"Assessment of the uptake of toxic heavy metals on cultivation of vegetables of family Solanaceae in contaminated soil"

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By

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CERTIFICATE

I feel great pleasure in certifying that the thesis entitled **"Assessment of the uptake of toxic heavy metals on cultivation of vegetables of family Solanaceae in contaminated soils"** *embodies a record of the results of investigations carried out by* **Mrs. Renu Tyagi** *under my guidance. I am satisfied with the analysis of data, interpretation of results and the conclusions drawn.*

I recommend the submission of thesis.

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KOTA

DATED: **December, 2014** **RENU TYAGI**

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CHAPTER – 1

INTRODUCTION AND LITERATURE REVIEWED ON THE SUBJECT

Heavy metals or trace elements are a large group of elements with higher density generally greater than $5 gm/cm^3$. These elements are important both industrially and biologically. Heavy metals occur naturally in earth's crust and surface soils in varying concentrations (13, 224). Natural Processes like weathering, erosion remove small amounts of metals from the bed rocks and allow them to circulate in water and air. Heavy metals like Zn, Se, Cu, and Fe are essential to maintain the metabolism of the human body and play important role in chemical, biological, biochemical and enzymatic reactions in the cells of plants, animals and human beings (228). Heavy metals are also known as 'trace inorganics', 'micronutrients', 'toxic elements' etc. More than 60 elements in various parts of human body have been detected, but only 17 are available in living cells (206). Heavy metals like Mn, Mo, Fe are more important as micronutrients while Ni, Cu, Co, V, Zn, W and Cr are of lower importance and can be toxic beyond the limits(75). Heavy metals like Cd, Pb, Mg, As, Sb, have no biological functions, but are rather toxic to living organisms (48, 58). Injury to vegetation caused by heavy metals has been well recognized in many botanical and chemical investigations during past years (250). Heavy metals occur in all ecosystems of the world. The total concentration of heavy metals in soil and water however varies from local to regional and further to continental level.

Heavy metals are very harmful in reference to their non biodegradable nature, long biological half lives and their potential to accumulate in different body parts. Most of the heavy metals are extremely toxic because of their solubility in water. Even at low concentrations heavy metals can have damaging effects in human beings and animals as there is no good mechanism for their elimination from the body. The heavy metals are taken up faster than they are metabolized or excreted. Even those heavy metals which are considered to be essential can become toxic in case present in excess. The heavy metals can impair important biochemical processes posing a threat to human health (88, 242).

Heavy metals can be toxic at source level of solubility; however only a few have been observed to cause phyto-toxicity in soils (27, 56). Soils contain these metals in form of inorganic compounds or they may remain bonded with organic matter, clays or as oxides. Lead and Cadmium are of interest not only because of phytotoxicity but also due to their uptake by the plants and then passing over in the food chain (25, 29, 68).

As the usage of metals increased inexorably, so did the pollution associated with it. Changes in the environment due to anthropogenic activities may have strong impact on the physiology and ecology of the organisms. Human activities and consequent developments have brought about degradation of all facets of the natural environment; physical, chemical, biological and social which are adversely affecting the quality of life (6). Rapid developments, increase in mining, industrial activities, have gradually redistributed many of the toxic metals from the earth crust to the environment, raising the chances of exposure through ingestion, inhalation or on skin contact.

Heavy metals can have different sources or origin e.g. Smelters (52, 118), tannery (169), mines (198), steel mills, coal fired power plants which can lead to metal pollution (266). Other sources of metal pollution are sewage sludge (55, 59), compost refuse, fly ash (129, 225), industrial wastes or effluents (71, 130, 132). Emission of heavy metals as particulate matter and gases from volcanoes, forest fires, crusted materials and continental dust have always been a natural input sources to soils and ecosystems (78, 81, 261, 262).

The spreading of urban waste and sewage sludge in agricultural fields has been a common practice since decades (32, 101, 186, 267). Sewage sludge, live stock manure, waste water irrigation are feasible alternatives(47, 163) for reutilization of residual resource of high nutrient and organic matter contents representing a good fertilizer or soil conditioner for plants and soil (226). Besides agricultural fields, recreational parks, golf courses, home gardens are also irrigated using waste waters from sewage plants. The solids from the sewage plants are processed and sold as soil amendments and low grade fertilizers (43, 155). Reclaimed lands are known to contain significant amount of metals and are being used for growing food crops and vegetables.

Pig and poultry manure generally contains elevated concentrations of Cu and Zn which improve food conversion efficiency. Arsenic was also used for this purpose (38, 172). Beneficial properties of sludge and manures are limited by their contents of potentially harmful substances such as heavy metals and organic micro pollutants (40, 196). Sludge and manure amendments are observed to improve physical properties of soil like soil aeration, water holding capacity and aggregation (239). The slightly alkaline property of the sludge and fly ash works as buffer against the acidity of acidic soils (42, 249). Alkaline pH of the soil may restrict the mobilization of heavy metals in the soil matrix and consequently metal uptake by crop plants, vegetables etc. may be controlled, thus reducing the heavy metal toxicity (82, 180, 241).

Waste water reuse such as industrial waste water, sewage water for applications like irrigating dry and semi dry regions is considered as a useful method to minimize the problem of water shortage (84, 85, 191, 208, 214, 215). The waste water may contain different types of pollutants including heavy metals which may cause heavy metal contamination in the vegetation due to irrigation with this contaminated water (46, 121, 162, 207, 210, 222, 227, 230). Mosleh Yhaia Y I and Omer Abed El-Hakeem Almagrabi (162) investigated the accumulation of heavy metals in some vegetables irrigated with waste water and sludge in three vegetable forms in Jeddah. The trend of heavy metal uptake in fruit type vegetables was Fe > Zn > Cd > Cu > Pb while Fe > Cd > Zn > Cu > Pb was the trend found in leafy vegetables. Similar trend was revealed by other researchers (124, 200, 216, 232).

Singh P K et al. (223) studied the effect of sewage and waste water irrigation on crops like wheat, gram, palak, methi and barseem and found that if the land with suitable topography, soil characteristics, proper drainage is available, sewage effluents can be put to good use as a source of irrigation and plant nutrients. Similar studies by Kiran D Ladwani et al. (136) and Sharma R K et al. (212) were also conducted revealing that these effluents contain high organic matter, and various nutrients. The results have shown improvement in the physical, chemical properties of soil, yield of crops, and quality of grains. However it was also found that the soils are contaminated by the heavy metals because of being irrigated with the waste water (2, 3). Soils may accumulate heavy metals to an extent which may cause clinical problems to animals and human beings because of the change in physico-chemical parameters of the soil and the vegetables grown may be loaded with heavy metals (86, 87, 96).

Bigdeli M and Seilsepour M (31) found the accumulation of heavy metals in vegetables irrigated by waste waters and industrial effluents in the farms of Shahre Rey Iran. Leafy vegetables tend to accumulate relatively higher concentrations of heavy metals in comparison to fruit type (12). They found that Cd, Pb, Zn, Cu etc. moved into the stems and leaves of, celery, coriander, spinach, dill, the most consumed part of the plants and in lower concentration in radish, green chillies and red chillies, tomatoes, egg plants consumed either by human beings or animals as fodder (24, 177, 178).

Food is the major intake source of toxic elements by human beings. Vegetables are used as staple part of food both in cooked and raw form (64). The recommended amount of vegetables in our daily diet is 300-350 gm per person (61). Heavy metal contamination of fruits and vegetables cannot be underestimated as these food stuffs are important components of human diet. It is therefore felt necessary to assess the levels of trace elements concentration in different varieties of fruits and vegetables (60, 174, 188, 275).

Atmospheric emissions are also a matter of great concern (92, 95). Leaded gasoline in vehicles is one of the major sources of Pb pollution in the cities worldwide (49). Luilo G B & Othman C C (147) reported that only 3% of Pb in the soil is translocated through roots to the shoots and fruits, rest are due to absorption through foliage. Sources like engine oils, corrosion of batteries, wear and tear of tyres, vehicular parts contribute for Cu, Pb etc. (20, 69). Moreover bitumen, mineral filler materials in asphalt road surfaces have also been reported to contain metals like Cu, Zn, Cd & Pb by Yan X et al. (269).

The heavy metals or trace elements play an important role in the metabolic pathways during the growth and development of plants when available in required concentrations. In addition to soil, plants function as a sink for atmospheric pollutants because of their capacity to act as efficient interceptions of air borne matter (107, 272).

The plants are widely used as passive bio-monitors in urban environments. There is no doubt that, leafy vegetables grown in the neighborhood of major highways can contain significant traces of Pb and Cd due to air borne metal particulates derived from vehicle emissions (10, 22, 91). The distribution of these metals (Pb and Cd) in the road side soils are strongly but inversely correlated with the distances away from the road side (111). The determination of metal content in vegetables is important from the point of view of crop yield technology, nutrition and health impacts.

Yargholi B et al. (271) investigated the trace metal content in different parts of vegetables. Nabula G et al. (165) also pointed out that leafy vegetables grown in road side areas were considered a potential source of toxic metals to consumers. Pb and Cd accumulation in several crops including horticultural crops as well as in soils and irrigation water in urban areas have been documented (94, 185) and compared with the concentration of Pb in the uncontaminated areas (182, 190).

Zamora P W et al. (276) assessed Pb concentrations in leafy vegetables in markets of Manila, Philippines. Washed and unwashed vegetables were compared for the heavy metal contents. They suggested that when compared with earlier studies (209, 211) results revealed proper washing of vegetables reduce concentrations of heavy metals suggesting that atmospheric deposition may be one of the important reasons for contamination (204, 274). Recently survey for heavy metals in vegetables conducted by Sharma R K et al. (213) presented data on heavy metal (Cu, Zn, Cd & Pb) concentrations in some key Indian vegetables such as palak (*Spinacia oleracea*) , lady finger (*Abelmoschus esculentus*) and cauliflower (*Brassica oleracea*) grown locally in suburban and rural areas and sold in urban open markets . It was hypothesized that atmospheric depositions in urban areas may increase the levels of heavy metals during transport and marketing, leading to significant contaminations of vegetables at the market sites than that at the production sites (23, 63, 237). Observed concentrations of Cu, Zn, Cd, Pb in the vegetables were also compared with Prevention of Food Adulteration (PFA) Act (21) and Joint FAO/WHO Food Standards Program (50), which are 30, 50, 1.5, 2.5 mg/g respectively, and as per European Commission (70), a standards of food contamination, it is 0.1 and 0.3 mg/g respectively for Cd and Pb. The contribution of heavy metal contamination through dietary intake of vegetables tested is also assessed on the basis of average daily consumption. Thus appropriate precaution can reduce the elevated levels of heavy metals in the vegetables (219, 240).

International & national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk of these metals which pose food chain contamination. However, intake of heavy metal contaminated vegetables may pose a threat to human health. Heavy metal contamination of the food items is the one of the most important aspects of food quality assurance (113, 114, 123, 126, 135, 143).

Islam Ejaz-ul et al. (103) revealed the factors affecting the thresholds of dietary toxicity of heavy metals in soil-crop system are soil pH, organic matter content, clay mineral, soil chemical and biological properties, crop species or cultivars. Similarly Tyler L D and Mc Bride M B (243) reported the effect of Ca ion, pH and organic acids on the uptake of Cd in Corn and Snap beans. It was found that increase in Ca ion concentrations of solution depressed the translocation of Cd by roots. Addition of humic acid to soils decreased the Cd activity and subsequent absorption of Cd by corn roots.

Lesser attention has been focused on the possible accumulation of heavy metals in small home gardens especially in rural areas and small towns. Various crops are cultivated using organic, inorganic fertilizers, agrochemicals, pesticides etc for enhancing the yield and quality, which may be the sources of heavy metals (125, 127, 128). Kabata-Pendias also suggested that agro-chemicals, phosphate fertilizers are important sources of heavy metals (117). Super phosphates and air-pollution can have acidifying effect on the soil hence facilitate the mobilization and uptake of heavy metals specially cadmium by plants (44, 173, 231, 235).

It is not completely possible to avoid exposure to toxic metals because people who are not occupationally exposed carry certain heavy metals in their body due to food, beverages or inhalation of air (23, 150, 151, 152, 153). It is however possible to reduce metal toxicity risk through life style choices that diminish the probability of harmful heavy metals uptake such as dietary measures that may promote safe metabolism or excretion of ingested heavy metals (65).

Food chain contamination by heavy metals has become a blazing issue in recent years because of their accumulation in the bio-system through contaminated water, soil and air. Fertilizers may be responsible for heavy metal addition in very small amounts however on the other hand sewage sludges may add them 100 times more in short duration (164, 199). Toxic metals in the atmosphere also get accumulated in soils through precipitation and fallout. Availability of heavy metals to plants is due to mining activities, industrial exhausts & effluents, atmospheric depositions, waste disposals, agro-chemicals (11, 19, 160, 161). However availability of heavy metals to plants depends on various physico-chemical properties of soil. Metal toxicity in plants is aggravated at higher temperature and low pH as it facilitates the mobility from roots to shoots. Therefore a better understanding of heavy metal sources, their accumulation in soil and their effect on the ecosystem is an important issue of the present day researches or risk assessment (57, 281).

The Phytotoxicity of heavy metals in plants can be seen, as plants develop some peculiar (229) symptoms or characteristics given as below-

Metals	**Symptoms/characteristics in plants**
Cadmium	Brown margin in leaves, chlorosis, necrosis, curled leaves, brown, stunted roots, reddish veins and perioles, reduction in growth, purple coloration.

Lead	Dark green leaves, stunted foliage, increased amounts of shoots.
Zinc	Chlorosis, stunted growth, reduction of root elongation.
Copper	Chlorosis, yellow coloration, purple coloration of the lower side of the midrib, less branched roots, inhibition of root growth.
Iron	Dark green foliage, stunted top and root growth, thickening of roots, brown spots on leaves, starting from the tip of lower leaves, dark brown and purple leaves some times in the same plant.

The accumulation of heavy metals by plants is based on uptake by root system and foliar adsorption due to deposition of particulate matter on the leaves (260). The relative toxicity of heavy metals beside depending on the physico-chemical properties of the soil depends on the genotype and the growth stage of plants or age of the plant (168, 183, 184). Similar results were obtained on studies carried out by Zarcinas B A et al. and Zehra S S et al. (278, 279). Their investigations also revealed that accumulation and translocation of heavy metals is dependent on plant species and type of crops cultivated on the contaminated soils.

The two main components of plants viz. the root system, which is in contact with the soil responsible for the absorption of water, minerals etc and the shoot system having leaves and stems responsible for adsorption of heavy metals (17). Diffusion due to concentration gradient or ion exchange are also responsible for the absorption of heavy metals along with water through the roots (141, 149). The movement of elements into roots occur either by passive diffusion through the cell membrane or by the more common process of active transfer against concentration or/and electrochemical potential gradients. The active uptake process is adapted by plants for absorption of essential trace metals (18).

The heavy metals which are a great threat to the environment and the biosphere as a whole are being derived from various anthropogenic sources. The heavy metals are biopersistent, once absorbed by an organism, may remain resident for years or over decades. In humans, most eventually excreted but on exposure causes various ailments. It may disturb the normal functions of central nervous system, liver, lungs, heart, kidney and brain; it produces hypertension, abdominal pain, skin eruption, intestinal ulcer & different types of cancer (93, 102, 253).

To protect public health, Government has developed guidelines as well as regulations that can be enforced by laws. Many agencies that have developed regulations for toxic substances include the United States Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and Food and Drug Administration (FDA). Federal organizations that develop guide lines or recommendations for toxic substances include the Agency for Toxic Substances and Disease Registry (ATSDR) (4, 5) National Institute for Occupational Safety and Health (NIOSH) and Bureau of Indian Standards (BIS).

Earlier studies by researchers have inferred that rapid urbanization, increased transportation, industrial revolution have posed a serious threat to the environment (115). Among other heavy metals, Pb and Cd have more hazardous effects on the environment and have widely polluted the urban agricultural lands (144, 187). Thus it has been recommended earlier as well as from recent studies that leafy vegetables should be grown at least 30m away from roads having high traffic. Studies revealed that plants accumulated small amount of Pb when the density of traffic was about 5000 vehicles per day, but there was a substantial increase in absorption of Pb when it reached to approx 35,000 vehicles per day (104, 108, 256).

Heavy metals like Fe, Cu, Zn, Ni and other trace elements are important for proper biological functions however their deficiency or excess may cause a number of disorders (131, 134). Prolonged consumption of food stuffs having higher concentration of heavy metals may result in various types of problems, disruption of numerous biochemical processes leading to cardiovascular, nervous, renal, kidney, liver and bone diseases (109). Under EPA regulations, public drinking water supplies are expected not to exceed 5 ppb of Cd in it. EPA also restricts the use of Cd in pesticides, so that they are not washed off into lakes, rivers, reservoirs, agricultural lands. The FDA limits the amount of Cd in food colors to 15 ppm. The OSHA limit for the amount of Cd in workplace air is 5 micro grams per cubic meter.

Cadmium toxicity has been extensively studied by various researchers. Kuboi T et al. (133) observed Cd uptake in 34 plants species of 9 plant families and found that Cd content was low in Leguminosae, moderate in Cucurbitaceae and high in Cruciferae and Solanaceae. Leafy vegetables are likely to accumulate Cd at higher levels in comparison to other crops. Lune P and Zwart K B (148) and Ni W Z et al. (171) reported that Cd accumulation in crops decreased linearly with increasing depth of soils, and for some crops the decrease was exponential. In reference, to the distance of the cultivated crops from the highways, Langer werff J V (138) reported that aerial contamination accounted for more that 40% of the Cd content of the radish grown at 200m from the highways. Cd remains readily available to the plants from both air and soil sources (268). The highest concentration of Cd in contaminated areas was reported for roots & leaves (201).

Concentrations of Cd, Hg, Pb, Cr, Fe, Co, Ni, Cu, Zn, Mo and As were determined by Agyarko K et al (8) in soils and leaves of plants from refuse dumpsites and background soils in two cities in Ghana, using a Thermo Finnigan Element 2 High Resolution Inductively Coupled Plasma Mass Spectrometric (HR-ICP-MS) instrument. The refuse dump soils were classified between 'uncontaminated to moderate' and strongly 'contaminated'. Pollution levels for Cd and Zn were higher than of the other metals. The refuse dump soil from the rural community was the least polluted with the metals. Fe and Ni loads in plants from the refuse dump soils in the cities and the municipality were beyond the normal range. Transfer ratios for Cd, Hg, Cu, Zn, Pb and Fe of plants from the back ground soils were higher than those from the refuse dump soils which might be due to the higher levels of organic matter, pH, phosphate, Ca and Mg in the refuse dump soils.

Different techniques were used by different researchers to determine heavy metal contents including modern analytical techniques such as AAS and ICP-AES, however there is no established quantitative method for determining directly the exact or fractional amount of metals that are bio-available to plants. Many factors such as variation in pH, temperature, nature of soil, redox condition, plant species, maturity or plant age play important role in the uptake of heavy metals.

EDTA is an effective extracting agent. Wang X H and coworkers (254) tried to find out the effectiveness of EDTA in extracting bio-available heavy metals in the soil samples relative to other indirect methods. Their investigation revealed that EDTA is an effective extracting agent because of its strong chelating ability for different heavy metals. Percentage extractabilities of metal followed the sequence of Cd > Zn > Cu > Pb. Main drawback is the non selective chelating nature of EDTA resulting into the removal of both toxic and non-toxic metals from the soil. Metals are an intrinsic component of the environment. Rapid urbanization and industrialization all over the world is causing the toxification and metallic pollution of environment. The situation being worse in the developing countries like India as they do not abide the rules of pollution control board. The toxification due to metals can pose threat to the life of human beings, thus is a matter of great concern.

The district Kota lies between $24^0$25’ and $25^0$51’ North latitudes and $75^0$31’ and $77^0$26’ East longitudes with the total area of 5217 sq. km. “Kota City” is located at extreme south of it at $25^0$11’ North latitude and $75^0$51’ East longitude occupying total area of 238.59 sq. km. with average height of 253.30 meters from mean sea level. The only perennial river “Chambal” originating from the hills of Western Madhya Pradesh passes through the district. According to 2011 census, total population of district is 1,950,491, out of which males are 1,023,153 and females 927,338. Kota is a well known industrial city of Rajasthan having large industrial units like KSTPS, Dcm-Shriram Consolidated Limited, Instrumentations Limited, Chambal Fertilizers and Chemicals Limited along with hundreds of small scale industries in and around the city. In last few decades Kota city has emerged as an ‘educational city’ of India because of its excellence in coaching for entrance examinations at national and state level technological institutes for engineering and medical courses. Round about 1.0-1.5 lakh population moves in due to these coaching centres. Most of the time the population remains concentrated in the area of new Kota city. In the desire to make quick profits out of anything available without any regard for the community as a whole residential colonies of this area have become and still becoming commercialized. The old city being comparatively congested is favoured by economically weaker sections of the society and most of the people of these sections are unresponsive to the environmental quality. Due to the migrating weaker sections of the people "Kachchi basties" have developed which are also responsible for the negative impact on the environment. Kota is also famous for its Kota Sarees and Kota Stone, but if the effluents are not properly treated and disposed it might become a hazard to the environment.

The climate of Kota division is characteristic of South Eastern Rajasthan with a long and intense hot summer, medium rainfall and a short mild winter. The temperature normally varies from 48^0C in June to 4.6^0C in January. The hot weather usually extends from the beginning of March to the end of June. During the month of May and June the weather is sultry, as the rocks get heated during the day, giving rise to hot winds which continue till late in night. The area is agriculturally rich, and use of fertilizers, insecticides and pesticides is common. The soils of Kota are complex, highly variable, reflecting a variety of parent materials, physiographic land features range of distribution of rainfall and its effects. As such different soils create different types of habitat for plant growth, therefore, the true choice and a forestation patterns on such kind of soils vary greatly. Soils are thus variable in their soils-water-plant relationship, conservation needs, and production potentials. As Kota is an industrial as well as educational city with agriculturally rich area there is a high probability of increasing pollution load due to various anthropogenic sources leading to further addition of heavy metals to the surface soils. The areas around Kota are well known for cultivating vegetables on large scale. Thus the area around the city is chosen as the study area keeping in view the greater risk of heavy metal uptake by the vegetables. Since vegetables whether raw or cooked are the staple part of our daily diet, the present topic has been chosen for the study.

CHAPTER – 2

METHODS AND METHODOLOGY

Selection of three vegetables and criteria for their selection

Three vegetables namely *Solanum tuberosum L.*, *Capsicum annuum L.* and *Lycopersicum esculentum L.* are selected on the basis of their wide spread use in various forms and significant food value. They are a part of staple diet in everyday routine of people not only in India but all over the world.

I ***Solanum tuberosum L. -*** *Over* past few decades *Solanum tuberosum L* commonly known as Potato have become the fastest growing staple crop in India. Potatoes in Rajasthan are cultivated as autumn crop planted around mid October and harvested in February or March. The optimum temperature required is from 15-20^{0}C, the night temperature should not increase more than 20^{0}C which is favorable for large sized tuber formation. Soil for cultivation should be loose, loamy and sandy for easier penetration of roots and tuber formation. A well drained, aerated and soil rich in organic matter favors proper tuber formation. Soil with 5.2-6.4 pH is ideal for potato cultivation.

Potatoes are an important source of energy because of the carbohydrates. It is a low calorie, high fiber food offering significant protection against, colon cancer, digestive disorders, and cardiovascular diseases (53, 98). It is a good source of vitamin K and C and also rich in Cu, Mn, P, Niacin and Pantothenic acid. It contains variety of phyto-nutrients having antioxidant activities (76, 142). Many important health promoting compounds carotenoids, flavonoids, caffeic acid and unique tuber storage proteins such as Patatin exhibits activity against free radicals (193).

II ***Capsicum annuum L. -*** Commonly known as chillies regarded as a wonder spice; it is a plant of tropical and subtropical region and grows well in warm and humid climate at a temperature of 25^{0}C–30^{0}C. Chilies can grow in all types of soils, though best in sandy loam and clayey loam. The soil must be well drained and aerated with a pH range of 6.5–7.0. Both green and red chilies are widely used as seasonings and spices. It is rich in vitamin A, C, B complex, Calcium, Magnesium, Iron and Potassium. It is a valuable herb all over the world and is good for the entire digestive and other organ systems. Use of chilies increases the effectiveness of other herbs when consumed together.

Capsaicin present in the chillies have many properties like carminative, stimulant, antispasmodic, analgesic, haemostatic, antiseptic and alternative astringent. Capsaicin is a safe and effective analgesic agent in the management of arthritis pain, herpes zoster related pain and headaches (146, 156, 255). Studies have revealed that Capsaicin has indispensable anti-cancerous activity and can prohibit proliferation in some cancerous cells (89, 236).

III *Lycopersicum esculentum L.* - Commonly known as tomato an important vegetable crop of India, is a warm season plant requiring an optimum temperature 20-24^{0}C, grows on fertile moisture retentive soil with a pH range of 5.5-7.0. Organic matter and NPK favors the growth. Mulching helps to prevent weeds, reduces leaf diseases, helps in distribution of water and generally makes the tomato plant stronger. After flowering the fruits reach maturity in 50-60 days. Tomatoes technically are fruits rather than vegetables, and are consumed raw as well as cooked.

Tomato is low in calories, excellent source of vitamin A, C, K, low in Na, saturated fats cholesterol. Uncooked tomatoes provide vitamin E. Besides tomato fruits, leaves and stems are used to make medicines (154). Tomatoes contain an important chemical Lycopene which plays important role in preventing various types of cancer (166, 139).

It is easier for the human body to use Lycopene that comes from tomato products like tomato paste, tomato juices rather than from fresh tomatoes. U.S. Department of Agriculture (USDA) and Purdue University researchers are developing tomatoes that will contain more than twice as much as Lycopene and have longer shelf life.

Lycopene acts as a powerful anti-oxidant; it has been extracted and injected into all sorts of food today as well as ground up and shaped up into multivitamin pills. It is widely used as an antiseptic agent because of its Nicotinic acids. It not only fights off viruses and infections but regulates cholesterol levels. It stimulates the blood flow. It is also helpful in preventing diabetes, heart diseases, cataracts, asthma, high blood pressure, osteoarthritis, common colds, digestive disorders etc (79).

