to model the dispersion of pollutants in surface and ground water and in the air, and can be applied to occupational health problems resulting from exposure to minerals.

Essential minerals and trace elements have well-characterized physiological functions
within the body and must be supplied by the diet. Dietary Reference Intakes for the various minerals and by life stage groups have been derived by the North American Institute of Medicine.

Inappropriate intakes and/or elevated requirements resulting from a range of conditions, including disease, malabsorption, some medicines, and excessive losses, will eventually lead to a state of deficiency or toxicity with associated pathophysiology. For many minerals, there are no simple, sensitive and specific biomarkers of status so deficiency or toxicity may not be diagnosed until fairly well advanced, at which point the patient may present with clinical signs or symptoms. With a poor diet, it is likely that multiple micronutrient deficiencies will occur, but there are also rare genetic mutations that affect the metabolism of single minerals or trace elements; these are usually unrelated to diet.

II. TRACE ELEMENT EXPOSURE: DEFICIENCY AND TOXICITY

Trace elements play an essential role in the normal metabolism and physiological functions of animals and humans. Some 22 such elements are known or thought to be "essential" for humans and other animals. "Macronutrients" are required in fairly large amounts (e.g., grams per kilogram of diet), whereas "micronutrients" are required in much smaller amounts (e.g., microgram-to milligrams per kilogram of diet). Sixteen elements are established as being essential for good health. Calcium, phosphorus, magnesium, and fluoride for example, are required for structural functions in bone and membranes. Sodium, potassium, and chloride are required for the maintenance of water and electrolyte balance in cells. Zinc, copper, selenium, manganese, and molybdenum are essential constituents of enzymes or serve as carriers (iron) for ligands essential in metabolism. Chemical elements are also important in the functioning of the endocrine system. For instance, iodine is an essential component of the thyroid hormone thyroxine, and chromium is the central atom of the hormone-like glucose tolerance factor. Because these are all critical life functions, the tissue levels of many "nutritionally essential elements" tend to be regulated within certain ranges, and dependent on several physiological processes, especially homeostatic control of enteric absorption, tissue storage, and/or excretion. Changes in these physiological processes may exacerbate the effects of short-term dietary deficiencies or excess of trace elements. Food is a major source of trace elements in humans and animals. However, other sources such as the deliberate eating of soil (geophagia) and water supplies may also contribute to dietary intake of trace elements. Diseases due to trace element deficiencies as well as excesses are known for iodine, copper, zinc, selenium, molybdenum, manganese, iron, calcium, arsenic, and cadmium. Endemic diseases correlative with soil deficiencies in selenium and iodine have been described in at least two general cases, the juvenile cardiomyopathy "Keshan Disease" and the iodine deficiency disorders including goiter and myxedematous cretinism respectively. In the following paragraphs, examples of adverse health effects due to trace element deficiencies and excesses are described. Chronic exposure to non-essential elements such as arsenic is also described.

Table 1. Major functions of minerals and trace elements

Minerals	
Calcium	Structural (bones, teeth), extracellular cation (neural transmission, muscle contraction, vascular tone)
Magnesium	>300 enzymatic processes, bone health, maintenance of intracellular levels of K and Ca
Phosphorus	Structural (bones, teeth, phospholipids), acid-base balance, protein activation via phosphorylation
Potassium	Intracellular cation (neural transmission, muscle contraction, vascular tone)
Sodium	Extracellular cation, membrane potential, membrane transport
Chloride	Extracellular anion, fluid and electrolyte balance, gastric juice
Trace elements	
Copper	Metalloenzymes, red blood cell formation, connective tissues
Fluoride	Not an essential nutrient but present as fluorohydroxyapatite in tooth enamel
Iodine	Thyroid hormones
Iron	Heme proteins, flavoproteins, other enzymes
Manganese	Metalloenzymes, bone formation
Selenium	Selenoproteins, thyroid hormone, redox status
Zinc	>100 enzymes, growth, development, gene expression

A. *Iodine Deficiency and Toxicity Diseases*

Geological factors contribute to both iodine deficiency and iodine toxicity by influencing the presence and distribution of iodine in soil, water, and subsequently the food chain. Here's how geological factors play a role in causing these conditions:

1) *Iodine Deficiency*

a) *Low Iodine Content in Soil:* Certain geological formations, such as those found in mountainous regions and areas with ancient seabed's, may have soil that is naturally low in iodine. When crops are grown in iodine-deficient soil, they absorb minimal amounts of iodine, leading to low iodine levels in the food produced. This deficiency in the food supply can result in inadequate iodine intake in human diets.

b) *Groundwater Composition:* Geological factors influence the composition of groundwater in a region. Areas with low iodine content in groundwater may have limited sources of iodine for irrigation, leading to lower iodine levels in crops. Inhabitants who rely on groundwater for drinking and cooking can also be at risk of iodine deficiency.

2) *Iodine Toxicity*

a) *High Iodine Content in Soil and Water:* Geological formations rich in iodine, such as those found in certain coastal regions and areas near volcanic activity, can lead to soil and water with elevated iodine levels. Crops grown in such soil can accumulate excessive amounts of iodine. Additionally, drinking water from these regions may contain high iodine levels. Consuming these iodine-rich crops and water sources can lead to iodine toxicity.

b) *Seawater Influence:* Coastal geological settings can introduce iodine from seawater into the local environment. Seafood harvested from these areas can have high iodine content due to the iodine-rich marine environment. Overconsumption of such seafood can contribute to iodine toxicity.

3) *Diseases Associated with Iodine Deficiency*

a) *Goiter:* Iodine deficiency can lead to an enlarged thyroid gland, known as a goiter [Fig 1]. The thyroid gland enlarges in an attempt to produce more thyroid hormones, resulting in a visible swelling in the neck.

b) *Cretinism:* Severe iodine deficiency during pregnancy can lead to cretinism in infants, characterized by profound intellectual and developmental impairments.

