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# Geo-medical problems Vis –a-Vis role of multi-level elemental anomalies through geo-genic sources emergence health disorder: A review

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## ABSTRACT

*Geo- mineral resources of the geosphere have released the number of elements as major, minor and trace amount in geo-chemical environment either naturally geological process or occupational geo-mining activities depending on their relative abundance of poly-metallic deposits in geologic complex terrain which adversely impacts on human and animals health directly or indirectly exposes through the air, water, soil and foodstuffs in perturbed system. These release elements comes either geo-genic or anthropogenic sources which may be found multi-level concentration as deficient or excess (toxicity) depends upon the intensity of geological exogenetic and endogenetic process involvement which results various types of health risk diseases by ingestion. The occupational health related geo-medical complications with special reference to opencast & underground geo-mining activities of mineralized and non-mineralization areas which creates reversible and irreversible diseases due to inhalation which creates reversible and irreversible diseases due to inhalation of multi-elemental toxic dusts in long-term exposures in the human body. This review paper is emphasized on a multi-faceted challenges of geo-medical problems in India and abroad which have been realized and presently demands to minimization of inverse impact of both geo-genic and anthropogenic (Mine out areas) through the contributions of a multi-layered responses of high level experienced expertees from the different fields with the management strategies and take awareness to the societal costs of environmental pollution.*

**Keywords:** Geo-medical, Geo-genic or anthropogenic diseases and minerals distribution in India.

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## INTRODUCTION

Geo-medical is defined as the bizarre health medical complications in the complex components of the earth system which deals with the relationship between natural as well as occupational geo-environmental factors and human and animals health by the accelerated geochemical environment through the geo-genic or anthropogenic contaminants either deficient or excess of trace elements utilized in the form of ingestion or inhalation by directly or indirectly to the soil, water, plants and air realms.

The medicinal use of minerals is most probably as old as mankind itself. There are references to the use of “medicinal earths” (clay/mud) in Mesopotamia, Ancient Egypt and Ancient Greece, to cure wounds and soothe skin rashes. For instance, in Ancient Greece Hippocrates (460–377 BC), regarded as the Father or Founder of Medicine, reported interesting information about medicinal earths in his book “On Airs, Waters, and Places”, and so did Aristotle (384–322 BC) who dedicated part of his life to biological research. Hippocrates reports the negative effects (corrosive, caustic, etc.) of arsenic minerals, much later identified as orpiment ($As_2S_3$) and realgar ($As_2S_2$), at that time extensively used as therapeutic agents. Recently, and according to the International Agency for Research of Cancer (IARC), arsenic and arsenic-containing compounds are considered as human carcinogens [1].

In India, things have just started with some seriousness. Geological Survey of India (GSI) has been identified as a nodal agency by IUGS for studies on medical geology. Although there has been some awareness regarding the importance of the subject [2, 3, 4], a lot remains to be done. One of the areas which need immediate attention is the study of trace elements in water, soil, sediment, rock, air, food and animal tissues, and to understand their long-term effect on health. It is high time we rise to occasion and realize that we have miles to go before we feel good.

## Mineralization Potential in India [5]

India has known for the good numerous world class economic minerals deposits in the form of metallic (extraction of industries materials), non-metallic and mineral fuels as a self sufficient. The important localities of the metallic deposits in India are found in different metallogenic epochs with geological favourable conditions.

Non-metallic economic minerals to include those which are largely utilized in industry for purposes other than the extraction of the metals. Many minerals like bauxite, magnesite and beryl, though non-metallic in physical properties, are used both for the extraction of the metal as well as for other industrial purposes. Similarly, a metallic mineral like pyrite is not primarily used for the extraction of the metal (iron) but for the extraction of sulphur.

### A. Ore in mafic and ultramafic igneous rocks

- ***Chromite*** ($FeOCr_2O_3$) is always associated with dunie and peridotite in Sukinda belt as a Stratiform-layered types (Cr-Ni) and Nausahi belt in the form of podiform types in Orissa with association of chromite and vanadiferous magnetite. The chromite and ilmenite (Fi-ores) deposits of Sitampundi complex in Tamilnadu associated with Anorthosite rocks. Besides these chromite is also found at Jojohatu in Singhbhum district in Jharkhand.
- ***Nickel*** ores in laterites are found in Sukinda, Cuttuk district in Orissa where pentlandite [(NiFe) S] is the main ore of nickel containing upto 22% Ni enriched soils are seen. Whereas Bhatin area of Bihar is associated with amphibolites rocks.

### B. Ores in acidic igneous rocks (Pegmatites and quartz veins):

- The note worthy ore of ***Tungsten*** in the form of wolframite;(Fe, Mn)$WO_4$ is known deposits from Degana, Sirohi and Agucha in Rajasthan, Agargaon in Maharashtra and also Chhendapathar, Bunkura district of West Bengal. Tin (Sn) associated rare metals Nb and Ta deposits are found in Bastar (**Chhattisgarh**), Koraput (***Orissa***) and Tosham (**Haryana**) localities.

### C. Ores in Carbonatites and alkaline rocks:

- In these rocks, rare earth elements (REEs) and ***Nb-Ta*** multiple oxide deposits were recorded in Sung Valley in **Meghalaya** and Sevathur in Tamil nadu state in India.

### D. Epigenetic Structurally Controlled or Strata bound hydrothermal deposits or Base-metal deposits:

- ***Copper***- ores deposits in India has been found as a native copper as Dras volcanic of Cretaceous-Ecocene age but workable quantity of copper ore is only Chalcopyrite ($CuFeS_2$). It is associated with pyrite ($FeS_2$), borrite ($Cu_5FeS_4$). The chalcopyrite by surface alteration changes into cuprite ($Cu_2O$), malachite ($CuCO_3.Cu.(OH)_2$) and azurite ($2CuCO_3.Cu(OH)_2$). Chalcopyrite occurs in igneous and metamorphic rocks as a sulphide ore of primary and secondary origin.
- The polymetallic associated copper ores (Cu ± U ± Ni ± Mo) are mainly confined into the Singhbhum Shear zone (Jharkhand) where migmatisation and ore-localisation are the main features within this shear zone, probably its genetically related. The working copper mines of this copper belt are done at Mosabani, Surda, Pathargora, Kendadin and Rakha centres. The Khetri copper belt in Rajasthan extends 80 kms from Singhana in Jhunjhun district to Raghunathgarh in Sikar district. The mineralization has taken place in phyllites, Schists and Slates of the Delhi system. A numbers of ore minerals associations such as chalcopyrite, pyrrhotite and pyrite are the main sulphide mineralization along with cobalt sulphides (cobaltite). The secondary copper ore minerals are qzurite, malachite, covellite (CuS) and chalcopyrite ($Cu_2S$). Evidences of wall-rock alternation are reported to be mainly silcification and at place also chaloritisation, biotisation and sericitisation in the host rocks.

The Malanjkhand copper ore deposits in Balaghat district in Madhyapradesh where three important open-cast mining centres such as Pinkupur, Birsa and Padritola. The major ore minerals are chalcopyrite and pyrite while the sphalerite (ZnS), chalcocite, covellite, molybdenite ($MoS_2$) occur in small quantity.

The Agnigundla mineralized belt (Cu-Pb deposits) in Guntur district of Andhra Pradesh is reported from Nallamalai series (Cumbum phyllite) of upper Cuddapah. The major localities depositions of this belt are found at Bondalamottu Nallakonda and Dhukonda. It is noted that the copper (Cu) deposits are confined to calcareous quartzites while lead (Pb) occurrences are seen in dolomites.

The others localities for the base metal deposits vis; polymetallic complex (Cu-Pb-Zn-Ag) at Rajpur-Dariba, Zawar (Pb-Zn-Ag), Rampur-Agucha (Cu-Pb-Zn-Ag) in Rajasthan; Sargipalli (Cu-Pb-Ag) in Sundergarh district in Orissa; Mamandur (Cu-Pb-Zn) in South Arkot district in Tamilnadu; Chidradurga (Cu-Pb-Cr) in Karnataka; Spiti-Lahaul (Pb-Zn-Sb) of Tertiary in Himachal Pradesh and Ambamata region (Cu-Pb-Zn ores ) in Gujarat having the complex base-metal mineralization.

The complex mineralizations were encountered and it restricted in large scale deposits mainly in Sonrai Formation and also some extent to Solda Formation of the Bijawar Group in Lalitpur district. The source of toxic metals and associated ore-minerals were reported from the Sonrai Formation in the Sonrai basin viz; Cu-ores, Pb-ores, Zn-ores and also PGM (Platinum Group Minerals) having sperrylite ($PtAs_2$), pentlandite (Ni), cobaltite (always occurs with primary sulphides, arsenides and oxides) and chalcopyrite associated with chromite bearing ultramafic rocks of Madawara igneous complex from Lalitpur district in Bundelkhand massif in Central India.

The mineralization of U-ore sulphides deposition are especially found at Jaduguda (Singhbhum Thrust belt) in Jharkhand of hydrothermal origin; Bhuj Formation in Gujarat; Bodal and Jajawal in Madhya Pradesh and also recorded in Main Central Thrust (MCT) in Himalayan belt. But U-Cu ores is hosted in carbon phyllites at Umra-Kalamagra in Udaipur district of rajasthan.

The economic deposits of gold (Au) in India are found only in Kolar gold field (tenor of the ore is about 7.42 gram/tonne) in Tumku district and Hutti gold field (gold content of the ore is about 4.8-7.5gram/tonne) in Raichur district of Karnataka which occurs as gold –bearing quartz reefs in hornblende schists, greenstone and amphibolites of Dharwar System. These gold deposits are believed to be of high temperature hypothermal origin. The native gold is associated with pyrrhotite and iron pyrite and also mixed with some silver (Ag).

### Ores in Sediments or Sedimentary rocks:

#### Iron ore:

The ***iron*** ore is the second largest mineral wealth deposits in India having the backbone of modern civilization. The chief ore mineral of iron is haematite ($Fe_2O_3$) and other minerals of minor importance are magnetite ($Fe_3O_4$), siderite ($FeCO_3$) and limonite ($2Fe_2O_3.3H_2O$).In banded-iron formation (BIF), the iron-ores are associated with the banded-haematite-quartzite (BHQ) in the Bailadila range (65%Fe) of Bastar district, Chhattisgarh known for richest deposits in the world (35 length and 9 kms width) with N-S trends; Dali Rajhara hills (55-66% Fe) of Durg distrct (M.P); Bababudan hills in Chickmagalur district of Karnataka occurs in detached patches of thick bands and lenses of haematite in BHQ of Dharwarian age and also iron-ore deposits at Ratnagiri and Chanda district in Maharashtra .In Goa region, the iron-ore deposits is generally hard and lumpy but in depth it is soft and powdery in the form of blue-dust type of haematite (59-61%Fe) used as a amenable to pelletisation. In concerns to the various forms of magnetite iron –ore deposits, the Kudremukh deposits (Karnataka) is famous for magnetite deposits; banded-magnetite-silica deposits occurs in Salem and Tiruchirapalli districts in Tamil nadu; apatite-magnetite formation in Singhbhum shear zone in Jharkhand and also reported as a titaniferous-vanadiferous magnetite associated deposits at Mayurbhanj district in Orissa.

Iron sulphide ore, such as pyrite ($FeS_2$) is mainly found at Amjhor in Bihar and Saladipura in Rajasthan.

The Mn-ore formation is associated with Precambrian Sausar Group of rocks at Chindwara, Balaghat in M.P and Bhandara, Nagpur in Maharshtra .The Mn-ore deposits are noticed in Panch Mahal and Baroda district in Gujarat and thought to be of epigenetic origin and occur in the form of tabular and irregular lenses in the highly folded phyllites and quartzites of Precambrian age. Pyrolusite ($MnO_2$) and psilomelane ($MnO_2.H_2O$) are the principle manganese ore minerals.

Uranium-gold (U-Au) in QPC (Quartz-Pebble-Conglomerate) are found mainly from Badampahar-Daiteri in Orissa and Dhanjori basin in Bihar. Some of the Uranium (U) in black shales at Kinnaur (Haimantha Shales) in Himachal Pradesh. In Lalitpur district of Uttar Pradesh, the U-mineralisation is associated with Gorakalan Shales hosted bitumen containing graphitic and Siliceous nature and also Rohini carbonate rocks with filiceous pyrite and Bandai calc-sandstone interbedded shales and pyrite of the Sonrai Formation and some extend to chloritic shales of the Solda Formation in Bijawar Group.