Doctors now recommend adding plenty of tomatoes in diet as blood purifier or thinner. It helps in getting rid of kidney and gall bladder stones. Since ancient times, Roman and Greeks used tomatoes to promote healthy and shiny skins. They contain anti ageing agents more than other fruits and vegetables, the combination of Lycopene and beta carotene makes it a healthy way to fight wrinkles and sun damage. Tomatoes when ingested are good for teeth, gums, healthy bones. Vitamin K in it prevents severe hemorrhages (217).

Lycopersicum esculentum L. belonging to family *Solanaceae* is a favorite home vegetable widely cultivated throughout the world with a large number of varieties. The plants are erect, branched aromatic covered with glandular hairs. It bears yellow flower. The fruit is classified botanically as a berry. It is propagated through seeds; the plant reaches a height of 2-3 feet.

Selection of Sampling Sites

The site selection for sampling is done in such a way so that it gives coverage to the areas where the probability of contamination is high around Kota city of Rajasthan state, keeping in view the objective of the study. The selected vegetables, *Lycopersicum escuentum L.* (Tomato), *Capsicum annuum L.* (Chillies*)*, and *Solanum tuberosum L.* (Potato), are grown widely in these areas and the local markets are fed by these for the consumption of the residing population. The following factors were considered for selection of the sample sites-

- (i) Sites where probabilities of contamination is considered higher due to different types of industries.
- (ii) Areas near the highways, to consider the loads of traffic, emission of gases and exhausts.
- (iii) Sites near the densely populated areas.
- (iv) Sites where probability of contamination is higher due to mode and source of irrigation.
- (v) Locations where contamination may be higher due to sewage treatment plants.
- (vi) Locations near dumpsites, landfills of Municipal Corporation.
- (vii) Locations of agricultural activities.
- (viii) Locations where loads of anthropogenic activities are considered high.

Standard Methods Used For Sampling

To assess and compare the uptake of heavy metals by three selected vegetables, the study was carried out with the plant parts of Tomato i.e. Leaves, Stems and Fruits of Tomato, Peeled & Unpeeled Potatoes, Red chillies & Green chillies. The two approaches undertaken for collection of samples for the study were-

- (i) Collection of samples of vegetables growing in natural conditions and the corresponding soils from different cultivation sites around Kota city.

(ii) Collection of samples of vegetables grown under controlled conditions in artificially contaminated culture media at various levels and the corresponding soils/compost.

(a) Sampling Spots - Total 10 locations around Kota city were selected for random sampling of vegetables & their corresponding soils. At one location 15-20 samples of each vegetable and similarly the soil samples were collected and combined to make a composite sample of the vegetable and the soil per site.

(b) Sampling containers - Zipped polyethylene pouches of 1 kg capacity of good quality were used.

(c) Amount of Samples - For determining heavy metals in soil & vegetable samples 500 gm of soil and 100 gm of the three chosen vegetable samples (dried, crushed powder) were collected. For determining the physicochemical parameters 500 gm of soil samples were kept in separate pouches.

(d) Labeling of samples - Every sample was coded properly, the sample bags were marked with the codes using permanent marker. All the information's regarding the sampling locations, source, date of collection and the allotted codes were recorded in the observation register to avoid any error or confusion.

(e) Collection of soil samples - In case of random sampling composite samples were made by collecting small portions of soils up to the desired depth (30 cm) using proper tools from 15-20 well distributed spots at a site moving zigzag. Initial scrapping of the surface litter was followed by soil collection. The collection of the soils from the representative areas were thoroughly mixed on a clear good quality polythene sheet. Any soil clod present was crushed and then it was ground with the help of wooden pestle & mortar. Then the bulk was reduced to about 500 gm by quartering process in which the entire soil mass is spread, mixed properly, divided into four quarters, two opposite ones were discarded and the remaining two were remixed and the task is repeated until 500 gm soil is left. These samples were further air dried. Soil samples were then sieved through 2 mm stainless steel sieve. The sieved soil was again thoroughly mixed and stored in polyethylene zipped bags.

In case of pot experiments soil samples were collected from pots. Five sets of pots & three pots in each set for each plant were packed with soil modified into compost and gradually contaminated at different levels of heavy metals artificially by adding the different metal salt solutions. The salt solutions were added at intervals. The samples were collected at the time of harvesting.

(f) Collection of Plant samples - For a meaningful plant analysis utmost care was exercised in plant sampling. The samples of vegetables were collected at maturity i.e. ripening of tomatoes, green & red chilies, and properly formed potato tubers. In case of *Lycopersicum esculentum L.* (Tomato) the whole plant was uprooted. The leaves, stems and fruits were separated and collected for samples. In case of *Capsicum annuum L.* (Chillies), green chilies and red chilies were collected separately i.e. at different stages of maturity where as in case of *Solanum tuberosum L.* (Potato) the tubers were collected at maturity. The potato tubers were collected by empting the pot when the soil was moist using proper tools carefully so that the tuber does not receive any cut to avoid contamination due to soil. All the samples were washed several times, later soaked in double distilled water for 2-3 hrs. then dried using good quality tissue paper. Each vegetable sample was cut into slices using stainless steel knife and spread on polyethylene sheets to sun-dry taking care of any dust deposition. Later the samples were dried in the oven at 60^0C for 48 hrs. This was repeated until complete drying. The samples were ground using electric mixer and grinder having stainless steel jar and the samples were sieved, using 0.5 mm sieve. The samples were again dried until constant weight. Later the samples were stored in zipped polyethylene bags which were properly marked until analyzed.

(g) Preservation of samples - The samples were kept at room temperature in a dust free atmosphere in cupboards to avoid any type of contamination.

(h) Time interval in between sample collection and analysis - To collect actual quality data it was ensured that the concentrations of heavy metals and the physicochemical parameters should not be altered between sampling & analysis.

The study sites chosen for random sampling fall under different areas ranging from industrial to commercial, as well as populated areas representing various probable sources of heavy metal contamination. The details (Table-1 & fig-1, 2) are as follows;

Sub-Urban Areas of Kota

Site 1 – Sinta

Site 2 – Ranpur

Site 3 – Talera

Site 4 – Tather

Site 5 – Badgaon

Site 6 – Nanta

Site 7 – Balita

Site 8 – Dhaker Kheri

Site 9 – Kaithoon

Site 10 – Rangpur

Sinta - This village is located at approximately 8 km from Kota city. Wide varieties of vegetables are grown in this region, along the bank of river Chambal. Domestic sewage, effluents in the canals might have affected surface quality of soil and the water used for irrigation.

Ranpur - It is situated close to the city. Kuber industrial area located here has various food processing units. Indiscriminate disposal of solid wastes and effluents on open unused land was observed in this industrial area. Improper disposal of sewage was also seen. Quality of soil may get altered due to domestic sewage, industrial effluents and various agricultural activities.

Talera- Located on NH-12 approximately 15 km from the city. Edible oil processing units, brick kilns, rice processing units etc are located in this area. Domestic sewage, effluents, coal ash, garbage affect the soil quality. Agriculture and horticulture is the main source of income for people living in this area.

Tather - It is located at NH-76 some mega edible oil processing units are located in this area. Due to the lack of effluent treatment plants, generally the effluents are disposed off on open land making the condition of soil worse. Quality of surface soil may alter due to domestic sewage, industrial effluents & agricultural activities.

Badgaon - Located on NH-12 approximately 10 km from the Kota city, has number of edible oil processing units, petrol pumps, garages, stone polishing units, effluents of the industries. Slurry from stone polishing units and oil and grease from petrol pumps and many garages affect the soil quality. People here mainly practice agriculture thus quality of soil is of a great concern.

Nanta - Non urban area getting converted into urban area located in the proximity of Kota at an approximate distance of 5 km from city. Karnimata Mandir, Abheda mahal are the famous picnic spots located here. The fly ash disposal from Kota Super Thermal Power Station is done here. The landfills of Kota Municipal Corporation are located here. Economy of the people here depends on animal husbandry and agriculture. Domestic sewage, fly ash, garbage affect the surface soil quality which is a matter of great concern.

Balita - Non urban area converting into urban area located on the bank of river Chambal. It is closely located to the city. Cultivation of vegetables is a common practice in this area. One STP in the ownership of Municipal Corporation is operating in this area where domestic sewage of Kota city is treated. Indiscriminate disposal of sewage sludge and treated water has made the conditions worse. The soil quality might have been influenced by domestic sewage, sludge, fertilizers, pesticides, STP treated water etc.

Dhaker Kheri - Village having a network of canal for irrigation, vegetable growing is the main agricultural practice. During the lean period underground water is used for irrigation. One STP in the ownership of Municipal Corporation is operating in this area where domestic sewage from Kota city is treated. Surface soil quality may be affected due to sewage sludge and treated water. Besides this fertilizers & pesticides may also be responsible for affecting soil quality.

Kaithoon - Town situated 20 km from Kota city famous for manufacturing of Kota Doriah sarees. The textile & printing effluents (dyes), domestic sewage and agricultural activities may have affected the soil surface.

Rangpur - It is located at an approximate distance of 13 km on the bank of Chambal river with the population totally dependent of agriculture. Domestic sewage, agricultural activities, industrial effluents and water quality used for irrigation affect the surface soil quality in the area. Since the soil is mainly used for agricultural purpose it becomes essential to assess the uptake of heavy metals from soil to different plant species with respect to their most usable part.

Standard Methods Adopted For Processing-

To determine heavy metal concentrations, a wet digestion method of the dried samples was adopted. 1 gm of each air-dried and sieved sample was ashen in a muffle furnace at 460^0C for 4 hrs. The ash was digested in 10 ml aqua-regia (1 part conc. HNO3 + 3 parts conc. HCl) at different temperatures for a total of nine hrs spreading over 2 hrs at 25^0C, 2 hrs at 60^0C, 2 hrs at 105^0C and 3 hrs at 125^0C. After digestion, the residue was cooled filtered and transferred to a 100 ml volumetric flask. The solution was made up to the mark using double distilled water. A blank digestion solution was made for comparison. A standard solution for each element under investigation was prepared for calibration. To determine physicochemical parameters required solutions were also prepared using double distilled water.

Standard Methods Adopted For Analysis-

The plants and their corresponding soil samples, collected from various locations were analyzed for heavy metal concentrations using standard methods to determine the degree of pollution (99, 119, 258). Soils were analyzed for various physicochemical parameters also. Heavy metals can be determined by various methods i.e. gravimetric, titrimetric, colorimetric, ion exchange chromatographic, polarographic, induced coupled plasma, flame photometric method and atomic absorption spectrophotometrically etc. Atomic absorption spectrophotometric method is widely used for the determination of heavy metals present either in high or low concentrations in soil or plant samples because the technique is relatively simple, versatile, accurate and free from major interferences. Sixty eight elements can be determined directly form AAS over a wide range of concentrations mg/L (ppm) to µg/L (ppb) levels with precision. The instrument is first calibrated with the standard solutions of metal, to be analyzed, using corresponding hollow cathode lamp of that metal. Metal measurements were performed with AAS, double beam and deuterium background correction. Hollow cathode lamps of Pb, Cd Zn, Fe & Cu were used at specific wavelengths. All samples were run in triplicates.

Physicochemical Parameters and Methods Adopted for their determination-

Organic matter, density, porosity & water holding capacity were determined by adopting standard techniques of soil analysis (1, 30, 41) and pH potentiometrically using glass calomel electrode (pH meter digital (Systronics India Ltd type-361). Conductivity was measured using conductivity bridge (Toshniwal). Chemical analysis for nitrate phosphate, sulphate, potassium, calcium and magnesium has been carried out following standard chemical analysis methods titrimetrically/ spectrophotometrically [UV spectrophotometer (Systronics India Ltd type-118)]. Atomic Absorption spectrophotometer (Schimadzu, AA-6300)/ Flame Photometer (systronics-128) (251). Only AR grade chemicals were used for chemical analysis.

Methodology-

Three vegetables belonging to family *Solanaceae*, *Lycopersicum esculentum L.* (Tomato), *Solanum tuberosum L.* (Potato), *and Capsicum annum L.* (Chilly) have been selected on the basis of their wide use in raw and cooked form not only in

India but all over the world (Tomatoes and chilies are widely used in raw forms in juices, soups, salads, and chutneys). To find out the uptake of heavy metals by these plants (leaves, stems and fruits of tomato, green and red chillies, peeled and unpeeled potato tubers were collected). Two different approaches were undertaken for study.

(i) By collecting and analyzing samples of vegetables grown under natural conditions and their corresponding soils from different probable contaminated cultivation sites randomly chosen around Kota city.

(ii) By collecting and analyzing samples of plants grown under controlled conditions in artificially contaminated culture media at various levels & corresponding soils/ composts.

According to above two approaches sampling of the following plants parts were done-

(1) Tomato - Leaves Stems and Fruits

(2) Chillies - Green chillies & Red chillies

(3) Potato - Peeled potato & unpeeled potato

Random sampling was done selecting probably anthropogenically contaminated 10 sites around Kota city. Sampling of tomato and green chillies was done in 4^{th} week of Dec. The red chillies and potato were collected in 1^{st} week of March during the three consecutive years 2012-2014. For pot experiments soils were first modified into compost, a suitable culture media for selected vegetables, later the pots were packed uniformly. Compost was prepared taking 4 parts loam, 4 parts sand, 4 parts cattle manure, 2 part leaf mould, ¼ part brick dust & ¼ part charcoal. All these ingredients were spread layer by layer in moist condition under the shade of big tree turning it fortnightly for 2 months. Afterwards all the ingredients were mixed properly, sieved through 8 mm mesh and the pots were packed. Free drainage was avoided using plastic trays kept beneath them. Each pot was filled with similar amount of compost. After compost preparation

Lycopersicum esculentum L. (Tomato) and *Capsicum annuum L.* (Chillies) plants of 5-6 inches height grown on separate nursery bed were planted. *Solanum tuberosum L.* (Potato tubers) were kept in open trays for 15 days till the eyes sprouted and reached 5-6 inches of height. These were then planted in the pots which were filled ¾ of height. Once the shoots grew to a height of 1 ½ feet, more compost was added to the pots. Five sets of pots, each with three replicas were designed for cultivation. Each pot was watered daily to keep the soil moist using measured quantity of water. The quantity of water varied according to the requirement of the plant and weather conditions. After 10 days different solutions of four different concentrations of 5 metals i.e. Pb, Cd, Zn, Fe & Cu were prepared separately and were added at regular intervals to 4 sets of potted plants out of five sets leaving one set of potted plants working as blank. During the cultivation period the temperature varied from 08^0C-32^0C.

Samples of tomato (leaves, stems and ripe fruits) and green chillies were done in 4^{th} week of December. Red chillies and potato were collected in 1^{st} week of March along with the soil from the same pot adopting standard methods described in the literature. Samples of plants and soils were marked accordingly.

Set 1- No addition of metals (blank)

Set 2- 05 mg/kg Pd, Cd, Zn, Fe & Cu respectively

Set 3- 10 mg/kg Pd, Cd, Zn, Fe & Cu respectively

Set 4- 15 mg/kg Pd, Cd, Zn, Fe & Cu respectively

Set 5- 20 mg/kg Pd, Cd, Zn, Fe & Cu respectively

Plant part samples and soil samples collected from random sampling and pot experiments were processed and analyzed. The whole procedure was done systematically following standard procedural methods taken from literature. Correlations between different metal contents of plant parts with different metal contents of corresponding soils were obtained using Karl Pearson's methods.

The results obtained are recorded in the tabular form, compared with the standard limits and discussed keeping in view the pollution level of the area. Percent uptake is calculated to indicate the risk factor. Physico-chemical parameters were determined to study the role or contribution of soil properties in the uptake of heavy metals by the plants. The study was carried out for three consecutive years 2012, 2013 & 2014 to minimize the chances of probability or error at any level.

Table-1

IDENTIFICATION CODES OF SITES CHOSEN FOR RANDOM SAMPLING

S.NO	Site Location	Identification Code on Map/ Site from where Samples were taken
1	Sinta	1
2	Ranpur	2
3	Talera	3
4	Tather	4
5	Badgaon	5
6	Nanta	6
7	Balita	7
8	Dhaker Kheri	8
9	Kaithoon	9
10	Rangpur	10

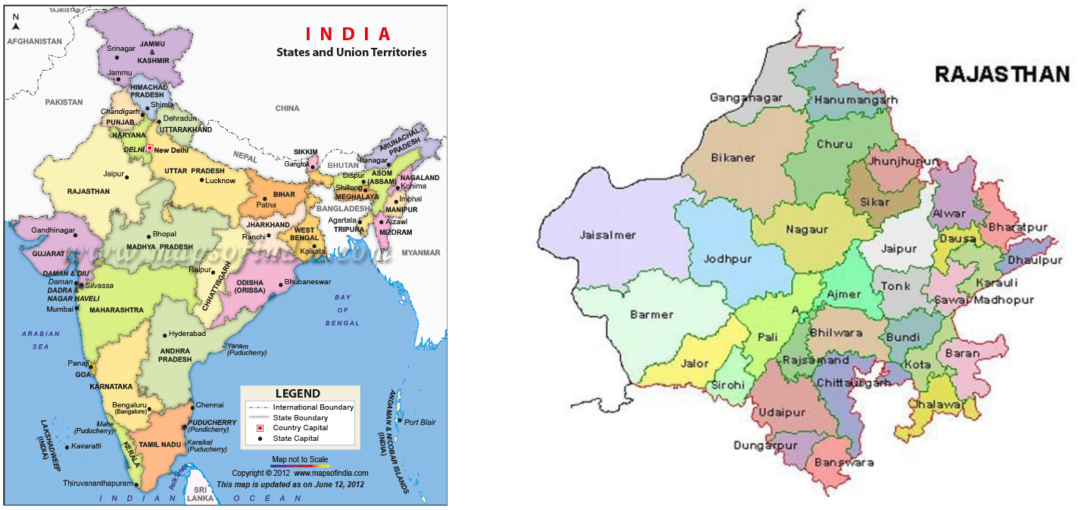

Figure-1

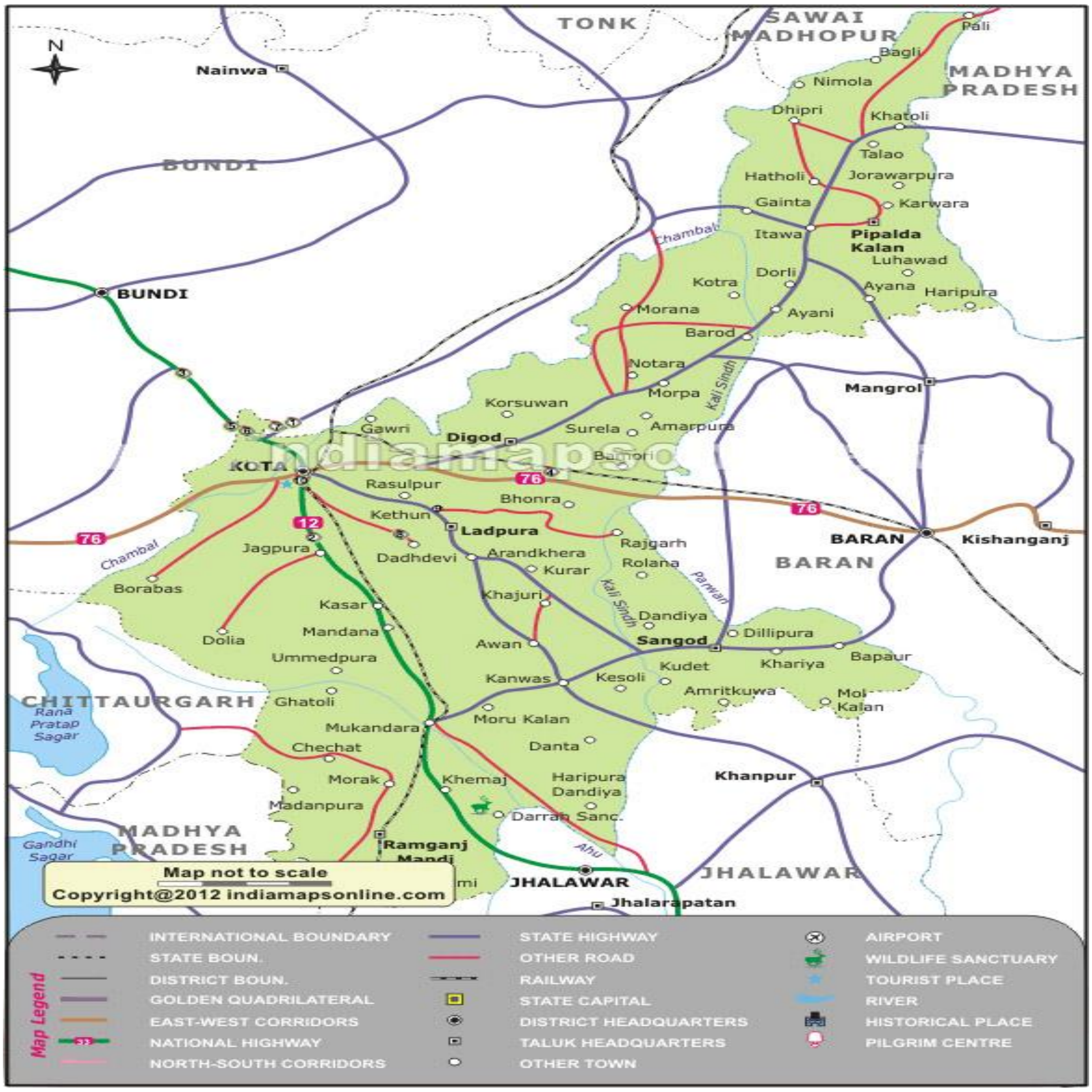

Figure-2
Map Showing Sampling Locations

CHAPTER - 3

OBSERVATIONS AND RESULTS

All the results obtained from analysis of plant part samples and corresponding soil samples collected during three consecutive years of study viz. 2012, 2013 and 2014 are recorded in tabular form. Results regarding three different chosen plants i.e. *Solanum tuberosum L.* (potato), *Capsicum annuum L.* (chillies), *Lycopersicum esculentum L.* (tomato) are summarized in tables RP1 to RP21 and PP1 to PP19, tables RC1 to RC21 and PC1 to PC19 and tables RT1, to RT21 and PT1 to PT19 respectively.

Tables RP1 to RP21, RC1 to RC21 and RT1 to RT21 are for randomly sampled potatoes, chillies and tomatoes respectively while tables PP1 to PP19, PC1 to PC19 and PT1, to PT19 are for the samples of potatoes, chillies and tomatoes grown, for pot experiments respectively.

Results of analysis of peeled and unpeeled potatoes collected from ten different sites randomly for different heavy metal concentrations are given in tables RP1, RP7, RP13 and for samples collected from pots are given in PP1, PP7 and PP13 year wise from 2012 to 2014. Results of analysis of corresponding soils for heavy metal determination are tabulated in tables RP2, RP8, RP14 and PP2, PP8, and PP14 for samples of random and pot experiments year wise from 2012 to 2014.The values are compared with standard limits (72).

Results of analysis of green and red chilies collected from ten different sites randomly for different heavy metal concentrations are given in tables RC1, RC7 and RC13 and for samples collected from pots are given in tables PC1, PC7 and PC13 year wise from 2012 to 2014. Results of analysis of the corresponding soils for heavy metal determination are tabulated in tables RC2, RC8 and RC14, PC2, PC8 and PC14 for samples of random and pot experiments year wise from 2012 to 2014. The values are compared with the standard limits (72).

Results of analysis of tomato leaves, stems and fruits collected from ten different sites randomly for different heavy metal concentrations are given in tables RT1, RT7 and RT13 and for samples collected from pots are given in tables PT1, PT7 and PT13 year wise from 2012 to 2014 results of analysis of corresponding soils for heavy metal determination are tabulated in tables RT2, RT8 and RT14, PT2, PT8 and PT14 for samples of random and pot experiments year wise from 2012 to 2014. The values are compared with the standard limits (72).

Correlations between different metal concentrations obtained for different plant part samples i.e. potato-peeled and unpeeled tubers, chillies-green and red chillies, tomato-leaves, stems and fruits and between different plant parts samples and soil samples are recorded in tables as follows

Potato – RP3a, RP3b, RP4, RP5a, RP5b. (Random)

PP3a, PP3b, PP4, PP5a, PP5b. (Pot)

Chillies – RC3a, RC3b, RC4, RC5a, RC5b. (Random)

PC3a, PC3b, PC4, PC5a, PC5b. (Pot)

Tomato – RT3a, RT3b RT3c, RT4, RT5a, RT5b, RT5c. (Random)

PT3a, PT3b, PT3c, PT4, PT5a, PT5b PT5c. (Pot)

Tables RP6, RP12, RP18, PP6, PP12,, PP18, RC6, RC12, RC18, PC6, PC12, PC18, RT6, RT12, RT18, PT6, PT12 and PT18 are the tabulated results obtained for the percent uptake of different heavy metals by the plant samples of *Solanum tuberosum L.* (potato), *Capsicum annuum L.* (chillies) and *Lycopersicum esculentum L.* (tomato) respectively in three studied years.

Physicochemical parameters analyzed for different corresponding soils in three different years are tabulated in tables RP19 to RP21, PP19, RC19 to RC21, PC19, RT19 to RT21 and PT19.

Observations regarding percent survival, plant growth, quality and yield are recorded for the three chosen plants during three consecutive years of study and have been summarized in table PCT.

Concentrations of all heavy metals are expressed in mg/kg. Correlations between various heavy metals in the plant samples, between metals in the soil samples and among the metals in plant and soil samples are obtained by calculating correlation coefficients using Pearson’s formula.

The percent uptake of heavy metals by plants from soil is calculated simply multiplying the ratio of metal concentration in plants to metal concentration in soil with hundred.

Data of organic matter, water holding capacity, porosity, nitrate, phosphate, sulphate, potassium, calcium, magnesium are given in percentage, density in gm/cm,^{3} pH is given according to Sorenson's scale and conductivity is expressed in is μ mho/cm.