4) *Diseases Associated with Iodine Toxicity*

a) *Hyperthyroidism:* Excessive iodine intake can disrupt thyroid function and lead to hyperthyroidism, a condition where the thyroid gland produces an excess of thyroid hormones. This can result in symptoms like weight loss, rapid heartbeat, and anxiety.

b) *Thyroiditis:* High iodine levels can trigger thyroiditis, which is inflammation of the thyroid gland. This can cause pain and swelling in the neck.

In both cases, understanding the geological factors of a region is crucial for addressing iodine-related health issues. Iodine supplementation, iodized salt programs, and educating the population about balanced iodine consumption are essential strategies to combat iodine deficiency. Monitoring iodine levels in local food sources and water and promoting moderation in iodine-rich regions are important for preventing iodine toxicity.

Ultimately, the geological context of an area significantly influences the presence of iodine in the environment, impacting the prevalence of iodine deficiency and toxicity diseases within the population.

Fig 1: Iodine deficiency Disease Goiter

Fig 2: Iodine deficiency Disease Cretinism

B. Iron Deficiency and Toxicity Diseases

Geological factors can play a role in both iron deficiency and iron toxicity by affecting the availability and distribution of iron in soil, water, and the food chain. Here's how geological factors contribute to these conditions:

1) *Iron Deficiency*
a) *Low Iron Content in Soil:* Geological formations and soil types can vary in their iron content. Soils with low iron content may result in crops that are deficient in iron. This deficiency is then passed on to humans who consume these crops. Iron is essential for the production of hemoglobin in red blood cells, and its deficiency can lead to anemia and related health issues.
b) *Acidic Soils:* Some geological regions have naturally acidic soils. Acidic soils can inhibit the absorption of iron by plants, making it more difficult for crops to take up the available iron. As a result, the iron content in these crops may be lower, contributing to iron deficiency in populations relying on such crops.

2) *Iron Toxicity*
a) *High Iron Content in Soil and Water:* Certain geological formations can contain higher levels of iron. If crops are grown in soil with excessive iron content, they can accumulate higher levels of iron. Moreover, iron-rich water sources in some regions can contribute to higher iron intake through drinking water.

3) *Diseases Associated with Iron Deficiency*
a) *Iron-Deficiency Anemia:* Insufficient iron intake leads to a decrease in the production of hemoglobin, the protein responsible for transporting oxygen in the blood. Iron-deficiency anemia [Fig 2] can result in fatigue, weakness, and decreased cognitive function.

4) *Diseases Associated with Iron Toxicity*
a) *Hemochromatosis:* Iron toxicity, also known as hemochromatosis [Fig 4], occurs when there is an excessive accumulation of iron in the body. While this condition is primarily related to genetic factors, consuming excessive iron from the diet can exacerbate the condition. Hemochromatosis can lead to damage to various organs, including the liver, heart, and pancreas.

In both cases, geological factors can influence the iron content of soil, water, and crops, which in turn affects the iron intake of human populations. Strategies to address these issues include:

5) *For Iron Deficiency*
a) *Iron Supplementation:* Providing iron supplements to individuals at risk of deficiency, particularly pregnant women and young children.
b) *Dietary Diversification:* Promoting a diverse diet that includes iron-rich foods, such as lean meats, legumes, leafy greens, and fortified foods.

6) *For Iron Toxicity*
a) *Water Source Monitoring:* Regularly monitoring iron levels in water sources to prevent excessive iron intake through drinking water.
b) *Balanced Diet:* Encouraging a balanced diet to prevent overconsumption of iron-rich foods, particularly for individuals who are at risk due to genetic factors.

While geological factors play a role in iron deficiency and toxicity, genetic factors, dietary choices, and cultural practices also contribute significantly to these conditions. Therefore, a comprehensive approach that takes into account both geological and non-geological factors is essential to addressing iron-related health issues.

Fig 2: Iron Deficiency Disease Anemia

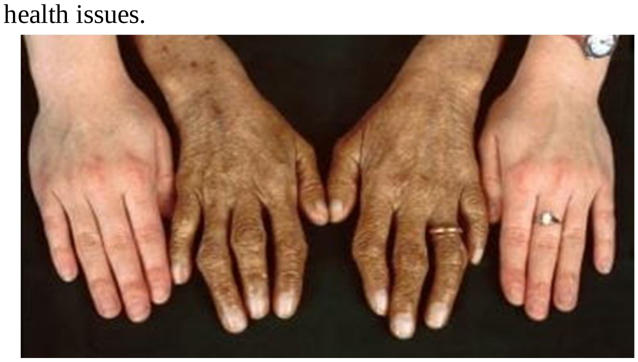

Fig 3: Iron Toxicity disease Hemochromatosis

C. Selenium Deficiency and Toxicity Disease

1) Selenium Deficiency

c) *Low Selenium Content in Soil:* Geological formations and soil types vary in their selenium content. Regions with selenium-poor soil may lead to crops that are deficient in selenium. This deficiency can then affect the selenium intake of animals and humans consuming these crops. Selenium is important for antioxidant function, thyroid hormone metabolism, and immune system health.

d) *Acidic Soils:* Just like with other nutrients, soil acidity can impact the availability of selenium to plants. Acidic soils can reduce the bioavailability of selenium, leading to lower selenium content in crops and the food chain.

2) Selenium Toxicity

a) *High Selenium Content in Soil and Water:* Geological formations with high selenium content can result in soil and water that contain elevated levels of selenium. This can lead to crops accumulating higher-than-normal levels of selenium, especially in areas with excessive selenium in groundwater. Crops grown in these regions can pose a risk of selenium toxicity when consumed.

3) Diseases Associated with Selenium Deficiency

a) *Keshan Disease:* A deficiency of selenium, often combined with other factors like viral infections and low antioxidant intake, has been linked to Keshan disease. This condition primarily affects the heart and can lead to an enlarged heart and heart failure.

b) Kashin-Beck Disease: Another condition associated with selenium deficiency, Kashin-Beck disease [Fig 5] primarily affects the bones and joints, leading to growth impairment and joint deformities.

