Analysis of soil nutrients and their simultaneous effect to human health in terms of toxicity: A pilot study

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Abstract

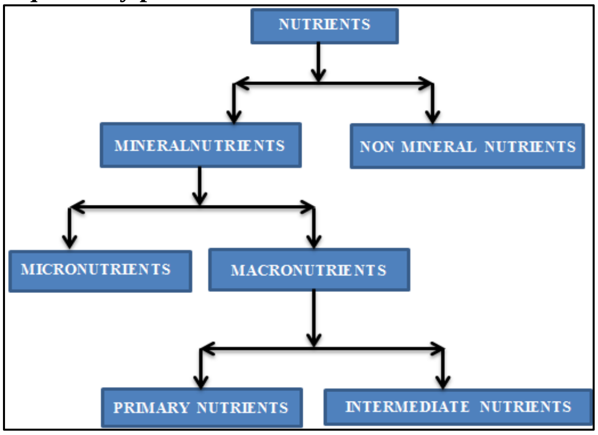
Soil contains a wide variety of mixtures including organic matters, minerals, nutrients required by plants. These nutrients are directly or indirectly related to human health. Soil is an important source of nutrients in our food supply. These types of imbalances in nutrients can cause negative effects on health. Soil provides many of the nutrients we require and can pass on harmful substances through the intake of food. Supply of any element may result in human toxicity even though the elements are essential for life. For any essential element there is an optimal range of concentration in humans, falling below this optimal range results in deficiency, whereas concentrations above the optimal range create toxicity. Soil mostly found near the industrial areas is dangerously contaminated with minerals like Sulphur, Boron, and Phosphorus etc. Also uncontrolled use of high quantity of fertilizers without having awareness and knowledge of their negative effects would also lead to toxicity. So, production of fruits, vegetables and crops on such contaminated soils prove to be dangerous to human health. Soil samples from twenty different areas (industrial as well as non-industrial areas) where native people grow plants for production of food were targeted, analysis of which have resulted in the extraction and detection of high levels of minerals. Chronic consumption of food from plants grown in such contaminated soils is one of the important and main reasons for negative health effects leading to toxicity and eventually increases the chance of mortality rates in humans.

Keywords: Soil, Nutrients, Minerals, Fruits, Vegetables, Consumptions, Toxicity, Humans.

Introduction

Soil consists of a mixture of organic matters, minerals, gases, liquids and organisms that in combinations support life. It is a medium for plant growth, water storage, supply, purification and is a modifier of Earth's atmosphere. The physical properties of soils for crop production are texture, structure, bulk density, porosity, consistency, temperature, color and resistivity. The essential elements would be present in the right proportions for healthy growth of the plant throughout. However, in the process of cultivation of plants, soil may require the addition of organic or inorganic fertilizers. Soil is a major and most important source of nutrients for plant growth. Nutrients supplied by the soil are called mineral nutrients. The non-mineral nutrients such as carbon (C), hydrogen (H) and oxygen (O) come from air and water sources during photosynthesis. Soil mineral nutrients are divided into two group's viz. the macro and micronutrients. The macro nutrients are further divided into two groups the primary and the intermediate nutrients. The primary nutrients are required by plants in relatively large proportions and include nitrogen (N), phosphorus (P) and potassium (K). The intermediate nutrients which are required by plants in medium quantities include calcium (Ca), magnesium (Mg) and sulphur (S). The micronutrients required by the plants in relatively small proportions include iron (Fe), boron (B), manganese (Mn), copper (Cu), zinc (Zn), molybdenum (Mo), nickel (Ni) and chlorine (Cl). Though the soil nutrients are separated into different groups but each nutrient is equally important.[1]

