Linking Human Health to Soil Health

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Charals Darwin considered that food could manipulate species and although referring to birds, said he could see no difficulty in parents being forced or induced to vary the food adopting the young ones to it, and thus any amount of diversity might be arrived at(Crawford and Marsh, 1989). He argued that there are two factors which determine evolution "natural selection" and what he described as "conditions of existence". Today we call this environment . In all the controversies over what the cause of diversity might be, no- one seems to have paid much attention to the factors in the environment that has the most obvious effect on any organism "the food" and in turn "the soil" that produces it. Evolutionists do not give enough emphasis to the obvious truth that a mutant that depends upon a nutrient it cannot get is not fit and will not survive; nor will an established species if its essential food supplies run out. Food is unique to a species. The milk of different species is not interchangeable; its composition is uniquely tailored to each individual species post-natal requirements. Cows milk is richer in protein than human milk but human milk is very much richer in essential fatty acids. Food contains a crucial qualitative element which makes possible various specializations within both the plant and animal kingdoms. This allows us to conclude that the food we ate throughout evolution had bearing on what we are today and it also decides our future. Unfortunately the link between the quality of food and the soil that produces it never received due attention that it deserved.

Food concerns every one and thereby, even if we do not realize, the soil which concerns every one. A healthy soil produces a healthy plant by supplying all its essentials and protecting it from diseases and pests(Janvir et al. 2007). Human beings and animals eating such plants are obviously healthier. Soil enters human body through various direct (Geophagia, dust inhalation) and indirect (contamination of fruits and vegetables and other food material, physical contact during field operation etc.) channels. Hence the health whether of soil, plant, animal or human beings is one and indivisible. If this is accepted then we must look at the mechanisms or processes that transmit the health within the soil to animals and human beings. Health is not a state but a dynamic process. Just like any nutrient cycle, the land on which soil, plant, animals and human beings exist can be compared to an electric circuit where soil-plant-animal-human beings are components of the circuit. Food chains are the living channels which conduct energy forward and death and decay of plants and animals return it to the soil which in turn gets worked up with solar energy, microbes and mineral matter to produce humus. Consequently there is a relationship between humus and human health. But neither soil scientists nor medical professionals have paid due attention to the relationship between soil and human health. To some extent this important issue was touched upon by geo-chemists and only in exceptional cases by medical scientists. In ayurveda a discipline called “Dravya guna shasthra and desha vichara” links the medicinal properties of the herbs to the soil, location and region that produces it. Interestingly veterinary science has been much more aware of this kind of relationship and an extensive literature exists on the problem of deficiency and excesses of mineral elements in animal nutrition(Lewis and Anderson, 1983, Mills, 1983, Froslie, 1990). I would make an attempt to link human health to soil under the following heads:

- Soil mineral depletion and human health
- Soil contamination with inorganic and organic pollutants and human health
- Soil contamination with pathogens and parasites and human health
- Geophagia and human health

Soil mineral depletion and human health:

Our body is made up of “Panchabhutas” (Earth, air, water, fire and Akash). Earth is our primary life support system supplying material like minerals, water and air. About 500 years back the great Kannada philanthropist Purandaradasa said *“Manninda Kaaya Manninda”* meaning our body is made up of earth and is finally returned to earth there by defining the concept of cycle. Our increased interest in how the earth works is due, in part, to the connection between soil and health. The task is not so much to see what no one has yet seen, but to think what no one has yet thought about what every body sees.

We can question to ourselves that what chemicals are associated with the following degenerative diseases/conditions: anemia, osteoporosis, chronic fatigue syndrome, goiter, fibrocystic breast disease, nervous disorders, cancer, diabetes, arthritis, multiple sclerosis, high cholesterol, Parkinson’s disease, Lou Gehrig’s disease, epilepsy, bladder and kidney disease, dysbiosis, celiac disease, IBS, Crohns disease, allergies, prostate disease, dizziness, heat stress ulcers and wound healing and even the common cold?

Most people would probably answer mineral deficiency because we relate a deficiency in them with the corresponding condition. More than 40% of human population suffers from mineral deficiency of varying degree. For example Iron deficiency ranked ninth among 26 risk factors included in the global burden of disease study, and accounted for 841 000 deaths and 35 057 000 disability adjusted life years lost. (Stoltzfus, 2003). Large sections of populations in Africa and Asia are at risk of dietary zinc deficiency and resulting high rates of stunting.(Anon, 2004) Correcting micronutrient deficiencies can help reduce child mortality(Jones et al. 2003) but it is unclear how these deficiencies can be dealt with at the population level. Chemical substances derived from the diet also affect human behaviour. A recent study demonstrated that providing the recommended daily allowance (RDA) of micronutrients assisted in the correction of ant-social behaviour of juveniles.

The foundation of human health is the quality of food we eat, which relies ultimately on the vitality of the soil on which it is raised. Soils seriously deficient in minerals cannot produce plant life competent to maintain our needs and with the continuous cropping and shipping away of those concentrates the condition become worse. Nobel Prize winner Dr.Alexis Carrel stated that Minerals in the soil control the metabolism of plants, animals and man. All of life will be either healthy or unhealthy according to fertility of the soil. Much before green revolution eating a healthy diet and avoiding all anti nutrients ensured supply of all the minerals needed to stay healthy. Today it is no longer the case as the nutrient content of our food is on the decline(Rogan, 1995, Oliver, 1997, Deckers and Vanclooster, 1998., Murphy et al. 2008). It means what we were eating in the yester years are not the same as what we are eating today. The present day food does not contain minerals and other nutrients in proper proportion and quantity to assure a healthy development in human beings and animals. In fact, the earth's crust contains most of the mineral nutrients our body needs, and the chemical composition of a rock, such as granite, is strikingly similar to the composition of the human body. However, the minerals in granite usually are not in a form that is easily assimilated and dissolved in the body. The rocks and minerals undergo weathering and forms soil that contains minerals that are easily available to plants. Ultimately it is the soil which is the prime source of minerals on which every living cell depends for its structure and function. Other biologically active substances like vitamins, enzymes, amino acids and a host of others include minerals as an integral part of their chemical structure. Dr Linus Pauling, who received two Nobel Prizes, one for chemistry and another for peace, made the link between insufficient nutrition intake and mineral depletion in soil. He asserted that this is highly detrimental to our health: “You can trace every sickness, every disease and every ailment to a mineral deficiency. Yet, all over the world, minerals are depleting from agricultural soils at an alarming rate. This depletion of mineral content of soil is the root cause of poor health of human beings and animals. Modern agricultural methods have resulted in the plants using an excess of 60 minerals with a return of only three.

The official report of the Earth Summit (1992) concluded “there is deep concern over continuing major declines in the mineral values in farm and range soils throughout the world”. This statement was based on data showing that over the last 100 years, average mineral levels in agricultural soils had fallen worldwide(Table 1) by 72% in Europe, 76% in Asia and 85% in North America. What has caused this staggering decline?.

Table 1. Depletion Levels (Percentages) of soil nutrients in the last 100 years in different regions of the world

Region	Per cent decline
North America	85
South America	76
Asia	76
Africa	74
Europe	72
Australia	55

Intensive farming, and the use of inorganic fertilisers, has gone on since 1920's in the west and 1950's in Asia and Africa but these fertilisers consist mainly of nitrogen, phosphorus and potassium. calcium, in the form of lime, and iron are sometimes added. The essential micronutrients are never deliberately replaced. Of late some of the micronutrients were supplied mostly through foliar sprays. Soil nutrient depletion is caused mainly because of increased crop yield per unit area compounded by highly imbalanced use of fertilizers skewed towards nitrogen(Table 2). Although long term fertilizer experiment results have shown depletion of mineral nutrients, at national level we do not have the data to show the extent of depletion of mineral elements in Indian soils.