Significant variations in levels of different metals and positive correlations with metal contents of corresponding soils are observed on analysis of the samples of the three chosen plants along with their corresponding soils from ten different sites around the Kota city, Rajasthan representing various sources of pollution.

The tendencies of chosen plants for uptake of different metals up to certain levels are further confirmed by pot experiments.

Table-RP1

Results of analysis of unpeeled and peeled potato tubers collected from different sites for different heavy metal concentrations (mg/kg) in year 2012

Metal	Plant parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	UPP	1.49	1.58	1.29	5.63	9.99	4.18	7.20	5.52	7.90	6.20	5.10	0.30
	PP	1.37	1.33	1.26	5.01	7.17	4.83	8.02	5.36	8.87	8.76	5.20	
Cd	UPP	0.32	0.89	0.51	1.13	1.91	1.31	1.00	1.00	2.12	1.56	1.18	0.20
	PP	0.47	0.86	0.43	1.07	1.85	0.73	1.79	1.73	2.03	1.43	1.24	
Zn	UPP	2.01	2.13	1.00	1.98	2.68	5.38	1.69	3.80	1.23	1.00	2.29	100.00
	PP	1.17	2.77	0.12	1.27	1.69	4.97	2.43	2.93	1.20	0.99	1.95	
Fe	UPP	13.54	25.68	14.52	16.75	35.61	23.42	16.94	15.91	14.00	6.20	18.26	200.00
	PP	10.54	20.18	13.45	16.38	34.18	20.67	15.69	13.23	14.29	5.12	16.37	
Cu	UPP	2.63	8.99	2.97	5.38	12.67	8.01	11.48	9.37	13.08	7.93	8.25	40.00
	PP	2.48	8.20	2.81	5.33	12.65	8.08	11.39	9.04	13.72	7.97	8.17	

UPP-Unpeeled potato
PP-Peeled potato

Table-RP2

Results of analysis of soils of different sites from where samples of unpeeled and peeled potato tubers are collected for different heavy metal concentrations (mg/kg) in year 2012

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	9.62	5.83	4.76	8.81	10.37	12.81	7.24	11.89	13.49	11.44	9.63	10-70
Cd	0.86	1.54	1.65	2.21	2.46	2.03	1.99	1.86	3.68	2.34	2.06	0.07-1.10
Zn	4.05	6.13	3.48	3.48	3.69	7.76	5.16	6.48	9.88	7.14	5.73	10-300
Fe	23.61	35.00	21.47	20.32	36.61	32.84	32.69	34.09	36.02	21.23	29.39	3000-5000
Cu	3.68	14.14	3.65	7.26	12.98	12.82	13.10	11.15	13.93	9.49	10.22	6-60

Table-RP3a

Correlation between average value of different heavy metal concentrations obtained on analysis of unpeeled potato tubers collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.84	1.00			
Zn	0.01	0.03	1.00		
Fe	0.26	0.24	0.45	1.00	
Cu	0.80	0.80	0.11	0.40	1.00

Table-RP3b

Correlation between average value of different heavy metal concentrations obtained on analysis of peeled potato tubers collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.86	1.00			
Zn	0.02	0.02	1.00		
Fe	0.01	0.20	0.32	1.00	
Cu	0.78	0.90	0.28	0.43	1.00

Table-RP4

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.54	1.00			
Zn	0.66	0.60	1.00		
Fe	0.30	0.36	0.46	1.00	
Cu	0.35	0.54	0.60	0.85	1.00

Table-RP5a

Correlation between average value of different heavy metal concentrations obtained from analysis of unpeeled potato tubers collected from all sites and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in UPP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.52				
Cd		0.91			
Zn			0.18		
Fe				0.62	
Cu					0.91

UPP-Unpeeled potato

Table-RP5b

Correlation between average value of different heavy metal concentrations obtained from analysis of peeled potato tubers collected from all sites and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in PP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.60				
Cd		0.73			
Zn			0.37		
Fe				0.60	
Cu					0.89

PP-Peeled potato

Table-RP6

Percent uptake of different heavy metals in unpeeled and peeled potato tubers at different sites in year 2012

Metal	Plant Parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	UPP	15.49	27.10	27.10	63.90	96.34	32.63	99.45	46.43	58.56	54.20
	PP	14.24	22.81	26.47	56.87	69.14	37.70	110.77	45.08	65.75	76.57
Cd	UPP	37.21	57.79	30.91	51.13	77.64	64.53	50.25	53.76	57.61	66.67
	PP	54.65	55.84	26.06	48.42	75.20	35.96	89.95	93.01	55.16	61.11
Zn	UPP	49.63	34.75	28.74	56.90	72.63	69.33	32.75	58.64	12.45	14.01
	PP	28.89	45.19	3.45	36.49	45.80	64.05	47.09	45.22	12.15	13.87
Fe	UPP	57.35	73.37	67.63	82.43	97.27	71.32	51.82	46.67	38.87	29.20
	PP	44.64	57.66	62.65	80.61	93.36	62.94	48.00	38.81	39.67	24.12
Cu	UPP	71.47	63.58	81.37	74.10	97.61	62.48	87.63	84.04	93.90	83.56
	PP	67.39	57.99	76.99	73.42	97.46	63.03	86.95	81.08	98.49	83.98

UPP-Unpeeled potato
PP-Peeled potato

Table-RP7

Results of analysis of unpeeled and peeled potato tubers collected from different sites for different heavy metal concentrations (mg/kg) in year 2013

Metal	Plant parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	UPP	1.01	1.53	1.61	5.28	8.13	4.48	8.93	5.42	8.00	9.37	5.38	0.30
	PP	0.34	1.47	1.13	5.28	8.07	4.32	8.26	5.40	7.95	8.70	5.09	
Cd	UPP	0.54	0.79	1.00	1.05	1.94	0.68	1.09	1.93	2.24	1.91	1.32	0.20
	PP	0.42	0.76	0.47	1.00	1.81	1.59	1.11	1.62	2.24	1.38	1.24	
Zn	UPP	2.48	2.32	2.61	1.00	2.94	4.37	2.68	3.39	5.66	5.48	3.29	100.00
	PP	2.22	2.14	2.63	0.91	1.73	4.23	2.14	2.99	5.01	4.81	2.88	
Fe	UPP	15.14	23.99	14.23	15.00	34.91	22.00	31.81	34.71	35.00	19.63	24.64	200.00
	PP	14.01	23.28	14.17	16.88	34.14	21.21	31.85	34.07	35.23	18.78	24.36	
Cu	UPP	2.50	8.01	2.18	4.99	12.09	7.89	11.36	9.23	13.94	8.99	8.12	40.00
	PP	2.49	8.23	2.95	4.92	12.68	7.71	11.72	8.66	13.87	8.37	8.16	

UPP-Unpeeled potato
PP-Peeled potato

Table-RP8

Results of analysis of soils of different sites from where samples of unpeeled and peeled potato tubers are collected for different heavy metal concentrations (mg/kg) in year 2013

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	8.81	6.73	6.34	8.12	9.98	12.33	7.69	11.48	13.64	13.13	9.83	10-70
Cd	1.08	1.30	1.02	2.11	2.43	2.05	1.39	1.99	3.52	3.26	2.02	0.07-1.10
Zn	4.63	3.96	3.47	3.65	3.89	7.63	5.49	6.52	10.01	9.83	5.91	10-300
Fe	21.67	32.13	20.49	20.65	34.92	31.22	33.03	35.13	35.63	23.41	28.83	3000-5000
Cu	4.83	14.04	5.01	5.93	12.96	12.93	13.62	11.65	13.99	11.83	10.68	6-60

Table-RP9a

Correlation between average value of different heavy metal concentrations obtained on analysis of unpeeled potato tubers collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.72	1.00			
Zn	0.50	0.58	1.00		
Fe	0.59	0.67	0.36	1.00	
Cu	0.79	0.71	0.54	0.90	1.00

Table-RP9b

Correlation between average value of different heavy metal concentrations obtained on analysis of peeled potato tubers collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.77	1.00			
Zn	0.32	0.32	1.00		
Fe	0.65	0.78	0.16	1.00	
Cu	0.80	0.83	0.32	0.91	1.00

Table-RP10

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.85	1.00			
Zn	0.90	0.79	1.00		
Fe	0.36	0.30	0.29	1.00	
Cu	0.44	0.46	0.49	0.87	1.00

Table-RP11a

Correlation between average value of different heavy metal concentrations obtained from analysis of unpeeled potato tubers collected from all sites and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in UPP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.56				
Cd		0.80			
Zn			0.94		
Fe				0.94	
Cu					0.89

UPP-Unpeeled potato

Table-RP11b

Correlation between average value of different heavy metal concentrations obtained from analysis of peeled potato tubers collected from all sites and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in PP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.58				
Cd		0.83			
Zn			0.93		
Fe				0.93	
Cu					0.88

PP-Peeled potato

Table-RP12

Percent uptake of different heavy metals in unpeeled and peeled potato tubers at different sites in year 2013

Metal	Plant Parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	UPP	11.46	22.73	25.39	65.02	81.46	36.33	116.12	47.21	58.65	71.36
	PP	3.86	21.84	17.82	65.02	80.86	35.04	107.41	47.04	58.28	66.26
Cd	UPP	50.00	60.77	98.04	49.76	79.84	33.17	78.42	96.98	63.64	58.59
	PP	38.89	58.46	46.08	47.39	74.49	77.56	79.86	81.41	63.64	42.33
Zn	UPP	53.56	58.59	75.22	27.40	75.58	57.27	48.82	51.99	56.54	55.75
	PP	47.95	54.04	75.79	24.93	44.47	55.44	38.98	45.86	50.05	48.93
Fe	UPP	69.87	74.67	69.45	72.64	99.97	70.47	96.31	98.80	98.23	83.85
	PP	64.65	72.46	69.16	81.74	97.77	67.94	96.43	96.98	98.88	80.22
Cu	UPP	51.76	57.05	43.51	84.15	93.29	61.02	83.41	79.23	99.64	75.99
	PP	51.55	58.62	58.88	82.97	97.84	59.63	86.05	74.33	99.14	70.75

UPP-Unpeeled potato
PP-Peeled potato

Table-RP13

Results of analysis of unpeeled and peeled potato tubers collected from different sites for different heavy metal concentrations (mg/kg) in year 2014

Metal	Plant parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	UPP	1.82	1.91	1.39	5.64	8.60	4.73	8.29	5.04	8.92	8.61	5.50	0.30
	PP	1.42	1.45	1.21	5.04	8.59	4.48	8.25	5.43	8.81	8.73	5.34	
Cd	UPP	0.32	0.81	0.32	1.32	1.03	0.92	1.88	1.91	2.04	1.52	1.21	0.20
	PP	0.28	0.76	0.24	1.09	1.03	0.82	1.78	1.67	2.02	1.37	1.11	
Zn	UPP	2.53	2.18	2.19	1.93	1.42	4.23	2.41	2.99	5.92	5.03	3.08	100.00
	PP	2.14	2.13	2.09	1.88	1.35	4.13	2.32	2.83	5.33	4.88	2.91	
Fe	UPP	15.24	24.02	15.32	16.00	34.83	19.10	16.13	42.00	31.69	20.47	23.48	200.00
	PP	14.36	23.29	14.96	16.75	34.21	21.67	32.01	34.15	34.18	18.63	24.42	
Cu	UPP	2.99	8.00	2.69	5.05	14.82	7.08	11.69	8.81	15.00	7.29	8.34	40.00
	PP	2.45	8.69	2.37	4.99	13.77	7.69	11.83	8.62	14.10	8.21	8.27	

UPP-Unpeeled potato
PP-Peeled potato

Table-RP14

Results of analysis of soils of different sites from where samples of unpeeled and peeled potato tubers are collected for different heavy metal concentrations (mg/kg) in year 2014

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	9.50	5.21	4.63	8.63	10.05	12.96	7.12	11.61	12.64	9.68	9.20	10-70
Cd	1.69	1.59	1.58	2.01	2.30	1.81	1.93	1.99	3.83	2.15	2.09	0.07-1.10
Zn	4.29	6.43	3.12	3.24	3.28	7.39	5.42	6.19	10.14	7.64	5.71	10-300
Fe	22.89	24.06	22.83	25.29	34.98	33.68	33.92	42.09	35.63	32.11	30.75	3000-5000
Cu	3.88	12.27	3.69	5.27	14.96	11.99	12.68	9.47	15.29	11.15	10.07	6-60

Table-RP15a

Correlation between average value of different heavy metal concentrations obtained on analysis of unpeeled potato tubers collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.78	1.00			
Zn	0.41	0.47	1.00		
Fe	0.34	0.49	0.13	1.00	
Cu	0.78	0.67	0.25	0.63	1.00

Table-RP15b

Correlation between average value of different heavy metal concentrations obtained on analysis of peeled potato tubers collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.82	1.00			
Zn	0.43	0.43	1.00		
Fe	0.65	0.76	0.12	1.00	
Cu	0.80	0.77	0.29	0.89	1.00

Table-RP16

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.56	1.00			
Zn	0.54	0.63	1.00		
Fe	0.68	0.46	0.47	1.00	
Cu	0.39	0.56	0.60	0.64	1.00

Table-17a

Correlation between average value of different heavy metal concentrations obtained from analysis of unpeeled potato tubers collected from all sites and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in UPP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.48				
Cd		0.62			
Zn			0.91		
Fe				0.75	
Cu					0.91

UPP-Unpeeled potato

Table-17b

Correlation between average value of different heavy metal concentrations obtained from analysis of peeled potato tubers collected from all sites and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in PP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.49				
Cd		0.68			
Zn			0.90		
Fe				0.83	
Cu					0.95

PP-Peeled potato

Table-RP18

Percent uptake of different heavy metals in unpeeled and peeled potato tubers at different sites in year 2014

Metal	Plant parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	UPP	19.16	36.66	30.02	65.35	85.57	36.50	116.43	43.41	70.57	88.95
	PP	14.95	27.83	26.13	58.40	85.47	34.57	115.87	46.77	69.70	90.19
Cd	UPP	18.93	50.94	20.25	65.67	44.78	50.83	97.41	95.98	53.26	70.70
	PP	16.57	47.80	15.19	54.23	44.78	45.30	92.23	83.92	52.74	63.72
Zn	UPP	58.97	33.90	70.19	59.57	43.29	57.24	44.46	48.30	58.38	65.84
	PP	49.88	33.13	66.99	58.02	41.16	55.89	42.80	45.72	52.56	63.87
Fe	UPP	66.58	99.83	67.10	63.27	99.57	56.71	47.55	99.79	88.94	63.75
	PP	62.73	96.80	65.53	66.23	97.80	64.34	94.37	81.14	95.93	58.02
Cu	UPP	77.06	65.20	72.90	95.83	99.06	59.05	92.19	93.03	98.10	65.38
	PP	63.14	70.82	64.23	94.69	92.05	64.14	93.30	91.02	92.22	73.63

UPP-Unpeeled potato
PP-Peeled potato

Pot Potato

Table-PP1

Results of analysis of unpeeled and peeled potato tubers collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2012

Metal	Plant part	Sets				
		Set 1	Set 2	Set 3	Set 4	Set5
Pb	UPP	0.52	2.14	4.98	8.11	11.22
	PP	0.59	2.13	4.96	8.03	10.12
Cd	UPP	0.32	1.94	3.01	5.36	7.63
	PP	0.31	1.91	3.00	4.18	7.18
Zn	UPP	1.32	2.57	6.96	8.76	11.38
	PP	1.31	2.48	6.13	8.23	11.29
Fe	UPP	5.63	6.82	9.94	14.64	18.69
	PP	4.18	6.48	9.49	13.48	17.43
Cu	UPP	2.17	3.01	4.11	5.12	9.43
	PP	1.98	2.99	4.10	5.00	9.01

UPP-Unpeeled potato
PP- Peeled potato

Table-PP2

Results of analysis of soils of different pots of different sets from where samples of unpeeled and peeled potato tubers are collected for different heavy metal concentrations (mg/kg) in year 2012

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set5
Pb	0.98	4.92	7.63	10.68	12.51
Cd	0.81	3.21	5.23	8.01	10.96
Zn	1.95	3.31	7.15	9.99	12.99
Fe	5.98	6.92	11.77	16.49	20.53
Cu	2.98	4.94	6.32	6.99	11.49

Table-PP3a

Correlation between average value of different heavy metal concentrations obtained on analysis of unpeeled potato tubers collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.99	0.97	1.00		
Fe	1.00	0.99	0.97	1.00	
Cu	0.95	0.96	0.91	0.95	1.00

Table-PP3b

Correlation between average value of different heavy metal concentrations obtained on analysis of peeled potato tubers collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.97	1.00			
Zn	0.99	0.99	1.00		
Fe	1.00	0.98	0.99	1.00	
Cu	0.93	0.99	0.95	0.96	1.00

Table-PP4

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.98	0.99	1.00		
Fe	0.96	0.99	1.00	1.00	
Cu	0.92	0.97	0.95	0.94	1.00

Table-PP5a

Correlation between average value of different heavy metal concentrations obtained from analysis of unpeeled potato tubers collected from different pots of different sets and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in UPP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		1.00			
Zn			1.00		
Fe				1.00	
Cu					0.99

UPP-Unpeeled potato

Table- PP5b

Correlation between average value of different heavy metal concentrations obtained from analysis of peeled potato tubers collected from different pots of different sets and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in PP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		0.99			
Zn			1.00		
Fe				0.99	
Cu					0.99

PP- Peeled potato

Table-PP6

Percent uptake of different heavy metals in unpeeled and peeled potato tubers from pots of different sets in year 2012

Metal	Plant part	Sets				
		Set 1	Set 2	Set 3	Set 4	Set5
Pb	UPP	53.06	43.50	65.27	75.94	89.69
	PP	60.20	43.29	65.01	75.19	80.90
Cd	UPP	39.51	60.44	57.55	66.92	69.62
	PP	38.27	59.50	57.36	52.18	65.51
Zn	UPP	67.69	77.64	97.34	87.69	87.61
	PP	67.18	74.92	85.73	82.38	86.91
Fe	UPP	94.15	98.55	84.45	88.78	91.04
	PP	69.90	93.64	80.63	81.75	84.90
Cu	UPP	72.82	60.93	65.03	73.25	82.07
	PP	66.44	60.53	64.87	71.53	78.42

UPP-Unpeeled potato
PP- Peeled potato

Table-PP7

Results of analysis of unpeeled and peeled potato tubers collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2013

Metal	Plant part	Sets				
		Set 1	Set 2	Set 3	Set 4	Set5
Pb	UPP	0.54	2.32	4.99	8.63	10.17
	PP	0.52	2.11	4.88	8.03	10.13
Cd	UPP	0.32	1.66	3.61	5.67	6.93
	PP	0.24	1.58	3.50	5.42	5.01
Zn	UPP	1.48	2.13	5.82	8.32	11.33
	PP	1.44	2.11	5.35	8.23	11.29
Fe	UPP	4.92	6.97	9.86	14.51	18.21
	PP	4.63	6.28	9.41	13.93	18.25
Cu	UPP	2.10	3.03	4.36	5.32	8.83
	PP	2.06	3.18	4.14	5.18	8.91

UPP-Unpeeled potato
PP- Peeled potato

Table-PP8

Results of analysis of soils of different pots of different sets from where samples of unpeeled and peeled potato tubers are collected for different heavy metal concentrations (mg/kg) in year 2013

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set5
Pb	0.98	4.93	7.51	10.34	12.39
Cd	0.79	2.43	5.98	8.25	11.29
Zn	1.96	3.62	6.99	9.89	12.98
Fe	5.99	6.98	11.60	16.98	21.03
Cu	2.71	4.64	6.98	8.80	12.16

Table-PP9a

Correlation between average value of different heavy metal concentrations obtained on analysis of unpeeled potato tubers collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	1.00	1.00			
Zn	0.99	0.99	1.00		
Fe	0.99	0.99	0.99	1.00	
Cu	0.93	0.94	0.97	0.97	1.00

Table-PP9b

Correlation between average value of different heavy metal concentrations obtained on analysis of peeled potato tubers collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.96	1.00			
Zn	0.99	0.99	1.00		
Fe	0.99	0.92	1.00	1.00	
Cu	0.94	0.81	0.96	0.97	1.00

Table-PP10

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.98	1.00	1.00		
Fe	0.96	0.99	0.99	1.00	
Cu	0.98	0.99	0.99	0.98	1.00

Table-PP11a

Correlation between average value of different heavy metal concentrations obtained from analysis of unpeeled potato tubers collected from different pots of different sets and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in UPP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		0.99			
Zn			1.00		
Fe				1.00	
Cu					0.98

UPP-Unpeeled potato

Table-PP11b

Correlation between average value of different heavy metal concentrations obtained from analysis of peeled potato tubers collected from different pots of different sets and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in PP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		0.94			
Zn			1.00		
Fe				1.00	
Cu					0.97

PP- Peeled potato

Table-PP12

Percent uptake of different heavy metals in unpeeled and peeled potato tubers from pots of different sets in year 2013

Metal	Plant part	Sets				
		Set 1	Set 2	Set 3	Set 4	Set5
Pb	UPP	55.10	47.06	66.44	83.46	82.08
	PP	53.06	42.80	64.98	77.66	81.76
Cd	UPP	40.51	68.31	60.37	68.73	61.38
	PP	30.38	65.02	58.53	65.70	44.38
Zn	UPP	75.51	58.84	83.26	84.13	87.29
	PP	73.47	58.29	76.54	83.22	86.98
Fe	UPP	82.14	99.86	85.00	85.45	86.59
	PP	77.30	89.97	81.12	82.04	86.78
Cu	UPP	77.49	65.30	62.46	60.45	72.62
	PP	76.01	68.53	59.31	58.86	73.27

UPP-Unpeeled potato
PP- Peeled potato

Table-PP13

Results of analysis of unpeeled and peeled potato tubers collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2014

Metal	Plant part	Set 1	Set 2	Set 3	Set 4	Set5
Pb	UPP	0.51	2.77	4.63	7.92	10.72
	PP	0.93	1.05	4.52	7.99	10.11
Cd	UPP	0.23	1.32	3.61	5.63	7.87
	PP	0.05	1.13	3.65	5.92	7.69
Zn	UPP	1.42	2.91	4.33	8.61	11.22
	PP	1.49	2.08	4.36	8.23	11.36
Fe	UPP	5.92	6.38	9.34	14.69	17.61
	PP	4.73	6.92	9.48	14.73	17.23
Cu	UPP	2.00	2.99	4.32	5.33	8.23
	PP	1.98	3.14	4.64	5.39	8.28

UPP-Unpeeled potato
PP-Peeled potato

Table-PP14

Results of analysis of soils of different pots of different sets from where samples of unpeeled and peeled potato tubers are collected for different heavy metal concentrations (mg/kg) in year 2014

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set5
Pb	0.99	4.99	7.59	10.41	12.47
Cd	0.75	2.72	5.41	7.14	10.00
Zn	1.94	3.69	6.98	9.89	12.95
Fe	6.43	7.32	12.01	16.23	21.98
Cu	3.14	4.99	6.28	7.21	11.59

Table-PP15a

Correlation between average value of different heavy metal concentrations obtained on analysis of unpeeled potato tubers collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.99	0.99	1.00		
Fe	0.98	0.99	0.99	1.00	
Cu	0.98	0.98	0.97	0.96	1.00

Table-PP15b

Correlation between average value of different heavy metal concentrations obtained on analysis of peeled potato tubers collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.99	0.99	1.00		
Fe	0.99	0.99	0.99	1.00	
Cu	0.95	0.97	0.97	0.96	1.00

Table-PP16

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.98	1.00	1.00		
Fe	0.95	0.98	0.99	1.00	
Cu	0.93	0.97	0.96	0.97	1.00

Table-PP17a

Correlation between average value of different heavy metal concentrations obtained from analysis of unpeeled potato tubers collected from different pots of different sets and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in UPP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		1.00			
Zn			0.98		
Fe				0.99	
Cu					0.99

UPP-Unpeeled potato

Table-PP17b

Correlation between average value of different heavy metal concentrations obtained from analysis of peeled potato tubers collected from different pots of different sets and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in PP				
	Pb	Cd	Zn	Fe	Cu
Pb	0.95				
Cd		0.99			
Zn			0.99		
Fe				0.98	
Cu					0.99

PP-Peeled potato

Table-PP18

Percent uptake of different heavy metals in unpeeled and peeled potato tubers from pots of different sets in year 2014

Metal	Plant part	Sets				
		Set 1	Set 2	Set 3	Set 4	Set5
Pb	UPP	51.52	55.51	61.00	76.08	85.97
	PP	93.94	21.04	59.55	76.75	81.07
Cd	UPP	30.67	48.53	66.73	78.85	78.70
	PP	6.67	41.54	67.47	82.91	76.90
Zn	UPP	73.20	78.86	62.03	87.06	86.64
	PP	76.80	56.37	62.46	83.22	87.72
Fe	UPP	92.07	87.16	77.77	90.51	80.12
	PP	73.56	94.54	78.93	90.76	78.39
Cu	UPP	63.69	59.92	68.79	73.93	71.01
	PP	63.06	62.93	73.89	74.76	71.44

UPP-Unpeeled potato
PP-Peeled potato

Table-RP19

Results of analysis of corresponding soils of different sites from where samples of unpeeled and peeled potato tubers are collected for different physicochemical parameters in the year 2012