Flowchart 1: Showing types of nutrients (minerals) required by plants



Changes due to various factors such as crop harvesting, leaching, erosion, fixation, volatilisation, addition of fertilizer, manure, compost and deposition and absorption of industrial contaminants occur in soil which affect the quantity and availability of nutrients. So, soil should be tested for its ability to supply nutrients required for growth of the plants. The soil test aids in revealing the nutrient contents. Another important factor is that soil has a considerable effect on human health, whether those effects are positive or negative, direct or indirect. Soil is an important source of nutrients in our food supply. These types of nutrient imbalances can cause negative effects on health. Soil provides many of the nutrients we require and can pass on harmful substances through the intake of food. Supply of any element may result in human toxicity even though the elements are essential for life. For any essential element there is an optimal range of concentration in humans, falling below this optimal range results in deficiency, whereas concentrations above the optimal range create toxicity. There are 14 elements essential for plant growth that comes from the soil, and many of these elements are also essential for human health.[2] These essential nutrients human diet directly by the consumptions of plants or its products.[3] Hydrogen, oxygen, carbon, nitrogen, sodium, potassium, calcium, magnesium, phosphorous, sulphur and chlorine make up 99.9% of the atoms in the human body, with all but hydrogen, oxygen and carbon having soil as their major source.[4] However, the remaining 0.1% consists of approximately 18 additional elements known as micronutrients or trace elements that are essential in small amounts to maintain human health.[2] So, soils providing plants with the proper nutrients for growth also contain many of the elements that are necessary for human health as well.

The idea that human health is tied to the soil is not a new one. As far back as circa 1400 BC the Bible depicts Moses as understanding that fertile soil was essential to the well-being of his people. Soils and human health studies include investigations into nutrient supply through the food chain.[5] Soil describes the general condition or quality of the soil resource. Organic matters contribute to maintenance of nutrient cycling and soil structure. Sequestration of C in soil also plays some role in regulating the emission of greenhouse gases such as methane and carbon dioxide. Factors as pH, bulk density and soil organic matter content determine the prevailing condition of the habitat within the range for a particular soil. Agricultural soils have been altered from their natural state by human interventions which are aimed at maximizing production functions and which, to some degree, always result in a loss of other ecosystem functions.[6] Studies have shown that long-term land application of P as fertilizer and animal wastes has resulted in elevated levels of soil P in many locations in the United States of America.[7] Food security could only be attained with increasing crop productivity. One of the major crop productivity constraints is the unavailability of crop nutrients. Both macro and micro nutrient deficiencies have been reported in most of the soils, which could be provided through various nutrient management practices.[8]

Health of humans is affected by the world's soils. Soils influence a variety of functions (e.g. as a plant growth medium; its importance on the cycling of water; as a foundation for buildings) that supports the human population. Through ingestion (either deliberate or involuntary), inhalation and dermal absorption, the mineral, chemical and biological components of soils can either be directly beneficial or detrimental to human health.[2]

In reality, world people are exposed to mixtures, not single chemicals. Although various substances may have totally independent actions, in many cases two substances may act at the same site in ways that can be either additive or non-additive.[9]

Material and Methods

Reagents and Chemicals

1	Potassium dichromate
2	Sulphuric acid
3	Sodium bicarbonate
4	Ammonium molybdate
5	Antymony Tartrate
6	Ascorbic Acid
7	Potassium Sodium Acetate
8	Acetic Acid
9	Morgan Reagent
10	Sodium Tetraphenyl Boron
11	Buffer Solutions, Anti-Flocculent
12	Sodium Acetate
13	Barium Chloride
14	Hydrochloric acid
15	Dithiozone
16	Propanol-1
17	Salicyclic acid
18	Trienthanol Amine
19	Sodium Chloride
20	Azomethine H

Study Protocol

Sample Size

Samples of soil are collected from 20 different areas (Industrial and non- industrial areas) of New Delhi, India. For each sample, 10 well distributed spots are targeted for sample collection. The soil samples from 10 distributed spots are mixed properly over clean sheets of paper. The bulk is reduced by quartering process. The soil is dried properly. The plant materials, residues, gravels etc. are removed. The soil samples are grinded properly. The entire quantity is then sieved through 0.3mm sieve. The sieved samples are remixed thoroughly before performing the analysis.

Table 1: Showing location of sample collection

S. No	Sample Codes	Places of Collection
1	S1	Mangolpuri Industrial Area
2	S2	Govindpuri
3	S3	Kattar Market, Mangolpuri
4	S4	Okhla Industrial Area
5	S5	Rohini
6	S6	Uttam Nagar
7	S7	Chandni Chowk
8	S8	Trans Yamuna Area
9	S9	Jahangirpuri
10	S10	Dwarka
11	S11	Ballimaran
12	S12	Janakpuri
13	S13	Mundka
14	S14	Bawana
15	S15	VivekVihar
16	S16	Wazirpur
17	S17	Mehruli-Gurgaon Road
18	S18	Rajouri garden
19	S19	AnandVihar
20	S20	Narela

Parameters of Samples testing

Examples of the soil parameters include amount of nutrients present in soil. The nutrients include both macronutrients and micronutrients. Examples of macronutrients include organic carbon, phosphorus (P), potassium (K), and sulphur (S). Examples of micronutrients include zinc (Zn) and boron (B).