4) Diseases Associated with Selenium Toxicity

a) *Selenosis:* Prolonged exposure to high levels of selenium, usually through the consumption of selenium-rich foods, can lead to selenosis [Fig 6]. Symptoms can include gastrointestinal disturbances, hair and nail changes, and in severe cases, neurological issues.

In both deficiency and toxicity cases, understanding the geological context of an area is crucial for assessing the potential risks to human health. Strategies to address these issues include:

5) For Selenium Deficiency

a) *Selenium Supplementation:* Providing selenium supplements to populations at risk of deficiency, especially in areas where soil selenium content is low.

b) *Dietary Diversification:* Encouraging a diverse diet that includes selenium-rich foods such as seafood, nuts, whole grains, and lean meats.

6) For Selenium Toxicity

a) *Water Source Monitoring:* Regularly monitoring selenium levels in water sources, particularly in areas with geological formations that are selenium-rich.

b) *Balanced Diet:* Promoting a balanced diet to prevent overconsumption of selenium-rich foods, particularly in regions where the local environment contributes to elevated selenium levels.

Geological factors play a significant role in shaping the selenium content of soil and water, which in turn affects the health of plant and animal populations and, ultimately, human populations. A comprehensive approach that considers geological, agricultural, and dietary factors is important for mitigating selenium-related health issues.

Fig 5: Selenium Deficiency Disease called Kashin-Beck Disease.


Fig 6: Selenium Toxicity Disease called selenosis

D. Copper Deficiency and toxicity Disease

Geological factors can influence the levels of copper in soil and water, thereby contributing to both copper deficiency and copper toxicity in human populations. Copper is an essential trace element that plays a crucial role in various physiological processes. Here's how geological factors contribute to these conditions:

1) Copper Deficiency

a) *Low Copper Content in Soil:* Geological formations and soil types vary in their copper content. Regions with copper-poor soil may lead to crops that are deficient in copper. This deficiency can then affect the copper intake of animals and humans consuming these crops. Copper is important for enzyme function, iron metabolism, and overall growth and development.

b) *Alkaline Soils:* Soil pH can influence the availability of copper to plants. Alkaline soils can reduce the solubility of copper, making it less available for uptake by plants. This can contribute to lower copper content in crops and the food chain.

2) Copper Toxicity

a) *High Copper Content in Soil and Water:* Geological formations with high copper content can result in soil and water that contain elevated levels of copper. This can lead to crops accumulating higher-than-normal levels of copper, especially in areas with excessive copper in groundwater or soil. Crops grown in these regions can pose a risk of copper toxicity when consumed.

3) Diseases Associated with Copper Deficiency

a) *Menkes Disease [Fig 7]:* A rare genetic disorder that results in severe copper deficiency due to impaired copper absorption. This condition can lead to developmental delays, neurological issues, and physical abnormalities.

b) *Copper Deficiency Anemia:* Copper is necessary for the absorption of iron from the intestines. Copper deficiency can indirectly lead to anemia due to impaired iron utilization.

4) Diseases Associated with Copper Toxicity

a) *Wilson's Disease [Fig 8]:* A genetic disorder that leads to the accumulation of copper in various organs, primarily the liver and brain. This can result in liver damage, neurological symptoms, and psychiatric issues.

b) *Acute Copper Poisoning:* Consumption of high levels of copper, often from contaminated water or food, can lead to acute copper poisoning. Symptoms can include vomiting, diarrhea, abdominal pain, and in severe cases, liver and kidney damage.

In both deficiency and toxicity cases, understanding the geological context of an area is important for assessing the potential risks to human health. Strategies to address these issues include:

5) For Copper Deficiency

a) *Copper Supplementation:* Providing copper supplements to populations at risk of deficiency, especially in areas where soil copper content is low.

b) *Dietary Diversification:* Encouraging a diverse diet that includes copper-rich foods such as organ meats, seafood, nuts, and whole grains.

6) For Copper Toxicity

a) *Water Source Monitoring:* Regularly monitoring copper levels in water sources, particularly in areas with geological formations that are copper-rich.

b) *Balanced Diet:* Promoting a balanced diet to prevent overconsumption of copper-rich foods, particularly in regions where the local environment contributes to elevated copper levels.

Geological factors play a significant role in shaping the copper content of soil and water, which in turn affects the health of plant and animal populations and, ultimately, human populations. A comprehensive approach that considers geological, agricultural, and dietary factors is important for mitigating copper-related health issues.

Fig 7: Copper Deficiency Disease Menkes Disease

Fig 8: Copper Toxicity Disease Wilson Disease

E. Zinc Deficiency and Toxicity Disease

Geological factors can influence the levels of zinc in soil and water, thereby contributing to both zinc deficiency and zinc toxicity in human populations. Zinc is an essential trace element that plays a crucial role in various physiological processes. Here's how geological factors contribute to these conditions:

a) *Low Zinc Content in Soil:* Geological formations and soil types vary in their zinc content. Regions with zinc-poor soil may lead to crops that are deficient in zinc. This deficiency can then affect the zinc intake of animals and humans consuming these crops. Zinc is essential for immune function, wound healing, and proper growth and development.
b) *High pH and Calcareous Soils:* High soil pH and calcareous soils can hinder the availability of zinc to plants. These conditions can reduce the solubility of zinc, making it less accessible to plant roots. As a result, crops grown in these soils might have lower zinc content.

1) Zinc Toxicity

High Zinc Content in Soil and Water: Geological formations with high zinc content can result in soil and water that contain elevated levels of zinc. Crops grown in these regions can accumulate higher-than-normal levels of zinc, especially in areas with excessive zinc in groundwater. Consuming crops and water sources with elevated zinc content can contribute to zinc toxicity.