Table 2. Consumption Ratio of NPK in India

Year	Nitrogen (N)	Phosphate (P)	Potash (K)
1960-61	7.2	1.8	1
1970-71	6.5	2.0	1
1980-81	5.9	1.9	1
1990-91	6.0	2.4	1
1996-97	10.0	2.9	1
1997-98	7.9	2.9	1
1998-99	8.5	3.1	1
1999-2000	7.1	2.8	1

The results of the long term fertiliser experiments conducted with different crop sequences in various agro ecological regions clearly indicate that application of N alone increased soil depletion of available P, thus causing fast appearance of P deficiency symptoms (Table 3). In plots fertilized with only N, 33-129% more soil P was removed as compared to plots receiving no N. The extent of P depletion was highest in alluvial soils (wheat belt) and least in red soils. They were so poor in P that there was little P to be removed (Nambiar and Abrol,1989).

Depletion in case of potash is particularly alarming. This is because many crops remove as much or more K than they absorb N, still potash application is less than 10% of total nutrient application and one-seventh of N application on the whole, in many cases much less (Table 4). In plots receiving N or N + P but no K fertiliser, the removal of soil K went up by 57% and 145% over the control plots.

In Punjab, which has one of the widest N:K_2O ratios, estimated crop removal of K is 709,000 tonnes or 38 times the amount of K_2O applied through fertilizer. In fact, potash removal in Ludhiana district alone is 7 times the entire state's consumption. On the whole potash removal is 1.4 times the N removal. Potash addition is less than 2% of the N applied. Punjab soils show annual depletion of 100 kg/ha, an alarming situation in the country's most intensively cropped state and leading foodgrain producer, particularly from the point of view of sustaining high yields. By and large, Punjab mirrors the situation in much of the Indio-Gangetic belt including Haryana, Uttar Pradesh and

Bihar. In horticultural crops such as banana and papaya huge quantity of potassium

Table 3: Depletion of soil by application of N only in intensive cropping sequence.

Location	Soil	Cropping sequence	kg P_2O_5/ha removed		% increase over control plot
			Control plot	N – only	
Barrackpore	Alluvial	Rice-Wheat-Jute	321	642	100
Ludhiana	Alluvial	Maize-Wheat-Cowpea	183	412	125
New Delhi	Alluvial	P. Millet-Wheat-Cowpea	160	366	129
Coimbatore	Black	F. Millet-Wheat-Cowpea	344	458	33
Jabalpur	Black	Soybean-Wheat-Maize	275	366	33
Hyderabad	Red	Rice-Rice	527	847	61
Bhubaneswar	Laterite	Rice-Rice	275	458	67
Palampur	Hill	Maize-Wheat-Potato	155	252	63
Pantnagar	Terai	Rice-Wheat-Cowpea	893	1,420	59

Table 4: Mean annual K balance in soils with optimal NPK dose over the years (1971-85)

Location	Potassium applied (kg/ha)	Potassium uptake (kg/ha)	Potassium balance (kg/ha)
Barrackpore	148	202	-54
Ludhiana	110	236	-126
New Delhi	82	103	-21
Coimbatore	44	267	-223
Jabalpur	66	436	-370
Hyderabad	49	170	-121
Ranchi	165	63	+102
Bhubaneswar	99	176	-77
Palampur	112	112	0
Pantnagar	70	312	-242

averaging more than one ton of potash per hectare is removed in each crop against a small amount added causing a serious mining of soil nutrients leading to nutrient imbalances and poor quality fruits (Ganeshamurthy et al. 2004).

Soil nutrient depletion, by itself may not ring an alarm in the short run. But by promoting vigorous growth, application of N alone results in a large increase in the removal of other nutrients (secondary and micronutrients) from the soil. Depletion of soil nutrients represents a deterioration on soil health, even though this is not visible to the naked eye the quality of food produced on these soils will certainly rises eyebrows. More than 95 per cent of the human diet is vegetative. Plants which absorb minerals from soil are either eaten directly by man or fed to animals and animals are then included in human diet. Thus plant availability of mineral nutrients in the soil is the prime factor of mineral supply to human beings. Hence soil health parameters that affect plant nutrients availability and absorption like soil organic matter, texture, pH and eH, drainage and more than anything else the management like manure and fertilizer application are crucial to the availability of mineral nutrients to human beings. Parent material, padogenic factors and climate also play an important role (Deckers and Steinnes, 2004).

Since 1950's there has been tremendous improvement in the yield levels of cultivated crops be it cereals, pulses or fruits and vegetables. For example Murphy et al.(2008) grew 56 historical and 7 modern spring wheat cultivars in one block under uniform management . They reported that the average yields of historical cultivars of wheat was 1.09t ±79 kg ha^{-1}. Whereas the modern cultivars yielded 1.915t ± 242 kg ha^{-1}. They also analysed these wheat for eight essential elements. For seven of the eight minerals the historical cultivars had significantly higher grain mineral concentration(Table 5) than the modern cultivars.

Table 5. Mineral concentration(mg kg-1) in modern and historical wheat cultivars

Mineral	Historical cultivars	Modern cultivars	% change
Ca	421.6±10.9	398.5±16.1	-6
Cu	4.8±0.1	4.1±0.2	-16
Fe	35.7±1.0	32.3±1.8	-11
Mg	1402.6±21.0	1307.6±25.6	-7
Mn	50.0±1.2	46.8±3.1	-7
P	3797.1±55.7	3492.7±119.3	-9
Se (µkg-1)	16.2±1.7	10.8±2.7	-50
Zn	33.9±0.9	27.2±1.9	-25

Although the increased yield in modern cultivars of crops could potentially increase the mineral content per acre of grain production, the mineral concentration per unit weight of cereals/pulses/fruits/vegetables is reduced. This has a cascading effect on meeting the recommended daily allowance (RDA) of minerals and vitamins and has a serious bearing on the relationship between RDA and AI(adequate intake). For example

Murphy et al.(2008) compared historical and modern wheat cultivars to meet the RDA or AI   They showed that for all eight minerals more bread is required to meet the RDA or AI in modern cultivars than in the historic cultivators. Females aged 19 to 30 would have to eat 10.6 slices of whole wheat bread made from historic cultivars high in Zn to reach the RDA but would require 15.2 slices of bread made from modern cultivars(Fig 1). For certain minerals like Se it is unreasonable to expect acquisition of

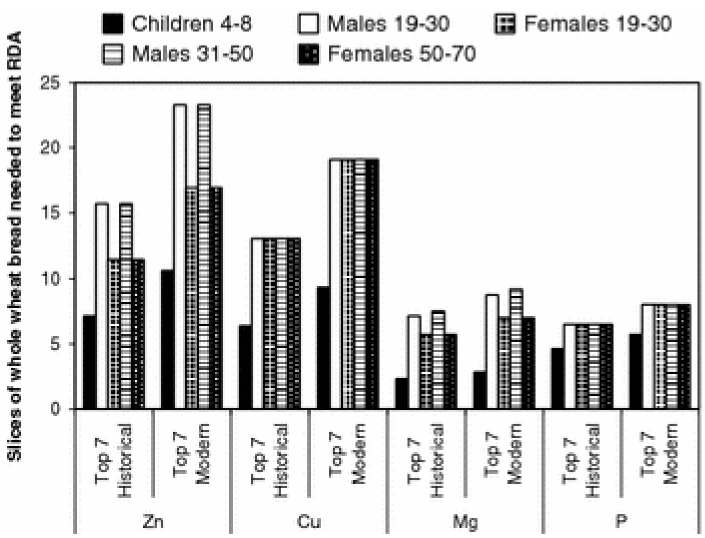


Fig. 1 Estimated numbers of slices of bread required to meet the Recommended Dietary Allowance (RDA) levels for Zn, Cu, Mg, and P, with flour from modern (denoted 'Top 7 Modern') and historical cultivars with high mineral concentrations (denoted 'Top 7 Historical'). Each slice is equivalent to 50 g whole wheat flour