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (μ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.521	41.51	42.11	1.135	5.9	172.7	0.0048	0.0062	0.037	0.43	0.28	0.0071
2	0.459	43.22	44.53	1.152	6.3	213.4	0.0039	0.0069	0.048	0.59	0.28	0.0082
3	0.556	41.12	42.69	1.105	7.1	220.7	0.0075	0.0052	0.045	0.48	0.35	0.0083
4	0.453	42.58	42.25	1.142	7.2	191.7	0.0061	0.0068	0.058	0.57	0.41	0.0091
5	0.621	43.67	45.85	1.056	6.9	204.8	0.0024	0.0057	0.051	0.51	0.26	0.0058
6	0.569	45.12	46.23	1.107	6.8	210.3	0.0071	0.0071	0.048	0.59	0.21	0.0079
7	0.615	42.85	50.26	1.194	7.2	181.6	0.0084	0.0078	0.071	0.69	0.14	0.0091
8	0.365	48.36	51.25	1.149	6.7	221.7	0.0051	0.0084	0.049	0.51	0.45	0.0087
9	0.468	42.67	53.11	1.134	6.5	189.5	0.0085	0.0085	0.057	0.5	0.42	0.0086
10	0.549	41.58	42.68	1.057	6.6	165.8	0.0048	0.0064	0.052	0.58	0.43	0.0058

Table-RP20

Results of analysis of corresponding soils of different sites from where samples of unpeeled and peeled potato tubers are collected for different physicochemical parameters in the year 2013

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (µ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.496	45.6	45.09	1.123	6.5	159.70	0.0091	0.0069	0.041	0.63	0.39	0.0089
2	0.485	42.4	44.28	1.145	6.7	186.40	0.0052	0.0051	0.059	0.62	0.42	0.0071
3	0.598	43.2	44.55	1.151	6.9	191.80	0.0052	0.0073	0.032	0.65	0.47	0.0093
4	0.487	46.1	48.32	1.139	5.9	175.60	0.0064	0.0069	0.042	0.49	0.33	0.0085
5	0.563	42.4	49.61	1.167	5.4	179.10	0.0041	0.0074	0.048	0.48	0.43	0.0087
6	0.517	46	47.53	1.144	7.2	211.80	0.0082	0.0079	0.062	0.63	0.49	0.0072
7	0.553	47.28	50.84	1.148	7.3	215.30	0.0029	0.0051	0.059	0.49	0.48	0.0068
8	0.518	46.9	51.46	1.15	7.1	187.90	0.0047	0.0067	0.038	0.55	0.33	0.0096
9	0.547	43.9	48.67	1.142	6.9	179.70	0.0052	0.0069	0.059	0.58	0.37	0.0093
10	0.591	47.8	48.27	1.157	6.9	175.60	0.0039	0.0072	0.042	0.61	0.49	0.0087

Table-RP21

Results of analysis of corresponding soils of different sites from where samples of unpeeled and peeled potato tubers are collected for different physicochemical parameters in the year 2014

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (μ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.553	43.2	43.28	1.162	6.9	128.30	0.0052	0.0075	0.041	0.53	0.31	0.0067
2	0.492	43.3	46.14	1.137	6.2	211.70	0.0058	0.0085	0.059	0.63	0.38	0.0081
3	0.521	46.8	45.79	1.149	6.7	212.70	0.0073	0.0059	0.06	0.62	0.45	0.0042
4	0.587	45.8	46.38	1.138	5.8	204.90	0.0069	0.0061	0.051	0.68	0.35	0.0085
5	0.586	47.9	48.91	1.127	6.9	211.70	0.0087	0.0072	0.059	0.59	0.29	0.0056
6	0.512	49.2	49.31	1.153	7.1	176.20	0.0087	0.0068	0.048	0.71	0.38	0.0059
7	0.485	43.57	51.89	1.177	7.2	213.30	0.0069	0.0079	0.052	0.72	0.25	0.0072
8	0.578	46.3	53.37	1.114	6.9	225.80	0.0035	0.0079	0.063	0.71	0.59	0.0075
9	0.612	47.1	43.85	1.134	6.8	198.90	0.0048	0.0061	0.044	0.63	0.62	0.0087
10	0.635	45.7	46.29	1.184	6.7	175.60	0.0052	0.0073	0.068	0.42	0.41	0.0069

Table-PP19

Results of analysis of reference soil/cultivation media for cultivation of samples of unpeeled and peeled potato tubers from different pots of different sets collected for different physicochemical parameters in three studied years i.e. 2012, 2013 and 2014

Year	Parameters /Set no.	Organic matter (%) X-Y	WHC (%) X-Y	Porosity (%) X-Y	Density gm/cm3 X-Y	pH X-Y	Conductivity (µ mho/cm) X-Y	Nitrate X-Y	Phosphate X-Y	Sulphate X-Y	Calcium X-Y	Magnesium X-Y	Potassium X-Y
2012	1	0.481-0.485	42.38-42.84	43.12-43.97	1.121-1.125	6.8-6.5	157.8-158.9	0.0042-0.0047	0.0050-0.0052	0.038-0.039	0.33-0.37	0.36-0.38	0.0061-0.0065
	2	0.481-0.493	41.82-42.35	43.22-44.25	1.122-1.135	6.7-6.9	159.6-219.2	0.0048-0.0054	0.0050-0.0061	0.037-0.041	0.35-0.42	0.35-0.42	0.0065-0.0067
	3	0.482-0.521	41.65-43.85	43.25-45.18	1.127-1.143	7.1-7.2	158.9-219.3	0.0048-0.0069	0.0059-0.0074	0.041-0.049	0.35-0.43	0.37-0.42	0.0062-0.0063
	4	0.486-0.561	41.82-45.15	43.97-46.25	1.123-1.155	6.9-6.7	159.4-248.3	0.0041-0.0072	0.0052-0.0068	0.041-0.059	0.32-0.49	0.37-0.49	0.0062-0.0079
	5	0.487-0.591	41.82-46.22	43.08-47.15	1.127-1.162	7.2-7.1	194.1-201.8	0.0035-0.0039	0.0052-0.0081	0.038-0.067	0.31-0.59	0.39-0.42	0.0063-0.0078
2013	1	0.452-0.419	41.91-42.01	42.12-42.98	1.139-1.138	7.1-7.6	194.7-211.5	0.0036-0.0039	0.0042-0.0047	0.027-0.047	0.40-0.43	0.36-0.32	0.0061-0.0082
	2	0.462-0.462	41.93-42.32	42.67-44.04	1.135-1.141	7.1-6.1	194.9-179.8	0.0037-0.0074	0.0049-0.0063	0.035-0.028	0.47-0.48	0.41-0.43	0.0062-0.0093
	3	0.416-0.417	41.89-43.67	42.35-46.25	1.132-1.158	7.0-6.8	178.6-212.9	0.0049-0.0055	0.0049-0.0061	0.029-0.055	0.43-0.45	0.39-0.45	0.0071-0.0074
	4	0.485-0.511	41.71-45.33	42.39-48.00	1.136-1.167	5.9-7.1	172.9-253.9	0.0048-0.0057	0.0046-0.0078	0.028-0.047	0.42-0.45	0.41-0.51	0.0072-0.0079
	5	0.483-0.529	41.87-45.63	42.41-55.57	1.131-1.172	6.8-7.2	172.6-214.9	0.0050-0.0063	0.0045-0.0089	0.029-0.063	0.42-0.53	0.41-0.46	0.0073-0.0089
2014	1	0.478-0.482	41.21-41.57	43.25-44.09	1.122-1.127	6.1-6.9	194.3-231.7	0.0050-0.0073	0.0052-0.0055	0.031-0.032	0.41-0.47	0.42-0.57	0.0074-0.0091
	2	0.479-0.511	41.09-45.87	43.12-46.17	1.126-1.135	6.5-6.8	194.6-231.4	0.0059-0.0082	0.0053-0.0067	0.033-0.058	0.42-0.49	0.52-0.53	0.0073-0.0081
	3	0.483-0.525	41.27-46.05	43.27-47.18	1.127-1.152	6.7-6.8	193.8-194.7	0.0039-0.0071	0.0052-0.0052	0.031-0.049	0.41-0.48	0.40-0.41	0.0072-0.0087
	4	0.483-0.571	41.02-46.38	43.61-49.24	1.137-1.167	6.2-6.3	159.6-218.7	0.0036-0.0047	0.0054-0.0071	0.031-0.048	0.49-0.51	0.39-0.41	0.0063-0.0089
	5	0.482-0.589	40.97-44.82	43.57-50.28	1.127-1.151	6.8-6.9	159.9-221.4	0.0048-0.0084	0.0052-0.0086	0.035-0.066	0.43-0.52	0.39-0.53	0.0062-0.0065

X- At the time of Plantation

Y- At the time of Harvesting

Table-RC1

Results of analysis of green and red chillies collected from different sites for different heavy metal concentrations (mg/kg) in year 2012

Metal	Plant Parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	GC	1.25	2.08	1.43	5.11	9.02	4.69	8.32	8.83	5.47	8.78	5.50	0.30
	RdC	1.27	2.23	1.13	5.24	9.00	4.73	8.38	8.92	5.63	8.94	5.55	
Cd	GC	0.38	0.97	1.01	1.02	1.85	0.68	1.62	1.73	0.66	1.39	1.13	0.20
	RdC	0.44	0.99	1.05	1.00	1.24	0.93	1.59	1.94	0.95	1.95	1.21	
Zn	GC	2.02	2.82	1.18	1.63	4.80	2.12	2.88	3.04	2.83	4.28	2.76	100.00
	RdC	2.00	2.39	1.72	1.38	4.91	2.64	2.90	3.51	2.05	4.39	2.79	
Fe	GC	13.03	24.63	14.92	15.22	33.63	19.38	32.11	34.19	22.09	17.36	22.66	200.00
	RdC	13.65	25.01	14.80	15.93	35.07	21.61	35.21	26.98	25.31	18.65	23.22	
Cu	GC	2.17	8.12	2.64	4.19	12.49	7.98	11.92	8.88	11.52	8.12	7.80	40.00
	RdC	2.28	8.94	2.19	4.63	12.63	8.23	12.43	9.48	13.64	10.02	8.45	

GC-Green chillies
RdC-Red chillies

Table-RC2

Results of analysis of soils of different sites from where samples of green and red chillies are collected for different heavy metal concentrations (mg/kg) in year 2012

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	9.76	4.97	8.83	9.62	11.49	10.27	10.79	14.68	7.34	12.83	10.06	10-70
Cd	0.68	1.65	1.44	3.59	2.88	2.16	2.61	2.59	1.73	2.19	2.15	0.07-1.10
Zn	3.97	6.53	2.75	3.69	7.78	5.64	7.83	6.42	5.68	5.17	5.55	10-300
Fe	18.79	40.12	21.03	19.01	35.92	33.87	35.96	35.41	25.69	24.73	29.05	3000-5000
Cu	3.66	10.12	9.54	5.26	12.66	12.81	12.73	11.12	14.53	10.67	10.31	6-60

Table-RC3a

Correlation between average value of different heavy metal concentrations obtained on analysis of green chillies collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.81	1.00			
Zn	0.75	0.64	1.00		
Fe	0.68	0.78	0.59	1.00	
Cu	0.73	0.57	0.73	0.81	1.00

Table-RC3b

Correlation between average value of different heavy metal concentrations obtained on analysis of red chillies collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.80	1.00			
Zn	0.76	0.76	1.00		
Fe	0.66	0.42	0.58	1.00	
Cu	0.74	0.48	0.59	0.84	1.00

Table-RC4

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.39	1.00			
Zn	0.17	0.33	1.00		
Fe	0.02	0.22	0.87	1.00	
Cu	0.06	0.18	0.65	0.63	1.00

Table-RC5a

Correlation between average value of different heavy metal concentrations obtained from analysis of green chillies collected from all sites and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in GC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.72				
Cd		0.63			
Zn			0.71		
Fe				0.82	
Cu					0.84

GC-Green chillies

Table-RC5b

Correlation between average value of different heavy metal concentrations obtained from analysis of red chillies collected from all sites and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in RdC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.70				
Cd		0.48			
Zn			0.64		
Fe				0.80	
Cu					0.83

RdC-Red chillies

Table-RC6

Percent uptake of different heavy metals in green and red chillies at different sites in year 2012

Metal	Plant parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	GC	12.81	41.85	16.19	53.12	78.50	45.67	77.11	60.15	74.52	68.43
	RdC	13.01	44.87	12.80	54.47	78.33	46.06	77.66	60.76	76.70	69.68
Cd	GC	55.88	58.79	70.14	28.41	64.24	31.48	62.07	66.80	38.15	63.47
	RdC	64.71	60.00	72.92	27.86	43.06	43.06	60.92	74.90	54.91	89.04
Zn	GC	50.88	43.19	42.91	44.17	61.70	37.59	36.78	47.35	49.82	82.79
	RdC	50.38	36.60	62.55	37.40	63.11	46.81	37.04	54.67	36.09	84.91
Fe	GC	69.35	61.39	70.95	80.06	93.62	57.22	89.29	96.55	85.99	70.20
	RdC	72.65	62.34	70.38	83.80	97.63	63.80	97.91	76.19	98.52	75.41
Cu	GC	59.29	80.24	27.67	79.66	98.66	62.30	93.64	79.86	79.28	76.10
	RdC	62.30	88.34	22.96	88.02	99.76	64.25	97.64	85.25	93.87	93.91

GC-Green chillies
RdC-Red chillies

Table-RC7

Results of analysis of green and red chillies collected from different sites for different heavy metal concentrations (mg/kg) in year 2013

Metal	Plant Parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	GC	1.15	2.08	1.59	5.61	9.34	4.28	8.12	8.62	5.98	8.16	5.49	0.30
	RdC	1.29	2.32	1.51	5.60	9.82	4.96	8.10	8.00	5.21	9.65	5.65	
Cd	GC	0.43	0.98	1.72	1.41	1.98	0.63	1.76	1.92	0.64	1.42	1.29	0.20
	RdC	0.32	0.99	1.75	0.01	1.03	0.53	1.70	1.04	1.08	1.94	1.04	
Zn	GC	1.26	2.69	3.02	1.53	4.99	2.62	2.14	3.42	2.92	4.02	2.86	100.00
	RdC	1.26	2.77	3.51	1.65	5.20	2.99	2.57	3.02	2.08	4.58	2.96	
Fe	GC	14.15	26.49	18.88	14.98	34.91	19.93	32.11	34.92	21.47	17.14	23.50	200.00
	RdC	16.00	26.63	19.90	13.23	32.68	20.05	33.63	35.91	22.49	17.82	23.83	
Cu	GC	2.03	9.33	2.94	4.59	12.68	7.09	11.08	8.12	12.01	7.98	7.79	40.00
	RdC	2.59	9.45	2.94	4.68	12.95	7.70	11.93	9.68	11.91	9.00	8.28	

GC-Green chillies
RdC-Red chillies

Table-RC8

Results of analysis of soils of different sites from where samples of green and red chillies are collected for different heavy metal concentrations (mg/kg) in year 2013

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	4.85	4.29	8.55	9.82	11.60	10.19	10.61	15.01	7.39	12.13	9.44	10-70
Cd	0.92	1.72	2.63	2.71	2.49	2.39	2.47	2.60	1.77	2.02	2.17	0.07-1.10
Zn	3.68	6.91	3.83	3.67	7.82	5.63	7.63	6.71	5.69	4.63	5.62	10-300
Fe	19.23	39.73	21.42	19.73	35.19	33.91	32.98	35.92	23.49	20.12	28.17	3000-5000
Cu	4.65	15.00	9.04	5.22	13.14	12.96	12.61	11.12	12.68	9.52	10.59	6-60

Table-RC9a

Correlation between average value of different heavy metal concentrations obtained on analysis of green chillies collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.61	1.00			
Zn	0.59	0.53	1.00		
Fe	0.61	0.62	0.53	1.00	
Cu	0.68	0.25	0.58	0.71	1.00

Table-RC9b

Correlation between average value of different heavy metal concentrations obtained on analysis of red chillies collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.32	1.00			
Zn	0.60	0.60	1.00		
Fe	0.48	0.36	0.37	1.00	
Cu	0.71	0.35	0.44	0.72	1.00

Table-RC10

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.71	1.00			
Zn	0.28	0.23	1.00		
Fe	0.17	0.24	0.87	1.00	
Cu	0.09	0.19	0.83	0.81	1.00

Table-RC11a

Correlation between average value of different heavy metal concentrations obtained from analysis of green chillies collected from all sites and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in GC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.82				
Cd		0.75			
Zn			0.49		
Fe				0.81	
Cu					0.80

GC-Green chillies

Table-RC11b

Correlation between average value of different heavy metal concentrations obtained from analysis of red chillies collected from all sites and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in RdC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.81				
Cd		0.19			
Zn			0.40		
Fe				0.79	
Cu					0.79

RdC-Red chillies

Table-RC12

Percent uptake of different heavy metals in green and red chillies at different sites in year 2013

Metal	Plant parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	GC	23.71	48.48	18.60	57.13	80.52	42.00	76.53	57.43	80.92	67.27
	RdC	26.60	54.08	17.66	57.03	84.66	48.68	76.34	53.30	70.50	79.55
Cd	GC	46.74	56.98	65.40	52.03	79.52	26.36	71.26	73.85	36.16	70.30
	RdC	34.78	57.56	66.54	0.37	41.37	22.18	68.83	40.00	61.02	96.04
Zn	GC	34.24	38.93	78.85	41.69	63.81	46.54	28.05	50.97	51.32	86.83
	RdC	34.24	40.09	91.64	44.96	66.50	53.11	33.68	45.01	36.56	98.92
Fe	GC	73.58	66.68	88.14	75.92	99.20	58.77	97.36	97.22	91.40	85.19
	RdC	83.20	67.03	92.90	67.06	92.87	59.13	101.97	99.97	95.74	88.57
Cu	GC	43.66	62.20	32.52	87.93	96.50	54.71	87.87	73.02	94.72	83.82
	RdC	55.70	63.00	32.52	89.66	98.55	59.41	94.61	87.05	93.93	94.54

GC-Green chillies
RdC-Red chillies

Table-RC13

Results of analysis of green and red chillies collected from different sites for different heavy metal concentrations (mg/kg) in year 2014

Metal	Plant parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	GC	1.53	2.19	1.69	5.68	8.99	4.62	8.37	8.73	5.64	7.95	5.54	0.30
	RdC	1.56	2.34	1.70	5.98	9.99	4.68	9.02	9.01	5.68	8.04	5.80	
Cd	GC	0.85	0.88	1.29	1.47	2.01	0.84	1.92	1.69	0.94	1.63	1.35	0.20
	RdC	0.83	0.84	1.30	1.49	2.38	0.99	2.04	1.86	0.92	1.68	1.43	
Zn	GC	1.63	2.74	3.12	1.62	3.48	2.92	2.61	3.58	3.01	4.65	2.94	100.00
	RdC	1.69	2.68	3.43	1.97	3.52	3.03	2.77	3.17	3.09	4.69	3.00	
Fe	GC	15.02	25.37	16.01	15.33	34.63	20.09	31.72	34.02	22.14	17.63	23.20	200.00
	RdC	15.68	26.07	16.98	15.43	34.65	21.00	31.16	33.99	23.15	18.60	23.67	
Cu	GC	8.83	10.14	2.29	4.43	13.86	7.39	11.38	8.41	13.48	7.42	8.76	40.00
	RdC	8.96	10.38	2.87	4.40	13.00	7.52	11.43	8.91	13.73	7.63	8.88	

GC-Green chillies
RdC-Red chillies

Table-RC14

Results of analysis of soils of different sites from where samples of green and red chillies are collected for different heavy metal concentrations (mg/kg) in year 2014

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	8.80	4.43	8.72	9.85	11.65	10.77	10.66	15.09	7.40	12.65	10.00	10-70
Cd	0.89	1.89	1.31	3.74	2.39	2.43	2.49	2.72	1.79	2.21	2.19	0.07-1.10
Zn	3.94	6.88	3.48	3.74	7.89	5.82	7.69	6.88	5.71	4.75	5.68	10-300
Fe	20.14	37.11	21.67	19.98	34.67	22.58	32.82	34.23	23.50	21.02	26.77	3000-5000
Cu	8.97	11.99	10.10	15.64	15.63	12.04	12.73	11.33	13.96	12.63	12.50	6-60

Table-RC15a

Correlation between average value of different heavy metal concentrations obtained on analysis of green chillies collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.82	1.00			
Zn	0.51	0.39	1.00		
Fe	0.67	0.60	0.32	1.00	
Cu	0.43	0.15	0.13	0.65	1.00

Table-RC15b

Correlation between average value of different heavy metal concentrations obtained on analysis of red chillies collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.86	1.00			
Zn	0.44	0.44	1.00		
Fe	0.69	0.64	0.22	1.00	
Cu	0.42	0.17	0.05	0.65	1.00

Table-RC16

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.41	1.00			
Zn	0.16	0.22	1.00		
Fe	0.02	0.14	0.89	1.00	
Cu	0.09	0.73	0.33	0.17	1.00

Table-RC17a

Correlation between average value of different heavy metal concentrations obtained from analysis of green chillies collected from all sites and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in GC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.74				
Cd		0.48			
Zn			0.29		
Fe				0.89	
Cu					0.35

GC-Green chillies

Table-RC17b

Correlation between average value of different heavy metal concentrations obtained from analysis of red chillies collected from all sites and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in RdC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.72				
Cd		0.48			
Zn			0.18		
Fe				0.90	
Cu					0.30

RdC-Red chillies

Table-RC18

Percent uptake of different heavy metals in green and red chillies at different sites in year 2014

Metal	Plant part	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	GC	17.39	49.44	19.38	57.66	77.17	42.90	78.52	57.85	76.22	62.85
	RdC	17.73	52.82	19.50	60.71	85.75	43.45	84.62	59.71	76.76	63.56
Cd	GC	95.51	46.56	98.47	39.30	84.10	34.57	77.11	62.13	52.51	73.76
	RdC	93.26	44.44	99.24	39.84	99.58	40.74	81.93	68.38	51.40	76.02
Zn	GC	41.37	39.83	89.66	43.32	44.11	50.17	33.94	52.03	52.71	97.89
	RdC	42.89	38.95	98.56	52.67	44.61	52.06	36.02	46.08	54.12	98.74
Fe	GC	74.58	68.36	73.88	76.73	99.88	88.97	96.65	99.39	94.21	83.87
	RdC	77.86	70.25	78.36	77.23	99.94	93.00	94.94	99.30	98.51	88.49
Cu	GC	98.44	84.57	22.67	28.32	88.68	61.38	89.40	74.23	96.56	58.75
	RdC	99.89	86.57	28.42	28.13	83.17	62.46	89.79	78.64	98.35	60.41

GC-Green chillies
RdC-Red chillies

Pot Chillies

Table-PC1

Results of analysis of green and red chillies collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2012

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	GC	0.61	2.97	5.43	8.07	10.72
	RdC	0.62	3.74	5.49	8.64	10.99
Cd	GC	0.31	2.23	3.81	5.43	8.71
	RdC	0.30	2.18	3.68	5.41	8.13
Zn	GC	2.82	2.43	5.14	8.12	11.62
	RdC	1.12	2.18	5.08	8.02	11.39
Fe	GC	4.63	6.43	10.22	15.11	18.43
	RdC	4.92	8.98	11.39	16.39	28.43
Cu	GC	2.14	3.21	5.98	5.61	9.47
	RdC	2.38	3.58	5.78	6.31	9.91

GC-Green chillies
RdC-Red chillies

Table-PC2

Results of analysis of soils of different pots of different sets from where samples of green and red chillies are collected for different heavy metal concentrations (mg/kg) in year 2012

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set 5
Pb	0.99	5.17	7.91	10.79	12.95
Cd	0.73	2.81	5.81	7.67	10.71
Zn	2.97	3.68	7.52	9.83	12.95
Fe	6.48	9.92	11.89	16.94	28.61
Cu	2.93	4.84	5.99	6.83	11.19

Table-PC3a

Correlation between average value of different heavy metal concentrations obtained on analysis of green chillies collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.96	0.96	1.00		
Fe	0.99	0.98	0.98	1.00	
Cu	0.95	0.97	0.93	0.93	1.00

Table-PC3b

Correlation between average value of different heavy metal concentrations obtained on analysis of red chillies collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.98	0.98	1.00		
Fe	0.95	0.98	0.97	1.00	
Cu	0.96	0.99	0.98	0.98	1.00

Table-PC4

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.96	0.99	1.00		
Fe	0.90	0.95	0.95	1.00	
Cu	0.93	0.96	0.95	0.99	1.00

Table-PC5a

Correlation between average value of different heavy metal concentrations obtained from analysis of green chillies collected from different pots of different sets and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in GC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.99			
Zn			0.98		
Fe				0.95	
Cu					0.97

GC-Green chillies

Table-PC5b

Correlation between average value of different heavy metal concentrations obtained from analysis of red chillies collected from different pots of different sets and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in RdC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.99			
Zn			1.00		
Fe				1.00	
Cu					0.99

RdC-Red chillies

Table-PC6

Percent uptake of different heavy metals in green and red chillies from pots of different sets in year 2012

Metal	Plant part	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	GC	61.62	57.45	68.65	74.79	82.78
	RdC	62.63	72.34	69.41	80.07	84.86
Cd	GC	42.47	79.36	65.58	70.80	81.33
	RdC	41.10	77.58	63.34	70.53	75.91
Zn	GC	94.95	66.03	68.35	82.60	89.73
	RdC	37.71	59.24	67.55	81.59	87.95
Fe	GC	71.45	64.82	85.95	89.20	64.42
	RdC	75.93	90.52	95.79	96.75	99.37
Cu	GC	73.04	66.32	99.83	82.14	84.63
	RdC	81.23	73.97	96.49	92.39	88.56

GC-Green chillies
RdC-Red chillies

Table-PC7

Results of analysis of green and red chillies collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2013

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	GC	0.64	3.42	4.98	8.60	10.36
	RdC	0.32	0.30	2.46	2.47	3.18
Cd	GC	0.32	2.46	3.18	5.43	8.14
	RdC	0.30	2.47	3.27	5.53	8.11
Zn	GC	1.02	2.04	5.39	8.68	11.63
	RdC	1.36	2.11	5.48	8.43	11.49
Fe	GC	5.82	6.34	10.14	14.43	18.63
	RdC	6.88	8.42	13.42	18.51	20.49
Cu	GC	2.24	3.21	5.67	6.98	8.68
	RdC	2.29	3.26	5.73	6.01	8.59

GC-Green chillies
RdC-Red chillies

Table-PC8

Results of analysis of soils of different pots of different sets from where samples of green and red chillies are collected for different heavy metal concentrations (mg/kg) in year 2013