2) Diseases Associated with Zinc Deficiency

a) *Zinc Deficiency Disorders:* Zinc deficiency can lead to various health issues, including impaired growth, compromised immune function, skin disorders, and delayed wound healing.

3) Diseases Associated with Zinc Toxicity

a) *Zinc Overexposure:* High levels of zinc exposure, typically through occupational or environmental sources, can lead to symptoms such as nausea, vomiting, diarrhea, and abdominal pain. Prolonged exposure can result in more severe health issues.

In both deficiency and toxicity cases, understanding the geological context of an area is important for assessing the potential risks to human health. Strategies to address these issues include:

4) For Zinc Deficiency

a) *Zinc Supplementation:* Providing zinc supplements to populations at risk of deficiency, especially in areas where soil zinc content is low.
b) *Dietary Diversification:* Encouraging a diverse diet that includes zinc-rich foods such as meat, poultry, seafood, legumes, nuts, and whole grains.

5) *For Zinc Toxicity*
a) *Water Source Monitoring:* Regularly monitoring zinc levels in water sources, particularly in areas with geological formations that are zinc-rich.
b) *Balanced Diet:* Promoting a balanced diet to prevent overconsumption of zinc-rich foods, particularly in regions where the local environment contributes to elevated zinc levels.

Geological factors play a significant role in shaping the zinc content of soil and water, which in turn affects the health of plant and animal populations and, ultimately, human populations. A comprehensive approach that considers geological, agricultural, and dietary factors is important for mitigating zinc-related health issues.

F. Fluoride Deficiency and Toxicity Disease
a) *Low Fluoride Content in Soil:* Geological formations and soil types vary in their fluoride content. Regions with fluoride-poor soil may lead to crops that are deficient in fluoride. This deficiency can then affect the fluoride intake of animals and humans consuming these crops. Fluoride is essential for promoting dental health and preventing tooth decay.
b) *Low Fluoride Concentration in Water:* Geological formations also influence the fluoride content of groundwater. Areas with naturally low fluoride levels in groundwater may have limited sources of fluoride for drinking and irrigation. Inhabitants relying on such water sources can be at risk of fluoride deficiency.

1) *Fluoride Toxicity*
a) *High Fluoride Content in Soil and Water:* Geological formations with high fluoride content can result in soil and water that contain elevated levels of fluoride. Crops grown in these regions can accumulate higher-than-normal levels of fluoride, especially in areas with excessive fluoride in groundwater. Consuming crops and water sources with elevated fluoride content can lead to fluoride toxicity.

2) *Diseases Associated with Fluoride Deficiency*
a) *Dental Cavities:* Fluoride deficiency can lead to an increased risk of dental cavities and tooth decay, as fluoride helps strengthen tooth enamel and protect against acid attacks.

3) *Diseases Associated with Fluoride Toxicity*
a) *Dental Fluorosis:* Chronic consumption of high levels of fluoride, especially during tooth development, can lead to dental fluorosis, a condition characterized by discoloration and weakening of tooth enamel.
b) *Skeletal Fluorosis [Fig 9]:* Long-term exposure to high levels of fluoride can cause skeletal fluorosis, a condition that affects the bones and joints. It leads to joint pain, limited mobility, and bone deformities.

In both deficiency and toxicity cases, understanding the geological context of an area is crucial for assessing the potential risks to human health. Strategies to address these issues include:

4) *For Fluoride Deficiency*
a) *Fluoride Supplementation:* Providing fluoride supplements to populations at risk of deficiency, especially in areas with low natural fluoride content in soil and water.
b) *Fluoridated Water:* Implementing water fluoridation programs to ensure an optimal level of fluoride in drinking water for promoting dental health.

5) *For Fluoride Toxicity*
a) *Water Source Monitoring:* Regularly monitoring fluoride levels in water sources, particularly in areas with geological formations that are fluoride-rich.
b) *Balanced Diet:* Promoting a balanced diet and diversified water sources to prevent overconsumption of fluoride-rich foods and water.

Geological factors play a significant role in shaping the fluoride content of soil and water, which in turn affects dental and skeletal health. An integrated approach that considers geological, environmental, and dietary factors is essential for managing fluoride-related health issues.

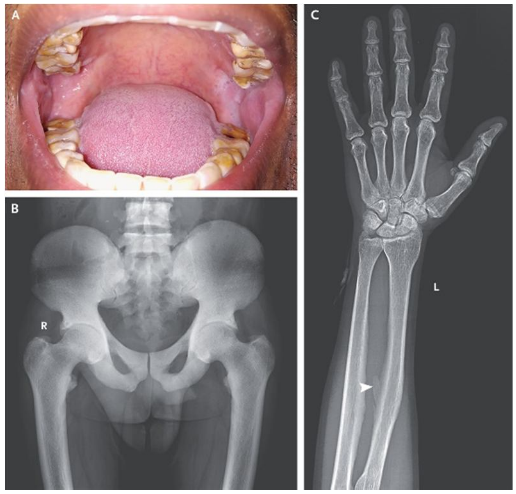

Fig 9: Fluoride Deficiency Disease called Skeletal Fluorosis

G. *Manganese Deficiency and Toxicity Disease*

Low Manganese Content in Soil: Geological formations and soil types vary in their manganese content. Regions with manganese-poor soil may lead to crops that are deficient in manganese. This deficiency can then affect the manganese intake of animals and humans consuming these crops. Manganese is important for bone health, enzyme function, and metabolism.

1) *Manganese Toxicity*
   a) *High Manganese Content in Soil and Water:* Geological formations with high manganese content can result in soil and water that contain elevated levels of manganese. Crops grown in these regions can accumulate higher-than-normal levels of manganese. Consuming these crops and water sources can contribute to manganese toxicity.

2) *Diseases Associated with Manganese Deficiency*
   a) *Manganese Deficiency Disorders:* Manganese deficiency can lead to various health issues, including impaired growth, skeletal abnormalities, and issues related to carbohydrate metabolism.