Instrumentation

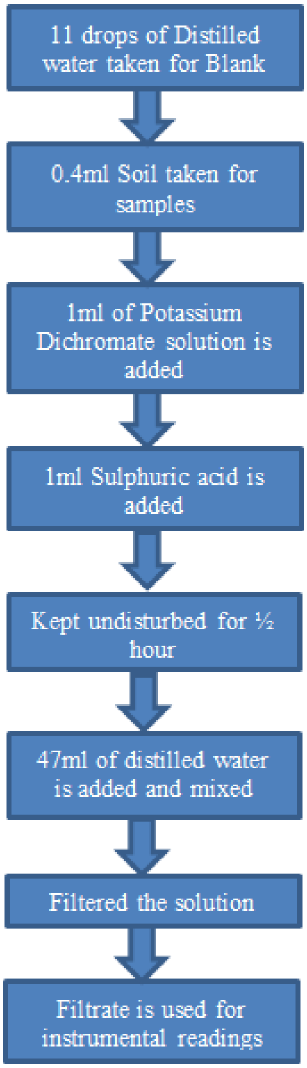
The soil parameter-testing unit includes one or more of photo-detector units. Further, the photo-detector unit comprises of a lighting unit adapted to illuminate one or more soil samples. The lighting unit further comprises one or more light sources having illuminating different colors such red, blue, green, and combination thereof.

The photo-detector unit further includes a light sensing unit adapted to detect a light reflected or refracted from the soil samples when the light source illuminates the soil samples.[10]

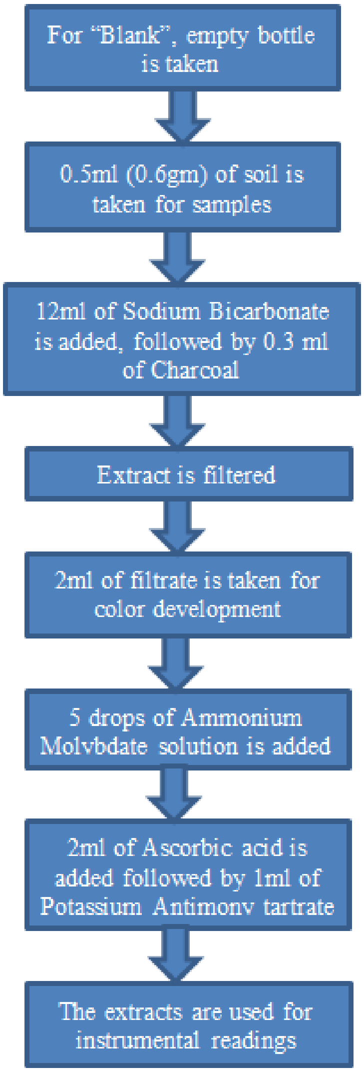
Sample Preparation

Organic carbon (Non mineral nutrient), Phosphorus (Macro-primary nutrient), Potassium (Macro Primary nutrient), Zinc (Micro nutrient), Boron (Micro Nutrient), Sulphur (Macro intermediate nutrient) are extracted from the collected soils samples following the standard operating procedure mentioned below. Extraction and analysis is done for 3 consecutive days for each soil sample.