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set 5
Pb	0.97	5.32	7.31	10.36	12.52
Cd	0.89	2.69	5.68	7.59	10.68
Zn	1.65	3.47	7.26	9.48	12.43
Fe	7.62	8.49	14.40	18.91	21.59
Cu	2.64	4.42	5.79	7.06	11.47

Table-PC9a

Correlation between average value of different heavy metal concentrations obtained on analysis of green chillies collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.98	0.98	1.00		
Fe	0.97	0.97	1.00	1.00	
Cu	0.98	0.97	0.99	0.98	1.00

Table-PC9b

Correlation between average value of different heavy metal concentrations obtained on analysis of red chillies collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.87	1.00			
Zn	0.94	0.94	1.00		
Fe	0.94	0.96	0.99	1.00	
Cu	0.96	0.96	0.98	0.96	1.00

Table-PC10

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.98	1.00	1.00		
Fe	0.95	0.98	0.99	1.00	
Cu	0.94	0.97	0.96	0.93	1.00

Table-PC11a

Correlation between average value of different heavy metal concentrations obtained from analysis of green chillies collected from different pots of different sets and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in GC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.98			
Zn			0.99		
Fe				0.99	
Cu					0.95

GC-Green chillies

Table-PC11b

Correlation between average value of different heavy metal concentrations obtained from analysis of red chillies collected from different pots of different sets and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in RdC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.90				
Cd		0.98			
Zn			0.99		
Fe				1.00	
Cu					0.97

RdC-Red chillies

Table-PC12

Percent uptake of different heavy metals in green and red chillies from pots of different sets in year 2013

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	GC	65.98	64.29	68.13	83.01	82.75
	RdC	32.99	5.64	33.65	23.84	25.40
Cd	GC	35.96	91.45	55.99	71.54	76.22
	RdC	33.71	91.82	57.57	72.86	75.94
Zn	GC	61.82	58.79	74.24	91.56	93.56
	RdC	82.42	60.81	75.48	88.92	92.44
Fe	GC	76.38	74.68	70.42	76.31	86.29
	RdC	90.29	99.18	93.19	97.88	94.91
Cu	GC	84.85	72.62	97.93	98.87	75.68
	RdC	86.74	73.76	98.96	85.13	74.89

GC-Green chillies
RdC-Red chillies

Table-PC13

Results of analysis of green and red chillies collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2014

Metal	Plant Parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	GC	0.59	2.64	4.98	8.01	10.61
	RdC	0.57	2.98	5.05	8.12	10.93
Cd	GC	0.28	2.01	4.91	5.38	8.62
	RdC	0.29	2.21	4.62	5.01	8.98
Zn	GC	0.98	1.19	5.62	8.81	10.63
	RdC	1.42	2.01	5.77	8.99	10.98
Fe	GC	4.41	6.01	10.62	15.98	18.99
	RdC	4.63	6.94	11.98	16.94	21.04
Cu	GC	2.17	3.83	5.62	6.01	9.62
	RdC	2.27	3.92	5.77	6.13	10.21

GC-Green chillies
RdC-Red chillies

Table-PC14

Results of analysis of soils of different pots of different sets from where samples of green and red chillies are collected for different heavy metal concentrations (mg/kg) in year 2014

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set 5
Pb	0.99	5.17	7.43	10.93	12.59
Cd	0.79	2.94	5.23	7.94	10.41
Zn	1.78	3.27	7.61	9.31	12.43
Fe	5.39	7.85	12.48	17.69	22.43
Cu	2.75	4.59	6.99	7.51	12.16

Table-PC15a

Correlation between average value of different heavy metal concentrations obtained on analysis of green chillies collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.98	0.96	1.00		
Fe	0.99	0.96	0.99	1.00	
Cu	0.97	0.99	0.93	0.94	1.00

Table-PC15b

Correlation between average value of different heavy metal concentrations obtained on analysis of red chillies collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.97	1.00			
Zn	0.98	0.98	1.00		
Fe	0.99	0.96	1.00	1.00	
Cu	0.96	1.00	0.93	0.95	1.00

Table-PC16

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.97	0.99	1.00		
Fe	0.97	1.00	0.99	1.00	
Cu	0.93	0.97	0.97	0.97	1.00

Table-PC17a

Correlation between average value of different heavy metal concentrations obtained from analysis of red chillies collected from different pots of different sets and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in GC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		0.98			
Zn			0.99		
Fe				1.00	
Cu					1.00

GC-Green chillies

Tables-PC17b

Correlation between average value of different heavy metal concentrations obtained from analysis of red chillies collected from different pots of different sets and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in RdC				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		0.97			
Zn			0.99		
Fe				1.00	
Cu					1.00

RdC-Red chillies

Table-PC18

Percent uptake of different heavy metals in green and red chillies from pots of different sets in year 2014

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	GC	59.60	51.06	67.03	73.28	84.27
	RdC	57.58	57.64	67.97	74.29	86.81
Cd	GC	35.44	68.37	93.88	67.76	82.80
	RdC	36.71	75.17	88.34	63.10	86.26
Zn	GC	55.06	36.39	73.85	94.63	85.52
	RdC	79.78	61.47	75.82	96.56	88.33
Fe	GC	81.82	76.56	85.10	90.33	84.66
	RdC	85.90	88.41	95.99	95.76	93.80
Cu	GC	78.91	83.44	80.40	80.03	79.11
	RdC	82.55	85.40	82.55	81.62	83.96

GC-Green chillies
RdC-Red chillies

Table-RC19

Results of analysis of corresponding soils of different sites from where samples of green and red chillies are collected for different physicochemical parameters in the year 2012

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (µ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.632	47.23	47.98	1.141	6.9	186.7	0.0068	0.0072	0.064	0.49	0.36	0.0081
2	0.549	46.35	48.32	1.127	7.1	255.1	0.0071	0.0069	0.059	0.58	0.28	0.0068
3	0.428	49.03	46.18	1.111	6.8	218.3	0.0062	0.0089	0.051	0.68	0.29	0.0063
4	0.594	42.12	45.93	1.173	6.4	195.8	0.0069	0.0071	0.066	0.59	0.19	0.0074
5	0.621	44.25	49.18	1.155	7.2	187.1	0.0071	0.0058	0.073	0.53	0.11	0.0076
6	0.528	46	52.64	1.138	6.8	236.4	0.0079	0.0062	0.085	0.55	0.39	0.0079
7	0.339	43.28	47.85	1.123	6.9	195.6	0.0058	0.0078	0.081	0.64	0.48	0.0068
8	0.417	47.36	52.14	1.145	7.1	215.5	0.0045	0.0075	0.038	0.81	0.41	0.0084
9	0.642	41.59	47.15	1.158	6.6	148.5	0.0035	0.0081	0.086	0.59	0.35	0.0095
10	0.605	48.75	46.23	1.164	6.8	231.8	0.0058	0.0073	0.061	0.55	0.28	0.0091

Table-RC20

Results of analysis of corresponding soils of different sites from where samples of green and red chillies are collected for different physicochemical parameters in the year 2013

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (μ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.561	47.38	78.65	1.125	6.8	214.30	0.0063	0.0089	0.068	0.43	0.41	0.0055
2	0.449	44.15	42.23	1.138	6.5	218.10	0.0081	0.0063	0.059	0.57	0.39	0.0057
3	0.462	46.17	47.56	1.165	6.6	209.30	0.0042	0.0074	0.063	0.63	0.31	0.0081
4	0.528	46.28	43.11	1.121	6.9	181.70	0.0027	0.0059	0.032	0.61	0.43	0.0063
5	0.552	42.14	51.37	1.163	7.6	213.40	0.0055	0.0062	0.049	0.48	0.25	0.0097
6	0.481	47.19	48.35	1.112	5.9	225.80	0.0059	0.0075	0.061	0.47	0.57	0.0072
7	0.449	43.23	49.56	1.184	6.6	192.70	0.0023	0.0059	0.048	0.51	0.33	0.0068
8	0.563	45.85	47.23	1.153	6.3	175.20	0.0065	0.0064	0.027	0.62	0.19	0.0086
9	0.591	43.28	48.36	1.175	6.9	234.20	0.0059	0.0075	0.074	0.57	0.41	0.0082
10	0.552	46.29	49.67	1.139	6.8	199.50	0.0074	0.0073	0.049	0.38	0.32	0.0078

Table-RC21

Results of analysis of corresponding soils of different sites from where samples of green and red chillies are collected for different physicochemical parameters in the year 2014

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (µ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.573	47.38	47.15	1.175	5.9	213.90	0.0083	0.0081	0.0063	0.58	0.24	0.0053
2	0.621	45.82	48.19	1.163	6.8	175.60	0.0064	0.0053	0.0058	0.61	0.19	0.0092
3	0.598	47.37	46.38	1.185	6.9	223.80	0.0073	0.0065	0.0068	0.63	0.39	0.0081
4	0.569	43.59	51.19	1.128	6.5	215.90	0.0035	0.0052	0.0073	0.59	0.48	0.0058
5	0.368	47.32	50.25	1.115	7.1	219.50	0.0048	0.0079	0.0069	0.77	0.46	0.0089
6	0.605	47.65	50.24	1.141	7.3	184.70	0.0051	0.0051	0.0074	0.72	0.12	0.0093
7	0.541	42.69	46.23	1.137	5.6	195.60	0.0049	0.0064	0.0051	0.72	0.47	0.0084
8	0.612	45.39	45.21	1.142	6.2	165.30	0.0067	0.0078	0.0039	0.61	0.38	0.0075
9	0.581	47.65	47.32	1.163	6.7	217.40	0.0075	0.0056	0.0063	0.64	0.25	0.0072
10	0.528	47.12	46.32	1.115	6.9	223.10	0.0068	0.0058	0.0067	0.63	0.53	0.0082

Table-PC19

Results of analysis of reference soil/cultivation media for cultivation of samples of green and red chillies from different pots of different sets collected for different physicochemical parameters in three studied years i.e. 2012, 2013 and 2014

Year	Parameters/ Set no.	Organic matter (%) X-Y	WHC (%) X-Y	Porosity (%) X-Y	Density gm/cm^3 X-Y	pH X-Y	Conductivity (μ mho/cm) X-Y	Nitrate X-Y	Phosphate X-Y	Sulphate X-Y	Calcium X-Y	Magnesium X-Y	Potassium X-Y
2012	1	0.483-0.489	39.54-40.22	43.12-43.97	1.123-1.126	6.7-6.8	153.2-154.9	0.0032-0.0036	0.0041-0.0053	0.031-0.035	0.32-0.35	0.36-0.37	0.0051-0.0053
	2	0.481-0.512	40.55-41.12	42.64-43.64	1.124-1.131	6.6-6.8	155.8-166.9	0.0037-0.0049	0.0042-0.0059	0.036-0.041	0.36-0.39	0.34-0.38	0.0053-0.0062
	3	0.482-0.514	41.14-44.26	41.89-47.25	1.122-1.141	6.3-6.7	155.6-189.3	0.0038-0.0067	0.0054-0.0071	0.034-0.045	0.35-0.46	0.32-0.43	0.0051-0.0059
	4	0.483-0.567	40.83-46.25	42.18-48.37	1.123-1.152	6.1-6.7	152.5-215.3	0.0057-0.0068	0.0043-0.0063	0.039-0.048	0.34-0.47	0.31-0.46	0.0052-0.0064
	5	0.485-0.589	40.73-46.75	41.05-41.25	1.125-1.169	5.8-6.8	153.4-214.6	0.0042-0.0069	0.0050-0.0057	0.041-0.057	0.33-0.42	0.37-0.42	0.0050-0.0061
2013	1	0.421-0.453	41.68-4255	40.84-43.67	1.121-1.125	7.1-7.7	170.3-171.5	0.0041-0.0042	0.0053-0.0069	0.040-0.069	0.36-0.41	0.39-0.46	0.0053-0.0075
	2	0.428-0.432	41.85-44.21	40.21-45.32	1.123-1.138	6.9-7.1	175.3-184.6	0.0051-0.0062	0.0052-0.0074	0.045-0.071	0.35-0.45	0.38-0.59	0.0056-0.0057
	3	0.428-0.445	41.97-45.15	41.54-51.64	1.130-1.136	6.8-6.9	171.8-199.1	0.0043-0.0081	0.0053-0.0065	0.043-0.048	0.36-0.49	0.40-0.46	0.0055-0.0070
	4	0.456-0.487	42.08-46.21	41.28-49.34	1.131-1.139	6.8-6.8	176.2-184.6	0.0051-0.0055	0.0054-0.0068	0.045-0.048	0.37-0.44	0.41-0.47	0.0056-0.0072
	5	0.425-0.513	42.32-47.08	41.81-47.89	1.130-1.169	6.7-6.8	211.9-235.6	0.0053-0.0067	0.0054-0.0078	0.044-0.052	0.38-0.51	0.41-0.52	0.0057-0.0082
2014	1	0.432-0.435	42.05-42.95	41.97-44.65	1.123-1.164	6.5-6.9	175.8-231.2	0.0051-0.0073	0.0054-0.0085	0.045-0.066	0.38-0.60	0.41-0.42	0.0067-0.0068
	2	0.486-0.487	42.26-45.75	41.86-42.75	1.130-1.137	6.3-6.5	184.7-189.2	0.0051-0.0088	0.0044-0.0059	0.043-0.077	0.40-0.49	0.42-0.47	0.0068-0.0076
	3	0.437-0.489	42.57-56.38	41.32-49.36	1.131-1.178	6.7-6.9	174.8-175.8	0.0042-0.0069	0.0041-0.0047	0.039-0.067	0.41-0.43	0.41-0.45	0.0069-0.0071
	4	0.439-0.527	42.85-45.85	41.65-45.32	1.130-1.152	6.7-6.8	175.8-214.2	0.0063-0.0071	0.0052-0.0059	0.037-0.062	0.39-0.47	0.42-0.56	0.0067-0.0082
	5	0.485-0.552	42.13-43.77	41.66-42.14	1.122-1.164	6.8-6.9	199.2-200.3	0.0043-0.0089	0.0056-0.0071	0.036-0.053	0.48-0.55	0.41-0.51	0.0069-0.0088

X- At the time of Plantation

Y- At the time of Harvesting

Table RT-1

Results of analysis of leaves, Stems and fruits of tomato plants collected from different sites for different heavy metal concentrations (mg/kg) in year 2012

Metal	Plant parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	TL	1.83	2.65	1.48	5.23	8.31	4.62	9.93	9.27	5.64	9.84	5.88	0.30
	TS	1.46	2.64	1.23	4.21	8.01	4.05	9.73	9.27	5.49	9.56	5.57	
	TF	1.23	2.02	1.13	5.23	8.32	4.56	9.78	9.03	5.42	9.56	5.63	
Cd	TL	0.83	0.82	0.93	1.17	1.38	0.77	1.95	2.01	0.93	1.59	1.24	0.20
	TS	0.72	0.81	0.82	1.02	1.23	0.65	1.98	1.90	0.78	1.43	1.13	
	TF	0.66	0.89	0.26	1.02	1.02	0.69	1.95	1.84	0.58	1.12	1.00	
Zn	TL	2.69	2.43	1.76	1.99	3.02	3.62	5.01	3.67	2.73	4.00	3.09	100.00
	TS	2.62	2.66	1.38	1.93	2.89	3.00	4.29	3.32	2.65	3.92	2.87	
	TF	2.58	2.63	1.13	1.89	2.88	2.90	4.25	3.18	2.63	3.99	2.81	
Fe	TL	15.98	25.99	14.94	17.05	34.00	18.99	37.39	35.44	21.99	17.64	23.94	200.00
	TS	15.91	25.81	14.52	16.43	33.00	18.13	36.23	35.42	21.58	16.99	23.40	
	TF	15.76	25.44	14.68	16.43	33.69	17.45	35.66	35.42	21.40	16.97	23.29	
Cu	TL	2.84	8.84	2.72	4.78	11.94	8.01	12.63	8.01	9.13	7.97	7.69	40.00
	TS	2.37	8.49	2.52	4.33	11.73	7.90	12.00	8.01	9.32	7.84	7.45	
	TF	2.25	8.33	2.14	4.28	11.64	7.89	11.98	8.43	10.00	7.72	7.47	

TL-Tomato leaf

TS- Tomato stem

TF- Tomato fruit

Table-RT2

Results of analysis of soils of different sites from where samples of leaves, Stems and fruits of tomato plants are collected for different heavy metal concentrations (mg/kg) in year 2012

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	10.69	4.68	8.46	9.46	10.89	7.89	11.46	16.95	7.89	12.49	10.09	10-70
Cd	1.64	1.56	1.29	3.59	2.96	1.85	2.86	2.55	1.64	2.59	2.25	0.07-1.10
Zn	4.25	6.44	2.75	3.14	5.46	4.48	7.85	6.24	5.95	4.96	5.15	10-300
Fe	18.52	39.68	20.42	19.97	35.29	28.77	38.21	36.41	23.18	19.42	27.99	3000-5000
Cu	3.89	9.28	9.48	5.92	12.96	8.14	12.69	10.25	11.42	8.45	9.25	6-60

Table-RT3a

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato leaves collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.88	1.00			
Zn	0.78	0.69	1.00		
Fe	0.66	0.71	0.59	1.00	
Cu	0.71	0.49	0.67	0.80	1.00

Table-RT3b

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato stems collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.86	1.00			
Zn	0.81	0.70	1.00		
Fe	0.68	0.75	0.57	1.00	
Cu	0.74	0.51	0.69	0.78	1.00

Table-RT3c

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato fruits collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.79	1.00			
Zn	0.77	0.73	1.00		
Fe	0.64	0.79	0.53	1.00	
Cu	0.72	0.56	0.69	0.77	1.00

Table-RT4

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.47	1.00			
Zn	0.18	0.11	1.00		
Fe	0.06	0.13	0.77	1.00	
Cu	0.10	0.13	0.63	0.64	1.00

Table-RT5a

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato leaves collected from all sites and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in TL				
	Pb	Cd	Zn	Fe	Cu
Pb	0.68				
Cd		0.62			
Zn			0.71		
Fe				0.87	
Cu					0.81

TL-Tomato leaf

TableRT5b

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato stems collected from all sites and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in TS				
	Pb	Cd	Zn	Fe	Cu
Pb	0.68				
Cd		0.58			
Zn			0.77		
Fe				0.87	
Cu					0.82

TS- Tomato stem

Table-RT5c

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato fruits collected from all sites and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in TF				
	Pb	Cd	Zn	Fe	Cu
Pb	0.67				
Cd		0.63			
Zn			0.76		
Fe				0.86	
Cu					0.82

TF- Tomato fruit

Table-RT6

Percent uptake of different heavy metals in tomato leaves, stems and fruits at different sites in year 2012

Metal	Plant parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	TL	17.12	56.62	17.49	55.29	76.31	58.56	86.65	54.69	71.48	78.78
	TS	13.66	56.41	14.54	44.5	73.55	51.33	84.9	54.69	69.58	76.54
	TF	11.51	43.16	13.36	55.29	76.4	57.79	85.34	53.27	68.69	76.54
Cd	TL	50.61	52.56	72.09	32.59	46.62	41.62	68.18	78.82	56.71	61.39
	TS	43.9	51.92	63.57	28.41	41.55	35.14	69.23	74.51	47.56	55.21
	TF	40.24	57.05	20.16	28.41	34.46	37.3	68.18	72.16	35.37	43.24
Zn	TL	63.29	37.73	64	63.38	55.31	80.8	63.82	58.81	45.88	80.65
	TS	61.65	41.3	50.18	61.46	52.93	66.96	54.65	53.21	44.54	79.03
	TF	60.71	40.84	41.09	60.19	52.75	64.73	54.14	50.96	44.2	80.44
Fe	TL	86.29	65.5	73.16	85.38	96.34	66.01	97.85	97.34	94.87	90.83
	TS	85.91	65.05	71.11	82.27	93.51	63.02	94.82	97.28	93.1	87.49
	TF	85.1	64.11	71.89	82.27	95.47	60.65	93.33	97.28	92.32	87.38
Cu	TL	73.01	95.26	28.69	80.74	92.13	98.4	99.53	78.15	79.95	94.32
	TS	60.93	91.49	26.58	73.14	90.51	97.05	94.56	78.15	81.61	92.78
	TF	57.84	89.76	22.57	72.3	89.81	96.93	94.41	82.24	87.57	91.36

TL-Tomato leaf
TS- Tomato stem
TF- Tomato fruit

Table-RT7

Results of analysis of leaves, Stems and fruits of tomato plants collected from different sites for different heavy metal concentrations (mg/kg) in year 2013

Metal	Plant Parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	TL	1.82	2.02	1.89	3.54	7.22	3.79	8.52	8.52	4.63	6.63	4.86	0.3
	TS	1.66	1.98	1.34	3.47	7.01	3.71	8.43	8.48	4.56	6.63	4.73	
	TF	1.64	1.98	1.33	3.48	7.14	3.26	8.35	8.27	4.48	6.6	4.65	
Cd	TL	1.27	1.83	0.32	1.77	0.96	1.01	2.69	2.63	0.59	0.53	1.36	0.2
	TS	1.13	1.65	0.29	1.29	1.02	0.79	2.65	2.52	0.55	0.49	1.24	
	TF	1.03	1.64	0.25	1.02	0.84	0.74	2.65	2.48	0.52	0.47	1.16	
Zn	TL	2.82	1.75	1.61	0.81	3.00	4.23	4.21	3.52	3.73	4.28	3.00	100
	TS	2.73	1.57	1.58	0.83	2.97	4.00	4.26	3.52	3.62	4.17	2.93	
	TF	2.73	1.20	1.58	0.64	2.97	3.98	4.25	3.44	3.98	4.17	2.89	
Fe	TL	16.75	31.73	11.53	15.62	34.77	18.63	35.83	18.72	22.28	19.98	22.58	200
	TS	16.43	31.73	11.43	15.01	34.28	18.63	35.99	18.38	22.13	19.82	22.38	
	TF	16.42	31.66	11.29	15.68	34.77	18.34	35.98	18.23	22.03	19.78	22.42	
Cu	TL	3.71	8.29	4.65	6.13	8.00	7.49	8.88	7.71	6.00	4.31	6.52	40
	TS	3.59	8.18	4.38	6.01	7.99	7.43	8.56	7.29	6.23	4.18	6.38	
	TF	3.56	8.04	4.33	5.48	7.95	7.40	8.51	7.11	6.58	4.97	6.39	

TL-Tomato leaf

TS-Tomato stem

TF-Tomato fruit

Table-RT8

Results of analysis of soils of different sites from where samples of leaves, stems and fruits of tomato plants are collected for different heavy metal concentrations (mg/kg) in year 2013

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	11.01	5.43	8.14	9.12	10.20	8.10	9.41	16.52	8.00	12.55	9.85	10-70
Cd	1.77	1.92	1.66	3.14	2.12	1.94	4.10	2.85	1.98	2.69	2.42	0.07-1.10
Zn	3.63	7.24	2.70	3.14	4.96	4.62	4.98	6.92	5.12	4.40	4.77	10-300
Fe	20.10	40.52	21.00	20.02	35.63	19.49	40.43	35.94	22.62	20.12	27.59	3000-5000
Cu	8.00	15.15	6.19	15.43	15.00	8.82	10.22	10.25	11.44	18.00	11.85	6-60

Table-RT9a

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato leaves collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.45	1.00			
Zn	0.61	0.02	1.00		
Fe	0.47	0.39	0.27	1.00	
Cu	0.48	0.64	0.16	0.74	1.00

Table-RT9b

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato stems collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.55	1.00			
Zn	0.66	0.15	1.00		
Fe	0.48	0.47	0.29	1.00	
Cu	0.47	0.61	0.17	0.75	1.00

Table-RT9c

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato fruits collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.54	1.00			
Zn	0.61	0.14	1.00		
Fe	0.49	0.48	0.23	1.00	
Cu	0.53	0.56	0.26	0.80	1.00

Table-RT10

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.31	1.00			
Zn	0.14	0.09	1.00		
Fe	0.03	0.39	0.75	1.00	
Cu	0.02	0.25	0.26	0.17	1.00

Table-RT11a

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato leaves collected from all sites and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in TL				
	Pb	Cd	Zn	Fe	Cu
Pb	0.63				
Cd		0.70			
Zn			0.28		
Fe				0.82	
Cu					0.13

TL-Tomato leaf

Table-RT11b

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato stems collected from all sites and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in TS				
	Pb	Cd	Zn	Fe	Cu
Pb	0.62				
Cd		0.69			
Zn			0.26		
Fe				0.82	
Cu					0.16

TS-Tomato stem

Table-RT11c

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato fruits collected from all sites and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in TF				
	Pb	Cd	Zn	Fe	Cu
Pb	0.62				
Cd		0.68			
Zn			0.21		
Fe				0.81	
Cu					0.22

TF-Tomato fruit

Table-RT12

Percent uptake of different heavy metals in tomato leaves, stems and fruits at different sites in year 2013

Metal	Plant parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	TL	16.53	37.20	23.22	38.82	70.78	46.79	90.54	51.57	57.88	52.83
	TS	15.08	36.46	16.46	38.05	68.73	45.80	89.59	51.33	57.00	52.83
	TF	14.90	36.46	16.34	38.16	70.00	40.25	88.74	50.06	56.00	52.59
Cd	TL	71.75	95.31	19.28	56.37	45.28	52.06	65.61	92.28	29.80	19.70
	TS	63.84	85.94	17.47	41.08	48.11	40.72	64.63	88.42	27.78	18.22
	TF	58.19	85.42	15.06	32.48	39.62	38.14	64.63	87.02	26.26	17.47
Zn	TL	77.69	24.17	59.63	25.80	60.48	91.56	84.54	50.87	72.85	97.27
	TS	75.21	21.69	58.52	26.43	59.88	86.58	85.54	50.87	70.70	94.77
	TF	75.21	16.57	58.52	20.38	59.88	86.15	85.34	49.71	77.73	94.77
Fe	TL	83.33	78.31	54.90	78.02	97.59	95.59	88.62	52.09	98.50	99.30
	TS	81.74	78.31	54.43	74.98	96.21	95.59	89.02	51.14	97.83	98.51
	TF	81.69	78.13	53.76	78.32	97.59	94.10	88.99	50.72	97.39	98.31
Cu	TL	46.38	54.72	75.12	39.73	53.33	84.92	86.89	75.22	52.45	23.94
	TS	44.88	53.99	70.76	38.95	53.27	84.24	83.76	71.12	54.46	23.22
	TF	44.50	53.07	69.95	35.52	53.00	83.90	83.27	69.37	57.52	27.61