In concerns to U-ores in phosphorites evidences is recorded in Mussoorie Syncline of the Uttarakhand. In Laitpur district of Uttar Pradesh, where the genetic significance of high Uranium concentration (1.67-129.67µ/g) was recorded in phoshorites (i.e, Rock Phosphate) of the Palaeo-Proterozoic Bijawar Group in which apatite [$Ca_5(PO_4)_3(F,Cl,OH)$] is the essential phosphate mineral while quartz and feldspars are the dominant gangue minerals in the phosphorites. The positive correlation of U with $P_2O_5$, CaO and U/$P_2O_5$ indicate a close association of Uranium with phosphate mineral like collophane [$3Ca_3(PO_4)_2CaCO_3,F_2O.H_2O$].

In Gollapilli beds of Andhra Pradesh are famous for Sandstone type of Uranium deposits but calcrete type of Uranium deposits is reported at Jodhpur in Rajasthan. Beach and inland placers of Ti-Th-Zr ores are found on the East and West oceanic coastal tracts. Monazite [(Ce, La, Th, Yt)$PO_4$] is a phosphate of cerium (Ce) metal for the chief ore thorium (Th) which commercial deposits only in beach sands of East-coasts in Orissa (mouth of Mahanadi river), Andhra Pradesh (both monazite and ilmenite near Visakhapatnam coast) and Tamil nadu (Manavalakurichchi) states of India. In the west-coasts especially in Kerala state, where huge deposits of monazite occur in beach sands of Travan core and Chavara near Quilon and its exploited in large scale.

Bauxite ($Al_2O_3.2H_2O$) is a secondary product in between monohydrate diaspore ($Al_2O_3.H_2O$) and trihydrate gibbsite ($Al_2O_3.3H_2O$). Bauxite deposits occurrences in India and mining centres viz; Amarkantak, Katni, Jabalpur, Balaghat, Sarguja, Bilaspur, Mandla and Khandwa in Madhya Pradesh; Kolhapur, Ratnagiri and Kolba in Maharashtra; Belgaum and Chickmagalur in Karnataka; Salem in Tamil nadu; Jamnagar and Kaira in Gujarat; Ranchi and Palamu in Bihar; Kalahandi and Sambalpur in Orissa and also at Sileru Agency tracts and Araku Velley in Andhra Pradesh. Most of the East-coast bauxite is formed due to weathering of Khondalite rock [quartz ± sillimanite ± garnet ± k-feldspar ± plagioclase ± graphite]. It is noted that the laterite contains above 50% $Al_2O_3$ called bauxite. Laterite is a weathered rock product in which alumina ($Al_2O_3$) is below 40% and Fe2O3 is between 20-30%.

## Manganese Ores:

The manganese ore deposits of India are essential of sedimentary and residual origin. Originally, the manganese was deposited as manganiferous sediment and later it was metamorphosed. Where the manganiferous sediment was pure ,directly oxide ore mainly braunite ($Mn_2O_3.Mn.SiO_3$) was formed but where the manganiferous sediment was impure, gondite (spessertite Mn-garnet + Rhodonite $MnSiO_3$ + quartz rock) as a syngenetic type of deposition in M.P- Maharashtra zone or Kodurite rock (garnet + orthoclase + Mn-pyroxene + quartz association) as a syngenetic reef deposition and replacement deposition also in Bihar (Chaibasa area in Singhbhum district)-Orissa (Keonjhar district)-A.P zone (Shrikakulam district) in association with rocks of the Iron-ore Series. The gondite is a metamorphic rock which consists of spessertite ($3MnO.Al_2O_3.3SiO_2$), rhodonite ($MnSiO_3$) and quartz ($SiO_2$). The gonditic manganese ore deposits are formed from the oxidation of gondites. During weathering, most of the silica and alumina are removed and manganese minerals, chiefly psilomelane ($MnO_2.H_2O$), pyrolusite ($MnO_2$) and wad (massive earthy form of Mn-oxide) are formed. In this way, residual enrichment deposits are formed at many places.

## Cadmium Ore:

The only important ore of cadmium is greenockite (cdS,77.8% cd) which occurs as an orange yellow stain or coating on zinc sulphide (sphalerite) and it is only rarely found in workable quantities .In India, the lead-zinc sulphide ore of zawar mines in Rajasthan contains a small percentage of cadmium (about 0.06%) but 0.23% cd in zinc concentrate. Cadimum is also reported to occur in small amounts in the zinc ore of Riasi and Udhampur districts of J&K and in the lead zinc ore of Almora and Tehri-Garhwal districts of Uttarakhand and Bhotang in Sikkim. Cadmium is obtained as a by product from the fumes and flue dusts of smelter treating cadmium-bearing zinc, lead, copper ores and also as a by product from the refining of zinc. For the purpose of industrial uses ,cadmium sulphide forms pigments of brilliant golden yellow, orange red or redidish brown colours and is used in paints, enamels, soap, ceramic glazes, papers, textiles leather and other products. Cadmium salts are also used in photographic films, lithography and medicine.

**Cobalt Ores:**
Cobalt is an important alloying metal. A mixture of cobaltite (CoAsS;Co.35.5%) and danaite (cobaltiferous arsenopyrite FeAsS with Co replacing part of Fe), locally known as “Sehta” occurs with copper pyrites and iron pyrites in black states (Delhi system) in some copper mines of the Khetri-Jaipur region (Rajasthan). It was used to be recovered by crushing the slates and sold to the Jaipur Jewellers for production of beautiful glazes of their enamel work. Linnaeite ($CO_3S_4CO$.67.9%) has been recognized in some of the copper ores of Sikkim. The manganese ore (wad) of Kalahandi (Orissa) and Jhabua and Hoshangabad districts of Madhya Pradesh and some chromites of Keonjhar (Orissa) are reported to contain a small percentage of cobalt and nickel oxides.

A small quantity of cobalt will be obtained as a by- product from the Khetri copper ores when smelted and from the Sikkim copper ores when worked. Cobalt deposits are oxidized in the upper portion to “cobalt blooms” (hydrated sulphates, arsenates and carbonates) of which Erythrite [$CO_3As_2O_8.8H_2O$] is important, its crimson or peach-red coloured encrustation on the associated gangue material giving an indication of the presence of cobalt in the area. Cobalt oxide (chiefly Asbolite CoO, $ZMnO_2.4H_2O$) occurs in impure mixtures of manganese oxides and other oxides, as a result of weathering of rocks which contain some cobalt in addition to other oxides.

Iron cobalt alloys are therefore used for making permanent magnets and magnetic steels which have great lifting power. Metallic cobalt (in powder form) is used as a binding material in the manufacture of cemented tungsten carbide (WC) and tantalum carbide for tips of cutting tools, armour-piercing projectiles and mining drills. It is also used as a binder for diamond or diamond dust in cutting tools.

**Nickel Ores:**
Ores primarily worked as sources of nickel may be classified as

1. Sulphides, especially nickeliferous pyrrhotite ($Fe_nS_{n+1}$) in which the metal is frequently present as the mineral pentlandite [(Ni,Fe)S]. Pentlandite has brass yellow colour, intermediate between that of pyrite ($FeS_2$) and copper pyrite ($CuFeS_2$);
2. Silicates or oxidised ores, especially garnierite (nickeliferous serpentine) [Ni.Mg $SiO_3.nH_2O$]shows apple green and
3. Arsenical ores, especially arsenide niccolite (Ni,As) which is characterized by pale copper-red colour. The primary ores of nickel are oxidized on surface to green-coloured” nickel blooms”.

In India, nickel is an important constituents in the Singhbhum copper ores in Bihar, being present in the form of pentlandite (Ni,Fe)S and Violarite [$(Ni,Fe)_3O_4$], contained as irregular microscopic patches in the pyrrhotite associated with the copper pyrite of the ore. The copper ore of Singhbhum contains 0.08% of Ni. Nickeliferous pyrrhotite is reported to be associated with thin asbestos veins in the ultrabasic rocks in Udaipur and it is also found amongst the copper ores of Khetri and other places of Rajasthan and nickel will be recovered as a by- product when electrolytic copper is produced from these ores.

Complex sulphide ores consisting of pyrrhotite, pyrite, chalcopyrite and molybdenite and containing both nickel and cobalt as well as minute quantites of gold and silver, occur in Tovala taluk in Kerala. A small quantity of nickel has been detected in the pyrrohotite and chalcopyrite associated with the gold-quartz reefs of Kolar field and in the lateritic soil and rocks associated with the chromite bearing ultrabasic rocks in Hassan district (Mysore). Nickeliferous deposits also occur in the Morch and other areas of Manipur. Garnierite (nickeli-ferous serpentine)-bearing foliated rock has been reported from Lowa Gold mines area in Dhanbad district and nickel-ore has been found in small but significant proportion associated with the thorium ore in Singhbhum district of Bihar. A basic nickel carbonate (Zaratite ) has been described from the chromite deposits of Naushahi in Keonjhar district and nickeliferous chromite have been found in Saruabil, Sukrangha and Sukinda areas of Cuttak district in Orissa. Nickel and cobalt are also found in traces in some of manganese ores like psilomelane and wad of M.P and Maharashtra.

**Mo-ores:**
Molybdenum is one of the strategic minerals for India. Molybdenite ($MoS_2$; 60%Mo) is soft (H=1-1.5), heavier (sp. gravity=4.7-4.8), lead-grey colour with metallic luster and splits easily into thin flakes represent flexible but not elastic. It greatly resembles graphite when pure. This molybdennite is associated with acid igneous rocks like granite in which it occasionally occurs as disseminations, but the commercial deposits are found in pegmatites and quartz veins connected with such rocks. Molybdenite ore mineral in Andhra Pradesh (Godavari district, in pegmatite);

Tamilnadu (Maduari district, is aplite and pegmatite veins); Karnataka (Kolar, in pegmatite of oorgaum mine); Kerala (Tovala taluk, with nickeliferous pyrrhotite); Bihar (Hazaribagh district, associated with some lead-copper-zinc ores); Rajasthan (Kishangarh, in elaeolite-syenite pegmatite) and Assam (Khasi hills, in granite-gneiss).

Granite-hosted molybdenite ($MoS_2$) mineralization (60% Mo) from Archaean Bundelkhand Craaton (ABC) is predominantly associated with Bundelkhan Tectonic Zone i.e, "Raksa Shear zone "represent the localized shear zones which was possibly hydrothermal origin for the Molybdenum (Mo) bearing quartz occurring within variable deformed different granitoids variants of Archaean Bundelkhand Craton based on fluid inclusion study.

Molybdenite is identified as bluish-grey coloured, very soft mineral having a metallic lusture and greenish grey streak. It is flaky in nature and easily peels off with pocket knife. In Lalitpur district, at Hasarkhurd Temple where molybdenite (52 ppm) is hosted in shear quartz veins; Jharar village (Mo+ pyrite+ chalcopyrite+ galena+ sphalerite) molybdenite occur in the form of massive is hosted in medium-grained pink porphyritic granitoids and also other places in the same district such as Gugar area where molybdenite encountered in the form of clots mineralization hosted in the brecciated granitoid body.

**Arsenic Ores:**

The important mineral of metal arsenic (As) are arsenopyrite ($FeAsS_2$; 46% As; also called mispickel); realgar ($As_2S_3$ ;70% As) and orpiment (AsS,61% As).Realgar is recognized easily by its red or orange colour whereas orpiment by its fine lemon-yellow colour. Arsenic minerals are seldom mined as ore for the extraction of the metal. Arsenopyrite shows silver-white to steel gray metallic colour and by giving spark and emitting garlic odour when struct with steel hammer. These minerals occur in veins or as volcanic and hotspring deposits. Realgar and orpiment, both natural and artificial are used as paint pigments and also used in tanning for removal of hair and in fire-works as it burns with intense white light and also in the manufacture of insecticides, weed killers and lead shots.

An important arsenopyrite occurs in a 30 cm thick seam, with chalcopyrite, on the northern flank of the Sampathar Hill in Kalimpong area in Darjeeling district W.Bengal. Some of the Khetri copper belt (Rajasthan) contains a mixture of cobaliferous arsenopyrite and cobalite, locally called "Sehta".