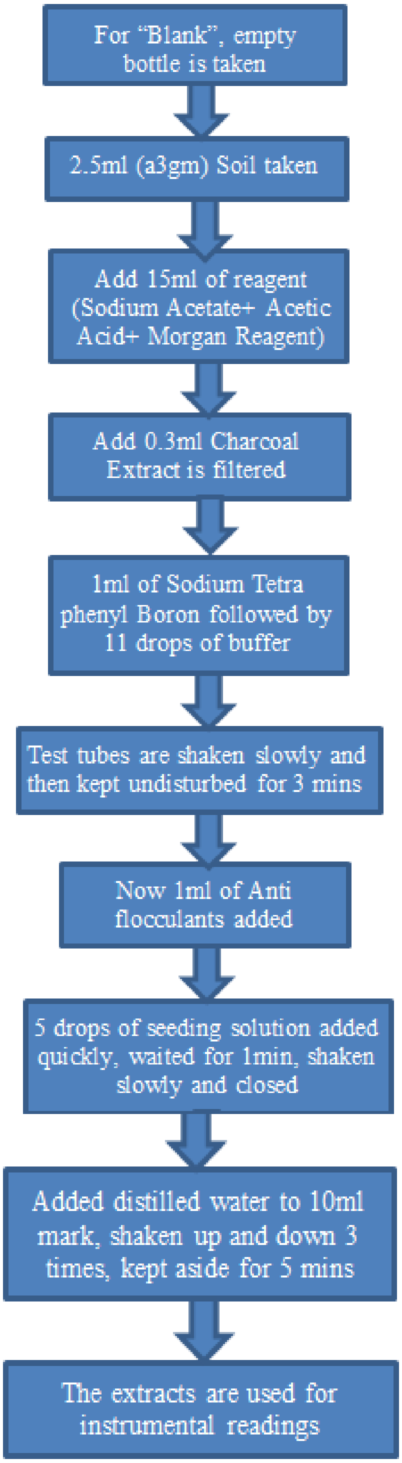
Flowchart 2:
Extraction of Organic Carbon



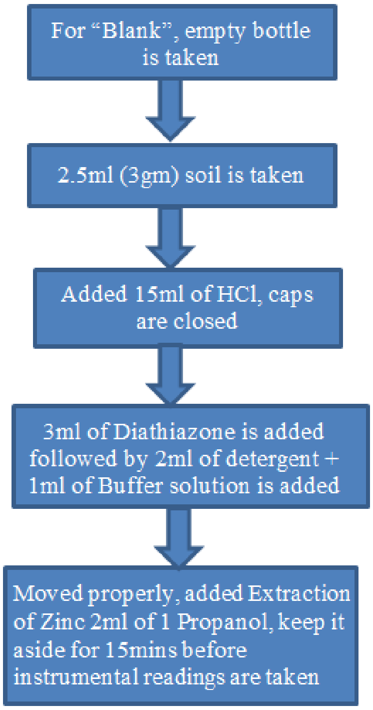
Flowchart 3:
Extraction of Phosphorus



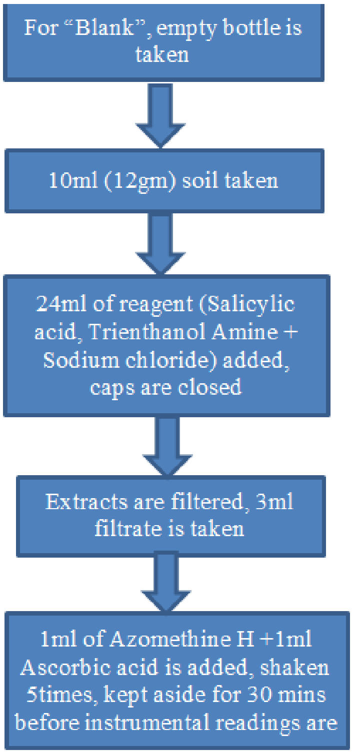
Flowchart 4:
Extraction of Potassium



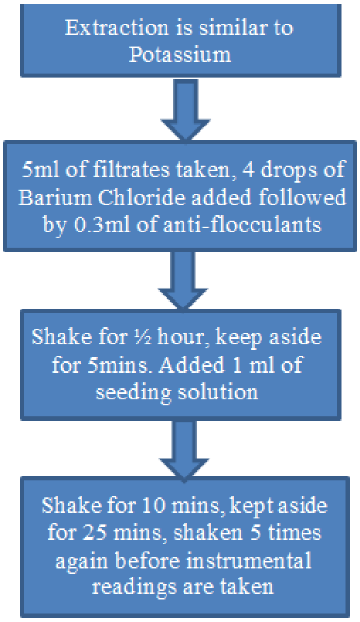
Flowchart 5:
Extraction of Zinc



Flowchart 6:
Extraction of Boron



Flowchart 7:
Extraction of Sulphur



Principle of sample preparation and instrumentation

Soil parameter to be tested is the amount of nutrients present in the soil. The extraction reagent extracts the nutrient in the portion of soil. Thereafter, a color is developed by mixing color-developing reagent. Based on the selection of one or more nutrients, the data processing unit selects a light source in the photo-detector unit for illuminating one or more soil samples. Accordingly, the light sensing unit in the photo-detector unit then measures light reflected/ refracted from the one or more soil samples as color intensity.