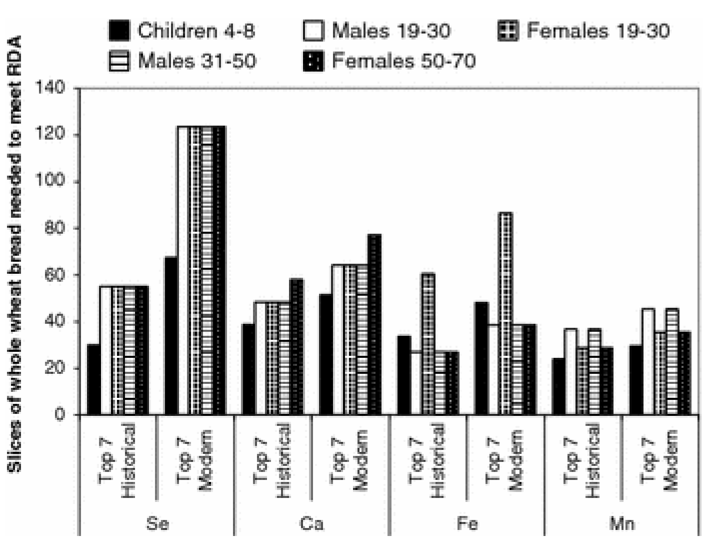


Fig. 2 Estimated numbers of slices of bread required to meet the Recommended Dietary Allowance (RDA) or Adequate Intake (AI) levels with flour from modern (denoted 'Top 7 Modern') and historical cultivars with high mineral concentrations (denoted

'Top 7 Historical'). RDA was used for Fe, and Se. AI was used for Ca and Mn. Each slice is equivalent to 50 g whole wheat flour

a significant percentage of the RDA of certain minerals from eating whole wheat bread. To reach RDA of Se we would require consumption of 55 slices of bread made from historic cultivars whereas we require 123.5 slices from modern wheat cultivars (Fig 2). Would these not lead to obesity ?

Vegetables are probably the best indicators of change to mineral content, because of their rapid growth and short life cycles. David Thomas (2003) reported that hundreds of years of farming have depleted the soil of the minerals we need in our food. From his studies in UK he reported that the fruit, vegetables and cereals which form the bulk of our diet have been found to be deficient in a range of minerals and trace elements compared to those 50 years ago(Table 6). Similar findings were found in animal-derived foodstuffs, including meat and dairy produce.

Table 6. changes in mineral content of different types of vegetables (27 varieties), fruit (17 types) and meat (10 cuts) measured between 1940 and 1991.

Mineral	Vegetable	Fruit	Meat
Sodium (Na)	-49%	-29%	-30%
Potassium (K)	-16%	-19%	-16%
Phosphorous (P)	+9%	+2%	-28%
Magnesium (Mg)	-24%	-16%	-10%
Calcium (Ca)	-46%	-16%	-41%
Iron (Fe)	-27%	-24%	-54%
Copper (Cu)	-76%	-20%	-24%

There are many reasons why minerals and trace elements have been diminished. This includes the depletion of the soil itself by long-term farming, highly imbalanced and excessive use of NPK fertilisers, (trace elements are never deliberately added), changes in varieties of plants grown and loss of micro and other organisms in the soil. In addition to the overall mineral depletion changes recorded, significant changes also have taken place in the ratio of one mineral to another. Given that there are known critical ratios of certain minerals within our physiology (Ca:P, Na:K, Mg:Ca, Fe:Cu) the changes(Table 7) in these ratios were calculated for each individual vegetable.

Table 7. Changes in critical mineral ratios in different types of vegetables measured between 1940 and 1991

Ratios	1940	1991
Ca:P	1:2	1:1
Na:K	1:10	1:17
Mg:Ca	1:4.8	1:3.4
Fe:Cu	1:10	1:30

The figures, therefore represent a significant change in the ratio between minerals which in turn could well have a significant influence on our bio-chemistry.

A comparison between the nutritive values of selected vegetables reported by USDA in 2000 with those reported in 1963 showed (Table 8) that Vitamin A in some vegetables such as carrots seemed to have actually increased, along with some minerals. But in nearly all other fruits and vegetables there showed large decreases in many nutrients. Vitamin C in sweet peppers had dropped from 128mg to 89mg. Vitamin A in apples had dropped from 90mg to 53mg.

Table 8 Changes in the nutritive values of selected vegetables between 1963 and 2003. (LE Magazine March 2001)

Vegetables	Vitamin C	Vitamin A	Calcium	Potassium	Magnesium
Beets	-50	+90.0	0	-10.0	-8.0
Spinach	-45.1	-17.1	+6.5	+18.7	-10.3
Corn	-41.7	-29.7	-33.3	-3.6	-22.9
Collards	62.0	-41.2	-28.6	-51.5	-82.2

Some of the essential elements that are essential for human health are not essential for plants. Crop yields are therefore, not affected by them and farmers donot apply and cannot afford to spend money on applying them. There is normally no thought of increasing the trace element content of crops so that the ultimate consumer may be healthier (Newnham, 1982). This is one of the reasons for micronutrient deficiencies in human diet. In discussing the role of B deficiency in arthritis Newnham (1982) stated: it becomes evident that arthritis and rheumatism is a disease of modern living brought on by a universal exploitation of the soil. In order to have a healthy population we must have a foundation in a healthy soil.

Intake of mineral elements from the soil environment varies according to the species and forage behaviour. Wild animals for instance forage over extensive areas and therefore stands a reasonable chance to ingest the necessary critical load of essential elements. But the animals, particularly ruminants, reared for food are vulnerable to low levels of essential elements because of confined grazing areas and food that is fed to them. The case with human beings are different. Understanding the link between soil health and human health is made more complicated by the developments in modern societies world over following rapid change in world trade pattern and enormous improvement in transport of food. Supply of food and water usually originate from a wide area, either because man travels over great distances or food and water are transported over long distances (water is the second most important source of minerals in human diet, Piispanen, 1990). For these reasons the geographical correlations between mineral elements and human health status are limited to isolated locations where people live on local agricultural produce and drink water from local water sources. Intrinsic soil fertility determines the carrying capacity of the land and hence the food supply situation of the local population (Deckers and Vanclooster, 1998). Recurrent food shortage and wide spread malnutrition and mineral deficiencies are common in developing countries. Incidentally the soils in a number of developing countries are infertile. Oliver (1997) stated that minerals in food depends upon lifestyle, sex, age, and general wellbeing of people; children, elderly and pregnant women are particularly vulnerable to deficiency or toxicities of trace elements(Rogan, 1995): children because they often eat a limited range of food and are growing rapidly and neonates and elderly because they absorb trace elements poorly.

This deficiency in our diet is made even worse by radical changes to our eating habits. There has been a massive increase in manufactured, convenience foods, often referred to as 'junk food'. These are high in saturated fats, sugars and processed carbohydrates. These foods have, over the last 30 years, as the norm and there is a generation of children who have eaten little else and regard it as an appropriate diet. Consequently, we have created a society which is *overfed but malnourished of micro-nutrients.* These factors have contributed to the rise in certain degenerative diseases, such as diabetes, obesity, cardiovascular disease and osteoporosis etc.

Soil contamination with inorganic and organic pollutants and human health:

Industrialization went along with uncontrolled growth of industrial wastes. World over these wastes are dumped in to the soil either directly or after partial treatment. Industrial wastes, city sewage sludge, domestic wastes, mining spoils, degrading materials and other wastes often contain high concentrations of inorganic (heavy metals, nitrates, cyanides etc.) as well as organic (halogenated hydrocarbons, polychlorinated biphenols, polyaromatic hydrocarbons etc.) pollutants. If these components are not contained in the soil then they can get into the human nutrition cycle via food chain, dust, aerosols, irrigation water, ground water and drinking water. The soil profiles that receive these wastes become reservoirs of chemicals which ultimately play an important role in human health. Once the buffering capacity of the soil for pollutant exceeds, a breakthrough will occur and dangerous pollutants may flow into the ground water cycle and endanger human health.