**Baryte deposits:**

Workable deposits of barite [$BaSO_4$; 65.7%BaO] occur in Andhra Pradesh (Cuddapah, Anantpur and Kurnool districts) as fissures veins (usually up to 2 meters thick) or as replacement deposits in the limestones of Vempalle Stage (Cuddapah System) or in the intrusive trap sills. It is associated with crysotile asbestos [$3MgO.2SiO_2.H_2O$; Serpentine asbestos] at some localities; and in Rajasthan (Alwar ,Jaipur and Bharatpur districts) as fissure veins in Alwar Quartzites (Delhi System).It also occur in Bihar (Ranchi and Singhbhum district), Himachal Pradesh (Sirmur district), Jammu & Kashmir (Riasi district), Orissa (Gangpur and Sundergarh districts), Tamilnadu (Salem and N. Arcot district) and Punjab (Narnaul and Patiala districts).

**Beryl [$Be_3Al_2Si_6O_{18}$; 5%Be, 14%BeO]:**

It is one of the atomic energy mineral and is therefore being stock-piled by the Atomic Energy Department. Large deposits of beryl generally occur in India in zoned pegmatites with a quartz core, and beryl is more commonly associated with green interlocked mica and black spotted mica. Beryl crystals have been found at many places in the pegmatites of Andhra Pradesh (Nellore, Srikakulam and Vishakhapatnam districts), Bihar (Hazaribagh, Monghyr and Gaya districts) and Rajasthan (Ajmer, Jaipur, Kishangarh, Tonk, Bhilwara and Udaipur districts).Beryl crystals up to 6 m long,1-2m in diameter and weighing more than 20 tonnes, have been reported from some Rajasthan pegmatites. The emerald gem variety (grass-green variety) occur only in Rajasthan (Ajmer and Udaipur districts).Emerald crystals occur here in metamorphic talc-biotite-actinolite schists of Aravalli age near their contact with pegmatites and quartz veins of post Delhi (Erinpura) age .Some rose pink variety morganite and yellow coloured approaching as a crystal of golden beryl are occasionally reported from Rajasthan beryl pegmatites. The aquamarine (blue-variety) variety of beryl are found in some of the pegmatites of Jammu & Kashmir (Ladakh district), Mysore (Bangalore district) and Tamilnadu (Coimbatore district).Aquamarine are occasionally obtained as a by-product of the corundum and sappire mining in kashmir.

The oxide and carbonate of beryllium activated by Uranium Salts or rare earths are used in luminescent paints. Beryllium nitrate with thorium nitrate is used in the manufacture of gas mantles. Dusts and fumes of beryllium and its compounds are highly poisonous and plants for their manufacture have to adopt protective measures for the workers against the toxic effects.

**Magnesite [$MgCO_3$;47.8 MgO]:**
This is isomorphous with carbonates of Ca, Mg and Fe. The principal magnesite deposits in India are found in Tamilnadu (Chalk hills magnesite and Selam magnesite), Mysore (Dodkanya and Dodkatur areas in Mysor and Hassan districts); Uttarakhand (Someshwar and Bageshwar areas in Almora district); Andhra Pradesh (Kurnool district, associated with Steatite deposits); Bihar (Singhbhum district, as talc-magnesite rock containing 59% talc); Gujarat (Idar, crystalline breunnerite variety containing isomorphous $FeCO_3$ associated with tremolite-calcite rocks) and Rajasthan (Ajmer, Dungarpur ,Pali and Jodhpur districts). India has extensive deposits of high grade magnesite. It is mostly used in the form of refractory bricks in steel, lime and other furnaces; some quantity is consumed in the manufacture of sorel cement and magnesium sulphate (Epsom salts), for artificial silk, tanning and pharmaceutical industries; and a small quantity of magnesite is used in rubber and glass industries. Research on the preparation of magnesium metal and light metal alloys is actively being pursued at the National Metallurgical Laboratory of C.S.I.R.

**Zircon ($Zr.SiO_2$; 49.5 Zr, 67.2% $ZrO_2$):**
This has crystallized as tetragonal prism terminated by pyramids, having hardness of 7.5 and specific gravity about 4.7 and shows adamantine luster. Zircon occurs as an accessory mineral in all plutonic rocks, more commonly in granite, syenite and diorite and is more abundant in pegmatities associated with them and also commercially obtained from placer deposits, in which it occurs usually as rounded grains or crystals. The beach sands of Kerala and Tamilnadu are the principle sources of industrial zircon, which is recovered as a co-product of ilmenite, rutile and monazite. It is known that the zircon is next to diamond in brilliance or fire due to its high refractive index, strong double refraction and strong dispersive power. Zircon is an outstanding acidic refractory mineral because it is chemically inert, is a good heat conductor ,and high melting point (2190$^o$C) and does not show any shrinkage on being heated upto 1750$^o$C. Zirconia crucible can be used for melting platinum in air in high frequency furnaces. Pure zirconium is widely used for in nuclear apparatus because it is strong, resists corrosion, has a high melting point and cladding material in atomic reactors. A small amount of hafnium (HF) element obtained now as a by-product from commercially produced zirconium has been used in carbide cutting tools and fluorescent powders, and due to its high neutron absorption factor is important for nuclear energy equipment.

In India ,zircon have been reported to occur as crystals in pegmatites at Assam (Cherrapunji, Khassi hills); Bihar (Abraki Pahar in Gaya and Domchanch in Hazribagh districts); Uttarakhand (Kedarnath in Garwal district); Orissa (Rasul in Cuttack district); Tamilnadu (Kangyam in Coimbatore, Kadavur in Tiruchirapalli and Seithur in Ramanathapuram districts); and Kerala (Appiyode in Eranlel Taluk).The beach sands of Kerala and Tamilnadu have contain another zirconium mineral baddeleyite ($ZrO_2$). At places, cyrtolite is uraniferous ziron. There are the more common gem varieties of zircon occurrences like Hyacinth and Jacinth (yellowish red variety), Jargoon (straw-yellow variety) and colourless zircon (Matura diamond of Srilanka).

**Fluorite ($CaF_2$; 48.9%F):**
It commonly occurs as cubes or octahedrons and shows fluorescence and phosphorescence. Fluorite usually occur in hydrothermal fissure veins, associated with galena (PbS), zinc blende (ZnS), quartz, barite and calcite or as irregular bedding replacement deposits, especially in limestone, or as encrustations in vugs. It is also found as a gangue mineral are some pneumatolytic veins containing tin and tungsten ores, and also as a minor accessory mineral in some granites, pegmatites, gneisses and volcanic rocks.

**In India, important deposits of fluorite occur in Madhya Pradesh, Rajasthan and Gujarat. In Madhya** Pradesh, the mineral occurs in Durg district (Chandi Dungri) in quartz veins of pegmatitic origin developed along a narrow shear zone in granite. On an average, the deposit contains 26-36% $CaF_2$, and the gangue minerals are chiefly quartz and feldspar with sporadically scattered grains of galena (PbS) and pyrite ($FeS_2$). Other occurrences of fluorite in Madhya Pradesh are in Raipur, Jabalpur and Rewa districts. In Rajasthan, fluorite is found in Dungarpur, Sikar, Alwar, Jhunjhunu, Nagaur and Ajmer districts. In Gujarat, a fluorite deposit occurs in Ambagaon hills of Chhota Udaipur (Baroda district) and is likely to prove to be the biggest deposits in India. The mineral also occurs in the Sabarkantha district of this state.

The chemical use of fluorite is primarily for making hydrofluoric acid, and is used in the etching of glass, making artificial cryolite ($3NaF.AlF_2$) for used as an electrolyte in the reduction of alumina to the metallic state and also in the manufacture of numerous organic and inorganic fluorine compounds and gaseous fluorine which are used in making refrigerants, insecticides, antiseptic, aviation fuels, fluorocarbon plastics and in the separation of Uranium isotopes and production of atomic bombs.

**Asbestos:**
It is a general term applied to a group of naturally occurring fibrous minerals than can be easily split into fibres, capable of being spun together. Commercially, asbestos is classified into two main types. According to the mineralogical group to which it belongs into two types; (1) Serpentine asbestos i.e, crysotile ($3MgO.2SiO_2.H_2O$) and Picrolite (woody fibres); (2) Amphibole asbestos which includes the fibrous varieties of tremolite ($CaO.3MgO.4SiO_2$), actinolite [$CaO.3(Mg,Fe)O.4SiO_2$], anthophyllite [$(Mg,Fe)O.SiO_2$], amosite (Fe-rich anthophyllite) and crocidolite, $NaFe(SiO_3)_2.FeSiO_3$ (blue asbestos). Amosite and crocidolite types of asbestos are not known to occur in India.

In India, important workable deposits of chrysotite asbestos occur in Andhra Pradesh (Cuddapah and Kurnool districts) at the contact of the Serpentinised magnesian limestone and dolomites with the sills of traprock. The mineral occurs as thin cross-fibre veins, both in the serpentine rock as well as in the uppermost part of the trap rock, and is quite suitable for spinning purposes .Minor occurrences of chrysotile are known is Rajasthan (Dungarpur and Nagaur districts), Mysore (Mysore district), Uttarakhand (Chamoli district) and Assam (Naga hills). The amphibole asbestos is more common in India than the chrysotile one. Most of it is the tremolite-actinolite variety. Important deposits of amphibole asbestos variety occur in Andhra Pradesh (Anantapur and Kurnool districts); Bihar (Singhbhum and Ranchi districts); Madhya Pradesh (Jhabua and Sausar districts); Maharashtra (Bhandara district); Gujarat (Subarkantha district); Mysore (Hassan, Bangalor, Bijapur, Chitaldrug, Kadur, Mysore and Shimoga districts), Orissa (Mayurbhanj and Sundergarh districts); Rajasthan (Ajmer, Alwar, Bhilwara, Dungarpur, Jhunjhnu, Sirohi, Jodhpur and Udaipur districts); Tamilnadu (Salem and Coimbatore districts); Uttar Pradesh (Mirzapur district) and Uttarakhand (Garhwal and Kumaon districts). Anthophyllite asbestos is reported from the Hassan district of Mysore and Nilgiris in Tamilnadu. India has sufficient resources of tremolite-actinolite asbestos but the resources of chrysotile asbestos are very limited.

**Apatite ($Ca_3(F,Cl)(PO_4)_2$):**
Though phosphorus (P) is one of the common elements in the earth's crust, it is found concentrated enough only in the case of certain minerals like apatite and rock phosphate (phosphorite). Other sources of phosphorus are the phosphatic nodules, phosphatic limestones , phosphatic guano and basic blast furnace slag. All life requires phosphorus for its existence. The primary origin of all phosphates (whether mineral or organic) is apatite (fluo-apatite, $3Ca_3P_2O_8CaF_2$ or chlor-apatite, $3Ca_3P_2O_8CaCl_2$; both containing about 41-42% $P_2O_5$). In other words its composition is a double salt of calcium phosphate with calcium chloride and fluoride. Apatite is the most abundant crystalline phosphate mineral and is found as an accessory mineral in practically all kinds of igneous rocks. Ii is found usually in pegmatites. Primary phosphorus from apatite in igneous rocks is supplied to the soil by weathering agencies or carried by water to the rivers and thence to the sea, usually in the form of phosphoric acid and its salts.

The mineral apatite deposits occurs in many places in India especially in the mice- bearing pegmatite in Hazaribagh district and also in the Singhbhum district (in association with magnetite-apatite rocks between Dhadkidih in the Seraikela area and Khejurdari in Dhalbhum and it is said to extend further eastwards into Mayurbhanj in Orissa). The grade of Singhbhum apatite produced ranges from 11-29.24%$P_2O_5$ (Av.16%). The reserve of apatite from three important producing areas such as Nandrup Sector (from Itagarh to Rajdiha), Patharghara Sector(from Rakha mine to Dhobani) and Sungri Sector (from Mosabani to Khejurdari) are averaging 10-25% $P_2O_5$ upto a depth of 30 meters. In Andhra Pradesh, small amount of apatite are found in the manganese mines of Garbham, Devada and other areas of Srikakulam district and Sitaramapuram area of Vishakhapatnam district (apatite associated with altered mica vermiculite and magnetite occurs as veins),where apatite is a universal constituent of the Kudurite series of manganese bearing rocks and often occurs in the lithomarge (clayey rock associated with laterite occurring between the lateritic cap and the underlying basaltic or gneissic parent rock ) resulting from the decomposition of these rocks and also another area of apatite deposit is Kashipatnam in the same Vishakhapatnam district. Small amount of apatite are also won from the mica dumps of Nellore district. Other localities for the apatite deposits are encountered in Gujarat (Narukot area), in Rajasthan (apatite bearing schists are reported from Dungarpur district), Tamilnadu where apatite (crystal of bluish-green) bearing pegmatites veins are found in the Kottagudi area near

Bodinayakanur and also bluish-green apatite in small pockets is found in pegmatites near Kabbur and Arsekere as also near Hole Narsipur and at Malvanghatta near Channarayapatna in Karnataka.