The measured color intensity is proportional to the amount of nutrient extracted in the soil sample.

Prior to performing soil testing on the soil samples, the user prepares a blank solution for each of the selected one or more nutrients to be tested. The blank solution is a solution in which no nutrient is present and is used as a negative control. The blank solutions are tested by the soil parameter-testing unit in a same manner the soil samples are tested. Upon testing the blank solutions, the soil samples are tested. The soil parameter-testing unit then determines value of the one or more soil parameter based on the color intensity measure for both the blank solution and the soil samples[10].

Result

	Organic Carbon= %ge Range=0-1.7%	**Sulphur=mg/kg Range=0-150**	**Potassium=kg/ha Range=0-400**	**Boron=mg/kg Range 0-5**	**Phosphorus=kg/ha Range 0-80**
Samples	**Average**	**Average**	**Average**	**Average**	**Average**
S1	0.004233	215.5766667	123.6667	1.82	881.2333333
S2	0.0033	121.1533333	235.3333	3.543333333	876.9333333
S3	0.0031	77.54666667	256.4667	44.52333333	59.06666667
S4	0.002367	223.32	165.7667	4.54	828.6666667
S5	0.0026	142.8933333	333.4667	42.08	76.86666667
S6	0.003433	81.94	122.7333	87.75333333	832.9666667
S7	0.003567	225.5266667	175.0333	22.08666667	24.3
S8	0.002267	221.2833333	222.1333	4.2	842.9

S9	0.002267	281.8866667	266.2	3.43	68.07333333
S10	0.001533	93.12333333	233.4667	1.536666667	85.6
S11	0.0016	233.0633333	213.7	27.56	93.5
S12	0.0016	54.05666667	252.3	2.68	103.7333333
S13	0.002767	62.22333333	343.9333	52.25333333	46.55
S14	0.0021	242.88	205.5	5.016666667	15.54
S15	0.0025	218.76	256.1667	56.04666667	810.7333333
S16	0.002433	272.1133333	246.1667	101.7533333	813.9333333
S17	0.0026	101.9933333	214.2667	54.7	72.23333333
S18	0.0026	132.0166667	288.0667	44.56666667	62.59666667
S19	0.0032	222.9566667	207.4667	47.23	801.6666667
S20	0.003333	301.6266667	216.2667	98.04333333	125.7333333
ZINC=mg/kg Range 0-10mg/kg					
S1	23.9				
S2	22.56667				
S3	23.66667				
S4	34.76667				
S5	43.96667				
S6	48				
S7	35.4				
S8	36.5				
S9	34.96667				
S10	45.53333				
S11	35.36667				
S12	32.23333				
S13	28.8				
S14	37.1				
S15	32.26667				
S16	33.36667				
S17	28.7				
S18	48.86667				
S19	42.23333				
S20	43.36667				

Organic Carbon =% ge Range= 0-1.7%

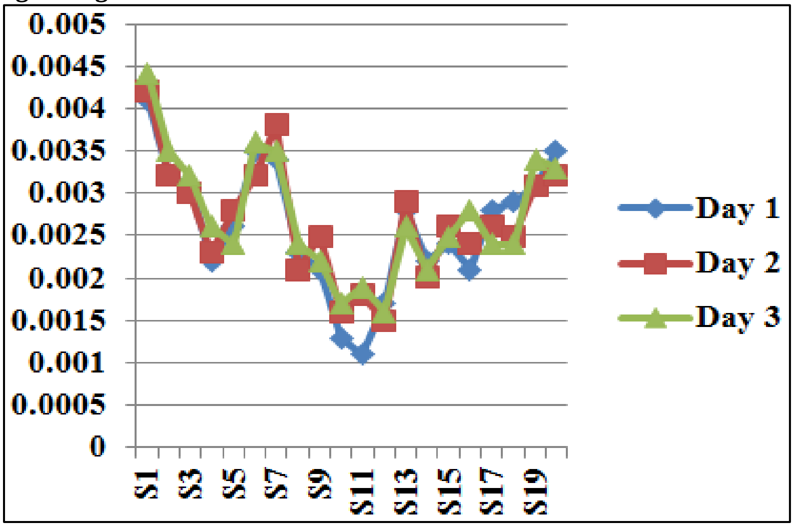


Fig. 1:

Sulphur=mg/kg Range= 0-150

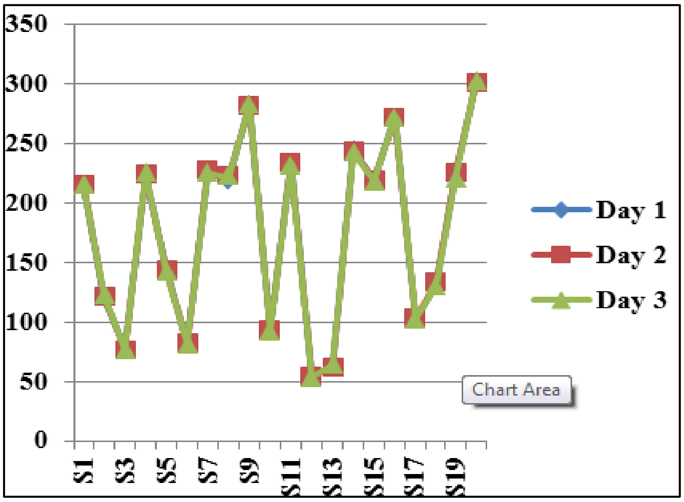


Fig. 2

Potassium=kg/ha Range= 0-400

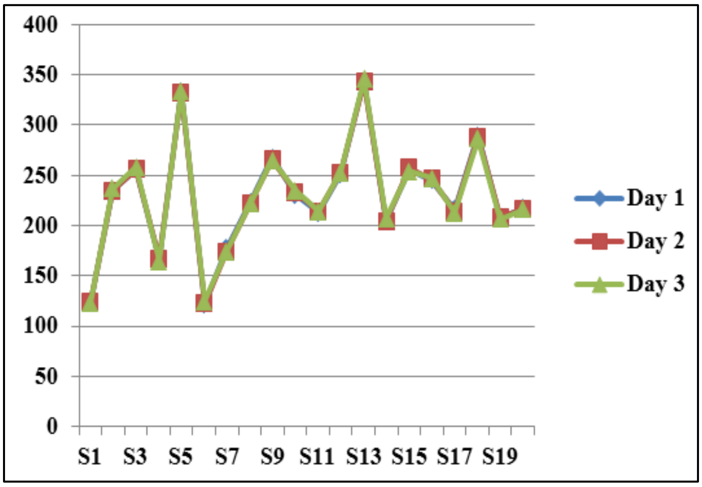


Fig. 3

Boron=mg/kg Range= 0-5

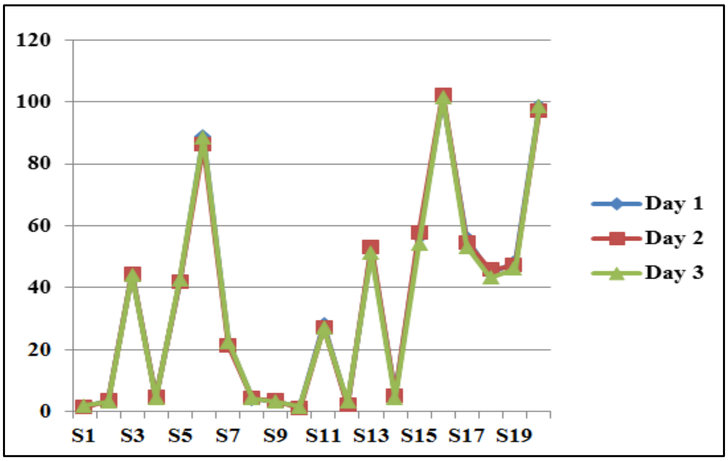


Fig. 4

Phosphorus=kg/ha Range 0-80

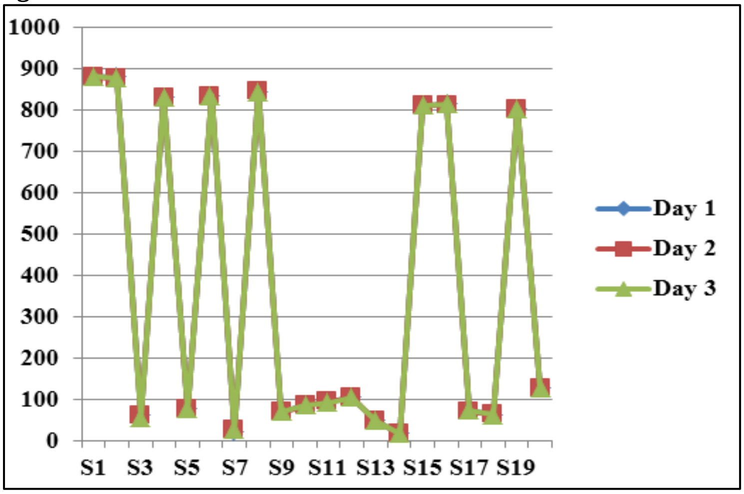


Fig. 5

Zinc=mg/kg Range 0-10

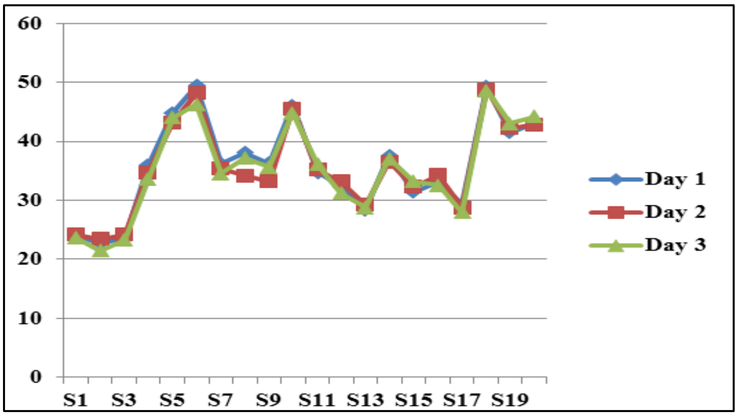


Fig.6

Discussion

Soil has a considerable effect on human health, whether those effects are positive or negative, direct or indirect. Soil is an important source of nutrients in our food supply. These types of nutrient imbalances can cause negative effects on health. Soil provides many of the nutrients we require and can pass on harmful substances through the intake of food. Supply of any element may result in human toxicity even though the elements are essential for life. For any essential element there is an optimal range of concentration in humans, falling below this optimal range results in deficiency, whereas concentrations above the optimal range create toxicity.[3-4] Soils play a major role in all of these areas of quality food production and security. Exposure to heavy metals through soil contact is a major human health concern.[12]

Organic carbon (Non mineral nutrient), Phosphorus (Macro-primary nutrient), Potassium (Macro Primary nutrient), Zinc (Mico nutrient), Boron (Micro Nutrient), Sulphur (Macro intermediate nutrient) are extracted from the collected (20) soil samples.

Out of 20 soil samples, all samples showed presence of high amount of Zinc (0-10) mg/kg. Zinc (Zn) is an essential micronutrient for normal healthy growth in plants, animals and humans that uptake as a divalent cation (Zn^{2+}) by plants. Zinc is playing principal metabolically role in plants. Zinc absorption capacity is reduced by high phosphorus utilization and zinc in plant and soil has an antagonism state with phosphorus (negative interaction), therefore zinc utilization is essential to obtain high yield and quality in crops.