3) *Diseases Associated with Manganese Toxicity*
   a) *Manganism:* Chronic exposure to high levels of manganese, often through occupational or environmental sources, can lead to manganism. This condition resembles Parkinson's disease and is characterized by tremors, muscle rigidity, and other neurological symptoms.

In both deficiency and toxicity cases, understanding the geological context of an area is important for assessing the potential risks to human health. Strategies to address these issues include:

4) *For Manganese Deficiency*
   a) *Manganese Supplementation:* Providing manganese supplements to populations at risk of deficiency, especially in areas where soil manganese content is low.
   b) *Dietary Diversification:* Encouraging a diverse diet that includes manganese-rich foods such as nuts, whole grains, legumes, and leafy greens.

5) *For Manganese Toxicity*
   a) *Water Source Monitoring:* Regularly monitoring manganese levels in water sources, particularly in areas with geological formations that are manganese-rich.
   b) *Balanced Diet:* Promoting a balanced diet to prevent overconsumption of manganese-rich foods, particularly in regions where the local environment contributes to elevated manganese levels.

Geological factors play a significant role in shaping the manganese content of soil and water, which in turn affects the health of plant and animal populations and, ultimately, human populations. A comprehensive approach that considers geological, agricultural, and dietary factors is important for mitigating manganese-related health issues.

III. THE ROLE OF MINERALS AND TRACE ELEMENTS IN THE ETIOLOGY AND MANAGEMENT OF VARIOUS DISEASES OR DISORDERS

The following section will highlight conditions where the risk of deficiency can be increased and may warrant detailed investigations of mineral nutritional status

A. GI Tract

Iron deficiency is frequent in inflammatory bowel disease (IBD) due to blood loss. Zinc deficiency is also a problem, and low serum zinc concentrations have also been reported in Crohn's disease and in ulcerative colitis. Serum selenium is low in IBD, and the activity of glutathione peroxidase, a selenium-dependent enzyme, is decreased in some patients with Crohn's disease and ulcerative colitis. Celiac disease patients have global malabsorption problems, and gluten-free diets may not contain an adequate level of some micronutrients such as magnesium; microcytic anemia (iron deficiency) is very common, and these patients are also at risk of developing low bone mineral density (BMD), where calcium and vitamin D play a key role.

B. Pancreas

Patients with chronic pancreatitis are generally undernourished; selenium appears to be the mineral most frequently noted as being deficient, but this is thought to be due to malabsorption or increased oxidative stress rather than an inadequate intake.

C. Kidney

High phosphorus intakes are associated with the parenchymal deposition of calcium phosphate precipitates, which causes kidney damage; therefore, phosphorus intake should be reduced according to the glomerular filtration rate (GFR):

a) GFR 25–70 ml/min, phosphorus 8–10 g/kg/day
b) GFR <25 ml/min, phosphorus 5–10 g/kg/day.

A low phosphorus (and protein) diet will reduce calcium intake; therefore, calcium supplements may be required. Patients with renal failure cannot maintain mineral homeostasis by urinary excretion, and this increases the risk for development of clinically hazardous blood or tissue concentrations. Patients with chronic kidney disease (CKD) need to consume a diet low in sodium, potassium and phosphorus, but may need additional calcium, iron and magnesium. CKD-mineral and bone disorder is a new term for a common clinical entity observed in patients with CKD that involves abnormal mineral metabolism, bone disease and vascular calcification. CKD-mineral and bone disorder can manifest as one or more abnormalities of calcium, phosphorus, vitamin D metabolism, or parathyroid hormone; abnormalities in bone turnover, mineralization, volume, linear growth, or strength, and vascular or other soft-tissue calcification. Specific clinical practice guidelines for kidney transplant patients include monitoring serum calcium and phosphorus and hematological measurements (to diagnose anemia).

D. Bone

The human skeleton contains 1–1.5 kg of calcium and 0.8–1 kg of phosphorus. Rickets and osteomalacia are caused by calcium, phosphorus, and/or vitamin D deficiency, whereas osteoporosis is characterized by a reduction in BMD due to a combination of genetic and environmental factors. Long-standing calcium deficiency plays a contributory role in the etiology of osteoporosis, partly as a result of the reduced absorption associated with low vitamin D status (limited sunlight exposure and low dietary intake of vitamin D), but also from increased calcium excretion with diuretics and renal failure. Vitamin D and calcium supplements may be recommended for postmenopausal women who are housebound. Corticosteroid treatment for IBD, rheumatoid arthritis and other conditions leads to bone mineral loss. In systemic lupus erythematosus, significant reductions in BMD have been observed in premenopausal patients, related and unrelated to corticosteroid use. In IBD, where a low BMI may be an additional factor, there is a high prevalence of osteopenia, with Crohn's disease patients being more severely affected than those with ulcerative colitis. Patients undergoing organ transplantation are also at high risk of osteoporosis; bone loss is rapid after organ transplantation, and occurs mainly in the first 6 months. High intakes of calcium (e.g., 1,000 mg/day) and vitamin D (e.g., 500 IU/day) may reduce the rate of bone loss in some patients.

E. Cardiovascular System

Potassium deficiency or excess may predispose to cardiac rhythm disturbances. Intakes are inversely related to the incidence of hypertension and stroke. Water hardness (and hence calcium intake) is inversely related to coronary heart disease, as is magnesium intake. Recent evidence has emerged showing that disease-specific mortality risks are elevated for cardiovascular disease and ischemic heart disease with calcium intakes >1,400 or <600 mg/day. Risk of stroke may be increased with low calcium intakes (<700 mg/day). Sodium intakes are weakly associated with blood pressure in epidemiological studies, and the effect of reducing sodium intake varies between individuals, being most pronounced in the elderly and in Afro-Caribbeans.