**Rock Phosphate and Phosphatic Nodules (Phosohorite):**
In India, phosphatic rock and nodules are found in Rajasthan, Tamilnadu and Uttarakhand. In Rajasthan, major deposits of phosphorite Udaipur, Jaisalmer and Barmer districts.

The first recorded commercial production of phosphate rock from Udaipur district and Rajasthan is likely to be a major producer of rock phosphate in India. The rock phosphate deposits of Jhamar-Kotia (bedded type deposit with thickness about 18kms) area near Udaipur the reserves have been estimated about 40 million tonnes of material with 20-30% $P_2O_5$. Phosphorite deposits have been located in Jaisalmer district where phosphorite occurrences associated with the highly folded Birmania Formations (Palaeozoic) carry sizeable reserves, 20kms from Barmer railway station in that district .In Uttarakhand, true phosphorite (which are directly or indirectly of sedimentary of marine origin) as well as phosphatic nodules are found in the Mussoorie area and also in Niti area of Kumaon district .In concern to the Mussoorie area,the phosphatic nodules are confined to the black shales and cherts of lower Tals, but the $P_2O_5$ content is very low ranging from 0.02 to 7.8% . In Almora district, a lenticular band of phosphatic limestone is noticed in the stromatolitic limestones occurring near Chhani Gad on the Takula to Bageshwar road. In Pithoragarh district, occurrences of phosphorite are noticed between Berinag and Bhuligaon in association with stromatolitic limestones, where best develop near the contact of the calcareous and quartzite formation. Besides these, magnesite is, however, usually present along with the phosphorite in the Pithoragarh district. In Tamilnadu, phoshatic nodules are found in the Tiruchirapalli district (near Sirukanbur between Uttatur and Chittalai) and South Arcot district (between Tuttipattu and Akasampattu villages). In Himachal Pradesh, phosphatic nodules are found in the Chamba, Simla, Mahasu and Sirmur districts. In the Chamba district, these nodules occur in association with the Saloni slates (Infra-Krols) from the Chikoli bridge area, Torota, Dhulan, Khamot and Bhatimund areas. In the Simla and Mahasu districts of Himachal Pradesh, phosphate deposits are found in the Pachmunda, Rajgarh and Sharaon basins in the Krol sandstones as continuous bands ,streaks, stringers and discoidal pellets in chert. The $P_2O_5$ content varies from trace to 20%. In the Sirmur district, the phosphate deposits are associated with the Subathu Formations. **According to the Geological Survey of India (GSI**), near Khasanibal and Nunkhul section in the Pir Panjal range (J&K), where bands of phospharite and nodules are found scattered in a 10 meters thick zone in upper Permian limestones and shales. The $P_2O_5$ content ranges from 20-30%.

**Saltpetre [Nitre; $KNO_3$; 46.5%$K_2O$]:**
It is used mainly in the manufacture of explosives (cf.Gun powder), in glass manufacture, in tempering steels, and in the manufacture of matches and fire-works. It is also used sometimes as fertilizers.

Potassium nitrate ($KNO_3$) is formed wherever organic nitrogenous substances decay in contact with potassium salts, the reaction being brought about by nitrifying bacteria. Saltpetre is natural product formed in the soil of the alluvial areas of India under peculiar conditions of climate and environment. In many areas, the percolating water dissolves the potassium nitrate, brings it to the surface by capillary action and deposits it as efflorescence (saline earth). The crude earth which is collected from the surface in those areas is locally called “Lona Matti”(or Loni Malti) and the saltpetre is recovered from it by first dissolving out the mixed salts (mostly potassium nitrate, sodium chloride and sodium sulphate) present in the soil and then roughly separating them by fractional crystallization. The crude saltpetre varies greatly in composition and some of it is used as a fertilizer especially in tea plantations and the rest is also used in the manufacture of soaps and matches and in the glass and ceramic industries. In India, saltpetre is found as a efflorescence (saline earth) and their producing centre in Punjab mainly from the districts of Ferozepore (villages of Moga, Bhaga, Ferozepore, Fazilka and Muktsar), Sangrur (villages of Cheema, Sunam and Barnala and Gurdaspur ). In Haryana, Saltpetre occurrences are mostly found in the districts of Gurgaon (locatities; Ballabgarh, Faridabad, Palwal, Hathin and Pataudi); Jind (localities; Safidon, Uchana, Kalayat and Jind); Karnal (localities; Pundri, Gohla and Kaithal) and Rohtak (Jhajar, Ganaur, Gohana, Nahar and Kakhoda). In Uttar Pradesh, it is found in the district of Allahabad, Ghazipur, Kanpur and Varanasi; the production is, however, much less, about 1/10th of that of Bihar. Saltpetre is produced in Bihar from the districts of Champaran, Darbhanga, Gaya, Monghyr, Saran, Muzzaffarpur and Shahabad where high grade saltpetre contains as much as 66.07% of potassium nitrate. In Andhra Pradesh, saltpetre producing centres in the districts of Anantpur, Guntur and Kurnool and in Tamilnadu, saltpetre is produced Tiruchirapalli, Madurai, Coimbatore and Salem districts. In the Salem district, it is mainly found around Mohanur and Velur villages on the banks of the Cauvery river and at Chittalandur near Tiruchengode.

### Selenium (Se):

In India, selenium of 99.5% purity is obtained during the electrolytic refining of copper ores by the Hindustan copper Ltd. It is utilized in the manufacture of photoelectric cells, burglar alarm, red glass, drugs etc. Selenium is not only primarily recovered in electrolytic copper refining slime but also along with other precious metals such as gold, platinum and palladium. Inorganic pigments containing selenium produce colours ranging from red to deep maroon which fine applications in ceramic and plastic where heat, light and chemical stability are essential. Electrical rectifier's fabricators consume about 5% for low voltage condenser products.

### Kyanite and Sillimanite:

The kyanite deposit of Lapsa Buru (Kharsawan, in Singhbhum district) is the largest deposit of its kind in the world and also largest producer of this mineral. Sillimanite deposit of Sonapahar (in Khasi Hills, Assam) considered as the world's largest. Another important deposit of Sillimanite in India is of Pipra (Rewa, M.P**).**

**Table: 1-Shows the natural source of trace elements in rocks, ores and minerals**

| Rocks/Ores/Minerals | Trace Elements |
|---|---|
| Shale and Bituminous shale | V, U, As, MO, Cu, Ni, Co, Cd, Ag, Au, Pt, Se, AL |
| Iron Ore | Fe, V, As, Sb, Se |
| Manganese ore | Mn, Ba, Li, K, Ti, W, Co, Ni, Cu, Zn, Pb |
| Limestone/dolomite | Ca, Mg, Fe, Ba, Sr, Pb, Mn |
| Olivine | Fe, Ni, Co, Mn, Zn, Cu, Mo, Cl |
| Hornblende | Fe, Ni, Co, Mn, Zn, Cu, Mo, Cl |
| Augite | Al, Ni, Co, Mn, Se, V, An, Cu, Ga |
| Biotite | Mn, Fe, Al, Rb, Ba, Ni, Co, Li, Mn, V, Zn, Cu, Ga, F |
| Apatite | Pb, Sr, F, Rare earths |
| Anorthite | Al, Sr, Cu, Mn, Ga |
| Andesite | Al, Sr, Cu, Mn, Ga |
| Oligoclase | Al, Cu,Ga |

*Source-S. K. Kar and Surendra Prasad; GEOLOGY AND PUBLIC HEALTH*

### Exposure of Minerals:

Minerals s.l. being present in the environment where man lives can interact, either positively or negatively with the human body. Although being essential to human health, some chemical elements in macro or micronutrients can be good, toxic or lethal, depending on the individual dosage. Non-essential chemical elements can also be tolerable, toxic or lethal, depending on the dosage too. This principle was established long ago. According to Paracelsus (1493–1541 AC) "all substances are poisons; there is none which is not a poison; the right dose differentiates a poison and a remedy". Fig. 2 shows the Periodic Table distinguishing essential from toxic elements as well as those considered as essential and toxic. The intake of minerals and non-toxic or toxic chemical elements by food, water, soil (through geophagy) or dust takes place either by ingestion, inhalation or dermal absorption [6]. Ingestion is the most common pathway of exposure for the general people, whereas inhalation and dermal sorption are significant in certain occupational settings [7].

Dietary deficiencies and excesses with repercussion on human health involve other essential chemical elements characterized by specific functions such as Ca, Mg, K, Na, Fe, Zn, Cu, F, and Se [8, 9, 10, 11]. The deficiency of these elements can cause health problems. Many health problems are related to dietary deficiencies of certain essential chemical elements. Life style, particularly dietary, is an important environmental factor that decisively conditions the human health. There is an old aphorism "We are what we eat" that expresses this fact very well. Combs [11] reports several examples of geologic impacts on nutrition. For instance, iodine (I) is one essential trace element in human nutrition. According to Nordberg and Cherian [12], both the United Nations Organization (UNO)[13] and the World Health Organization (WHO)[14] estimated that one billion people are at risk of iodine deficiency disorders (IDD), 211 million with goitre (enlargement of the thyroid gland), 5.1 million with severe cognitive and neuromotor deficiency, and many more with less severe neuropsychological defects. Iodine deficiency can lead to the so-called hypothyroidism whereas the excess of iodine intake can lead to the so-called hyperthyroidism responsible for the cancer of the thyroid [15,16,17].