[11] Out of 20 soil samples, 11 samples showed high Sulphur content, 9 samples showed presence of Sulphur within normal range i.e (0-150) mg/kg. Sulfur from all sources must either be in the sulfate form or be converted to the sulfate form before it can be used by plants. As mentioned above, organic matter is the major reservoir of sulfur in most soils. Except for sulfur fertilizers and irrigation water, the other sources listed contribute minor amounts. This high content of sulfate indicates high levels of air contamination with SO_2 around the refinery which negatively effects the environment and public health that this populated area.[13] Sulfur is one of the essential elements in all living things including plants. About 95 percent of the total sulfur content of most soils is contained in the organic matter which is broken down and is mineralized into the sulfates. Sulfate-sulfur can then be taken up by the roots of growing plants. Most of the fuels that are burned for heat, power and transportation contain some sulfur. When these fuels are burned, the sulfur escapes as sulfur dioxide gas (SO_2). Sulfur dioxide which gets dissolved in rainwater and reaches the soil as sulfate-sulfur, Sulfur dioxide in the atmosphere is highest in industrialized areas. Some of the pesticides also contain sulfur. **C**ommercial fertilizers supplied considerable sulfur in addition to the nitrogen, phosphorus, and potassium. Irrigation water is also an important source of sulfur in some areas.[14]