F. Cancer

Mineral deficiencies can occur in some cancer patients due to low intake (cachexia), excessive losses (e.g., blood loss) and cytokine-mediated inflammatory response which reduces iron absorption. Low serum zinc can be normalized in a few weeks with zinc supplements of 50 mg/day. Serum copper, present mainly in ceruloplasmin, may be elevated in patients with tumors due to changes in ceruloplasmin metabolism. It is homeostatically controlled by desialylation in the liver but may be resialylated at the tumor cell surface leading to an increase in blood copper concentration.

IV. OTHER VULNERABLE GROUPS OR CONDITIONS WITH INCREASED RISK OF MINERAL DEFICIENCY

The Academy of Nutrition and Dietetics (formerly American Dietetic Association) has published Evidence-Based Nutrition Practice Guidelines for a number of diseases and vulnerable groups.

A. Patients with Anorexia Nervosa

Calcium deficiency is common due to low intakes of dairy products. Iron and zinc deficiencies are also common because of the avoidance of red meat, leading to iron deficiency anemia, lack of appetite and loss of taste sensation. Potassium and phosphate losses may be high from vomiting and use of laxatives and diuretics, and this may lead to cardiac abnormalities and heart failure.
Refeeding places additional demands on the heart through the increased requirements for potassium and phosphate, so care must be taken when instituting nutritional therapy in order to avoid refeeding syndrome.

B. Pregnancy

Iron deficiency anemia is one of the most common pregnancy complications. Screening should be carried out at the first prenatal visit and regularly throughout the pregnancy. The recent recommendations for antenatal care from the WHO are a daily supplement of 30–60 mg iron, together with 400 µg folic acid, to reduce the risk of low birthweight, maternal anemia and iron deficiency. Studies have shown that high hemoglobin values are associated with adverse pregnancy outcomes; however, iron supplementation cannot, in itself, raise hemoglobin to these levels; thus, adverse outcomes are more likely secondary to underlying conditions that are responsible for the high hemoglobin values.

C. Infants and Children

Deficiencies of trace elements, particularly iron and zinc, are common due to low body stores, improper feeding, and/or increased losses e.g. recurrent infections. Iodine and selenium deficiencies are endemic in particular geographical areas where the mineral is lacking in the earth's crust. In infants and young children, deficiency impairs thyroid function and may have a negative impact on brain development, causing cretinism.

D. Parenteral Nutrition

This mode of nutrition should provide essential minerals and trace elements appropriate for the life stage, although not all essential nutrients can be mixed in a parenteral solution, e.g. iron. Mineral and trace element status should be monitored and nutrients supplied via other routes if necessary. Requirements of young children are different from those of adults and specialist pediatric preparations must be used. Deficiencies in zinc and selenium occur most commonly because selenium is often not added to the solution and levels of added zinc may be too low. There are nutrition guidelines for critical care patients. There are also comprehensive guidelines on pediatric parenteral nutrition.

V. TOXICITY OF ESSENTIAL AND NON-ESSENTIAL ELEMENTS

A. Arsenic

It is a ubiquitous, naturally occurring metalloid that may be a significant risk factor for cancer after exposure to contaminated drinking water, cigarettes, foods, industry, occupational environment, and air. The WHO safe limit for arsenic in drinking water is 10 μg/L. Among the various routes of arsenic exposure, drinking water is the largest source of arsenic poisoning worldwide due to high concentration of arsenic in deeper levels of groundwater.

Acute effects: The immediate symptoms include vomiting, abdominal pain. Muscle cramping and death in extreme cases Long-term effects: due to high levels of inorganic arsenic, skin lesions and hard patches on palms and soles of the feet (hyperkeratosis), skin cancer Acute effects: The immediate symptoms include vomiting, abdominal pain. Muscle cramping and death in extreme cases Long-term effects: due to high levels of inorganic arsenic, skin lesions and hard patches on palms and soles of the feet (hyperkeratosis Fig.10), skin cancer (Arsenicosis Fig. 11), cancers of bladder and lungs, developmental effects, diabetes, pulmonary disease and cardiovascular disease. cancers of bladder and lungs, developmental effects, diabetes, pulmonary disease and cardiovascular disease Arsenic levels are much higher in the shallower Holocene age aquifers than in the deeper Pleistocene age aquifers The ultimate source of arsenic in the groundwater is high Himalaya rocks and Indo-Burman ranges Minerals like biotite, magnetite, ilmenite, olivine, pyroxene and amphibole contains arsenic, when they get weathered in the catchment area and in the deposits in alluvial plains, they release arsenic. This arsenic is absorbed by secondary minerals like iron hydroxides like goethite When these sediments encounter organic rich reducing conditions, releases arsenic into groundwater During, Pleistocene age, the high Himalayas were glaciated, lesser amount made its way onto alluvial plains. During Holocene age, glacier melted and arsenic made its way on to alluvial plains Arsenic contamination of groundwater is an alarming problem on a global scale. In several parts of the world, biogeochemical processes have resulted in dissolution of naturally occurring as into groundwater. Anthropogenic sources have been also elaborated in groundwater. By taking small steps we can control the excessive usage of groundwater and arsenic pollution further can be prevented from occurring.

Fig 10: Hyperkeratosis on sole. The patient died of lung cancer.

Fig 11: Signs of Arsenicosis: spots on the hands.

B. Nitrates as a Health Hazard

In India, high concentration of groundwater nitrate (more than 45 ppm) have been found in many districts of Andhra Pradesh, Bihar, Delhi, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamilnadu, Rajasthan, West Bengal and Uttar Pradesh. The highest groundwater nitrate concentration of 3080 ppm was found in Bikaner in Rajasthan. The study carried out by (A.G.S Reddy et al., 2007) in Anantapur district revealed that 65% of samples have shown nitrate levels above the desirable limit (45 ppm). Sources of nitrate in groundwater can be considered in four categories: Natural sources waste materials irrigated agriculture and row crop agriculture. The major sources include intensive animal operations with nitrate from over application of animal wastes, and irrigated and row crop agriculture, with nitrate from fertilizer-induced mineralization of soil organic nitrogen and from over application. Septic tank system and other sources, such as landfills can be concern in localized areas. High concentration of nitrate in the drinking water causes many serious health problems especially in children and young livestock. Due to its hazardous nature, the permissible limit of nitrate for drinking water has been reduced from 100 mg/l to 45 mg/l by the Bureau of Indian standards in recent years.