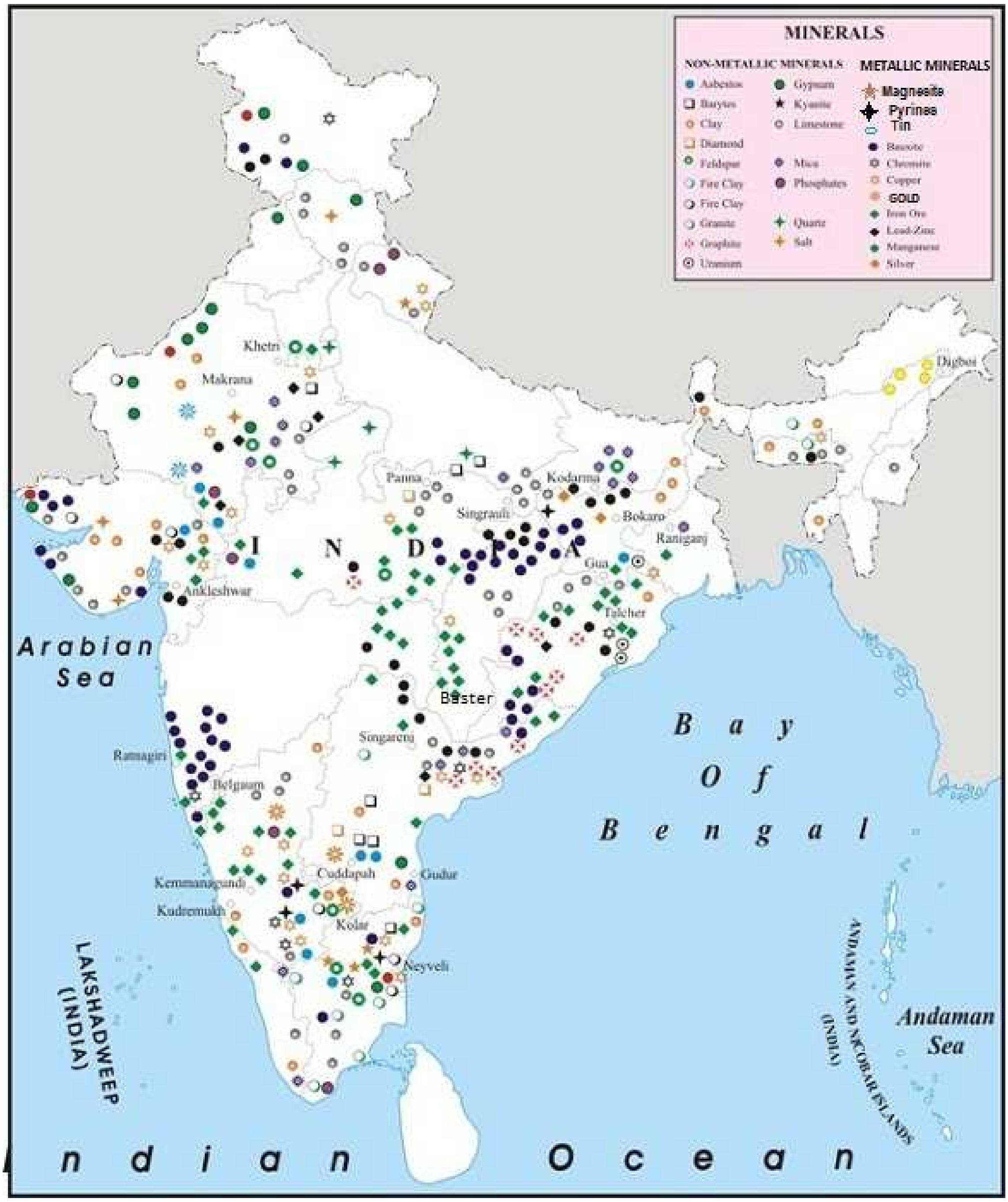

**Fig-1: Map showing non metallic and metallic minerals distribution in different areas of India. [71]**

**Geogenic Diseases:**
The geogenic processes leading to ill health is a major challenging task in India with an area of 3287263 sq.km and having a population of over 1 billion spread over 35 states and Union territories having varied geological domain. The land-water ecosystem developed in response to geological, geochemical and hydrodynamic processes vary from place to place. Thus, concentrations of various elements also vary. Areas of excess / deficient concentration of essential trace elements and heavy metals related to health are therefore not well defined. Although no systematic studies have so far been carried out to establish geological linkage with diseases, case histories of endemic diseases

are reported from different parts of India. Three major endemic diseases on account of [18]. geogenic reasons are related to deficiency or excess concentrations of trace elements, metals and non metals

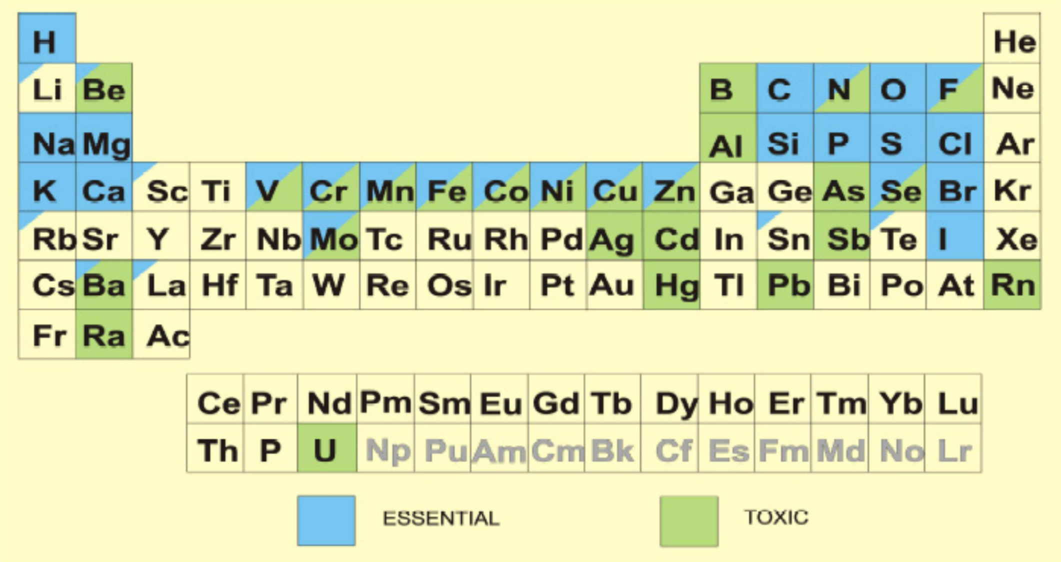

**Fig-2- The periodic table of elements showing those elements essential to human health and those considered or known to be toxic or undesirable. Note that some elements fall in both categories, others are possibly essential for living organisms (Source: Groundwater Geochemistry and Health, 1996; reproduced with kind permission of the British Geological Survey)[70]**

### (1) Arsenic

Exposure to arsenic occurs via ingestion, inhalation, dermal contact and the parenteral route to some extent. Drinking water contaminated with arsenic is a major public health problem. Acute and chronic arsenic exposure via drinking water has been reported in many countries of the world, where a large proportion of the drinking water is contaminated with high concentrations of arsenic. General health effects associated with arsenic exposure include cardiovascular and peripheral vascular disease, developmental anomalies, neurologic and neurobehavioural disorders, diabetes, hearing loss, portal fibrosis, hematologic disorders (anemia, leukopenia and eosinophilia) and cancers. Significantly higher standardized mortality rates and cumulative mortality rates for cancers of the skin, lung, liver, urinary bladder, kidney, and colon occur in many areas polluted with arsenic [19, 20 ,21, 22]. In Bangladesh, India, China, Taiwan, Vietnam, Mexico, and elsewhere, high levels of arsenic in drinking water have caused serious health problems for many millions of people .Geoscientists from several countries are working with public health officials to seek solutions to these problems. By studying the geological and hydrological environment, geoscientists are trying to determine the source rocks from which the arsenic is being leached into the ground water. They are also trying to determine the conditions under which the arsenic is being mobilized. For example, the arsenic might be desorbed and dissolved from iron oxide minerals by anaerobic (oxygen-deficient) groundwater, or it might be derived from the dissolution of arsenic-bearing sulfide minerals such as pyrite by oxygenated waters. Understanding the mechanisms by which arsenic is mobilized will permit the public health officials around the world to identify aquifers that may pose a threat to their communities. Undetectable in its early stages, arsenic poisoning takes between 8 and 14 years to impact on health, depending on the amount of arsenic ingested, nutritional status, and immune response of the individual. Arsenic is toxic substance to human health and toxicity depends on the amount of arsenic intake, which is classified into acute, sub-acute and chronic toxicity respectively. It is a silent killer. It is 4 times as poisonous as mercury and its lethal dose (LD) for human is 125 milligram. Drinking water contamination causes the last variety of toxicity. Inhalation, ingestion and skin contact are the primary routes of human exposure to the arsenic. Chronic arsenic ingestion from drinking water is known to cause skin cancer, and there is substantial evidence that it increases risk for cancers of the bladder, lung, kidney, liver, colon, and prostate. Recent studies have also shown that arsenic is associated with a number of non-neoplastic diseases, including cardiac disease, cerebrovascular disease, pulmonary disease, diabetes mellitus and diseases of the arteries, arterioles, and capillaries [23]. Individuals with chronic Hepatitis B infection, protein deficiency or malnutrition may be more sensitive to the effects of arsenic [24], World Health Organization WHO ,(1999), Children and older adults may be other groups at special risk. Observable symptom to the arsenic poisoning can be thickening and discoloration of skin, stomach pain, nausea, vomiting, diarrhea, numbness in hand and feet, partial paralysis, blindness.

### Occurrence in India

Arsenic contamination in ground water affecting major parts of southern West Bengal is well known. Abnormal concentrations (above permissible limit of 50 ppb) of arsenic in ground water is reported from a 400-km-long and 60-km-wide belt covering seven districts of West Bengal. Arsenic contamination is also reported from areas in Chhattisgarh, Bihar, U.P. and Tamil Nadu. Arsenic pollution in Bengal basin extends from Kaliachak in Malda district in the north to Ramnagar under Baruipur block of South 24-Parganas district in the south. Ground water occurring mainly within shallow aquifer, in general 20-60 m below ground level (bgl) contains arsenic varying from <.05 ppm to 1 ppm. Higher concentration of arsenic to the tune of 3500 ppb (3.5 ppm) as dissolved pollutants within the depth range of 13 to 128 m bgl is also reported. Surface water, shallow unconfined ground water in dug wells and deeper aquifer below the contaminated layers generally show arsenic content below toxic limit. Studies show that sedimentary column of Holocene age are the most affected geological unit of Bengal delta plain. Isotope studies have indicated the age of shallow aquifer layers, 20-50 years, whereas the deeper aquifer is as old as 5000-11000 years. Geochemistry of arsenic contaminated water indicates its alkaline nature (pH being above 7) – calciumbicarbonate type with high concentration of Fe. There is a positive correlation of arsenic with Ca, Mg, $HCO_3$, Fe and negative correlation with Cl and S in arsenic-rich ground water. $As^{+3}$ is more prevalent than $As^{+5}$. Regarding the source area for arsenic, various suggestions have been put forward. The Rajmahal hills in the north-west, Himalayas on the north, coal bearing Gondwana rocks of West Bengal, Bihar and Jharkhand and apatite (phosphorite) deposits in Singhbhum area could be potential source. Hydrogeochemical studies of arsenic dispersal in surface water and sediments of middle reaches in Ganga basin in parts of Uttar Pradesh, Bihar and M.P. were undertaken between Banda district (U.P), parts of Sidhi district, M.P. and parts of Shahabad and Rohtas districts in Bihar. However, in absence of large-scale database of trace-element analysis of the constituent rocks and sediments no positive correlation could be worked out. The mobilization of arsenic in ground water as one study suggests could be due to (i) the oxidation of arsenopyrite on one hand and (ii) the reduction of ferric hydroxides on the other. During transportation, dissolved arsenic occurs in the +5 oxidation state and adsorbed onto detrital particles. A concerted effort of focussed geochemical mapping and geochemical modelling of arsenic behaviour should produce desired results [19].

### (2) Iodine

Iodine intake via meat, fish and vegetables clearly mirror iodine concentrations of the soil environment. The connection between geologic materials and trace element deficiency is well documented for iodine. Iodine Deficiency Disorders (IDD) includes goiter (enlargement of the thyroid gland), cretinism (mental retardation with physical deformities), reduced IQ, miscarriages, and birth defects. In ancient China, Greece and Egypt as well as among the Incas, people affected by goiter, were given seaweed to provide the needed iodine [17].

Iodine originates from the ocean, from where it is released from the sea surface as methyl iodide, subsequently transported to the land and deposited on vegetation and topsoil through wet and dry deposition. The iodine content of surface soils decreases rapidly with increasing distance from the sea [25]. The span between low and high iodine soils is very large, from about 15 mg/kg in organic-rich soils near the coast [25] to less than 1 mg/kg in areas far inland. Iodine has long been known as an essential element for humans and mammals, where it is a component of the thyroid hormone thyroxene. Insufficient supply of iodine may lead to a series of iodine deficiency disorders (IDD), the most common of which is endemic goiter. Iodine deficiency during pre-natal development and the first year of life can result in endemic creatinism, a disease which causes stunted growth and general development along with brain damage. This brain damage may occur even when there is no obvious physical effect, and probably represents the most widespread current geomedical problem on Earth with as much as 1.6 billion people at risk [26]. The areas of the world currently most affected by IDD are largely located in developing countries of Africa, Asia, and Latin America [17], mainly in areas located far from the ocean. Even in some affluent countries of Western Europe however it has been suggested that as much as 50-100 million people may be at risk [27].Goitre is caused due to deficiency of iodine in human beings and animals. The minimum iodine intake recommended is 0.075 mg/day. According to an estimate taken a few decades ago, about 70 million people were suffering from iodine deficiency disorder (IDD) globally. The present scenario is much improved due to high intake of iodised salt and improved socio-economic conditions.

**In India**, goitre endemicity is confined to the sub- Himalayan tract. In major parts of the country deficiency of iodine in soil-water ecosystem is due to (i) heavy rainfall, (ii) steep gradient and poor vegetation cover resulting in quick run-off and little time for transfer of iodine. Deficiency of iodine in source areas is also related to the chemical composition of rock and soil. The goitre-eradication programme should include (i) tapping of deeper aquifer, (ii) effective control of flood menace, (iii) soil conservation, and (iv) educating people for modified dietary habits [19].