Out of 20 soil samples, 12 samples showed presence of high amount of Boron, 8 showed Boron within normal range of (0-5) mg/kg. Naturally occurring Boron is a widely occurring element in minerals found in the earth's crust. Boron is found in the environment primarily combined with oxygen in oxygen to form compounds called borates. Borate-containing minerals are mined and processed to produce borates for manufacture several industrial uses like industrial and consumer • glass and ceramics products • soaps, bleaches, and detergents • fire retardants • pesticides. Boron when enters the environment is released into air, water, and soil. Boron can be released from: • glass manufacturing plants • coal-burning power plants • copper smelters • agricultural fertilizer and pesticide usage. Exposure to boron can occur through food, mainly vegetables and fruits, as boron are an essential element in plants. The effect of boron on human health depends on how much boron is present, how you are exposed to it, and the length of exposure. Exposure to large amounts of boron over short periods of time can affect the stomach, intestines, liver, kidney, and brain and can eventually lead to death.[15]

Out of 20 soil samples, 8 samples showed presence of very high amount of Phosphorus, 4 samples showed presence of high amount of Phosphorus, 8 samples showed Phosphorus within normal range i,e, (0-80)kg/ha. Concentrated phosphoric acids are used in fertilizers for agriculture and farm production. Phosphates are used for special glasses, sodium lamps, in steel production, in military applications (incendiary bombs, smoke screenings etc.), and in other applications as: pyrotechnics, pesticides, toothpaste, detergents. In the natural world phosphorous is never encountered in its pure form, but only as phosphates. There can be more phosphate in rivers and lakes, resulting in excessive algae growth. Phosphorus can be found in the environment most commonly as phosphates. Phosphorus can be found in the environment most commonly as phosphates. Humans have changed the natural phosphate supply radically by addition of phosphate-rich manures to the soil and by the use of phosphate-containing detergents.[16]

Zinc is an essential trace element that can cause symptoms of deficiency and can be toxic when exposures exceed physiological needs. Risks of zinc excess Toxic effects in humans are most obvious. Intentional or accidental ingestion of large amounts of zinc leads to gastrointestinal effects, such as abdominal pain, vomiting and diarrhoea. At high concentrations zinc can be cytotoxic.[17]

Out of 20 soil samples, Organic Carbon and Potassium recovered from all 20 soil samples were found to within normal range i.e. (0-1.7)% and (0-400)kg/ha respectively. Organic matter makes up just 2–10% of the soils mass but has a critical role in the physical, chemical and biological function of agricultural soils. Carbon is a measureable component of soil organic matter. Organic matter contributes to nutrient turnover and cation exchange capacity, soil structure, moisture retention and availability, degradation of pollutants, greenhouse gas emissions and soil buffering. Soil organic matter (SOM) is mainly composed of carbon, hydrogen and oxygen but also has small amounts of nutrients such as nitrogen, phosphorous, sulphur, potassium, calcium and magnesium contained within organic residues.[18] Both nitrogen and phosphorus are constituents of the soil organic matter, but potassium is not. Soil organisms have a much lower requirement for potassium than plants do. Consequently, as organic residues decompose, most of the potassium is quickly released. The behavior of potassium in the soil is determined more by physical than by chemical or biological processes.[19]

Conclusion

The present research study has clearly shown the importance of quantity of nutrients found in the soil which is directly related to health of humans. Excess quantity of nutrients(minerals) in the soil are transported to the products i,e fruits and vegetables which in turn enters the food chain leading to toxicity to human health.

To improve the quality of soil, kitchen gardening in the industrial areas should be avoided. In the non-industrial area as well as in the industrial area, the population residing in or nearer to these locations should opt for generating soil health cards where the soil samples can be collected and sent to the laboratory for analysis of the nutrient contents. Based on the soil health cards, nutrients to be added or avoided would be known which will help to overcome and control soil toxicity and deficiency as well to greater extent.

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