Although methemoglobinemia (blue-baby syndrome) is the most immediate life threatening effect of the nitrate exposure, there are a number of equally serious long terms, chronic impacts. In numerous studies, exposure of high levels of nitrate in the drinking water has been linked to a variety of effects ranging from enlargement of the thyroid to 15 types of cancer and two kinds of birth defects and even hypertension . Research shows a definite relationship between increasing rates of stomach cancer with increasing nitrate intake . Through the effect of continuous consumption of high nitrate in water may not physically visible as in the case of fluoride, the local people have complained of recurring indigestion and gastrointestinal problems in the south eastern part of Anantapur district, Andhra Pradesh, India.

VI. OTHER MEDICAL GEOLOGY ISSUES

A. Geophagia

Geophagia (or geophagy) is also an area of concern in medical geology. Geophagia can be defined as the deliberate ingestion of soil, a practice that is common among members of the animal kingdom, including certain human populations. Soil may be eaten from the ground, but in many situations there is a cultural preference for soil from special sources such as termite mounds. Geophagia is considered by many nutritionists to be either a learned habitual response in which clays and soil minerals are specifically ingested to reduce the toxicity of various dietary components or as a built-in response to nutritional deficiencies resulting from a poor diet. Geophagy is attaining renewed and serious interest within the scientific research community.

B. Radon

Exposure to natural gases such as radon is potentially hazardous. Geologic materials are the most important factor controlling the source and distribution of radon. Relatively high levels of radon emissions are associated with specific types of bedrock and unconsolidated deposits, including some granites, phosphatic rocks, and shales rich in organic materials. The release of radon from rocks and soils is controlled largely by the types of minerals in which uranium and radium occur. Radon levels in outdoor air, indoor air, soil air, and ground water can be very different. Radon released from rocks and soils is quickly diluted in the atmosphere. Concentrations in the open air are normally very low and probably do not present a hazard (Appleton, 2005). Radon that enters poorly ventilated buildings, caves, mines, and tunnels can reach dangerously high concentrations.

C. Uranium

Uranium mining has a long history, but most scientists recognize that it is only for the last 30 years that the health effects of occupational exposures to radiation in mines has been discussed fully. Many of the studies focus around lung cancer, the risks of which are only now being evaluated more fully. This type of radiation-induced occupational cancer now appears to be one of the most important radiation injuries known to occur among workers occupationally exposed to ionizing radiation. Uranium mining creates risks in 2 ways, through dusts and through released radon - a radioactive gas of natural origin. Radon’s principal isotope is radon-222, stemming from uranium-238 present at various concentrations in all soils. Radon is found everywhere in the earth's atmosphere but has low reactivity by itself. However in the process of mining, dusts get inhaled by miners. For example, as one study reports on East German Uranium mines, in some mines in the past there was drilling with air floating and a lack of forced ventilation. Dust levels were very high and there was a significant inhalative incorporation of alpha- radiating substances, mostly from short-lived radon progeny. However, long-lived alpha-radiating substances such as uranium-238 contributed considerably to the radiation dose” [26] Radon particulate daughters are responsible for alpha irradiation of the bronchial epithelium. Epidemiological studies on miners indicate that radon exposure causes an increased risk of lung cancer in these workers but “how much?” and “how?” is still under investigation.

D. Asbestos

Asbestos is the name for a group of naturally occurring silicate minerals that can be separated into fibres. The fibres are strong, durable, and resistant to heat and fire. There are several types of asbestos fibres, of which three have been used for commercial applications: Chrysotile, or white asbestos, comes mainly from Canada, and has been very widely used in the U.S. It is white-gray in colour and found in serpentine rock. Amosite, or brown asbestos, comes from southern Africa. Crocidolite, or blue asbestos, comes from southern Africa and Australia. We selected “asbestos” as a whole, since it has been studied as a key mineral for its properties as a dangerous fibrous silicate. Dusts from other silicates show similar occupational health impacts, but have not achieved the notoriety of asbestos. Asbestos mining internationally has been found to create occupational health risks for miners and mineworkers in related processing industries.

The earliest data on the hazards of asbestos came from mine workers in the extraction process, but gradually it became clear that workers in all asbestos-using industries also showed signs of health impacts. The majority of studies focus on asbestos as a hazardous mined product and safety issues relate to exposure through breathing in asbestos particles in and around the mines. The most severe occupational exposure is that with the greatest contact with the asbestos particles in respirable form. Along with coal and other silicate dusts, the dangers of asbestos mining relate largely to damage to respiratory function and lungs.

VII. FUTURE PROSPECTS FOR MEDICAL GEOLOGY:

Medical geology is an emerging science and it is almost certain to achieve the status of an established field of science within a decade. Modern epidemiology requires a thorough understanding of the geochemical processes and pathways of essential and toxic elements and a clear integration of these different disciplines is being established.

The rapidly emerging scientific discipline of Medical Geology holds promise for increasing our environmental health knowledge base, and contributing to substantial tangible improvements in the well-being of the global community.

It will also be important to develop information material for the use of schools, public and private organizations interested in Medical Geology problems to show the impact of geologic factors on the well being of humans and animals, as well as arranging joint technical meetings to address issues of mutual concern amongst geoscientists and other disciplines concerned with Medical Geology

It would also be useful to encourage research in the area of producing more effective methodologies for the study of geological factors in environmental medicine and formulate recommendations for mitigation of effects of natural and man-induced hazardous geochemical conditions.

One of medical geology’s ultimate goals should be global baseline/background level monitoring. The geology, soils, and plants should be characterized in detail globally, using Medical Geology, Emerging Discipline 17 a consistent set of methodologies.