TL-Tomato leaf
TS-Tomato stem
TF-Tomato fruit

Tables-RT13

Results of analysis of leaves, stems and fruits of tomato plants collected from different sites for different heavy metal concentrations (mg/kg) in year 2014

Metal	Plant parts	Sites										Average	Standard acceptable limits
		1	2	3	4	5	6	7	8	9	10		
Pb	TL	1.52	2.63	2.40	5.73	7.68	5.05	9.83	9.51	7.17	8.99	6.05	0.30
	TS	1.42	2.14	2.31	5.46	7.42	5.01	9.80	9.44	7.08	8.92	5.90	
	TF	1.49	2.02	2.40	5.41	7.44	5.05	9.81	9.40	7.01	8.84	5.89	
Cd	TL	1.00	1.91	0.81	1.27	1.29	0.83	2.31	1.99	1.14	1.42	1.40	0.20
	TS	1.02	1.18	0.81	1.26	1.04	0.81	2.09	1.95	1.13	1.40	1.27	
	TF	1.00	1.13	0.88	1.98	1.02	0.84	2.02	1.94	1.01	1.40	1.32	
Zn	TL	2.13	2.23	1.58	1.63	2.18	3.61	4.60	3.63	2.28	4.21	2.81	100.00
	TS	2.48	2.08	1.47	1.92	2.80	3.17	4.60	3.49	2.15	4.21	2.84	
	TF	2.46	2.04	1.43	1.98	2.82	3.01	4.64	3.44	2.15	4.00	2.80	
Fe	TL	16.13	22.15	16.99	18.72	34.26	19.59	38.56	36.21	25.40	18.00	24.60	200.00
	TS	16.05	22.64	16.98	18.43	34.18	19.43	38.39	36.64	25.43	18.04	24.62	
	TF	16.04	22.34	16.94	18.32	34.14	19.42	38.41	36.10	25.44	18.14	24.53	
Cu	TL	2.61	8.57	3.79	4.99	12.19	8.18	12.34	10.00	11.92	8.44	8.30	40.00
	TS	2.19	8.45	3.77	4.96	12.00	8.63	12.31	9.88	12.00	8.45	8.26	
	TF	2.12	8.41	3.66	4.94	12.62	8.66	12.02	9.43	12.01	8.42	8.23	

TL-Tomato leaves
TS-Tomato stems
TS-Tomato fruits

Table-RT14

Results of analysis of soils of different sites from where samples of leaves, stems and fruits of tomato plants are collected for different heavy metal concentrations (mg/kg) in year 2014

Metal	Sites										Average	Standard acceptable limits
	1	2	3	4	5	6	7	8	9	10		
Pb	8.65	15.48	7.98	9.43	11.12	8.81	9.58	15.01	9.12	13.01	10.82	10-70
Cd	1.20	2.04	1.62	3.62	2.01	1.64	4.61	2.62	1.78	2.52	2.37	0.07-1.10
Zn	3.12	7.62	3.23	3.94	6.32	6.55	6.12	7.44	5.62	6.92	5.69	10-300
Fe	21.64	39.12	28.02	21.49	36.13	19.92	39.11	37.64	32.14	21.09	29.63	3000-5000
Cu	3.98	16.12	8.78	8.62	15.41	8.90	13.02	10.62	12.91	8.92	10.73	6-60

Table-RT15a

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato leaves collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.56	1.00			
Zn	0.70	0.54	1.00		
Fe	0.72	0.72	0.45	1.00	
Cu	0.76	0.55	0.50	0.80	1.00

Table-RT15b

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato stems collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.73	1.00			
Zn	0.76	0.70	1.00		
Fe	0.71	0.72	0.52	1.00	
Cu	0.75	0.46	0.52	0.78	1.00

Table-RT15c

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato fruits collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.60	1.00			
Zn	0.78	0.51	1.00		
Fe	0.71	0.49	0.57	1.00	
Cu	0.73	0.16	0.51	0.77	1.00

Table-RT16

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from all sites in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.09	1.00			
Zn	0.78	0.18	1.00		
Fe	0.49	0.30	0.49	1.00	
Cu	0.47	0.24	0.65	0.80	1.00

Table-RT17a

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato leaves collected from all sites and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in TL				
	Pb	Cd	Zn	Fe	Cu
Pb	0.28				
Cd		0.70			
Zn			0.60		
Fe				0.80	
Cu					0.78

TL-Tomato leaves

Table-RT17b

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato stems collected from all sites and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in TS				
	Pb	Cd	Zn	Fe	Cu
Pb	0.26				
Cd		0.78			
Zn			0.54		
Fe				0.81	
Cu					0.77

TS-Tomato stems

Table-RT17c

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato fruits collected from all sites and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in TF				
	Pb	Cd	Zn	Fe	Cu
Pb	0.24				
Cd		0.89			
Zn			0.52		
Fe				0.80	
Cu					0.79

TS-Tomato fruits

Table-RT18

Percent uptake of different heavy metals in tomato leaves, stems and fruits at different sites in year 2014

Metal	Plant parts	Sites									
		1	2	3	4	5	6	7	8	9	10
Pb	TL	17.57	16.99	30.08	60.76	69.06	57.32	102.61	63.36	78.62	69.10
	TS	16.42	13.82	28.95	57.90	66.73	56.87	102.30	62.89	77.63	68.56
	TF	17.23	13.05	30.08	57.37	66.91	57.32	102.40	62.62	76.86	67.95
Cd	TL	83.33	93.63	50.00	35.08	64.18	50.61	50.11	75.95	64.04	56.35
	TS	85.00	57.84	50.00	34.81	51.74	49.39	45.34	74.43	63.48	55.56
	TF	83.33	55.39	54.32	54.70	50.75	51.22	43.82	74.05	56.74	55.56
Zn	TL	68.27	29.27	48.92	41.37	34.49	55.11	75.16	48.79	40.57	60.84
	TS	79.49	27.30	45.51	48.73	44.30	48.40	75.16	46.91	38.26	60.84
	TF	78.85	26.77	44.27	50.25	44.62	45.95	75.82	46.24	38.26	57.80
Fe	TL	74.54	56.62	60.64	87.11	94.82	98.34	98.59	96.20	79.03	85.35
	TS	74.17	57.87	60.60	85.76	94.60	97.54	98.16	97.34	79.12	85.54
	TF	74.12	57.11	60.46	85.25	94.49	97.49	98.21	95.91	79.15	86.01
Cu	TL	65.58	53.16	43.17	57.89	79.10	91.91	94.78	94.16	92.33	94.62
	TS	55.03	52.42	42.94	57.54	77.87	96.97	94.55	93.03	92.95	94.73
	TF	53.27	52.17	41.69	57.31	81.89	97.30	92.32	88.79	93.03	94.39

TL-Tomato leaves

TS-Tomato stems

TS-Tomato fruits

Pot Tomato

Table-PT1

Results of analysis of leaves, stems and fruits of tomato plants collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2012

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	TL	0.71	3.60	5.84	8.76	12.34
	TS	0.63	3.22	5.49	8.23	10.77
	TF	0.58	3.14	5.47	8.19	10.61
Cd	TL	0.83	2.48	4.04	5.69	10.01
	TS	0.69	2.37	3.73	5.31	8.99
	TF	0.51	2.36	3.69	5.28	8.33
Zn	TL	1.36	2.83	5.95	8.99	11.83
	TS	1.22	2.68	5.81	8.71	11.74
	TF	1.13	2.41	5.41	8.19	11.66
Fe	TL	5.62	6.28	11.21	15.61	21.67
	TS	5.37	6.17	11.10	15.09	20.36
	TF	5.17	5.91	10.12	15.03	18.62
Cu	TL	2.90	3.64	4.99	5.82	10.52
	TS	2.72	3.15	4.92	5.83	10.14
	TF	2.18	3.12	4.80	5.69	10.07

TL-Tomato leaf

TS-Tomato stem

TF-Tomato fruit

Table-PT2

Results of analysis of soils of different sets from where samples of leaves, stems and fruits of tomato plants are collected for different heavy metal concentrations (mg/kg) in year 2012

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set 5
Pb	0.94	4.99	7.89	10.77	12.59
Cd	0.83	3.61	5.81	8.11	11.01
Zn	2.23	3.91	7.14	9.43	13.48
Fe	5.91	6.71	11.73	16.49	22.12
Cu	2.94	4.94	5.64	6.69	10.72

Table-PT3a

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato leaves collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.99	0.97	1.00		
Fe	0.98	0.98	0.99	1.00	
Cu	0.94	0.99	0.93	0.96	1.00

Table-PT3b

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato stems collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.99	0.98	1.00		
Fe	0.98	0.98	1.00	1.00	
Cu	0.94	0.98	0.96	0.97	1.00

Table-PT3c

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato fruits collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.99	0.99	1.00		
Fe	0.98	0.97	1.00	1.00	
Cu	0.94	0.98	0.97	0.95	1.00

Table-PT4

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2012

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.97	0.99	1.00		
Fe	0.94	0.98	0.99	1.00	
Cu	0.92	0.96	0.97	0.95	1.00

Table-PT5a

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato leaves collected from different sets and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in TL				
	Pb	Cd	Zn	Fe	Cu
Pb	0.98				
Cd		0.98			
Zn			1.00		
Fe				1.00	
Cu					0.99

TL-Tomato leaf

Table-PT5b

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato stems collected from different sets and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in TS				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.98			
Zn			1.00		
Fe				1.00	
Cu					0.98

TS-Tomato stem

Table-PT5c

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato fruits collected from different sets and analysis of corresponding soil samples in year 2012

Metal in Soil	Metal in TF				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.99			
Zn			1.00		
Fe				1.00	
Cu					0.99

TF-Tomato fruit

Table-PT6

Percent uptake of different heavy metals in tomato leaves stems and fruits at different sites in year 2012

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	TL	75.53	72.14	74.02	81.34	98.01
	TS	67.02	64.53	69.58	76.42	85.54
	TF	61.70	62.93	69.33	76.04	84.27
Cd	TL	100.00	68.70	69.54	70.16	90.92
	TS	83.13	65.65	64.20	65.47	81.65
	TF	61.45	65.37	63.51	65.10	75.66
Zn	TL	60.99	72.38	83.33	95.33	87.76
	TS	54.71	68.54	81.37	92.36	87.09
	TF	50.67	61.64	75.77	86.85	86.50
Fe	TL	95.09	93.59	95.57	94.66	97.97
	TS	90.86	91.95	94.63	91.51	92.04
	TF	87.48	88.08	86.27	91.15	84.18
Cu	TL	98.64	73.68	88.48	87.00	98.13
	TS	92.52	63.77	87.23	87.14	94.59
	TF	74.15	63.16	85.11	85.05	93.94

TL-Tomato leaf

TS-Tomato stem

TF-Tomato fruit

Table-PT7

Results of analysis of leaves, stems and fruits of tomato plants collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2013

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	TL	0.85	4.01	6.22	8.98	12.01
	TS	0.77	3.89	5.89	8.68	11.63
	TF	0.62	3.85	3.49	8.61	10.63
Cd	TL	0.66	2.99	3.84	6.16	9.26
	TS	0.56	2.91	3.68	5.88	8.92
	TF	0.37	2.01	3.17	5.23	8.01
Zn	TL	1.64	2.89	5.80	8.91	11.99
	TS	1.49	2.73	5.24	8.66	11.48
	TF	1.08	2.51	5.09	8.66	11.72
Fe	TL	6.17	6.93	12.01	16.11	20.41
	TS	5.52	6.32	10.51	15.81	19.11
	TF	5.23	6.01	9.01	15.01	18.30
Cu	TL	2.27	3.61	5.13	5.99	11.62
	TS	2.12	3.45	4.85	5.50	10.64
	TF	1.05	3.01	4.10	5.28	10.12

TL-Tomato leaf

TS-Tomato stem

TF-Tomato fruit

Table-PT8

Results of analysis of soils of different sets from where samples of leaves, stems and fruits of tomato plants are collected for different heavy metal concentrations (mg/kg) in year 2013

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set 5
Pb	0.98	4.99	8.01	10.63	12.72
Cd	0.88	3.19	5.64	8.98	11.42
Zn	2.04	3.82	6.99	9.24	12.79
Fe	6.96	7.38	12.91	16.97	21.18
Cu	2.63	4.99	5.41	6.31	11.63

Table-PT9a

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato leaves collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.99	0.98	1.00		
Fe	0.98	0.97	1.00	1.00	
Cu	0.94	0.96	0.94	0.94	1.00

Table-PT9b

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato stems collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.99	0.98	1.00		
Fe	0.97	0.96	1.00	1.00	
Cu	0.94	0.96	0.94	0.92	1.00

Table-PT9c

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato fruits collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.97	1.00			
Zn	0.97	0.99	1.00		
Fe	0.97	0.98	0.99	1.00	
Cu	0.93	0.98	0.96	0.93	1.00

Table-PT10

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2013

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.98	0.99	1.00		
Fe	0.95	0.99	0.99	1.00	
Cu	0.91	0.93	0.95	0.91	1.00

Table-PT11a

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato leaves collected from different sets and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in TL				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.98			
Zn			1.00		
Fe				1.00	
Cu					0.99

TL-Tomato leaf

Table-PT11b

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato stems collected from different sets and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in TS				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.98			
Zn			0.99		
Fe				1.00	
Cu					0.99

TS-Tomato stem

Table-PT11c

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato fruits collected from different sets and analysis of corresponding soil samples in year 2013

Metal in Soil	Metal in TF				
	Pb	Cd	Zn	Fe	Cu
Pb	0.94				
Cd		0.99			
Zn			0.99		
Fe				0.99	
Cu					0.99

TF-Tomato fruit

Table-PT12

Percent uptake of different heavy metals in tomato leaves, stems and fruits at different sets in year 2013

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	TL	86.73	80.36	77.65	84.48	94.42
	TS	78.57	77.96	73.53	81.66	91.43
	TF	63.27	77.15	43.57	81.00	83.57
Cd	TL	75.00	93.73	68.09	68.60	81.09
	TS	63.64	91.22	65.25	65.48	78.11
	TF	42.05	63.01	56.21	58.24	70.14
Zn	TL	80.39	75.65	82.98	96.43	93.75
	TS	73.04	71.47	74.96	93.72	89.76
	TF	52.94	65.71	72.82	93.72	91.63
Fe	TL	88.65	93.90	93.03	94.93	96.36
	TS	79.31	85.64	81.41	93.16	90.23
	TF	75.14	81.44	69.79	88.45	86.40
Cu	TL	86.31	72.34	94.82	94.93	99.91
	TS	80.61	69.14	89.65	87.16	91.49
	TF	39.92	60.32	75.79	83.68	87.02

TL-Tomato leaf
TS-Tomato stem
TF-Tomato fruit

Table-PT13

Results of analysis of leaves, stems and fruits of tomato plants collected from different pots of different sets for different heavy metal concentrations (mg/kg) in year 2014

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	TL	0.77	3.80	5.79	8.81	11.05
	TS	0.61	3.61	5.66	8.67	10.93
	TF	0.49	3.42	5.14	8.47	10.67
Cd	TL	0.51	2.77	3.91	5.73	8.83
	TS	0.48	2.64	3.40	5.21	8.35
	TF	0.23	2.58	3.29	4.73	7.98
Zn	TL	2.01	2.69	5.77	9.00	11.93
	TS	1.22	2.52	5.61	8.51	11.48
	TF	0.98	1.99	4.92	8.17	11.47
Fe	TL	5.98	7.21	11.98	14.92	19.80
	TS	5.61	7.10	11.03	13.83	19.24
	TF	4.92	6.14	10.17	13.68	18.58
Cu	TL	2.57	3.42	5.92	7.99	9.91
	TS	1.99	3.01	5.61	6.84	8.99
	TF	1.63	2.68	4.98	6.45	8.88

TL-Tomato leaf

TS-Tomato stem

TF-Tomato fruit

Table-PT14

Results of analysis of soils of different sets from where samples of leaves, stems and fruits of tomato plants are collected for different heavy metal concentrations (mg/kg) in year 2014

Metal	Sets				
	Set 1	Set 2	Set 3	Set 4	Set 5
Pb	0.98	5.01	7.61	10.61	12.92
Cd	0.81	3.01	5.62	7.77	11.48
Zn	2.89	3.44	7.28	10.53	13.64
Fe	6.42	8.72	13.15	17.12	20.64
Cu	2.99	4.82	6.89	8.78	11.03

Table-PT15a

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato leaves collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.99	1.00			
Zn	0.98	0.97	1.00		
Fe	0.98	0.98	1.00	1.00	
Cu	0.99	0.97	1.00	1.00	1.00

Table-PT15b

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato stems collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.99	0.97	1.00		
Fe	0.97	0.98	0.99	1.00	
Cu	0.98	0.97	0.99	0.99	1.00

Table-PT15c

Correlation between average value of different heavy metal concentrations obtained on analysis of tomato fruits collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.97	1.00			
Zn	0.98	0.97	1.00		
Fe	0.98	0.97	1.00	1.00	
Cu	0.98	0.97	0.99	1.00	1.00

Table-PT16

Correlation between average value of different heavy metal concentrations obtained from analysis of corresponding soils collected from different pots of different sets in year 2014

Metal	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd	0.98	1.00			
Zn	0.96	0.99	1.00		
Fe	0.98	0.99	0.99	1.00	
Cu	0.99	1.00	0.99	1.00	1.00

Table-PT17a

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato leaves collected from different sets and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in TL				
	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd		0.99			
Zn			1.00		
Fe				0.99	
Cu					0.99

TL-Tomato leaf

Table-PT17b

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato stems collected from different sets and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in TS				
	Pb	Cd	Zn	Fe	Cu
Pb	1.00				
Cd		0.99			
Zn			1.00		
Fe				0.99	
Cu					0.99

TS-Tomato stem

Table-PT17c

Correlation between average value of different heavy metal concentrations obtained from analysis of tomato fruits collected from different sets and analysis of corresponding soil samples in year 2014

Metal in Soil	Metal in TF				
	Pb	Cd	Zn	Fe	Cu
Pb	0.99				
Cd		0.99			
Zn			1.00		
Fe				0.99	
Cu					1.00

TF-Tomato fruit

Table-PT18

Percent uptake of different heavy metals in tomato leaves, Stems and fruits at different sets in year 2014

Metal	Plant parts	Sets				
		Set 1	Set 2	Set 3	Set 4	Set 5
Pb	TL	78.57	75.85	76.08	83.03	85.53
	TS	62.24	72.06	74.38	81.72	84.60
	TF	50.00	68.26	67.54	79.83	82.59
Cd	TL	62.96	92.03	69.57	73.75	76.92
	TS	59.26	87.71	60.50	67.05	72.74
	TF	28.40	85.71	58.54	60.88	69.51
Zn	TL	69.55	78.20	79.26	85.47	87.46
	TS	42.21	73.26	77.06	80.82	84.16
	TF	33.91	57.85	67.58	77.59	84.09
Fe	TL	93.15	82.68	91.10	87.15	95.93
	TS	87.38	81.42	83.88	80.78	93.22
	TF	76.64	70.41	77.34	79.91	90.02
Cu	TL	85.95	70.95	85.92	91.00	89.85
	TS	66.56	62.45	81.42	77.90	81.50
	TF	54.52	55.60	72.28	73.46	80.51

TL-Tomato leaf

TS-Tomato stem

TF-Tomato fruit

Table-RT19

Results of analysis of corresponding soils of different sites from where samples of tomato plant parts are collected for different physicochemical parameters in the year 2012

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (µ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.492	44.7	49.34	1.152	6.6	179.3	0.0064	0.0081	0.053	0.62	0.42	0.0068
2	0.631	47.2	50.11	1.16	7.1	201.1	0.0073	0.0091	0.069	0.68	0.46	0.0074
3	0.628	48.5	52.48	1.182	6.4	213.5	0.0075	0.0089	0.071	0.71	0.63	0.0089
4	0.553	47.1	46.05	1.167	6.2	241.2	0.0072	0.0075	0.085	0.74	0.34	0.0063
5	0.641	48.3	48.39	1.142	6.9	208.3	0.0048	0.0063	0.081	0.62	0.39	0.0052
6	0.524	54.1	46.21	1.141	6.6	185.3	0.0084	0.0095	0.064	0.68	0.43	0.0093
7	0.529	52.00	52.43	1.144	6.3	184.6	0.0091	0.0068	0.069	0.64	0.47	0.0095
8	0.622	50.4	49.31	1.149	5.9	248.5	0.0061	0.0063	0.075	0.67	0.52	0.0071
9	0.621	52.6	52.04	1.123	6.1	192.7	0.0068	0.0072	0.074	0.64	0.41	0.0077
10	0.674	52.4	47.08	1.047	6.2	213.4	0.0037	0.0074	0.081	0.62	0.41	0.0074

Table-RT20

Results of analysis of corresponding soils of different sites from where samples of tomato plant parts are collected for different physicochemical parameters in the year 2013

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (μ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.489	45.6	49.23	1.132	6.7	187.20	0.0065	0.0078	0.061	0.67	0.45	0.0069
2	0.640	47.4	50.17	1.159	7.2	211.30	0.0072	0.0083	0.073	0.76	0.43	0.0078
3	0.622	48.6	52.41	1.179	6.3	233.70	0.0079	0.0094	0.069	0.69	0.59	0.0083
4	0.559	47.4	46.25	1.163	6.5	248.00	0.0068	0.0078	0.087	0.72	0.37	0.0065
5	0.647	48.2	48.73	1.144	6.8	205.90	0.0053	0.0084	0.082	0.81	0.42	0.0058
6	0.523	54.7	46.45	1.138	7.1	189.70	0.0089	0.0093	0.073	0.73	0.46	0.0092
7	0.591	52.71	52.67	1.146	6.5	185.30	0.0094	0.0075	0.065	0.66	0.44	0.0096
8	0.633	50.9	49.03	1.151	6.3	213.70	0.0067	0.0068	0.069	0.61	0.57	0.0073
9	0.672	52.7	52.14	1.119	6.2	194.80	0.0067	0.0077	0.078	0.73	0.48	0.0078
10	0.673	52.5	47.98	1.043	6.1	224.00	0.0053	0.0071	0.083	0.60	0.42	0.0072

Table-RT21

Results of analysis of corresponding soils of different sites from where samples of tomato plant parts are collected for different physicochemical parameters in the year 2014

Parameters/Site no.	Organic matter (%)	WHC (%)	Porosity (%)	Density gm/cm^3	pH	Conductivity (µ mho/cm)	Nitrate	Phosphate	Sulphate	Calcium	Magnesium	Potassium
1	0.513	46.1	48.84	1.123	6.5	184.32	0.0068	0.0071	0.064	0.66	0.41	0.0067
2	0.648	47.4	50.27	1.161	7.1	214.30	0.0071	0.0085	0.071	0.71	0.46	0.0071
3	0.639	48.2	52.13	1.173	6.4	231.61	0.0073	0.0091	0.066	0.73	0.53	0.0085
4	0.628	47.8	46.33	1.164	6.6	248.11	0.0069	0.0077	0.085	0.77	0.39	0.0061
5	0.681	48.7	48.61	1.145	6.7	205.03	0.0057	0.0083	0.087	0.85	0.47	0.0052
6	0.525	54.9	46.94	1.137	7.3	188.71	0.0088	0.0094	0.079	0.79	0.45	0.0089
7	0.59	52.93	52.54	1.147	7.1	185.29	0.0093	0.0076	0.061	0.64	0.51	0.0097
8	0.641	51.6	49.81	1.149	6.8	212.68	0.0072	0.0069	0.067	0.69	0.59	0.0078
9	0.667	53.1	52.27	1.123	6.7	194.87	0.0069	0.0097	0.073	0.74	0.42	0.0075
10	0.671	52.9	47.27	1.143	6.5	224.01	0.0063	0.0081	0.081	0.63	0.46	0.0073

Table-PT19

Results of analysis of reference soil/cultivation media for cultivation of samples of tomato plant parts from different pots of different sets collected for different physicochemical parameters in three studied years i.e. 2012, 2013 and 2014