### (3) Fluoride Endemicity

Fluoride endemicity is caused due to deficient / excess intake of fluoride. About 96% of the fluoride in the body is found in bones and teeth. The range of fluoride intake, as per WHO standard, is 0.5 –1.5 mg/ litre. Fluoride is beneficial between 0.8 – 1.0 mg/litre for calcification of dental enamel of children below 8 years of age. Dental caries occur due to fluoride deficiency, while it causes dental and skeletal fluorosis if taken in excess of 1.5 mg/litre and 3.0 mg/litre respectively. The intake of fluoride is largely through drinking water. The fluoride in soil-water ecosystem is derived from various sources viz. parent rock, fluorine-rich volcanic ash, thermal power plant, industrial effluent and fertilizer.

### In India

The survey carried out indicates more than 62 million people spread over the 16 states of India, namely Jammu & Kashmir, Punjab, Haryana, Delhi, Uttar Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Kerala, Tamil Nadu, Orissa, Bihar, Jharkhand and Assam are affected by fluoride endemicity. Fluoride endemicity is most prevalent in states of Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Rajasthan and Uttar Pradesh. The geological linkage of fluoride being released in aqueous system is as vague as its distribution or its point of concentrations. The various studies carried out so far identified major linkage grouped into three broad classes, viz.

1. Fluoride enrichment in the drainage basin from source rocks like fluoride-bearing granite and within the structural basin indicating geological-cum-tectonic control of the fluoride concentration in an area.
2. The Quaternary sediments with volcanic ash containing high fluoride are geochemically reactive with Na replacing Ca in aqueous system resulting in enriched pockets.
3. Use of fertilizers in agricultural field and Industrial effluent causing surface/ground water contamination locally.

In India, the socio-economic status plays a vital role amongst the sufferers. The lack of knowledge of fluoride related diseases and social control at times lead to widespread sufferings. Abandoning the source is a welcome move besides clinical assistance. A multidisciplinary approach on fluoride problem is urgently required. The geochemical mapping of the country may help in identifying the (i) fluoride rich pockets (ii) the source, (iii) dispersions and mode of concentrations, etc and finally preparation of a multi-layered fluoride map of India in order to suggest remedial measures [19].

### (4) Cadmimum (Cd)

The cadmium is a rare element and is present in the natural environment in form of its various compounds, at a relatively low level. Cadmium is widely and increasingly used in industries for corrosion- protection coating, nickel-cadmium batteries and several other applications. It may enter the aquatic and ambient environment as a toxic pollutant from various anthropogenic sources such as zinc, copper and lead mining, various industries, Iron & steel, non-ferrous metals cement production etc, electroplating, phosphate fertilizers, nickel-cadmium batteries, coal utilization and tobacco smoking. In high concentrations, cadmium may affect human health. Cadmium contamination of the fishes was the main cause for the episodal pollution and endemic bone disease “itai-itai” reported from Japan, during which several hundreds of peoples were affected.

It is widely Distributed in nature, with an average concentration of 0.1 to 0.2 mg/kg in earth' crust. It is associated in small amounts with the zinc, lead and copper ores. Cadmium is not recovered as a mining product, but as a by product of the extraction, smelting and refining of other nonferrous metals such as zinc, lead and copper. The average cadmium content of sandstone has been reported to be 0.05 ppm and that of shale as 0.3 ppm. Sedimentary rocks and marine phosphate rocks contain about 15 mg/kg cadmium. Cadmium content of phosphate fertilizers varies between 2 and 200 mg/kg [28].

## In India

## AQUATIC ENVIRONMENT

Cadmium may be present in the aquatic environment at relatively low levels as inorganic complexes such as carbonates, hydroxides, chlorides or sulphates, or as organic complexes with humic acids. Even in polluted rivers the cadmium levels in aqueous phase may be significantly low and even sometimes below detection limit. Rivers and lakes in urban areas contain high concentrations of particulate matter and therefore most of the cadmium is adsorbed to suspended particles [28].

### Cadmium concentrations in Aquatic environment

Central Pollution Control Board has carried out an extensive study on Yamuna River water during 1999-2005. The maximum concentration of cadmium (0.02 mg/l) was recorded at Agra downstream during the year 2001, while most of the other time the cadmium was founded below detection limit. In sediment, cadmium is mainly associated with small particles of organic materials. Thus high content of cadmium is found in areas, where sedimentation rate of organic particles is comparatively higher [28].

### Ground Water

Ground water is an important source of water, as the surface water is getting scarcer day-by-day. Discharge of municipal wastewater and industrial effluents either onto land or surface water bodies, may percolate through soil and may affect ground water resources. Agricultural usage is also another route through which metallic ions could percolate to the ground water source. CPCB in collaboration with state pollution control boards carried out a study of ground water in various problem areas in the country and observed that cadmium ranged between not traceable to 0.224 mg/l [28].

### Coastal Water

Metals are natural constituents of seawater and are derived from erosion of ore bearing rocks, volcanoes etc. Rivers and atmospheric inputs also play an important role. In the open sea where the suspended solid are often low more than 99% of the cadmium exists in dissolved form. Among the oceans and seas the lowest concentration of cadmium is reported in the Sargasso Sea and Pacific Oceans while the highest in North Atlantic Ocean. The vertical distribution of cadmium in oceanic waters depicted nutrient like distribution, i.e., low concentration in surface waters which increases with depth. The cadmium contents in Indian Ocean waters varied between 0.01 and 25 µg/l. However, a maximum of 80 mg/l cadmium has been recorded in the coastal waters off Bombay [28]

## CADMIUM IN SOIL

Cadmium is much less mobile in soils than in air and water. The input of cadmium to the soils is from both natural and anthropogenic sources. Natural sources include underlying bedrock or transported parent material such as alluvium. The cadmium in soils occur at very low levels, but it is added to the soils by other products such as, fertilizers, phosphogypsum, certain zinc additives, bio-solids (sewage sludge), manures and other wastes. Cadmium added to the soil remains for a long time and it may take about 100 to 1000 years for leaching of cadmium from the soil to half. The higher concentration of cadmium have been reported in different rocks and ores.

**Table-2: Cadmium levels in ores and rocks (mg/kg)**

| Igneous metamorphic and sedimentary rocks | Zinc ores | Ores for iron & steel | Material for cement | Fossil fuels | Phosphate fertilizers | Copper and Lead ores |
|---|---|---|---|---|---|---|
| 0.02-0.25 | 200-1400 | 0.1-5.0 | 2.0 | 0.5-1.5 | 10-200 | ~500 |

Cadmium in non-agricultural soils generally not affect human health as it could not enter the human food chain but its indirect transfer from non-agricultural soil to agricultural soils via airborne or water transport may affect the food chain. Cadmium in agricultural soils is relatively immobile but become mobile under acidic conditions. The chemistry of cadmium in soil is controlled by the pH. Cadmium mobility increases with a decreasing pH of the soil. The guideline value for cadmium content in agricultural soils is 5.0 ppm. [28].

### (5) **Zinc**

Zinc is essential in the diets of plants and animals and key component of many enzymes. Zinc plays a role in reproduction and also sexual maturation. Zinc deficiency is characterized by poor growth and dwarfism, anorexia, Parakeratotic skin lesions, diarrhea, impaired testicular development, impaired immune function (including wound healing), and impaired cognitive function. Low zinc status is also thought to increase risk to osteoporosis and susceptibility to oxidative stress. Very high intakes of zinc, which have occurred due to inappropriate use of zinc supplements, can interfere with copper metabolism and deplete the body of copper. Chronic exposure to excess zinc (more than 100mgd$^{-1}$) can reduce immune function and HDL cholesterol [29]**.** Its extreme importance in immune competence [30] and it's possible role as anti-carcinogen. Next to whole grains, pulses and unpolished rice, red meat is an important source of daily Zn intake [31]. Zinc deficiency was first observed and reported among rural inhabitants of the Middle East in the early 1960s **.** Zinc deficiencies are not uncommon in the diet of the population in USA, with children inter alia exhibiting zinc deficiency "although there has been little evidence for nutritional deprivation" [30]. Dietary zinc deficiencies are also found in Sweden and other industrialized countries [32]**.** According to **Alloway** [33] zinc deficiency is the most widespread essential trace element deficiency in the world, perhaps affecting as much as one third of the world´s human population. Large areas of the world have soils that are unable to supply staple crops, such as rice, maize, and wheat, with sufficient zinc. Moderate zinc deficiency has been cited as a major etiological factor in the adolescent nutritional dwarfism syndrome in the Middle East, the cardinal features of which are severe delay of sexual maturation and dwarfism [34]**.** Recently it was suggested that fetal Zn deficiency contributes to the pathogenesis in adults [35]**.**

### (6) Nitrogen

Sources of nitrate in groundwater can be considered in four categories: (1) Natural sources (2) waste materials (3) irrigated agriculture and (4) 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 [36]**.**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 [37]. Research shows a definite relationship between increasing rates of stomach cancer with increasing nitrate intake [38]**.** Significant concentrations of $NO_2$ have been detected in plumes from the Mount St. Helens eruption [39]. If high concentrations are inhaled, hydrolysis of $NO_2$ results in the production of nitric acid, particularly in the lower respiratory tract (including the alveoli). Nitric acid in turn produces nitrates and nitrites, both of which are capable of producing cytotoxicity and disruption of cellular membranes. The clinical outcomes of $NO_2$ inhalation are in some respects comparable to those of contact with $SO_2$. Acutely, victims may suffer from chemical pneumonitis, pulmonary edema, ARDS, or fatal lung injury. Susceptible individuals may suffer from exacerbations of asthma, increased need for bronchodilators, and decreased pulmonary function [40]. Nitrate and phosphate are essential nutrients and in lakes and coastal marine waters they can cause algal blooms and ultimately eutrophication when massive algal growths cause all of the oxygen in the water to be depleted. This results in the death of the algae and other biota, which leads to masses of rotting organic matter. In addition, the leaching of nitrates into groundwater in some agricultural areas has caused problems when the ground waters are sources of potable waters. Such nitrate-rich waters have been shown to have caused methemoglobinemia in young babies due to nitrate interfering with the iron in blood which results in defective transport of oxygen. This is the cause of so-called "blue blood," and methemoglobinemia is sometimes referred to as "blue baby syndrome." It has also been suggested that ingestion of nitrates can contribute to gastric cancer when some of the nitrates are converted to nitrosamines, which are thought to be carcinogens [41].

### Occurrences of Nitrate in India :

Nitrate is one of the most common groundwater contaminants in rural areas and is reported from several areas in Tamil Nadu, Orissa, Karnataka, Maharashtra, Bihar, Gujarat, Madhya Pradesh , Rajasthan and other parts of India. As per the BIS Standard for drinking water the maximum desirable limit of Nitrate concentration in ground water is 45 mg/l with no relaxation. It is estimated that around 37.7 million Indians are affected by waterborne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to waterborne disease each year. Concentration of nitrate above 50 mg/l in drinking water should generate concern due to the health implications6. The occurrences of Nitrate in ground water have been shown on **the Table-3** by different districts of different states in India where nitrate has been found in excess of 45 mg/l in ground water [42].