Although the industrial, mining and urban pollutants are very potent they often affect only a small portion of the total land area. For example soils subjected to industrial, mining and urban pollution in India may not account for more than 0.5 % (0.75 m.ha.) of cultivated area of 141 m.ha. But the actual impact may be large since such areas are close to densely populated urban, industrial and mining areas and also because the pollutants may end up in domestic drinking waters, food produced in urban and periurban areas(UPA) or kickup with the dust in case of wind erosion. With rapid pace of urbanization, the percentage of India's population living in cities almost doubled to 27.8 per cent in 2001 from 14% at the time of independence. This is expected to accelerate even further and, by 2021, over 40 per cent of all Indians will be living in urban areas. The scale of urbanization in India can be seen in 6 mega cities (>5 million), 29 metro cities (>1 million) and 500 cities (>100,000). We will face enormous challenges, particularly, environmental pollution and health related problems (Ganeshamurthy et al. 2008).

Pollution in cities and other industrial pockets has a profound influence on agricultural lands in urban and periurban areas and consequential effect on the health of humans residing in such areas. Several pollutants affect human and animal health. However, non-degradable pollutants like heavy metals bother us much more than others.

Throughout history, heavy metal contamination has plagued mankind - undermining intelligence and inducing debasing behavior. Only now are we beginning to understand how heavy metals damage the brain. Heavy metals become toxic when they are not metabolized by the body and accumulate in soft tissues. Oliver (1997) compiled data (Table 9) on permissible levels of heavy metals in human diet, along with impact of both deficiency and toxicity on human health. The danger lies in the fact that once heavy metals enter into the soil-plant-animal continuum, their removal is extremely difficult and expensive

Table 9. Limits of deficiency and toxicity of metals in human beings and their impact on human health

Element	Recommended safe intake	Impact on health due to deficiency	Toxic limits	Impact on health due to toxicity
Arsenic	15-25 µg d^{-1} (adult)	-	3 mg d^{-1} for 2-3 weeks	Cancer of skin and internal organs, hyperkeratosis, hyperpigmentation, black foot, rashes
Cadmium	Maximum tolerable intake 70 µg d^{-1} children 2-25 µg d^{-1} adults 15-50 µg d^{-1}	--	220 µg kg^{-1} fresh weight	Renal tubular disfunction, proteinuria, glucosuria, aminoaciduria, itai-itai disease
Chromium	50-200 µg d^{-1}	Cardiovascular disease	--	--
Copper	Children 40µg d^{-1} Infants 80 µg d^{-1} adults 2 µg d^{-1}	Hypocupremic anaemia neutropenea, leucopenia Hypopigmentation of hair and skin, coronary heart disease, arthritis	children 150 mg d^{-1} adults 12 mg d^{-1}	--
Lead	children 9- 278 µg d^{-1} adults 20-282 µg d^{-1}	--	≥500 µg d^{-1} concentration in blood in children 250-500 µg L^{-1}	Encephalopathy(damage to brain), failure in reproduction, metabolic disorder, neurophysical deficit in children, affects the haematologic and renal systems
Selenium	100-200 µg d^{-1}	Kashin Beck disease Keshan disease	9 mg d^{-1}	Persistant adverse clinical signs developed with as high as 50% morbidity
Zinc	Deficient 0.2-0.3 mg d^{-1} Safe intake 15 µg d^{-1}	Hypogonadism, dwarfism, hepatosplenomegaly,	150 µg d^{-1}	Interference with reproduction, growth of embryo impaired

	Recommended upper limit 45 μg d^{-1}	geophagia, anaemia, premature birth, anorexia		

Use of agrochemicals has become a condition to maintain the present high production levels and to meet world food demand. Decay of a number of agro chemicals in the soil is slow; some of them are mobile and can move uncontrolled to ground and surface water. High concentrations of inorganic (nitrate, phosphate, copper, cadmium etc.) and organic (pesticides, fungicides and herbicides) chemicals may constitute a risk for human health , which is difficult to quantify. Thus the probability of toxins entering in to human and animal diet has increased. The direct effects of toxins in food and the indirect effect of toxicity of heavy metals on availability and absorption of essential metals results in a predictable increase in degenerative diseases both in human beings and animals. As already stated the decreased mineral content in cereals, pulses, oil seeds etc.has increased the possibilities of occurrence of degenerative diseases. In addition many of the essential elements and other nutrients are known to gives protection against toxicities of heavy metals in the body (Schauss, 1983). For example toxicity of Pb in the body is mitigated to a great extent by adequate supply of Zn, Fe, Ca, Vitamin C, E and S containing amino acids (Table 10).

Table 10. Nutrients Protective Against the Effects of Toxic Elements

Toxic Element	Protective Nutrients
Aluminum (Al)	Possibly magnesium. None other.
Arsenic (As)	Selenium; Iodine; Calcium; Zinc; Vitamin C; Sulfur; Amino Acids (Found in garlic, hen's eggs, and beans)
Cadmium (Cd)	Zinc, Calcium, Vitamin C, Sulfur Amino Acids
Lead (Pb)	Zinc, Iron, Calcium, Vitamin C, Vitamin E, Sulfur Amino Acids
Mercury (Hg)	Selenium, Vitamin C, Pectin, Sulfur Amino Acids

Since soils are getting depleted of minerals and the mineral content of food produced from modern cultivars are getting reduced, the possibilities of getting protection against toxicities of heavy metals from some of the essential elements and other nutrients gets reduced. This is an area which should receive due attention of soil scientists.

There are two major sources of heavy metals in UPA: Anthropogenic and Geogenic. While geogenic cases are rare in UPA (not discussed), anthropogenic cases are common in cities all over the world.

Air, water and soils are polluted with heavy metals through several anthropogenic activities like smoke-generating industries, effluent-generating industries, sewage, sludge, municipal solid and liquid wastes, fossil fuel burning, etc. Nriagu (1988) made an estimate of global emission of trace metals into the atmosphere, water and soil and stated that toxicity of all the metals being released annually into the environment far exceeded the combined total toxicity of all radioactive and organic wastes. This emphasizes the seriousness of heavy metal pollution compared to other pollutants and needs special attention to prevent or minimize entry of heavy metals into the environment.

The natural variability of heavy metal content in soils is very high. To ascertain contamination of any soil with heavy metals, one should have a reference level of each metal beyond which soil can be considered as contaminated. Unfortunately, reference levels for different soils are not available, or rather, are not feasible. The normal range of some of the heavy metals in soils reported by two different authors shows a very high degree of variability(Table 11). However, the extent of contamination due to anthropogenic activities can be judged far better by comprising with adjacent, non-polluted soils.

Table 11. Normal range of heavy metals in soil

Author	Pb	Cd	Ni	As	Se	Zn	Cu	Mo
Bowie and Thornton, 1985	10-150	<1-2	2-100	<5-40	<1-2	25-200	2-60	<1-5
Jorgensen, 1979	<10	<0.06	-*	-	-	<5	<20	-

*** = not analysed/not available**

Soils are highly buffered. Hence, any small and short- term application of sewage sludge and effluents containing heavy metals in low concentrations may not cause serious accumulation of heavy metals in bio-available forms. Therefore, plants grown on such soils may not absorb dangerous levels of heavy metals. However, long-term applications, as it happens in UPA, river beds, industrial pockets and other such areas, may lead to accumulation of heavy metals in soil to levels exceeding permissible limits. Levels of heavy metal accumulation in soils of UPA in different cities of India are summarized in Table 12. Variability in the content of heavy metals in these soils is so wide that it is difficult to draw any conclusion from this information, as, their initial levels are not available. The variability is due to several factors like i) amount and period of addition of wastes ii) heterogeneity in the type of material added to the soil, like industrial effluents, sewage effluent, sludge, city garbage iii) Type of soil like, light textured or heavy soils, iv) climate (heavy rainfall or low rainfall, extreme temperatures or moderate temperatures). However, one conclusion that can be drawn from these data is that in many such cases, the levels of heavy metals have not exceeded permissible levels for soils, proposed by PFA (Tables 12 & 13).