Year	Parameters /Set no.	Organic matter (%) X-Y	WHC (%) X-Y	Porosity (%) X-Y	Density gm/cm^3 X-Y	pH X-Y	Conductivity (µ mho/cm) X-Y	Nitrate X-Y	Phosphate X-Y	Sulphate X-Y	Calcium X-Y	Magnesium X-Y	Potassium X-Y
2012	1	0.443-0.449	39.32-39.57	39.13-40.18	1.131-1.135	6.9-6.8	161.5-161.8	0.0039-0.0047	0.0043-0.0049	0.041-0.042	0.31-0.32	0.34-0.35	0.0037-0.0039
	2	0.448-0.469	39.47-41.51	39.54-42.31	1.133-1.141	6.8-6.8	162.2-179.1	0.0041-0.0048	0.0047-0.0062	0.039-0.041	0.35-0.39	0.35-0.44	0.0037-0.0042
	3	0.450-0.512	39.12-43.11	40.12-43.21	1.136-1.140	6.5-6.8	164.9-178.3	0.0043-0.0052	0.0054-0.0062	0.038-0.052	0.34-0.47	0.32-0.47	0.0039-0.0051
	4	0.457-0.524	39.40-44.15	40.21-45.13	1.131-1.149	6.3-6.7	189.8-231.1	0.0042-0.0067	0.0067-0.0071	0.043-0.061	0.34-0.41	0.32-0.47	0.0038-0.0069
	5	0.452-0.547	40.32-47.26	39.56-47.22	1.133-1.160	6.9-7.0	204.1-221.9	0.0041-0.0072	0.0052-0.0083	0.039-0.067	0.34-0.42	0.31-0.33	0.0032-0.0071
2013	1	0.422-0.427	38.32-41.65	39.05-40.89	1.132-1.138	7.1-7.0	162.1-173.5	0.0043-0.0048	0.0043-0.0045	0.021-0.038	0.36-0.37	0.31-0.44	0.0041-0.0047
	2	0.433-0.469	39.11-42.29	39.63-42.07	1.134-1.146	6.9-7.1	163.9-216.7	0.0041-0.0049	0.0052-0.0059	0.031-0.035	0.36-0.38	0.34-0.52	0.0042-0.0053
	3	0.438-0.475	39.45-43.36	39.42-43.56	1.131-1.147	7.1-6.9	162.8-185.3	0.0043-0.0059	0.0061-0.0068	0.034-0.041	0.37-0.43	0.31-0.44	0.0041-0.0063
	4	0.438-0.564	40.43-44.26	39.84-44.13	1.138-1.166	7.2-6.8	189.4-245.9	0.0059-0.0065	0.0043-0.0062	0.030-0.051	0.37-0.42	0.33-0.48	0.0040-0.0072
	5	0.435-0.579	39.51-45.86	39.41-45.97	1.130-1.168	6.9-6.8	185.7-192.9	0.0051-0.0071	0.0045-0.0071	0.035-0.041	0.38-0.52	0.34-0.52	0.0043-0.0077
2014	1	0.448-0.469	39.38-41.65	40.14-41.85	1.137-1.139	6.9-7.1	238.7-255.8	0.0043-0.0045	0.0051-0.0067	0.046-0.041	0.36-0.44	0.33-0.37	0.0039-0.0041
	2	0.455-0.489	39.11-43.62	39.13-42.15	1.135-1.149	7.1-6.8	186.8-216.3	0.0042-0.0059	0.0044-0.0059	0.035-0.052	0.37-0.39	0.34-0.42	0.0040-0.0052
	3	0.453-0.511	40.23-44.82	40.17-42.16	1.138-1.150	6.7-6.9	245.9-255.7	0.0042-0.0066	0.0046-0.0071	0.039-0.061	0.37-0.42	0.34-0.47	0.0043-0.0067
	4	0.458-0.529	39.31-46.89	39.62-44.61	1.139-1.152	6.8-6.9	181.3-222.7	0.0041-0.0067	0.0045-0.0069	0.039-0.057	0.38-0.49	0.32-0.48	0.0043-0.0074
	5	0.453-0.564	39.24-47.75	41.15-47.53	1.134-1.171	6.2-6.7	172.5-189.7	0.0042-0.0079	0.0043-0.0061	0.061-0.068	0.38-0.53	0.35-0.51	0.0049-0.0082

X- At the time of Plantation

Y- At the time of Harvesting

Table PCT

General observations during pot experiments in the studied year 2012-2014

Name of Plants	Metal Concentration added (mg/kg)	Percent Survival (%)	Plant Growth	Quality	Yield of Product
Solanum tuberosum L.	0	93	Normal	Standard (as taken)	Standard (as taken)
	5	93	Same as normal	Equal to standard	Same as standard
	10	90	Same as normal	Equal to standard	Same as standard
	15	89	Same as normal	Nearly equal to standard	Slightly below the standard
	20	84	Slightly less than normal	Slightly lower then standard	Below the standard
Capsicum annuum L.	0	96	Normal	Standard (as taken)	Standard (as taken)
	5	95	Same as normal	Equal to standard	Same as standard
	10	92	Same as normal	Equal to standard	Same as standard
	15	91	Slightly less than normal	Nearly equal to standard	Slightly below the standard
	20	89	Less than normal	Slightly lower then standard	Below the standard
Lycopersicum esculentum L.	0	95	Normal	Standard (as taken)	Standard (as taken)
	5	93	Same as normal	Equal to standard	Same as standard
	10	90	Same as normal	Equal to standard	Same as standard
	15	89	Same as normal	Nearly equal to standard	Same as standard
	20	85	Slightly less than normal	Slightly lower then standard	Slightly below the standard

CHAPTER - 4

DISCUSSION ON FINDINGS

Heavy metals have become a chronic problem globally. Soil contamination and pollution has drastically increased due to urbanization and industrialization. Accumulation of heavy metals in plants is particularly dangerous since plants and vegetables are at the bottom of the food chain and are consumed by animals and humans. Consuming the vegetables contaminated with heavy metals has different detrimental effects on human health; therefore monitoring contamination of heavy metals will allow for avoiding unnecessary exposure.

A problem by itself within the whole problem of soil pollution is heavy metal pollution in the acidic soil both naturally acidic and those which have become acidic by the use of mineral fertilizers or acid rain. In general pH decrease leads to an increase in heavy metal mobility and thus to their higher chances of accumulation in plants and vegetables. Heavy metals have a toxic effect but detrimental impacts become apparent only when long term consumption of contaminated vegetables or plants occurs. Excessive build-up of heavy metals in human food chain can be regularly monitored by taking precautions at the time of production, transportation and marketing of vegetables.

Selected heavy metals and their known toxic effects; a brief discussion-

LEAD- Lead is represented by symbol Pb and atomic number 82. Lead as a soil contaminant is of a widespread issue, since lead is present as natural deposits and may also enter the soil through various ways. Major anthropogenic source of lead on a global scale include the combustion of fossil fuels e.g. traffic, non-ferrous metal production, iron and steel production. Gasoline leakage from underground storage tanks, waste lead paints or lead grindings from certain industrial operations, lead mines, fuel combustion. Sewage sludge applications, farmyard manures, refuge incineration are the major sources of lead pollution. Dust and soil lead-derived from flaking, weathering and chalking paint plus air borne lead fallout and waste disposal over the years, are the major proximate sources of potential childhood lead exposure. Lead in drinking water is intermediate but highly significant as an exposure source for both children and fetuses of pregnant women. Food lead also contributes to exposure of children and fetuses. Lead pigments used for coloring toys, tetra ethyl lead used as anti-knocking agents in petrol have been restricted and their use is discontinued because of health hazards. Lead is a poisonous metal that can damage the nervous system and can cause brain disorders. Young children are more vulnerable to lead poisoning because of their tendency to put chips of paint peels into their mouth or suck fingers contaminated with lead laced dust. The children naturally absorb more nutrients from their diet; similarly they absorb more toxicants than a mature body. Children can absorb 30-70 percent of lead from what they eat whereas adults may absorb only about 11 percent (170). Pregnant women showing no signs of lead absorption can pass on lead to her fetus on dangerous levels. Lead poisoning can cause neurological disorders, learning difficulties, poor healing, slow growth rate, mental retardation low IQ scores. It can lead to miscarriage. Chronic high level exposure in males can reduce fertility (74). Long term exposure can cause nephropathy, arthritis, memory impairments, insomnia, loss of concentration, abdominal pains, weakness of joints, anaemia and increase in blood pressure. Exposure at higher levels in children and adults can severely damage kidneys and brain and ultimately may cause death (90). According to Agency for Toxic Substances and Disease Registry (ATSDR, 1999b), the maximum acceptable limit of lead in food stuffs is around 1 mg/kg (7).

Lead is highly hazardous for plants and animals. Lead is incorporated into several crops through absorption by the roots from soil and through direct deposition on plant surfaces. The lead levels in various food crops amounted to 2-136 mg/kg for grains and cereals, 5-649 mg/kg for vegetables and 6-73 mg/kg for oils and fats (WHO/IPCS, 1995). The uptake of soil borne lead by vegetables is very low which explains low lead concentrations in root vegetables, tubers, seeds and fruits as lead is immobilized by the organic matter of soil besides other physico chemical factors. In leafy vegetables the accumulation of airborne lead largely exceeds the soil borne part taken up via roots. Air borne lead is mainly accumulated at the leaf surface and can be removed to a larger extent by washing of the vegetables (116).

CADMIUM- Cadmium is represented by symbol Cd and atomic number 48. Cadmium is an extremely toxic metal commonly found in industrial workplaces. Cadmium is mostly used in rechargeable nickel-cadmium batteries, Helium-cadmium lasers, as a barrier to control neutrons in nuclear fission. Blue, green phosphors for color picture tubes, black and white in other picture tubes. Cadmium pigments are used in strong orange, red and yellow colors, used by artists.

More common sources of cadmium entering the food chain are cereals growing in soil contaminated by sewage sludge, super phosphate fertilizers and irrigation water. Sea foods are also great sources of cadmium poisoning. Solder used to seal cans is also a common source of cadmium. Cadmium used in industry finds its way into many water supplies. Old galvanized pipes and new plastic (PVC) pipes are sources of cadmium in our drinking water (110).

Cadmium is another potential environmental hazard. Acute exposure to cadmium fumes and dust can result initially in metal fume fever which can lead to trachea-bronchitis, pneumonitis pulmonary edema and death (100). Ingestion of significant amount of cadmium may cause damage of liver and kidneys. The bones may become soft and loose mineral density causing osteomalacia and osteoporosis (62). Acute doses (10-30 mg/kg/day) of cadmium in human body can cause severe gastro intestinal irritation, vomiting, diarrhea and excessive salivation (26).

Tobacco smoking is the most important single source of cadmium exposure in the general population. On average smokers have 4-5 times higher blood cadmium concentrations and 2-3 times higher kidney cadmium concentration than non smokers (66). Mining in Japan contaminated Jinzu river with cadmium and traces of toxic metals causing the contamination of agricultural fields. Rice produced got contaminated causing cadmium poisoning resulting in itai-itai disease, renal abnormalities including proteinuria and glucosuria (175).

COPPER- Copper is represented by symbol Cu and atomic number 29. It is a ductile metal with very high thermal and electrical conductivity. It is widely used in electric wires, electromagnets, cathode ray tubes, vacuum tubes, plumbing and industrial machinery.

The United States Environmental Protection Agency (USEPA) has approved the registrations of these copper alloys as, 'antimicrobial materials with public health benefits" because copper alloy coated surfaces have natural intrinsic properties to destroy a wide range of micro-organisms e.g., staphylococcus, clostridium difficile, influenza A virus, adenovirus and fungi. Some proteins like haemocyania, cytochrome c oxidase and superoxide dismutase contain copper. Copper deficiency can produce anaemia, neutropenia, bone abnormalities, hypo-pigmentation, impaired growth, osteoporosis, abnormal metabolism because of its role in facilitating iron uptake.

Copper in blood exists in two forms: bound to ceruloplasmin (85-90%) and the rest 'free' loosely bound to albumin and small molecules. Free copper causes toxicity as it generates reactive oxygen species such as superoxide, hydrogen peroxide, the hydroxyl radical which damage proteins, lipids and DNA and may cause Alzheimer's disease (35). Accumulation of copper in tissues causes Wilson's disease. Acute Symptoms of copper poisoning by ingestion include vomiting, hematemesis (vomiting of blood), hypotension (low blood pressure), melena, coma, jaundice and gastrointestinal distress. Liver and kidney may get damaged on long term copper exposure (36).

Copper toxicity, called copperiedus refers to the consequences of an excess of copper in the body. This may occur from eating acidic foods cooked in uncoated copper cookware from exposure to excess copper in drinking water or other environmental sources. Marine life is at risk because of excess copper in water. Indian childhood cirrhosis (liver cirrhosis in children), has been linked to boiling of milk in uncoated copper cookware (39).

The U.S. Environmental Protection Agency's Maximum Contaminant Level (MCL) in drinking water is 1.3 mg/L. The Occupational Safety and Health Administration (OSHA) has set a limit of 0.1 mg/m^3 for copper fumes (vapor generated from heating copper) and 1.0 mg/m^3 for copper dust (fine metallic copper particles) and mists (aerosol of soluble copper) in workroom air during an eight hour work shift, 40 hours work week (73).

IRON- Iron is represented by symbol Fe and atomic number 26. Iron is widely used in machine tools, automobiles, structural components for buildings, bridges and various other constructions. Iron catalysts are traditionally used in the Haber-Bosch process for the production of ammonia and in Fishcer-Troph process for conversion of carbon-monoxide to hydrocarbons for fuel and lubricants. Iron (III) chloride finds use in water purification and sewage treatment, dyeing of cloth, as coloring agent in paints, as an additive in animal feed and as an etchant for copper in the manufacture of printed circuit boards.

Iron proteins are found in all living organisms viz. haemoglobin, iron-sulphur cluster myoglobin, nitrogenase cytochrome P-450, ferritin and rubredoxin. Many enzymes vital to life contain iron, such as catalase and lipo- oxygenases. MRI finds out the iron accumulation in the hippocampus of the brains for those with Alzheimer's disease and in the substantia nigra of those with Parkinson's disease (34). Iron is quite essential for plant and animal growth and the deficiency may cause various diseases. Its higher concentration also affects the plant growth. Large amounts of ingested iron can cause excessive levels of iron in the blood. High levels of free ferrous iron in blood reacts with peroxides to produce free radicals which are highly reactive and can damage DNA proteins, lipids and other cellular components.

Iron toxicity occurs when there is free iron in the cell, which generally occurs when iron levels exceed the capacity of transferring to bind the iron. Iron generally damages cells in the heart, liver causing significant adverse effects including coma, metabolic acidosis, shock, liver failure, coagulopathy, adult respiratory distress syndrome, organ damage and even death (97). Iron toxicity above 20 mg of iron for every kilogram of mass, and 60 mg per kilogram is considered a lethal dose. Over consumption of Iron, often the result of children eating large quantities of ferrous sulphate tablets intended for adult consumption is one of the most common toxicological causes of death in children under six. The Dietary Reference Intake (DRI) lists the tolerable Upper Intake Level (UIL) for adults as 45mg/day. The acceptable limit for human consumption of Iron is 8 to 11 mg/day, for children under 14 years old the UIL is 40 mg/day (5).

ZINC- Zinc is represented by symbol Zn and atomic number 30. Zinc is commonly used as an anti-corrosion agent, in antifouling paints, as white pigment in paints, catalyst in manufacture of rubber. Ingestion of zinc in larger amounts by human body may occur by consumption of acidic food or drink from a galvanized container or by ingestion of excessive quantities of Zn supplements.

Zinc is an essential mineral that is important for immune function, wound healing, normal taste and smell ability, DNA synthesis. Zinc is mostly present in brain, muscles, bones, kidneys and liver with the highest concentrations in prostate and eyes, plays important role in RNA and DNA metabolism, signal transduction and gene expression. Zinc also supports normal growth development during pregnancy, childhood and adolescence. Zinc containing enzymes are carbonic anhydrase and carboxy peptidase. In blood plasma zinc is bound to and transported by albumin and transferring.

Zn deficiency is usually due to insufficient dietary intake, but can be associated with malabsorption, acrodermatitis enteropathica, chronic liver disease, chronic renal disease, sickle cell disease, diabetes, malignancy and other chronic illness (270). Zinc deficiency in crop plants is the most common micronutrient deficiency. It is particularly common in high pH soils. Soils contaminated with zinc because of mining of zinc ores, refining, zinc containing sludge used as fertilizers can contain several grams of zinc per kilogram of dry soil. Excess of zinc in soil decrease the absorption of other essential metals like iron and manganese and is also helpful to decrease the absorption of toxic cadmium.

Though zinc is essential for human body but excessive absorption of zinc in body suppresses copper and iron absorption (4). The UK recommended ranges of zinc intake are 5.5-9.5 mg/day for males and 4.0-7.0 mg/day for females. A total of 50 mg/day intake of zinc is considered safe. Although an average of 7.0–16.3 mg/day of zinc is usually taken. The recommended dietary allowance for it is 15 mg/day for men and 12 mg/day for women according to ATSDR (1994a). The

U.S. Food and Drug Administration (FDA) have stated that zinc damages nerve receptors in the nose, which can cause insomnia. The consumption of fruit juices, canned food and fruits has resulted in parrot poisonings with zinc because of the use of galvanized cans (77).

Specified discussion on findings of present studies is given in two sections 1 & 2.

Section 1 includes discussion on findings for randomly sampled plant parts

Section 2 contains discussion on findings for plant parts sampled from pot experiments

[1] RANDOMLY SAMPLED PLANT PARTS [IN NATURE]

Discussion for selected plants is given under three different plant wise headings:

[A] POTATO

Unpeeled and peeled potato tubers along with their corresponding soils were randomly sampled from ten different sites around Kota city for three consecutive years 2012, 2013 and 2014. The results obtained are briefly discussed heavy metal wise;

Lead -

The plants grown in soils exposed to different amount of heavy metals accumulated different amounts of lead. As seen from tables RP1, RP2, RP7, RP8, RP13 and RP14 the amount of lead varied from 1.01 mg/kg to 9.99 mg/kg in unpeeled potato tubers. Peeled potato tubers showed 0.34 mg/kg to 8.87 mg/kg variation of lead concentration in three studied years. The highest concentration of lead 9.99 mg/kg was obtained in unpeeled potato tubers collected from site- 5 in the year 2012 while lowest concentration 1.01 mg/kg was obtained from unpeeled potato tubers collected from site-1 in the year 2013. Peeled potato tubers collected from site-9 in year 2012 showed highest lead concentration 8.87 mg/kg and lowest concentration 0.34 mg/kg was found in peeled potato tubers of site-1 in the year 2013.

Cadmium - As seen from tables RP1, RP2, RP7, RP8, RP13 and RP14 the concentration ranged from lowest 0.32 mg/kg in unpeeled potato tuber collected from site-1 in the year 2012 to the highest 2.24 mg/kg in unpeeled potato tubers collected from site-9 in the year 2013. Peeled potato tubers collected from site-3 had lowest concentration 0.24 mg/kg in the year 2014 and the highest concentration of 2.24 mg/kg was shown in peeled potato tubers collected from site-9 in the year 2013.

Zinc - In the present study the concentration of zinc was found highest 5.92 mg/kg in unpeeled potato tubers of site-9 in the year 2014, and a lowest of 1 .00 mg/kg in unpeeled potato tubers of site-3 in the year 2013. Peeled potato tubers of site-9 in the year 2014 also showed highest concentration 5.33 mg/kg and a lowest concentration 0.12 mg/kg was obtained for peeled potato tubers of site-3 in the year 2012. These results were interpreted from tables RP1, RP2, RP7, RP8, RP13 and RP14. Thus it can be said that range of zinc in unpeeled potato tubers was 1.00 to 5.92 mg/kg and for peeled potato tubers it was in the range 0.12 to 5.33 mg/kg in the three studied years.

Iron - Investigation of results obtained in tables RP1, RP2, RP7, RP8, RP13 and RP14 show the value of iron absorbed to a greater extent due to presence of higher iron concentration in soils of the studied area. The lowest concentration of iron 13.54 mg/kg obtained for unpeeled potato tubers was from site-1 in the year 2012 and the highest concentration of 42.00 mg/kg was for unpeeled potato tubers collected from site- 8 in the year 2014. Peeled potato tubers obtained from site-1 showed lowest concentration 13.54 mg/kg and highest concentration 35.23 mg/kg which were collected from site-9.

Copper - Copper is an essential element for plants and animals. Investigation of results obtained from tables RP1, RP2, RP7, RP8, RP13 and RP14 show that the range of copper uptake is within safe limits in case of potato tubers. The lowest concentration in unpeeled potato tubers obtained was from site-3 i.e. 2.18 mg/kg and the highest concentration 15.00 mg/kg was obtained in unpeeled potato tubers obtained from site-9. In case of peeled potato tubers the lowest concentration 2.37 mg/kg from site-3 and highest concentration 14.10 mg/kg from peeled potato tubers of site-9 was seen in the year 2014. The trend of minimum and maximum concentration was observed in all three studied years.

Results of heavy metal determination in potatoes reveal a clear dependence of metal concentration in the potato tubers on metal concentrations in the corresponding soil samples. Lower level of concentrations of metals under investigations was found in plants growing in less polluted areas than those in heavily polluted areas.

The correlation coefficients between different metals in unpeeled and peeled potato tubers separately with the corresponding soil samples are shown in tables RP3a, RP3b, RP4, RP9a, RP9b, RP10, RP15a, RP15b and RP16. It can be seen that the correlation is quite significant. The correlation matrices in tables RP5a, RP5b, RP11a, RP11b, RP17a and RP17b also show that most of the metal concentrations in unpeeled and peeled potato tubers and the corresponding soil samples are significantly correlated.

Percent uptake of different metals from soil to the potato tubers also shows that the sites where percent uptake shown in tables RP6, RP12 and RP18 is higher are more harmful for growing potatoes. However the results reveal that the heavy metal concentrations in the three studied years in case of potato tubers was seen in the order unpeeled potato tubers > peeled potato tubers thus it can be interpreted that the heavy metals get adsorbed near the peels and thus peeling may be beneficial, and may lead to less ingestion of heavy metals by human beings.

Therefore from present studies it can be easily concluded that among the ten different sites chosen for studies near Kota city the risk of uptake of toxic metals in *Solanum tuberosum L.* is highest at site- 9 and 10 decreasing in the order 8, 7 up to 3 and 1 which have lowest uptake. However the physicochemical conditions of the soils are also significant for the uptake of heavy metals.

[B] CHILLIES

Fruits of chilly plants at two stages, green chillies and red chillies were collected along with their corresponding soils randomly from ten different sites near Kota city for three consecutive years 2012, 2013 and 2014. The results obtained are briefly discussed here heavy metal wise;

Lead - The plants grown in the soils exposed to ten different sites/locations accumulated different amounts of lead. As seen from tables RC1, RC2, RC7, RC8, RC13 and RC14 the amount of lead varied from lowest concentration 1.15 mg/kg at site -1 in the year 2013 to a highest concentration 9.34 mg/kg at site-5 in the year 2013 in case of green chillies. Lowest concentration of 1.27 mg/kg at site-1 in the year 2012 and highest concentration 9.99 mg/kg at site-5 in year 2014 was obtained in red chillies. Higher concentration of lead in red chillies than green chilies was observed in three studied years.

Cadmium - As seen from tables RC1, RC2, RC7, RC8, RC13 and RC14 cadmium concentration ranged from lowest 0.38 mg/kg at site-1 in the year 2012 to highest concentration 2.01 mg/kg at site -5 in year 2014 in green chillies. In red chillies 0.01 mg/kg of lowest concentration was obtained at site-1 in the year 2013 while highest concentration 2.38 mg/kg was obtained in year 2014 at site-5. Most of the cadmium concentration values were higher in red chillies than green chillies in three studied years.

Zinc - In the present study the concentration of zinc was found highest in green and red chillies, both collected from site-5 i.e. 4.99 mg/kg in green chillies and 5.20 mg/kg in red chillies in the year 2013, while lowest concentration was found in green and red chillies collected from site-1 i.e.1.26 mg/kg for both, green and red chillies in the year 2013. The range of zinc concentration in green chillies varied from 1.26 mg/kg to 4.99 mg/kg and red chillies showed the variation from 1.26 mg/kg to 5.20 mg/kg as seen/interpreted from tables RC1, RC2, RC7, RC8, RC13 and RC14 in three studied years.

Iron - Present investigation showed higher concentration values of iron owing to iron rich soils in the areas selected for study. As seen from tables RC1, RC2, RC7, RC8, RC13 and RC14 the range of iron in green chillies varied from 13.03 mg/kg to 34.92 mg/kg. The variation in red chillies was from 13.23 mg/kg to 35.91 mg/kg. Lowest concentration in green chillies 13.03 mg/kg was obtained from site-1 in the year 2012 while highest 34.92 mg/kg in green chillies was obtained from site-8 in the year 2013. Lowest concentration in red chillies 13.23 mg/kg was obtained from site-4 in the year 2012 and highest concentration 35.91 mg/kg at site-8 in same year 2012.

Copper - Present studies reveal that the concentration of copper varied from 2.03 mg/kg to 13.86 mg/kg in green chillies and in red chillies the variation ranged from 2.19 mg/kg to 13.73 mg/kg. The lowest concentration 2.03 mg/kg in green chillies was obtained from samples collected from site-1 in year 2013 and highest concentration 13.86 mg/kg was found in samples collected from site-5 in year 2014. Samples of red chillies collected from site 9 in year 2014 showed highest concentration 13.73 mg/kg and lowest concentration 2.19 mg/kg in samples collected in year 2012 from site-3. Investigation of tables RC1, RC2, RC7, RC8, RC13 and RC14 show that sites-3 and site-4, have low concentration of copper uptake in green chillies and red chillies in all three studied years.

Results of heavy metal determination in green chillies and red chillies and their corresponding soil samples revealed a clear dependence of metal concentrations on their metal concentration in the corresponding soil samples. Lower level of concentrations of metals under investigations was found in plants growing in less polluted areas than those in more polluted areas. The correlation coefficients between different metals in green chillies and red chillies and the corresponding soil samples are shown in tables RC3a, RC3b, RC4, RC9a, RC9b, RC10, RC15a, RC15b and R16. It can be seen that they are significantly correlated. The correlation matrices in tables RC5a, RC5b, RC11a, RC11b, RC17a and RC17b also show that most of the metal concentration in green chillies and red chillies and the corresponding soil samples are significantly correlated. Percent uptake of different metals from soil to chillies also shows that sites where percent uptake as shown in tables RC6, RC12 and RC18 is higher are more harmful for growing chillies.

The results reveal that the heavy metal concentrations in the three studied years in case of chillies varied with the stage of maturity. It is seen from results that in most of the samples collected from various sites in three studied years the uptake of heavy metals found was greater in red chillies than green chillies.

Therefore from present studies it can be concluded that among the chosen ten different sites near Kota city the risk of heavy metal uptake in *Capsicum annuum L.* is highest at site-5, decreasing in the order 8, 7 up to 4 and 3. However the physicochemical conditions of the soils are quite responsible for the uptake of heavy besides, plant species, etc.