**Table 3: List of Districts Showing Localized Occurrence of Nitrate (>45 mg/litre) in Ground Water in Different States of India**

| Sl. No. | State | Parts of Districts having Nitrate > 45 mg/litre |
|---|---|---|
| **1** | Andhra Pradesh | Adilabad, Anantpur, Chittoor, Cuddapah, East Godavari, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Mahbubnagar, Medak, Nalgonda, Nellore, Nizamabad, Prakasam, Ranga Reddy, Srikakulam, Visakhapatnam, Vizianagaram, Warangal, West Godavari |
| **2** | Bihar | Aurangabad, Banka, Bhagalpur, Bhojpur, Kaimur(Bhabua), Patna, Rohtas, Saran, Siwan |
| **3** | Chattisgarh | Bastar, Bilaspur, Dantewada, Dhamtari, Jashpur, Kanker, Kawardha, Korba, Mahasamund, Raigarh, Raipur, Rajnandgaon |
| **4** | Delhi | Central Delhi, New Delhi, North Delhi, North West Delhi, South Delhi, South West Delhi, West Delhi |
| **5** | Goa | North Goa |
| **6** | Gujarat | Ahmadabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dohad, Jamnagar, Junagadh, Kachchh, Kheda, Mehsana, Narmada, Navsari, Panchmahals, Patan, Porbandar, Rajkot, Sabarkantha, Surat, Surendranagar,Vadodara, |
| **7** | Haryana | Ambala, Bhiwani, Faridabad, Fatehabad, Gurgaon, Hissar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendragarh, Panchkula, Panipat, Rewari, Rohtak, Sirsa, Sonepat, Yamuna Nagar |
| **8** | Himachal Pradesh | Una |
| **9** | Jammu & Kashmir | Jammu, Kathua |
| **10** | Jharkhand | Chatra, Garhwa, Godda, Gumla, Lohardaga, Pakaur, Palamu, Paschimi Singhbhum, Purbi Singhbhum, Ranchi, Sahibganj |
| **11** | Karnataka | Bagalkot, Bangalore, Belgaum, Bellary, Bidar, Bijapur, Chikmagalur, Chitradurga, Davangere, Dharwad, Gadag, Gulburga, Hassan, Haveri, Kodagu, Kolar, Koppal, Mandya, Mysore, Raichur. Shimoga, Udupi, Uttara Kannada |
| **12** | Kerala | Alappuzha, Idukki, Kollam, Kottayam, Kozhikode, Malappuram, Palakkad, Pathanamthitta, Thiruvananthapuram, Thrissur, Wayanad |
| **13** | Maharashtra | Ahmednagar, Akola, Amravati, Auragabad, Beed, Bhandara, Buldana, Chandrapur, Dhule, Gadchiroli, Gondia, Hingoli, Jalgaon, Jalna, Kohlapur, Latur, Nagpur, Nanded, Nandurbar, Nashik, Osmanabad, Parbhani, Pune, Sangli, Satara, Solapur, Wardha, Washim, Yavatma |
| **14** | Madhya Pradesh | Anuppur, Ashok Nagar, Balaghat, Barwani, Betul, Bhind, Bhopal, Burhanpur, Chhatarpur, Chhindwara, Damoh, Datia, Dewas, Dhar, Gwalior, Harda, Hoshangabad, Indore, Jabalpur, Jhabua,Katni, Khandwa, Khargaon, Mandla, Mandsaur, Morena, Narsimhapur, Neemuch, Panna, Raisen, Rajgarh, Ratlam, Rewa, Sagar, Satna, Sehore, Seoni, Shahdol, Shajapur, Sheopur, Shivpuri, Sidhi, Tikamgarh, Ujjain, Umaria, Vidisha |
| **15** | Orissa | Angul, Balasore, Bargarh, Bhadrak, Bolangir, Baudh, Cuttack, Deogarh, Dhenkanal, Gajapati, Ganjam, J.Singhpur, Jajpur, Jharsuguda, Kalahandi, Kendrapara, Keonjhar, Khurda, Koraput, Malkangiri, Mayurbhanj, Nawapada, Nayagarh, Phulbani, Puri, Sambalpur, Sundergarh, Sonapur |
| **16** | Punjab | Amritsar, Bhathinda, Faridkot, Fatehgarh Sahib, Firozepur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Mansa, Moga, Muktsar, Nawan Shahr, Patiala, Rupnagar, Sangrur |
| **17** | Rajasthan | Ajmer, Alwar, Banaswara, Baran, Barmer, Bundi, Bharatpur, Bhilwara, Bikaner, Chittaurgarh, Churu, Dausa, Dhaulpur, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhalawar, Jhunjhunun, Jodhpur, Karauli, Kota, Nagaur, Pali, Partapgarh, Rajsamand, Sirohi, Sikar, Sawai Madhopur, Tonk, Udaipur |
| **18** | Tamil Nadu | Chennai, Coimbatore, Cuddalore, Dharmapuri, Dindigul, Erode, Kancheepuram, Kanyakumari, Karur, Madurai, Namakkal, Nilgiris, Perambalur, Pudukkottai, Ramanathapuram, Salem, Sivaganga, Theni, Thiruvannamalai, Thanjavur, Tirunelveli, Thiruvallur, Trichi, Tuticorin, Vellore, Villupuram, Virudhunagar |
| **19** | Uttar Pradesh | Agra, Aligarh, Allahabad, Ambedkar Nagar, Auraiya, Badaun, Baghpat, Balrampur, Banda, Barabanki, Bareilly, Basti, Bijnor, Bulandshahr, Chitrakoot, Etah, Etawa, Fatehpur, Firozabad, GB Nagar, Ghaziabad, Ghazipur, Hamirpur, Hardoi, Jaunpur, Jhansi, Kannauj, Kanpur Dehat, Lakhimpur, Mahoba, Mathura, Meerut, Moradabad, Muzaffarnagar, Raebareli, Rampur, Sant Ravidas Nagar, Shahjahanpur, Sitapur, Sonbhadra, Sultanpur, Unnao |
| **20** | Uttrakhand | Dehradun, Haridwar, Udhamsinghnagar |
| **21** | West Bengal | Bankura, Bardhaman |

*Source-Jain & Sharma , 2008[69]*

### (7) Iron

The most common Iron ores are Magnetite ($Fe_3O_4$), Hematite ($Fe_2O_3$), Goethite (FeO(OH)), Limonite ($FeO(OH).n(H_2O)$) or Siderite ($FeCO_3$) and is fourth most abundant element by weight in the earth's crust. Iron compounds are essential to human and animal for carrying oxygen around the blood stream. Iron deficiency leads to Anaemia, lethargy, apathy, fatigue; and reduced physical performance the body. In pregnancy, iron deficiency increases the risk of premature delivery, low birth weight, and infant and maternal mortality [32].

Iron is an important element in all living organisms, as key component of haemoglobin, myoglobin and a number of enzymes. The most important iron sources in the human diet are meat, eggs, vegetables and cereals. Among traditional societies in Uganda, [43] found evidence that direct ingestion of Fevia geophagia accounted for a major proportion of the RDI.

Numerous conditions, other than genetic hemochromatosis, can lead to chronic accumulation of iron in the liver. Among these are the hereditary anemias listed in. In transfusion-dependent b-thalassemia major, the iron overload is severe and, over a period of months or years, can lead to congestive heart failure, hypothyroidism, diabetes mellitus, hepatomegaly, fibrosis, and cirrhosis [44, 45]. Iron overload has been reported in a number of inherited metabolic diseases, including hereditary tyrosinemia, Zellweger's syndrome, congenital atransferrinemia, aceruloplasminemia, Wilson's disease after penicillamine therapy [46] porphyria cutanea tarda, and alpha-1 antitrypsin (AAT) deficiency. In the last condition, no association between genetic hemochromatosis and AAT deficiency was found in one study [47]. In another study, the association of AAT deficiency and genetic hemochromatosis led to an earlier onset of cirrhosis in genetic hemochromatosis, but it did not increase the risk of hepatocellular carcinoma [48]**.** In porphyria cutanea tarda, 60 to 70% of patients have mild to moderate iron overload, and approximately 10% have increases in the range of genetic hemochromatosis; the major cause is the presence of mutations of the HFE gene [49]**.** Hepatic iron accumulation can occur in a number of acquired diseases of the liver . The ones discussed briefly here are chronic hepatitis C, nonalcoholic and alcoholic steatohepatitis, cirrhosis, and post-portacaval shunt surgery. Hepatic iron accumulation occurs in chronic hepatitis C. In one study from Italy, 10% of patients with chronic hepatitis C had an elevated hepatic iron content [50]. Stainable iron in sinusoidal cells and portal tracts reflects an increased hepatic iron concentration, and elevated serum iron values have been linked to poor responses of chronic hepatitis C to interferon therapy. In one study, hepatic iron accumulation was found to be significantly associated with histologic activity and cirrhosis [51]**.**

Iron overload may adversely affect the heart in patients with hemosiderosis or primary hemochromatosis. The most common cause of death in patients with hemochromatosis is from cardiac failure and arrhythmias followed by cirrhosis and hepatocellular carcinoma. Histologically, these changes are similar to dilated cardiomyopathy with abundant stainable iron present within myocytes. Most patients with hemochromatosis- related cardiomyopathy have a genetic predisposition to iron overload (primary hemochromatosis); significant cardiac failure in patients with hemosiderosis secondary to blood transfusions is rare. There is little evidence that elevated serum iron plays a role in idiopathic dilated cardiomyopathy, although the data are conflicting [52, 53].

The body has no method of controlling iron excretion; therefore, dietary excesses may lead to iron overload . The most likely excesses result from dietary supplements or alcoholic beverages brewed in iron containers [54]. Genetic factors are also important in chronic iron overload (hemochromatosis). The medical literature covering the experimental and epidemiological relationship between excess iron stores and coronary artery disease has been recently reviewed [55]. It has long been appreciated that males have a higher incidence of atherosclerosis than females and have greater body iron stores; however, a causative link between iron and atherosclerosis has not been fully established, and a recent prospective study has shown no relationship between iron stores (serum ferritin) and the development of ischemic heart disease [56].

### (8) Manganese

Manganese is an essential trace element with an estimated daily nutritional requirement of 30–50mgkg-1 of body weight. Manganese is required for several enzymes involved in carbohydrate metabolism. Absorption rate is influenced by actual intake, chemical form, and the presence of other metals, such as iron and copper, in the diet. In infants and young animals very high absorption rates of manganese have been observed. The biological half-time of manganese in humans has been determined to be about 12–35 days, depending on the nutritional status. The major route of excretion of manganese is through the biliary system, and a low tissue level is maintained by this mechanism. Because of its chemical similarity to iron, manganese also binds to iron-binding proteins such as transferrin. Interactions between manganese, iron, and lead have been shown in rats [57]**.** Although manganese is not very toxic, its increased tissue accumulation can cause toxic effects in the brain and lung. Excessive absorption of manganese from lungs can increase its accumulation in the brain. Brain damage has been reported in miners exposed to manganese dioxide dust, and it can progress to irreversible brain injury similar to Parkinson's disease. The most important biochemical effects of manganese are on the metabolism of various neurotransmitter substances such as dopamine. The selective injury of catecholamine neurons by manganese is similar to 6-hydroxydopamine-induced neuronal injury, and it may be related to a generation of toxic free radicals. Certain manganese compounds such as manganese carbonyl compounds have been used as anti-knocking agents to replace lead in several countries. The long-term effects of these compounds on people, especially the elderly, should be monitored because of its known effects on catecholamines in brain and its relation to Parkinson's disease. The interactions of other metals on the neurotoxicity of manganese should also be studied to understand the mechanisms involved in metal-induced neurotoxicity.

Manganese (Mn) functions as a cofactor for enzymes in antioxidant defense (mitochondrial superoxide dismutase), gluconeogenesis (pyruvate carboxylase, phosphoenol–pyruvate carboxykinase), glycoprotein biosynthesis (glycosyl transferases), nitrogen metabolism (arginase, glutamine synthase), and cholesterol biosynthesis (farnesyl pyrophosphate synthetase).

Little is known about the mechanisms of absorption, transport, or cellular uptake of manganese, although the element is widely distributed in non calcified tissues with the greatest concentrations in the liver [58]**.** The greatest route of manganese excretion appears to be the bile in which it is released in bound form. There is little available evidence of manganese deficiency in humans, although studies in experimental animals have shown effects on fetal survival, normal skeletal development (i.e., shortened limbs, twisted legs, lameness), ataxia, glucose tolerance, and hepatic steatosis.

Manganese bearing minerals like Pyrolusite ($MnO_2$), Braunite, ($(Mn^{2+}Mn^{3+}{}_6)(SiO_{12})$), Psilomelane ($(Ba,H_2O)_2Mn_5O_{10}$) and Rhodochrosite ($MnCO_3$) are source Mn for plants and animals. Manganese compounds are essential to life normal for skeletal development, deficiency of manganese may results into shortened limbs, twisted legs, lameness, ataxia, glucose tolerance, and hepatic steatosis and infertility in mammals [32]**.**

### (9) Chlorine

Chloride is mainly supplied through minerals like Halite, Carnallite ($KMgCl_3.6H_2O$), and Sylvite (KCl). Chloride is essential for humans, animals and plants. It controls the electrochemical regulations; acid-base balance and osmotic control of water distribution. Because of excessive consumption of chlorinated water researchers reported higher incidences of cancer of the esophagus, larynx, rectum and breast and of Hodgkins Diseases. [59] Most of the chlorine at the Earth's surface is present in the oceans. Thus atmospheric supply of chlorine in the form of marine salt aerosols is a dominant source of chlorine in surface soil, at least in coastal regions [25].Chloride ($Cl^-$) is the major extracellular anion maintained at a concentration of 100–110mmol $L^{-1}$ in that fluid. Like $Na^+$, there is no control over Cl absorption, and homeostasis is affected by renal reabsorption/ elimination. The transport and cellular uptake of Cl- is effected by a number of transporters including a $K^+$–$Cl^-$ co-transporter, a $Na^+$–$K^+$–$2Cl^-$ co-transporter, Cl—$HCO_3$ exchangers, cystic fibrosis transmembrane conductance regulator (mutation of this causes cystic fibrosis), $Ca^{+2}$-activated $Cl^-$ channels, voltage-regulated Cl- channels, and mechanically activated $Cl^-$ channels [60].