Once heavy metals enter the soil system, they may undergo several changes depending upon physical, chemical and biological properties of the soils. Bioavailability of these heavy metals is very important as this is a gateway for entry of heavy metals into the food chain. Current information(Ganeshamurthy et al. 2008) on the effect of long term application of sewage and industrial effluents, sludge, garbage etc. on the available

Table 12. Heavy metal content (Total) in soils of UPA in different cities in India

Source	Zn	Cu	Fe	Mn	Cd	Pb	Co	Ni	Cr
Bangalore	71.8	3.52	-*	-	0.35	35.2	-	-	-
Kolkata	1300	160	212	16	4.0	170	-	-	126
Durgapur	309	41.5	-	-	6.11	180	-	-	-
Varanasi	87.9	33.5	-	145.7	2.7	18.3	-	15.6	79.3
Ludhiana					1.1		24.1	43.9	
Coimbatore	397.4	157.1	-	-	8.1	175.5	-	171.4	114.9
Hyderabad	2.9	4.3	386	39	0.4	8.1	5.0	1.4	6.0
PFA standard	300-600	135-270	-	-	3-6	25-50	-	75-150	-

*** = not analysed/not available**

heavy metal status of soils in different UPA areas is presented in Table 14. Here again there is wide variability in the bioavailable fractions of heavy metals in these soils attributed mainly to the nature of waste material applied, period of application and soil type. However, one point that emerged from these data is that application of domestic origin sewage water which contains low concentration of micronutrients and very low concentration of heavy metals may not lead to accumulation of these metals in soils.

Texture of soil has profound influence on the pattern of heavy metal accumulation. Light- textured soils accumulated lower levels of heavy metals than heavy soils under similar conditions. However, no direct study on such effects has been conducted anywhere. It has been found that bioavailability of heavy metals in light textured soils of Sakkimangalam and Avanigapuram were more or less similar in sites that received sewage water for eight years or 50 years (Jayabaskaran and Sriramulu, 1996). But, Ukkadam sewage farm on clay soils contained higher bioavailable heavy metals after 40 years of sewage water irrigation than the silty clay loam soils of Avanigapuram after 50 years of sewage irrigation (Table 14).

Heavy metals are immobile in soil. As a result, these accumulate mainly in surface soils which are, unfortunately, the zone of prime root activity in crops. Profile analysis of soils collected from sewage and effluent irrigated areas showed no build up of heavy metals below 45 cm depth (Table 15).

A majority of the cities and towns in India are located on the banks of rivers, rivulets and streams. The number of cities on the banks of Ganga alone is 27. River beds in all these cities and towns are put under cultivation of vegetables and fodders. Unfortunately, these river bed soils are among the most polluted soils because of their frequent inundation

Table 13. Permissible level of heavy metals (mg L^{-1}) in water, soil and plants as recommended by various organizations

Organization	Fe	Mn	Cu	Zn	Ni	Cr	Co	Cd	Pb	As
					Drinking water					
USPH standards	0.3	0.05	1.0	-	-	0.05	-	0.01	0.05	0.05
WHO standards	1.0	0.50	1.5	-	-.	0.05	-	0.01	0.10	0.05
					Sewage water					
Pes Cod,1992	-	0.2	0.2	2.0	2.0	0.1	-	0.01	0.5	na
FAO,1979	-	-	-	-	2.0	1.0	-	0.05	2.0	na
The Environmental Protection Rules, 1986, India	3.0	2.0	3.0	5.0	3.0	2.0	-	2.0	2.0	na
					Soil					
PFA, India	na	na	135-270	300-600	75-150	na	na	3-6	250-500	na
Austria	na	na	100	300	100	100	50	5	10	na
Canada	na	na	100	400	100	75	25	8	200	na
Poland	na	na	100	300	100	100	50	3	100	na
Japan	na	na	125	250	100	na	Na	Na	400	na
Great Britain	na	na	100	300	50	50	Na	3	100	na
Germany	na	na	50	300	100	200	-	2	500	na
					Vegetables and Food					
PFA	na	na	30	50	1.5	0.2	na	1.5	2.5	1.1

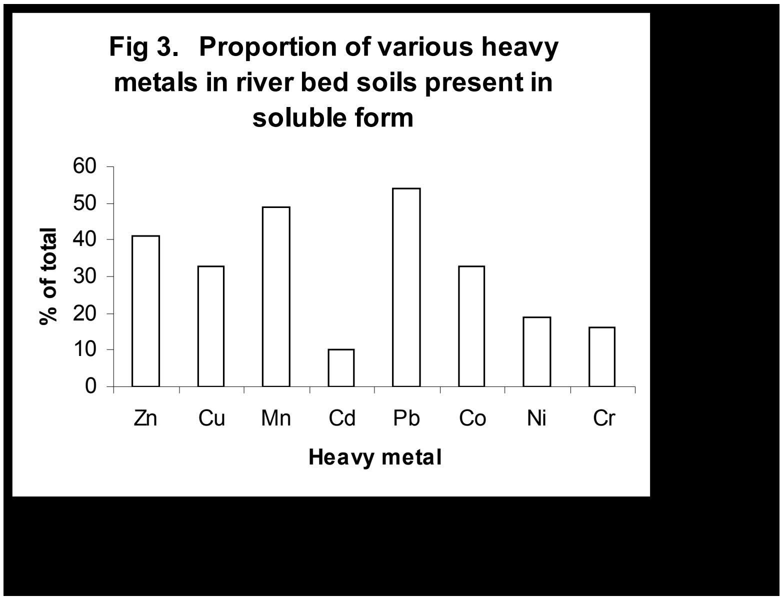
Table 14. Bioavailable heavy metal status of soils treated with different sources of wastes

Source	Zn	Cu	Fe	Mn	Cd	Pb	Co	Ni	Cr	As	Hg
Indo-Gangetic plain-Alluvial soils											
IARI (NewDelhi)											
Domestic sewage	5.0	3.3	23.3	12.1	-*	2.2	-	0.4	-	-	-
Tubewell	2.2	1.1	6.7	9.8	-	1.7	-	0.2	-	-	-
Jalanandhar (Delhi)											
Sewage effluents	14.7	4.20	39.7	18.9	-	-	-	1.27	1.72	2.09	-
Tubewell	2.9	0.99	13.8	14.3	-	-	-	0.56	0.81	1.87	-
Keshopur(Delhi)											
Sewage effluents	6.77	5.42	40.30	5.17	0.15	2.34	-	0.91	-	-	-
Tubewell	1.92	1.79	9.22	5.69	0.14	1.65	-	0.36	-	-	-
Ludhiana(Punjab)											
Sewage effluents	4.38	5.5	36	10.9	0.07	1.88	-	0.37	0.57	1.02	0.51
Malerkotla(Punjab)											
Sewage effluents	5.56	2.5	11	7.9	0.04	1.41	-	0.32	0.36	0.56	0.38
Samrala(Punjab)											
Non-Sewage effluents	1.67	2.2	17	8.9	0.06	1.24	-	0.42	0.39	0.77	0.61
Varanasi (U.P)											
Sewage effluents	15.63	30.41	82.79	229.3	3.8	22.48	-	-	4.25	-	-
Patna (Bihar)											
Sewage sludge	11.4	14.5	54.9	19.4	0.21	10.2	-	-	-	-	-
Ganga delta-Alluvial soils											
Howrah											
Sewage effluents	19.4	-	-	-	0.02	0.18	-	-	0.60	-	ND
Kolkata											
Sewage effluents	281	36	115	24	0.45	104.3	1.8	9.45	12.5	-	-
Non-sewage effluents	3.5	2.25	53.5	21.6	0.006	4.25	0.9	4.40	3.15	-	-
Deccan Plateau- Red soils											
Bangalore											
Sewage effluents	0.03	0.101	-	-	Tr	0.73	-	0.01	0.10	-	-
Hyderabad											
Fresh garbage	6.8	10.9	16.2	16.0	0.14	10.5	0.40	0.46	0.34	-	-
Control	1.0	0.9	6.5	9.0	ND	0.04	0.04	0.05	ND	-	-
Avaniyapuram (TamilNadu)											
Sewage effluents	10.6	6.9	32.3	37.0	0.20	5.7	0.4	6.9	2.7	-	-
Sakkimangalam (TamilNadu)											
Sewage effluents	5.9	5.7	32.3	39.0	0.10	3.7	0.20	4.9	2.9	-	-
Ukkadam											
Sewage effluents	10.4	9.7	28.5	37.0	0.20	6.30	0.50	14.6	3.8	-	-