More synthesis studies are needed. The needs of medical geologists should be communicated to appropriate partners in the medical community.

For instance, mortality reporting criteria are highly variable. A system for accurately determining and recording cause of death must be standardized. Long-term monitoring and tracking of as wide a variety of geologic materials as possible is to be promoted, given the inability to predict what issues will become major problems in the future. By doing so, our ability to detect changes in the environment will improve; based on sensible uses of models, potentially deleterious changes may be predicted.

When selecting which variables to monitor, medical geologists must consider the realm of civics; i.e., practical matters such as laws and regulations. Links to the agricultural sector must be built, especially with those working with foods.

Public awareness of the benefits of medical geology needs to increase to generate positive attitudes that will facilitate recruitment. A recurring theme from the working group was the need to assemble presently disparate information into one place.

VIII. CONCLUSION

The objectives of Medical Geology are to identify harmful geologic agents, determine the conditions of exposure that promote deteriorating health conditions, and develop sound principles, strategies, programs and approaches necessary to eliminate or minimize health risks. Interaction and communication is necessary between the geosciences, biomedical, and public health communities to protect human health from the damaging effects of physical, chemical and biological agents in the environment. We recommend that medical geology be included in higher education curricula so that students will be aware of the connection between geology and health and encouraged to pursue a career in Medical Geology. The rapidly emerging scientific discipline of Medical Geology holds promise for increasing our environmental health knowledge base, and contributing to substantial tangible improvements in the well-being of the global community. An important task is to foster acceptance of the subdiscipline medical geology. This may facilitate support for research by raising awareness among funding agencies and decision-makers. The general public must be educated on the value of this field, not only for its promise of finding practical, effective solutions to serious public health problems, but because people can encourage their elected leaders to champion this important cause. Given the philosophy and goals of the ISEH, a liaison between the Society and the IUGS Medical Geology Initiative would likely benefit both Organizations. These complementary communities together can forge a strong, self-sustaining interdisciplinary scientific discipline-Medical Geology.

IX. ACKNOWLEDGEMENTS

I am Very Thankful to My University Professors for Their Kind and Constant Support and Help.

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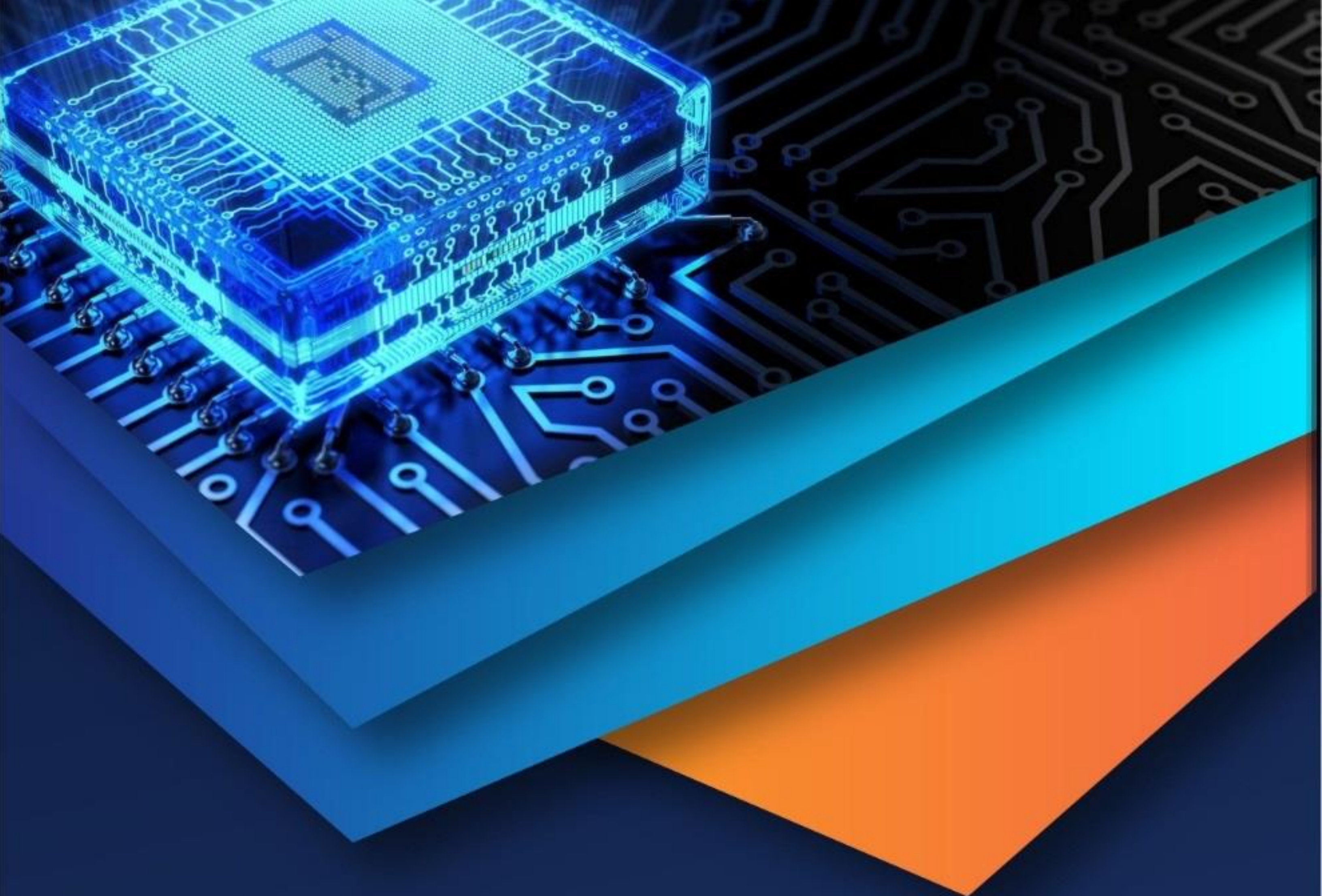

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