### (10) Chromium

The function of chromium in the human body seems closely associated with that of insulin, and most Cr-stimulated reactions depend on insulin [31].

The most important ore of Chromium is Chromite ($FeCr_2O_4$) and Crocoite ($PbCrO_4$). Chromium is an essential element and has a role in glucose metabolism. Chromium supplementation lowers circulating glucose levels, increases plasma insulin, and produces a favorable profile of plasma lipids [61].

Chromium (III) was already established as an essential dietary component in the 1950s. Many studies have been conducted to elucidate the biological role of chromium but have had a low degree of success. A major problem is the low concentration in tissues and body fluids and the high risk of contamination of samples. It was not until the 1980s that reliable analytical methods

were developed. Over the course of 30 to 40 years of analytical efforts, the so-called normal serum level of chromium in humans has been decreasing by orders of magnitude. It has been suggested that chromium is integral to the glucose tolerance factor (GTF). Efforts to purify this factor have led to the detection of nicotinic acid, glycine, glutamic acid, and cysteine, as well as chromium [62]**.** Recent years have witnessed a plethora of activity related to the elucidation of a potential role for trivalent chromium in mammalian carbohydrate and lipid metabolism at a molecular level. In the 1980s, the isolation and characterization of a unique chromiumbinding oligopeptide known as low-molecular-weight chromium-binding substance (LMWCr) or chromodulin were reported [63]. The oligopeptide has a molecular weight of about 1500Da and is comprised of only four types of amino acid residues (*i.e.*, glycine, cysteine, glutamate, and aspartate). Despite its small molecular weight, it binds four equivalents of chromic ions, apparently in a tetranuclear assembly, as necessitated by charge balance arguments [64]**.** Chromodulin has an intriguing ability to potentiate the effects of insulin on the conversion of glucose into carbon dioxide or lipid. No other naturally occurring chromium-containing species potentiates insulin action in this manner [64].How chromium is absorbed and transported is still uncertain. It appears that transport is mediated by transferrin, the main iron-transporting protein (molecular weight, 80 kDa). This may be due to the fact that transferring usually carries only about a 30% load of iron so it has unused transportation capacity. Transferrin is also thought to be a transporter of various trace elements. Recent reports on the effects of insulin on iron transport and the relationship between hemochromatosis and hepatic iron overload and diabetes suggest that transferrin may actually be the major physiologic chromium transport agent [65]**.** Hexavalent chromium compounds have been established as being carcinogenic. Chromate easily enters cells through the sulfate channel and is quickly reduced by, for example, glutathione. The ultimate step of the metabolic pathway yields Cr (III) inserted within the cell nucleus, where it cross-links DNA to proteins. Recent results indicate that glutathione is not only a primary target for oxidation by chromate but also acts as an efficient ligand-stabilizing Cr (V) in a dimeric bridged cluster [66]**.**

**Table-4: Major heavy metal contaminated sites in India**

| Chromium | Lead | Mercury | Arsenic | Copper |
|---|---|---|---|---|
| Ranipet, Tamil Nadu<br>Kanpur, Uttar Pradesh<br>Vadodara, Gujarat<br>Talcher, Orissa | Ratlam, Madhya Pradesh<br>Bandalamottu Mines, Andhra Pradesh<br>Vadodara, Gujarat<br>Korba, Chattishgarh | Kodaikanal, Tamil Nadu<br>Ganjam, Orissa<br>Singrauli, Madhya Pradesh | Tuticorin, Tamil Nadu<br>West Bengel<br>Ballia and other districts, U.P* | Tuticorin, Tamil Nadu<br>Singbum Mines, Jharlkand<br>Malanikahnd, Madhya Pradesh |

*(Source: Gautam SP, CPCB, New Delhi, RC Murty*, Indian Institute of Toxicology Research, personal communication)*

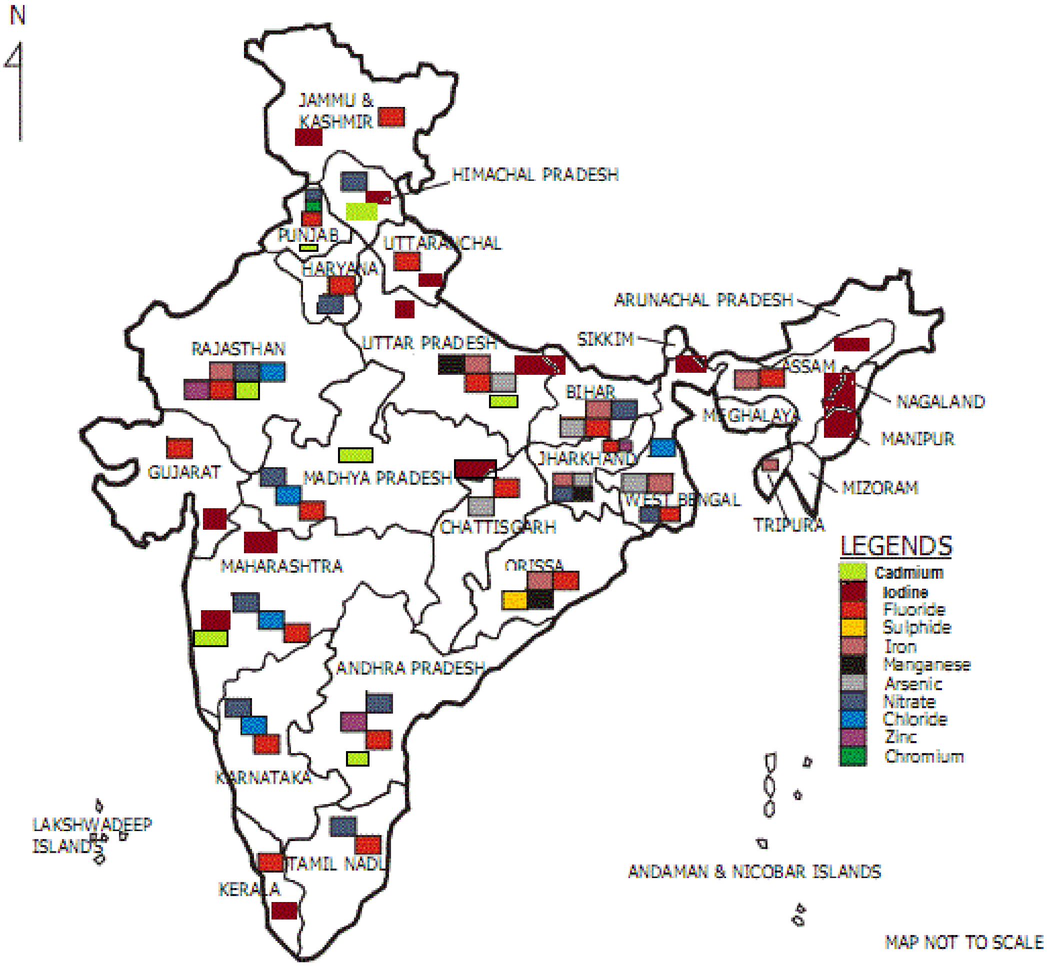

**Fig-3: Map showing excess / deficient concentration of essential trace elements and heavy metals related diseases are reported at different parts of India. [72]**

**Importance of medical geology:**

The importance of medical geology on the application to human and animal health can be emphasized by the following examples as summed up by Dissanayake and Chandrajith (1999)[67].

**i.** More than 30 million people in China alone suffer from dental fluorosis caused by the excess of fluoride in drinking water. This is clearly related to the geochemistry of the groundwater among some other factors. Many countries, such as South India, Sri Lanka, Ghana, Tanzania among others also have very high incidences of dental (and in some cases) skeletal fluorosis.

**ii**. Nearly 1 billion people (notably in developing countries) suffer from Iodine Deficiency Disorders (IDD) caused by the lack of iodine in the diet. These diseases include endemic goitre, cretinism, foetal abnormalities among others. The relationship between the geochemistry of iodine in the rocks, soil, water, sea and atmosphere on the incidence of IDD is one of the most interesting research studies that is now creating global interest among scientists.

**iii**. Arsenic is a toxic and carcinogenic element present in many rock forming minerals including iron oxides, clays and in particular sulphide minerals. When this arsenic gets into the groundwater through oxidation and subsequently into the human body through drinking water, serious health hazards can occur. Well documented cases of chronic arsenic poisoning are known in southern Bangladesh, West Bengal (India), Vietnam, China, Taiwan, Chile, Argentina, and Mexico. Skin diseases are the most typical symptoms of chronic exposure to arsenic in drinking water, including pigmentation disorders; hyperkeratosis and skin cancer, but other renal, gastrointestinal, neurological, haematological, cardiovascular and respiratory symptoms can also result. The study of the medical geochemistry of arsenic is now being recognized by several governments as a priority area of study.

**iv.** Recent evidence indicates that cancer, after heart diseases, is the leading killer in many industrialized societies and is largely due to environmental factors. A large number of causative factors which have been isolated are in one way or other environmental. Historically research into the causes of cancer was often based on the hypothesis that all cancers are environmentally caused until the contrary was proved. Geochemistry therefore plays an important role in the etiology of cancer. A good example from developing countries that affects millions of poor people is the contamination of drinking water by nitrogenous matter such as human and animal wastes, nitrogen containing fertilizers etc. The common diseases caused by this are stomach and oesophageal cancer and methaemoglobinaemia (‘blue baby’ syndrome), caused by excess nitrates. The passage of these chemical species from the environment into the food chain and into the human body is mostly geochemical and the medical geochemistry of cancer has developed into an intriguing field of research .

**v.** Podoconiosis or non-filarial elephantitis, affects large populations in Ethiopia, Kenya, Tanzania, Rwanda, Burundi, Cameroon and the Cape Verde Islands. The most interesting feature observed was that the affected areas were consistently associated with red clay soils. Analysis of lymph nodes from diseased tissues showed the presence of micro particles consisting predominantly of aluminium, silicon, and titanium. It was suggested that the pathological agent is a mineral from volcanic bedrocks, probably the amphibole eckermanite **.** In this case too, the importance of research into medical geology is obvious.

**vi.** The main causes of low production rates among grazing livestock in many developing countries are probably linked to under nutrition. However, mineral deficiencies and imbalances in forages also have a negative effect. The assessment of areas with trace element deficiency or toxicity problems in grazing livestock has traditionally been executed by mapping spatial variations in soil, forage, animal tissue or fluid compositions. Regional stream sediment geochemical data sets collected principally for mineral exploration already exist in many developing countries. The application of these data sets for animal health studies in tropical regimes is now being developed **.**

**vii**. One of the most intriguing yet, not very well defined aspects is the geochemical correlation between the incidence of cardiovascular diseases and the water hardness in the areas concerned. In several countries and areas, a negative correlation has been observed between water hardness of the country or region and its death rate due to heart diseases .Even though a causal effect still cannot be ascribed to this geochemical correlation, the effect of trace elements in drinking water on heart diseases is worthy of serious study. It is of interest to note that such a negative association between water hardness and cardiovascular pathology is evident in both industrialized and developing nations.

## Concerns for the future

Regional differences in chromium, copper, iron, iodine, selenium, and zinc in the human diet occur both in developed and developing countries, but their effects are usually more evident in the latter, largely because of malnutrition and reliance on local food products [31]. Moreover effects of infectious diseases are likely to be more serious in a population already suffering from imbalances in the diet. The total extent of problems related to trace element deficiencies in developing countries is potentially very large, and further work is required in order to identify the full scale of these problems and eventually solve them. However, the main problem in the 21st century related to human nutrition is obviously the still rapidly increasing population worldwide. At the same time the area of agricultural land is decreasing, due to factors such as urbanization, desertification, and increased soil erosion. During the last few decades the global human population growth has been outpaced by a dramatic increase in amount of food produced per area of land, facilitated by the use of high-yielding crop varieties, chemical fertilizers and pesticides, irrigation, and mechanization [67]. The strong intensification however has also had several negative effects worldwide [68], and the production potential of existing agricultural land has been affected by reduced soil fertility in many areas.

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