Table 15. Profile distribution of heavy metals in soils treated with industrial effluents

Soil depth	Ukkadam Farm, Tamil Nadu (Jeyabaskaran and Sriramulu,1996)				Periurban Patna (Mean of 11 sites) (Sakal *et al*., 1992)					
	Zn	Cu	Fe	Mn	Zn	Cu	Fe	Mn	Pb	Cd
0-15	15	16	50	70	4.19	5.21	40.98	13.93	3.95	0.075
15-30	11	9	25	40	2.30	1.85	24.36	9.94	2.50	0.047
30-45	5	3	9	15	1.87	1.08	15.76	8.89	2.20	0.043
45-60	2	1	2	3	1.75	0.88	14.17	8.06	1.99	0.038

with heavy -metal rich water during monsoon. The most worrying feature of such sites is that a large proportion of accumulated heavy metals remains in highly mobile and leachable form, which is directly available for absorption by plants. Dry river beds of Kharaai river in the industrial city of Jemshedpur had 8400 ppm Fe, 10 ppm Ni, 7 ppm Pb, 200 ppm Cu, 90 ppm Cr and 5 ppm Co, all above permissible levels (Sinha *et al*., 2002). Analysis of dry river bed soils of periurban Kanpur, where Ganga flows through the heart of the city, showed (Fig. 3) that a major part of accumulated heavy metals was in the leachable form (Farooq *et al*., 1999). Leafy and succulent vegetables of short duration mainly are grown on such soils, as they find immediate market in the adjacent urban areas. This is a matter of serious concern as these are short duration crops and are heavy accumulators (Varalakshmi and Ganeshamurthy, 2007) favored by high availability of heavy metals in soils.



Protected cultivation of vegetables in periurban areas is on the increase. Cultivation in poly houses is generally done on artificial beds created within by dumping organic manures of varying types. The source of such organic manures may vary but, being in the vicinity of cities organic manures are likely to get mixed with sewage sludge and other city solid wastes. Data on extent of heavy metals in the bed material and crops grown in such poly houses are not available. This is a point which calls for attention of researchers.

Soil contamination with pathogens and parasites and human health:

Soil is a reservoir of human pathogens and parasites. Being a recipient of wastes of all kind, soil contains high concentrations of helminthes, enteric pathogens and other bacterial, viral and fungal pathogens. Human beings are in contact with soil permanently either directly or indirectly via food, water and air. Therefore soil acts as a major vector and serves as a major source of disease causing agents to humans. On the basis of origin of etiological agents human diseases associated with soil have been classified by Weissman et al.(1976) into four categories viz., (1) Soil associated diseases which are caused by opportunistic or emerging pathogens that belong to normal soil micro biota (e.g. *Aspergillus fumigatus* – a common fungus occurring in soil that can infect lungs via inhalation of spores), (2) Soil related diseases which result in intoxication from the ingestion of food contaminated with entero or neurotoxins (e.g. *Clostridium botulinum, C.perfrigens and Bacillus cereus*), (3) Soil based diseases caused by pathogens indigenus to soil (e.g. *Clostridium tatani, C. perfringens and Bacillus anthrocis)* and (4) Soil borne diseases caused by enteric pathogens which get in to soil by means of human and animal excreta including bacteria, viruses, protozoa and helminthes. Some of the major types of organisms that are housed in soil and are transmitted to human beings are listed in table 16.

Table 16. Some important soil, water and air borne human pathogens

Bacteria	Viruses	Protozoa	Helminths
Salmonella sp. Vibrio cholera Shigella sp. Campylobacter jejuni Yersinia sp. Escherichia colii O157:H7	Hepatitis A Hepatitis E Enteric adinovirus Polio virus type 1 and 2 Echoviruses Coxsackieviruses Norwalk viruses	Entamoeba histolytica Giardia intestinalis Cryptosporidium parvum	Ascaris lumbricoides Necatur americanus Trichuris trichiura Strongloides stercolaris

Origin of human pathogens in soil : Use of soil as dumping sites for all kinds of wastes created by anthropogenic activities causes contamination of soil by pathogens and parasites. Due to intrinsic characteristics of soil any member of allocthonous or indigenus micro biota will eventually end up in an aquatic environment or be dispersed in aerosols. Sewage and sewage sludges derived from waste water treatment are disposed of in to agricultural lands, lawns, gardens or open land fills. India produces 42 million tons of solid wastes annually(Table 17). In most of the cities there is crude dumping of these wastes in land fills in periurban areas and these will find their final destination in cultivated land nearby. The total waste water generated in urban India is of the order of 200 Mm^3d^{-1}. A population of 6 million in Bangalore city alone is generating about 800 million liters of waste water a day(Ganeshamurthy et al. 2008). Human and animal excreta are used as manure in many countries including India. Pathogens present in such material enter soil and survives for long time because of high concentration of organic material present around them which serves as insulator. Typical survival time of pathogens and parasites in such waste material varies from less than few days to several months (Table 18)(Feachem et al. 1983). Use of such wastes without proper treatment causes significant infections with intestinal nematodes and bacteria in farmers and consumers (Blum and Feachem, 1985). Dumping sites without leachate collection system pose threat to contamination of water. Such leachates percolate through soil profiles and contaminate ground water. Upon use of such water for irrigation will act as a source of pathogens in soil. Hence there is increased concern about increase in soil-borne diseases in human beings. Before liquid and solid wastes are disposed several treatments are given to down the concentration of pathogens and parasites These include aerobic and anaerobic digestion, alkaline stabilization, conditioning, dewatering, freezing, heat drying and composting. These treatments though lower the concentrations of parasites and pathogens do not eliminate them. Since their infection doze is very low composting practices do not completely eliminate the risk of infection(Hay, 1996., Ply-Forshell and Ekesbo, 1993).

Table 17. Waste generation in Indian cities.

Total quantity of solid waste generated in urban areas	1.15 lakh tone per day
Waste generated in 6 mega cities	21,100 tone per day % of total garbage = 18.35*
Wastes generated in metro cities (1 million plus)	19,643 tone per day % of total garbage = 17.08
Wastes generated in other class I cities(0.1 million plus)	42635.28 tone per day % of total garbage = 37.07
Total	83,378.28 tone per day % of total garbage = 72.50

* = If wastes produced in all class I cities is tackled percentage of waste scientifically managed would be 72.50% of total waste.

Table 18. Survival time of some parasites and pathogens present in human and animal excreta in soil.

Organism	Survival time
Cysts and eggs of helminthes	Several months
Entero viruses Thermo tolerant coli forms Salmonella sp.	< 20 days
Vibrio cholera	< 10 days

Environmental protection agency (EPA) of USA suggests further treatments specifically to reduce the pathogens and parasites load to specific levels. The material thus produced are called biosolids. EPA further classifies these into A and B groups. Class A bio solids may contain 10^3 CFU/g dw of thermo tolerant coli forms, <4 CFU of Salmonella, plaque forming units/g dw of enteric viruses and viable helminthes eggs/g dw. These are considered safe for use in home gardens, lawns etc.. Class B biosolids may contain 10^6 CFU/g dw of thermo tolerant coli forms like E.coli, S.shigella, C.cryptosporidium, Giardia, Norwalk viruses, entero viruses etc (NIOSH, 2002). It is permitted for land application but access to such sites are limited to public and live stock grazing for allowing natural die-off of pathogens. In most developing countries no such regulatory measures are available and even if available enforcement is not seen. In many countries untreated waste water is used to irrigate crops mostly in densely populated periurban areas. It serves as a source of pathogens and parasites to soil and is a high risk to farmers and consumers of food produced on such lands(Straus, 1994., Ganeshamurthy et al. 2008). Even though standards are developed based on scientific information, however, these standards lack information on risk assessment. One of the major problem in safe disposal of wastes is lack of sensitive and robust methods for detection of pathogens and parasites. Disposal of wastes involve risk to public health because of the following reasons: (1) They may be a contamination source for food and water because the fate of pathogens and parasites in the soil is not well understood, (2) The infection doze is very low in some organisms like Giardia, Cryptosporidium, enteric viruses, helminthes. This is specially so in immunocompromised and elderly people, (3) There is possibility of regrowth of pathogens(Hay, 1996., Yeager and Ward, 1981) (4) Organisms used for assessing safety index like coli forms does not accurately predict the presence of pathogens and (5)Unknown agents present in wastes may cause diseases and methods for their detection not yet developed(Morbidity and mortality, 2000).

Soil properties and pathogen survival: Several soil properties influence the survival of pathogens and parasites in the soil environment. These properties also influence the transfer of these organisms to human beings.

Soil clay content has a strong influence on survival and proliferation of microorganisms. Due to surface charge of pathogens and parasites they are adsorbed to soil particles. This protects bacterial cells and viral particles by creating a barrier against predators and parasites (Roper and Marshall, 1978). Further as the clay content of soil increases the die-off rate of them reduce drastically (Gerba and bitton, 1984). Hence survival chances of human pathogens and parasites are more in sandy soils than clay soils. This property of soils may be used for selecting sites for application of sewage, sewage sludge and other wastes to soil and also in selecting dumping sites. Soil texture also influences the movement of pathogens and parasites in soil. Clay soils restrict the movement whereas sandy soils promote it (Abu-Ashour et al. 1994., Sinton, 1986).

The activity of pathogens and parasites and their survival in soil is influenced by soil pH. As the pH of soil goes down (within certain limits) the activity and survival chances increases. This is probably due to the influence of pH on the adsorption characteristics of both soil clay surface and pathogens and parasites. The inactivation rate of pathogens are higher in neutral and alkaline soils and lower in acid soils(Santamaria and Taranzos, 2003).

Soil cation exchange capacity, cation concentration and base saturation of soil clays also has direct relationship with the adsorption behaviour of pathogens and parasites in soil(Santamaria and Tranzos, 2003). Higher the base saturation and cation concentration in soil higher is the ability of the soil to adsorb and retain pathogens and parasites in the soil. This consequently affect microbial survival in soil.

Soil temperature has profound influence on survival, proliferation and transport of bacterial and viral pathogens in soil. Lower the temperature higher is the survival of pathogens in soil. In a laboratory study involving polio virus type 1, it was observed that as the temperature increased from 15^0C to 40 ^{0}C there was significant increase in the inactivation rate (Straub et al. 1992).

Both quality and quantity of organic matter in soil affects the survival and proliferation of pathogens and parasites in soil. Soluble organic matter content has direct effect on survival rate of microbial pathogens. This is probably because high concentration of organic matter around the cells of pathogens and parasites may act as insulator and protect them in addition to supplying food. If the concentration of degradable organic matter is more in soil it favors regrowth of bacterial pathogens.

Water is essential for survival of living beings. Favorable soil moisture levels favors survival of pathogens and parasites in soil. As the soil dries up the population of bacterial and viral pathogens goes down. Movement of microorganisms in soil is dependent on water saturation in the soil as movement takes place in liquid phase. Microorganisms move rapidly under saturated conditions because all pores are filled with water. This allows microorganisms to pass through the soil. However, proximity of cells to soil particles favor adsorption on clay surfaces and thus restricting movement to a few centimeters. Soils prone to surface run-off and leaching favors rapid movement of microorganisms. On such soils during rainfall pathogens spread through run-off from places where wastes have been applied or by leaching through the soil profiles. This is the reason for increased bacterial and viral contamination of ground water during heavy rainfall. In a study presence of coliforms were monitored in both shallow (9.4 m) and deep (153.3 m) tube wells during rainy season. Coli forms were detected in both shallow and deep tube wells with bacterial contamination coinciding with the heaviest rainfall (Gerba and Bitton, 1984).

Soil dust transportation as a source of pathogens and pollutants:

Our country is better described as "a country of heat and dust" Dust storms are common during spring , summer and autumn season in northern India. Wind blows during dry seasons in other parts of the country and carries dust with it. Global transport of dust has received better attention (Griffin, 2007, Griffin et al. 2001) than local events. But the dust storms have both local and transcontinental impacts. By some estimates as much as 2 billion metric tons of dust are lifted into the earths atmosphere every year(Griffin et al. 2001) . Drifting with the suspended dust particles are soil pollutants such as herbicides, pesticides, heavy metals and significant number of microorganisms. An analysis of the transcontinental dust storm has shown to contain 25% of the species as plant pathogens and 10% as opportunistic human pathogens. Strong evidences are available that the fallout has direct consequences on human health.

Desertification is a global phenomenon of land degradation, which reduces the natural potential of the ecosystems and is the major source of dust in major continental dust storms. Half the land in India is now affected by desertification and this impairs the ability of land to support life. It is particularly devastating because of its self-reinforcing nature. Desertification due to over grazing, suboptimal cropping, extensive cultivation of one crop, use of chemical fertilizers and pesticides, shifting cultivation without adequate period of recovery, industrial and mining activities, logging and illegal felling, forest fires and unsustainable water management are the major source of dust for continental dust storms. Poor soil coverage, suboptimal cropping, loose soil, frequent tillage, low organic matter content of the soil, poor aggregation, etc. lead to generation of soil dust from agricultural land. Dusts blowing from concentrated sources such as sewage and sludge treated lands and dumping sites which are located near thickly populated cities are very dangerous as they carry pathogens and pollutants and affect sizable population in the cities. Hence dusty winds originating from periurban agricultural lands blowing in the city pose a serious threat to human health.

On an average human beings breath 17 times per minute and breaths 25 pounds of air daily which accounts for 30.5 cubic inches per breath. With an average of 0.0368 gram of dust per cft of air over a period of 10 hours(Average period of a dust storm), an individual breaths 6.6240g of dust during an average dust storm (Blue, 1938). The inherent dust toxicity is due to differences in native soil elemental composition, atmospheric alteration, size fractions, extreme particulate load(Abrahams, 2002., Harrison and Yin, 2000., Zonobetti and Schwartz, 2005). Toxicity of dust from dust storm or down stream wind transport may be influenced by atmospheric material as a result of particulate/pollutant aerosolization during cloud formation or cloud capture. Toxic metals such as arsenic, mercury occur in dusts in down wind environment at concentrations higher than regional crustal concentrations (Holmes and Miller, 2004). Dust clouds may contain high concentrations of organics composed of plant debris and microorganisms and may pickup additional loads of fungal spores, bacteria and viruses, pollen etc. as the cloud moves through and sandblast down wind terrestrial environment (Griffin et al. 2001., Jaenicke, 2005). All these potential dust may negatively influence human health in regional and down wind environment. Dust borne microorganisms in particular can directly impact human health via pathogenesis, exposure of sensitive individuals to cellular components (pollen and fungal allergens) and the development of sensitivities ie., asthma through prolonged exposures.

In many parts of India, basic sanitary facilities are lacking. Many rivers which flows through arid and semi arid regions of the country are the repositaty of all types of wastes including animal feces. Dry river and lake beds which contain lots of pollutants and pathogens serve as a source of air borne dust (Ganeshamurthy et al. 2008). Later all of these land somewhere affecting human health. Some of the disease outbreaks like conjunctivitis, meningitis etc. can be correlated with the local and regional dust events. High rate of asthma in certain localized pockets particularly in and around Bangalore city is possible to link with the dust events.

Though it is not possible to prevent generation of dust and their drifting by wind, it is possible to minimize it through management of surface soils. Different management strategies need to be adopted for different situations. In arid and semi arid regions approach should include: better water management to keep the soil wet and keeping the surface covered with crops or their stumps during dry seasons to minimize dust levels. Management interventions like minimum tillage, stubble mulching and other soil conservation practices also aid in minimizing the generation of dust from arid soils. In periurban areas and other down wind areas, selecting suitable sites, treating wastes to free them from pollutants and pathogens, aforestation of disposal sites with close planting etc. will prevent both dust generation and entry of pollutants and pathogens into food chain.

Geophagia and human health:

Geophagia is a Greek word referring to the habit of eating soil. It is an intentional and repeated ingestion of soil material and is a complex eating behaviour with incomprehensible aetiology. It has a very long history and is amazingly wide spread. Records of geophagia stretches back to 3500 BC in India, Egypt and China. There is a reference to geophagia in Mahabharata (3500 BC) where Balarama and the other boys complained to Yasoda that Krishna had eaten earth. Yashoda opens the mouth of lord Krishna only to see his viraat swarupa. Literally what it means is difficult to comprehend but as a soil scientist one can say it did contain mineral nutrients and had detoxifying effects. Hominids (Homo erectus or Homo sepia) eating soil has been documented from the pre historic sites at the Kalambo Falls in Zambia (Clark, 1969). The clay eating habit of Otomac tribe along the river Orinoco in South America is mentioned in the travel documents of Von Humboldt between 1799 and 1804. There is a mention that in Peru mothers gave their children lumps of clay to keep them quiet(Halsted, 1968). Reinbacher (2003) reported that at least 2000 years ago specially minted clay coins called “Terra sigillata” which had supposed medicinal properties were sold in Greek markets . He said people must have felt that there was something to it and so they ate it. The question is what was that some thing? remains in dispute. It is generally assumed that geophagia may help supplement mineral nutrients and thus should not be dissuaded, particularly in subsistence communities. This is largely based on the assumption that a large proportion of mineral nutrients in geophagic materials is potentially available for absorption in the body.

Geophagia is considered both good and bad for human health. It is common among children, pregnant women and adolescent girls all require more than the normal level of nutrition to cope up with the pace of their growth. Eating soil in such cases satiates extreme hunger, compensates mineral deficiencies and detoxifies food. Eating clay earth during famine is reported from China, and many African countries. Recently in Sudan clay cakes being sold as food became news. In North Carolina it is eaten for general health, in Zimbabwe it is eaten to treat diarrhea. Different types of clays contain different levels of trace elements that could supplement a poor diet(Aufreiter et al. 1997).

Researchers differ in their opinion about compensating mineral deficiencies through eating clays. Hooda et al.(2004) made a detailed study by using a simulated stomach conditions. They reported that nutrients get tightly bound to the lattice structure of clay particles and seriously reduce the availability of Zn, Fe, Cu Mn etc. Further they said that as the level of acidity is increased the more tightly minerals are held by the clays. These findings disproves the hypothesis of mineral compensation through geophagia. But this did not explain whether these bound nutrients are absorbed by the body through other mechanisms like enzyme mediated absorption, legand exchange etc. Further the properties of clay minerals in soil can affect their ability to supplement nutrient deficiencies. Clays with higher CEC and higher saturation level have greater ability to supplement trace elements like Zn, Cu, Fe, Mn, Se etc(WHO, 1996) than clays with lower CEC and lower saturation. If observations of Hooda’s team is correct then clays with higher CEC may virtually reduce the availability of minerals as they can take-up minerals from stomach and inhibit their absorption by the body. For example Ca rich clay has adverse effect on Zn utilization and Fe rich clay on Cu, Zn, Se etc (Mills, 1996). Further humus in the soil chelates with Fe which makes it unavailable leading to anemia (Moynahan, 1979). From these observations it is difficult to understand whether geophagia or malnutrition comes first.

Prasad(1991) reported that Zn deficiency may cause geophagia. His study involved several young Iranian men who suffered from stunted growth and slower sexual development all of whom ate clays every day. When they were given Zn supplements they matured sexually and lost the desire to eat clay. He inferred that a lack of Zn leads to hypogeusia – a taste diminishing disorder which makes clay attractive and reinforce geophagia, leaches more Zn and starts the cycle all over again. Supplementing such patients with Zn reduces their desire to eat clay.

Often geophagic patients are infected with helminthes, particularly, hook worms. This also causes anemia. Supplementing diets of geophagic children having anemia with Fe did not stop them eating clay. Non-infected anemic children were also found geophagic. This explains that hook worm in clay did not cause nutrient deficiencies (Nchito et al. 2004).

Exchange reactions of clays eaten may help in absorption of dietary toxins such as alkaloids, tannins and microbial toxins. For example many in North (Pomo Indians) and South America ate clay to detoxify bitter potatoes (John and Duquette, 1991). Sardinians also ate clay to make acorns more palatable. Many pregnant women have morning sickness during the first quarter of pregnancy. This is a period when women are geophagic and appears as an evolutionary step to derive benefits arising out of geophagia. The clay detoxifies the toxins that enter the body through food like solanin of bitter potatoes, nicotine of tobacco etc. and protect the fetus against these toxins and other carcinogens and mutagens. Loosing nutrients through geophagia is probably negligible compared to the benefits of throwing out the toxins(Sera et al. 2004).
There are many medical problems that arise out of geophagia. It is held responsible for hepatosplenomegaly (enlargement of liver and spleen), dwarfism, hypogonadism (sexual immaturity, ingestion of parasites and pollutants, oedema and even tetanus(Halsted, 1968.,Minnich et al. 1968., WHO, 1996). Price and plant (1990) reported an interesting case of non-filarial elephantiasis the podoconidiosis. In this small worms present in soil causes swelling of the legs by blocking the lymph nodes. The disease is common in tropical highlands having Nitisols (fine reddish brown soils) in parts of Ethiopia, Kenya, Tanzania, Burundi, and Cape Verde. Very small particles of kaolin, amorphous silica and quartz and iron were found in phagosomes of macrophages. The specific role of these soil minerals is still not yet clear and needs investigation. An outbreak of elephantiasis in 1987 in Addis Ababa was linked to the dust storm which affected the area in the dry season.

Available literature shows that understanding of geophagia is not complete. There are strong evidences both for and against geophagia. A clear understanding of geophagia requires the knowledge of soil science, biochemistry, epidemiology and even ethnography. Hence an interdisciplinary approach is required to answer the question whether geophagia is beneficial or harmful. In the current situation where lots of pollutants and toxins are entering body through food chain and other means the detoxifying effects of clay needs thorough investigation where soil scientists can play an important role. Supplementing mineral nutrients through soil is an area which needs systematic study based on body chemistry and properties of clay. Quality of soil plays an important role in this. In the days to come we may expect soil as medicines either as detoxicants or mineral supplements if geophagia is completely understood.

Conclusions:

Food concerns every one and thereby the soil which produces the food concerns every one. The health whether of soil, plant, animal or humanbeings is one and indivisible. The food produced and consumed today contains lower concentration of minerals and other nutrients because of depletion of soils and deterioration of soil health. Consequently we have created a society which is over fed but malnourished of minerals and vitamins. These factors have contributed to the rise in human degenerative diseases. Multifold increase in anthropogenic activities has led to increased production of wastes leading to pollution of soil, water and air. The buffering capacity of soils for pollutants is exceeding the limits and dangerous pollutants are entering food chain endangering human health. Pathogens entering soil survives for a long time as soil organic matter act as insulators and soil clays protect them by adsorbing on their surface. Re growth of organisms take place in soil if soluble organic matter is available. Hence soil acts as a major vector and also serves as a major source of disease causing agents to humans. Half of Indian land is affected by desertification of varying degree. Several agricultural practices like poor surface soil management, poor water management, monocropping, over tillage etc. have contributed to the generation of huge quantities of dust which are transported over long distances carrying with it pollutants, pathogens and particulate matter. Inhelation of such dust affects human health and many of the disease outbreaks can be correlated with local and regional dust events. Geophagia is an area which has not been understood clearly. There are strong evidences both for and against it. Linking human health to soil requires the knowledge of soil science, biochemistry, human physiology, pathology, epidemiology and even ethnography. If the link is clearly understood soil management can be suitably altered to contain human diseases. For this a strong interdisciplinary approach is required.

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