[C] TOMATO

Tomato plants (leaves, stems and fruits) along with their corresponding soils were randomly sampled from ten different sites around Kota city for three consecutive years 2012, 2013 and 2014. The heavy metal wise results obtained are briefly discussed as:

Lead - The plants grown around Kota city in the soils probably exposed to heavy metals accumulated different amounts of lead. As can be seen from tables RT1, RT2, RT7, RT8, RT13 and RT14, the amount of lead in tomato leaves varied from 1.48 mg/kg to 9.93 mg/kg in the three studied years. Lead concentration varied between 1.23 mg/kg to 9.80 mg/kg in tomato stems and 1.13 mg/kg to 9.81 mg/kg in tomato fruits. The lowest amount of lead in leaves, stems, and fruits of tomato plants was at site -3 in the year 2012 and the highest concentration was as follows:-

Tomato leaves 9.93 mg/kg for site-7 in year 2012

Tomato Stems 9.80 mg/kg for site-7 in year 2013

Tomato fruits 9.81 mg/kg for site- 7 in year 2014

Cadmium - Tables RT1, RT2, RT7, RT8, RT13 and RT14 show the minimum concentration of cadmium absorbed by tomato leaves, stems and fruits as 0.32, 0.29 and 0.25 mg/kg respectively for site-3 in the year 2013. The maximum concentration absorbed was 2.69, 2.65 and 2.65 mg/kg for tomato leaves, stems and fruits respectively which were seen in the year 2013 at site -7.

Zinc - In the present study the concentration of zinc was found lowest 0.81, 0.83 and 0.64 mg/kg in tomato leaves, stems and fruits at site-4 in the year 2013. Highest concentration in tomato leaves and stems was obtained at site-7 in year 2012, which was 5.01, 4.29 mg/kg. The highest concentration in tomato fruits at site-7 in the year 2014 was 4.64 mg/kg.

Iron - Present investigation shows the value of iron much higher than other heavy metals owing to iron rich soils. As seen from tables RT1, RT2, RT7, RT8, RT13 and RT14 the range of iron concentration was 11.53, 11.43 and 11.29 mg/kg in tomato leaves, stems and fruits which was lowest at site-4 in the year 2013. 37.39 mg/kg at site-7 in year 2012 and 38.39, 38.41 mg/kg at site-7 in year 2014 was highest concentration found in tomato leaves, stems and fruits respectively.

Copper - Copper is an essential element for plants and animals. The lowest concentration 2.61, 2.12 and 2.12 mg/kg was found in tomato leaves, stems and fruits in year 2014 at site-1, while the highest concentration was 12.63, 12.31 and 12.32 mg/kg at site- 7 in tomato leaves stems and fruits as seen from tables RT1, RT2, RT7, RT8, RT13 and RT14.

Results of heavy metal determination in plant parts i.e. tomato leaves, stems and fruits revealed a clear dependence of metal concentrations in soils. Lower level of metal uptake was seen in plant parts which grew on less contaminated sites, more polluted the soil, more will be the uptake.

The correlation coefficients between different metals in plant part samples of tomato and corresponding soil samples are given in tables RT3a RT3b RT3c, RT4, RT9a RT9b RT9c, RT10, RT15a RT15b RT15c and RT16. The correlation matrices in tables RT5a, RT5b, RT5c, RT11a, RT11b, RT11c, RT17a, RT17b and RT17c shows that most of the metal concentrations in plant parts and corresponding soil samples are significantly correlated.

Percent uptake of different metals from soils to plant parts also shows that the sites where the uptake tables RT6, RT12 and RT18 is higher are more harmful for cultivation of tomatoes. In general the results show that the uptake of heavy metals studied are in the order tomato leaves > tomato stems > tomato fruits i.e. the translocation of most of the heavy metals is low to the most edible part fruits in case of tomatoes.

Therefore it can be concluded from the present studies that regarding the 10 sites around Kota city the risk of heavy metal uptake in *Lycopersicum esculentum L.* is highest at site-7 decreasing in the order site-8, 5, 9 to lowest at site -3.

II- PLANT PARTS SAMPLED FROM POT EXPERIMENTS-[UNDER CULTIVATION]

DISCUSSION FOR STUDIED PLANTS IS GIVEN AS UNDER (PLANT AND METALS WISE)

[A] POTATO

Cultivated potatoes in pots have shown a trend of increasing metal ion uptake as the concentration of metal ion increases in soil. In present study the unpeeled potato tubers and peeled potato tubers were analyzed for metal ion concentration.

Lead - As can be seen from tables PP1, PP2, PP7, PP8, PP13 and PP14 the plants were cultivated adding five different concentrations of lead solutions, which accumulated different amounts of lead in all the three studied years. Lead by its nature is molecularly sticky and is not very mobile so most of the lead adheres to the roots of the plant and the uptake is less but once it enters into the plants it may be transported into the shoots, leaves and occasionally in the fruits. As the concentration of lead solution increased from set-1 to set-5 an increase in uptake of lead was seen. The increase was steady but when 20mg/kg of lead solution was added, it did not show much uptake, indicating that it is not necessary in case of lead that its uptake reaches the higher limits on increasing the concentration of lead in soil four times. Concentration of lead was found highest in set-5 i.e.11.22 and 10.13 mg/kg for unpeeled potatoes and peeled potatoes, which was treated with 20mg/kg lead solution. Set-1 which was untreated showed lowest concentration for both unpeeled potatoes and peeled potatoes i.e. 0.51 and 0.52 mg/kg. Up to certain level, uptake of metal ions increased with the increase in metal ion concentration of soil.

Cadmium - During the three studied years the cadmium concentration ranged from 0.23 mg/kg to 7.87 mg/kg in unpeeled potatoes and 0.05mg/kg to 7.69 mg/kg in peeled potatoes. It can be seen from tables PP1, PP2, PP7, PP8, PP13 and PP14 that maximum concentration i.e. 7.87 mg/kg and 7.69 mg/kg for unpeeled potatoes and peeled potatoes of cadmium was recorded in the plant samples of set-5 which was treated with the solution containing highest concentration of cadmium salt i.e. 20 mg/kg. While minimum concentration for unpeeled potatoes and peeled potatoes i.e. 0.23 mg/kg and 0.05 mg/kg was recorded for plant samples collected from set-1 which was untreated in the three studied years. A gradual increase in uptake was shown in set-2 and set-3 as they were treated with increasing amount of cadmium salt solutions.

Zinc - Similar trend of increase in zinc uptake was seen in plant samples in the three studied years that as the concentrations of metal in soil increases the uptake also increases. It can be seen from tables PP1, PP2, PP7, PP8, PP13 and PP14 that concentration of zinc was found highest in unpeeled and peeled potato tubers of set-5 i.e. 11.38 mg/kg and 11.36mg/kg respectively which was treated with 20mg/kg of metal salt solution. While the lowest concentration of zinc was observed in the unpeeled potato and peeled potato tubers of set-1 i.e. 1.32 mg/kg and 1.31 mg/kg respectively,which was untreated.

Iron - In the present investigation higher concentration of iron is related to the iron rich soil of the selected area for study. As seen from tables PP1, PP2, PP7, PP8, PP13 and PP14 the concentration of iron was found to be highest in unpeeled potatoes and peeled potato tubers of set- 5 i.e. 18.69 mg/kg and 18.25 mg/kg respectively as it was treated with highest concentration of salt solution, 20 mg/kg. Iron concentration was found to be lowest in unpeeled potato and peeled potato tubers i.e. 4.92 mg/kg and 4.63 mg/kg respectively for set-1, which was untreated.

Copper - The concentration of copper has shown a maximum of 9.43 mg/kg in unpeeled potato tubers to a minimum of 2.00 mg/kg in the same samples. While a maximum of 9.01 mg/kg to a minimum of 1.98 mg/kg was seen in peeled potato tubers in the three studied years. As seen in tables PP1, PP2, PP7, PP8, PP13 and PP14 the maximum uptake was found for samples of set-5 and the minimum for samples for set-1. Set-5 was treated with 20 mg/kg and set-1 was untreated with salt solutions. Copper is one of the essential elements for plants and animals. The anthropogenic sources of copper distribution are pesticides, fertilizers, industrial waste and sewage sludge.

Results of heavy metal determination in unpeeled potato and peeled potato tubers and the corresponding soil samples of pot experiments show dependence on the concentrations of heavy metals added to the pots in three consecutive years 2012, 2013 and 2014. Lower level of concentrations of metals under investigation were found in the samples grown in pots which were treated with lower concentrations of metal solutions than those which were treated with higher ones. The correlation coefficients between different metals in plant samples and the corresponding soil samples are given in tables PP3a, PP3b, PP4, PP9a, PP9b, PP10, PP15a, PP15b and PP16 The correlation matrices also show that most of the metal concentrations in plants and corresponding soil samples are significantly correlated as shown in table PP5a, PP5b, PP11a, PP11b, PP17a and PP17b .Correlation shows that the uptake trend is approximately the same because all metal solutions were added in increasing concentrations. The same trend was seen for the three consecutive years of study.

Percent uptake of different metals from soil to the plants also show that pots where percent uptake, as in tables PP6, PP12, and PP18 is higher for one or two metals in comparison to others are more prone to uptake that metal and even a small increase of that metal in soil can lead to higher uptake. However the uptake may be due to the physicochemical conditions of the soil which might be favorable.

Therefore the pot experiments further confirm the results obtained with randomly sampled unpeeled and peeled potatoes that the uptake of different heavy metals increase with increase in concentrations of metals in soils to a certain limit. Results have also indicated that the heavy metals in case of potato tubers are adsorbed and thus peeling to some extent can lower the heavy metal concentration. Thus proper washing and peeling can make the potatoes safer to some extent for their use, if cultivated in soils contaminated with some extent of heavy metals, though the uptake is mainly governed by physicochemical parameters of soil for a plant species.

[B] CHILLIES

In case of chillies the samples were collected at two stages of ripening the green chillies and fully ripe red chillies. These samples were analyzed separately for heavy metal uptake.

Lead - Results tabulated in tables PC1, PC2, PC7, PC8, PC13 and PC14 show different amounts of lead accumulated in green chilies and red chillies during three years of study. Concentration of lead was found highest in the samples of set-5 i.e. 10.72 mg/kg and 10.99 mg/kg for green chillies and red chillies respectively, this set was treated with highest concentration of lead metal solution i.e. 20mg/kg. While lowest concentration was observed in plant samples i.e. green chillies and red chillies, 0.59 mg/kg and 0.32 mg/kg respectively of set-1 which was untreated.

Cadmium- As seen from tables PC1, PC2, PC7, PC8, PC13 and PC14 the concentration of cadmium ranged between 0.28 mg/kg to 8.71 mg/kg for green chillies and 0.29 mg/kg to 8.98 mg/kg for red chillies in the three studied years. The maximum concentration for both samples was recorded for plant samples from set-5 which was treated with salt solution of highest concentration i.e. 20 mg/kg and the minimum values were obtained for samples of set-1 which was untreated during three studied years. A steady increase in metal uptake was seen with respect to increase in concentration in soil.

Zinc - During present study, uptake of zinc also shows that an increase of heavy metal concentration in soil, results in its higher uptake. As seen from tables PC1, PC2, PC7, PC8, PC13 and PC14, highest concentration was found for plant samples of set- 5 treated with highest concentration of salt solution i.e.20mg/kg. The highest range was 11.63 mg/kg and 11.49 mg/kg for green chillies and red chillies respectively. Samples of set-1 which was untreated in the studied years showed minimum uptake 0.98 mg/kg and 1.12 mg/kg for green chillies and red chillies respectively. A gradual increase for uptake of metals was seen in set-2 and set-3.

Iron - Concentration of iron was found much higher in the samples which signify iron rich soils of the area selected for study. Tables PC1, PC2, PC7, PC8, PC13 and PC14 show that concentration of iron was found highest in plant samples of set-5 which was treated with highest concentration of salt solution i.e. 20 mg/kg and lowest in plant samples of set-1, which was untreated. Green chillies and red chillies showed a maximum in the range of 18.99 mg/kg to 28.43 mg/kg and a minimum in the range of 4.41 mg/kg to 4.63 mg/kg respectively in the studied years.

Copper - Considering the results obtained in tables PC1, PC2, PC7, PC8, PC13 and PC14 it was revealed that plant samples of set -5 showed maximum absorption of metal ion while samples of set -1 showed minimum absorption. The minimum and maximum range of copper absorbed by green chillies and red chillies was 2.14 mg/kg, 2.27 mg/kg and 9.62 mg/kg, 10.21 mg/kg respectively. Set-2 and Set-3 results reveal a higher absorption trend with respect to the higher concentration of metal solution in soil.

Results of heavy metal determination in chillies and the corresponding soil samples of pot experiments revealed a clear dependence on the concentrations of metals added to the pots during three years 2012, 2013 and 2014 of study. A lower uptake of metals was seen in plants grown in pots which were fed with lower metal ion concentration than those which were fed with higher concentrations of metal salts. Studies revealed that uptake of heavy metals by plants are dependent on the maturity level also. Analysis of green and red chillies for uptake of heavy metal was found to be in the order:

Red chillies > Green chillies.

The correlation coefficients between different metals in plant samples and corresponding soil samples are shown in tables PC3a, PC3b, PC4, PC9a, PC9b, PC10, PC15a, PC15b and PC16. The correlation matrices also show that most of the metal concentrations in plants and corresponding soil samples are significantly correlated as represented in tables. PC5a, PC5b, PC11a, PC11b and PC15a, PC15b. Correlation reflects that the uptake trend is approximately same because solutions were added in increasing metal concentrations.

Percent uptake of different metals from soil to the plants also show that the pots where percent uptake as in tables PC6, PC12 and PC18 was higher were more susceptible to uptake of that metal and even a small increase in level of that or those metals in soil can lead to much higher uptake or in other words the physicochemical conditions of soil are more favorable for uptake of metals in these pots.

Therefore pot experiments further confirm the results obtained with randomly sampled analysis of green chillies and red chillies that maturity level and the physicochemical conditions of soil govern the uptake of heavy metals for a plant species.

General discussions regarding percent survival, plant growth, quality and yield of products clearly reveal that there is no recordable change within studied range of concentrations of Pb, Cd, Fe, Cu and Zn metals. At 20mg/kg slightly negative changes were observed i.e. comparatively less percent survival, less plant growth, lower quality and yield than the standards taken then (Plants grown in culture media without adding metals).

[C] TOMATO

Lead - Interpretation of results from the tables PT1, PT2, PT7, PT8, PT13 and PT14. Show that the plants cultivated with five different concentrations of lead accumulated different amounts of lead in all three studied years. Concentration of lead was found to be highest in the samples of set-5. In the present study the plant part considered are tomato leaves, tomato stems and tomato fruit. Set-5 was treated with lead metal solution i.e.20mg/kg, the accumulation of lead in tomato leaves, tomato stems and tomato fruits of set-5 was highest i.e. 12.34, 11.63 and 10.63 mg/kg respectively. While the lowest concentration was observed in plant samples of set-1 i.e. tomato leaves, tomato stems and tomato fruits like 0.71, 0.61 and 0.49 mg/kg respectively, which was untreated and as the added metal concentration increased the uptake also increased.

Cadmium - Analysis of the plant parts i.e. tomato leaves, tomato stems and tomato fruits of set-5 which were treated with highest concentration of cadmium solution i.e.20mg/kg in tables PT1, PT2, PT7, PT8, PT13 and PT14 show that the uptake of cadmium was highest ranging from 10.01, 8.99 and 8.33 mg/kg respectively and were lowest in set-1 which was untreated i.e. 0.51, 0.48 and 0.23 mg/kg respectively for tomato leaves, tomato stems and tomato fruits for the three studied years.

Zinc - Present studies have shown an increase in heavy metal uptake as the concentration increases in the soil. Results of from tables PT1, PT2, PT7, PT8, PT13 and PT14 revealed that the concentration of zinc was found to be highest in samples of set- 5 i.e., 11.99, 11.74 and 11.72 mg/kg in tomato leaves, tomato stems and tomato fruits respectively as this set of plants were treated with highest concentration of salt solution i.e. 20mg/kg, while the lowest concentration of zinc was found in the plants of set-1 which was untreated. The observed concentrations in tomato leaves, tomato stems and tomato fruits were 1.36, 1.22 and 0.98 mg/kg respectively. It was observed that as the concentration of added salt solution increased the uptake of zinc also increased as shown by set-2 and set-3.

Iron - During present investigation the absorption of iron was found to be higher than other metals which can be related to the iron rich soil selected for the study. Tables PT1, PT2, PT7, PT8, PT13 and PT14 shows that the concentration of iron is highest in the samples of set-5 i.e. 21.67, 20.36 and 18.62 mg/kg in tomato leaves, tomato stems and tomato fruits respectively. While it was found to be lower in samples of set-1 which was untreated, 5.62, 5.37 and 4.92 mg/kg in tomato leaves, tomato stems and tomato fruits respectively. The trend was found to be similar for all the three years of study showing that uptake of heavy metal increased with the increase in its concentration in soil.

Copper - The concentration of copper also showed a similar trend. Investigation of tables PT1, PT2, PT7, PT8, PT13 and PT14 indicated that plants of set-5 have shown maximum absorption of copper i.e. 11.62, 10.64 and 10.12 mg/kg in tomato leaves, tomato stems and tomato fruits respectively. While set-1 which was untreated, showed lowest concentrations in tomato leaves, tomato stems, and tomato fruits i.e. 2.27, 1.29 and 1.05 respectively.

Results of heavy metal determination in plant parts of tomato i.e. tomato leaves, tomato stems and tomato fruits and the corresponding soil samples of pot experiments revealed a clear dependence on the concentrations of the metal solutions added to the pots in three consecutive years 2012, 2013 and 2014. Lower level of concentrations of metals under investigation were found in tomato plants grown in pots treated with solutions containing lower concentration of metals than those which were treated with the solutions containing higher ones. Moreover investigation of plant parts generally revealed that the uptake of heavy metals from the corresponding soils in all the sets with low as well as higher concentration of heavy metals in soils were found to be in the order:

Tomato leaves > Tomato stems > Tomato fruits

The correlation coefficient between different metals in plant part samples and corresponding soil samples are shown in the tables PT3a, PT3b, PT3c, PT4, PT9a, PT9b, PT9c, PT10, PT15a, PT15b PT15c and PT16. The correlation matrices also show that most of the metal concentrations in plant parts and corresponding soil samples are significantly correlated as shown in tables PT5a, PT5b, PT5c, PT11a, PT11b, PT11c and PT17a, PT17b and PT17c.

Correlation shows that uptake trend is approximately same because all the metal solutions were added in increasing metal concentrations.

Percent uptake of different metals from soil to the plant parts also show that the pots where percent uptake as in tables PT6, PT12 and PT18 was higher, were prone to uptake of that metal and even a smaller increase in level of those metals in soil can lead to much higher uptake. The physicochemical conditions of soil are also of great concern for the uptake of heavy metals by the plants.

Pot experiments further confirm the results obtained from randomly sampled tomato plant parts that the uptake of metals increases with increase in their concentrations in soil to a certain limit and physicochemical parameters play important role besides the plant species.

CHAPTER - 5

REMEDIATION, SUGGESTIONS AND RECOMMENDATIONS

Globally everyone is potentially vulnerable to the toxic effects of heavy metals. Many toxic heavy metals are ubiquitous in our environment. Researches in the field of environmental medicine reveals the detrimental effects of heavy metals on the functioning of heart, immune system, nervous system etc (9) growing fetus, young children are more susceptible (120).

Metals and their compounds present in the soil fractions vary in the degree of mobility. The bioavailability depends on physical, chemical, biological processes and interaction between them. Various anthropogenic activities without taking any safety measures have caused the problem of heavy metal pollution in the soils which is not going to disappear overnight; on the contrary it will remain as a legacy of mass industrial and anthropogenic activity for many generations and is likely to escalate further in future. Most of the plant species whether crops or weeds are unable to survive on highly contaminated soils due to the toxic effect of heavy metals (257). Thus it is of prime importance to regulate the heavy metal pollution in the soil and to remediate them (259,264).

Zhang X et al. (280) have suggested the use of bio-char to remediate contaminated soils. Bio-char has a large surface area and a high capacity to adsorb heavy metals and organic pollutants in soil through adsorption and other physicochemical reactions. Bio-char is typically an alkaline material which can increase soil pH and effectively stabilize heavy metals. The mechanism is electrostatic interaction and precipitation in case of heavy metals while surface adsorption, partition and sequestration in case of organic contaminants. Similar suggestions are also given by Paz-Ferreiro J et al. and Tang J C et al. (189, 238).

Shrivastav et al.(234) suggested the use of bricks as the geochemical monitor of heavy metal fall out and their study clearly demonstrated the practical feasibility of the above concept at least in some parts of the world. The study indicated that the soil concentrations of Lead, Zinc and Chromium rose initially until between 1950 and 1960 and then fell sharply especially over the last 2-3 decades which was explained as the outcome of socioeconomic fluctuations on a local scale and climatic changes on a global or regional scale.

Plants are able to influence the availability of heavy metals in the rhizosphere due to root exudates and other mechanisms resulting in a change in their phyto-extraction capability. The modern technology of intercropping has been introduced to photo-extract heavy metals from the polluted agricultural soils. Li et al (140) conducted pot experiments to study the effects of 7 intercrops on cadmium uptake by maize. Intercrops included cowpea (*V. unguiculata L.*), purple haricot (*L. Purpureus L.*), chickpea (*C. arietinum L.*), alfalfa (*M. sativa L.*), teosinte (*E. Mexicana schrad*), amaranath (*A. paniculatus L.*) and rapeseed (*B. napus L.*). Most legumes substantially increased cadmium uptake by maize during vegetative growth. Leaf tissues of maize grown with legumes averaged 5.05 mg/kg higher cadmium than, grown with non legumes or 2.42 mg/kg higher than control. Among all chickpea resulted in higher bio-concentration factor of 2.0 and a large transfer factor of 0.55 thus can be regarded as valuable intercrop for enhancing cadmium extraction from soil by maize. However similar studies with willow, indian mustard, vetivar grass also have been reported from various parts of the world (45, 202, 203, 218), yet further studies are going on for better results.

Studies have revealed that most commonly used hyper accumulator plants for phyto extraction of metals, evolved on soils where moisture is limited throughout the year. As plants like Thelaspi, Alyssum and Berkheya are commercially used and are frequently moved from the point of evolution to location where environmental conditions are significantly different, mainly the soil moisture. It was observed that higher biomass of all tested species was generally greater at higher soil moisture and inhibited at low soil moisture. Highest foliar concentrations of Zinc or Nickel were found at two highest water holding capacities of 80 and 100% (15). It can be suggested that above three species can be commercially used as phyto-extracter under non native conditions and the technology can be applied to a wide and diverge range of soil types, climatic conditions and irrigation regimes.

Bu-Olayan A H et al. (37) assessed the heavy metal contents of different desert plants in the areas of Kuwait representing the residential, industrial and recreational sites and concluded that trace metal concentrations were observed the least in the soil when compared to three parts of the desert plant i.e. leaves > shoot > root. Thus trace metal mobilization from soil to these plants characterized them as trace metal pollution indicator. Some higher plant species have developed heavy metal tolerance strategies which enable them to survive and reproduce in highly metal contaminated soils. Strategies of tolerance of heavy metal uptake by three plant species growing near a metal smelter were studied by Dahmani Muller N et al. (54).

Alpaslan B and Yukselon M A (14) suggested stabilization/ solidification/ immobilization techniques which decrease leaching potential of heavy metals from soil by the addition of chemical additives like activated carbon, clay, zeolites, sand, cement etc proving to be cost effective solution for heavy metal contaminated sites. Similar results were shown by liming of soils/ sludges also (33).

Toxicity Characterization Leaching Procedure (TCLP), leaching test developed by United States Environmental protection Agency (UPEPA) were conducted for different additives. Results showed that lime and cement are significantly effective in lead immobilization with 80% over other additives.

Similar results of chemical stabilization of heavy metals are also reported by Barthel J and Edwards S (28) using phosphate based chemicals for stabilizing in-situ or ex-situ, whose strength and effectiveness has been verified using TCLP test parameters and Multiple Extraction Procedure (MEP). EPA has approved the use of non hazardous chemical additive that permanently stabilizes a wide range of heavy metals. This treatment can be applied in wet and dry form, in situ or ex-situ, stabilizing the metal within 24 to 48 hours, though increasing the volume of stabilized waste by 1 to 3%. Metal phosphate compounds have extremely low solubility potential values (Ksp) indicating that it is virtually impossible to dissolve metal-phosphate complexes, thus metal bioavailability is significantly reduced.

Contaminated soil with heavy metals cause many environmental and health problems requiring an effective technological solution. Various technologies are being used to remediate the contaminated soil and ground water. General and conventional approaches for the remediation include isolation, immobilization, toxicity reduction, physical separation, extraction etc.

Physical removal/Excavation and washing- Perhaps one of the oldest technique used for the remediation of contaminated soil, includes excavation and physical removal of soil. Advantages include the complete removal from the contaminated sites (263). Disadvantages include the fact that the contaminants are simply moved to a different place where they must be monitored, the risk of spreading contaminated soil and dust particles during removal and transport of contaminated soil and the relatively high cost. Excavation can be the most expensive option when large amounts of soils are to be removed or disposed. **Surfactant washing** is an ex-situ process; the possible configurations include excavation of contaminated matrix, heaping on the plastic liners or other impermeable barriers and irrigating the piles of contaminated material with washing solutions such as surfactant. **Batch washing** of the contaminated soil in tanks or lined pits and continuous flow washing in counter current or normal modes are other techniques employed. In situ surfactant flushing on the other hand involves the delivery of surfactant solution to the contaminated medium by irrigation and / or injection wells. The contaminant laden surfactant is pumped out through recovery wells (83). It has been shown that crop selection and rotation can effectively reduce the transfer of heavy metals into the human food chain as some plants/crops/vegetables are hyper-accumulators. The cadmium accumulation by crop species are found to be in the following order- Leafy vegetables > root vegetables > grain crops. (112, 221).

Stabilizing metals in the soil:- Heavy metals can be left on site and treated in a way that reduces or eliminates their ability to adversely affect human health and environment. This process is sometimes called stabilization. Kene D R et al.(122) suggested the use of fly ash to stabilize the heavy metals in soil by affecting the physico-chemical properties and decreasing their mobility. Several reports have shown that cadmium concentration can be reduced by the applications of zinc fertilizers. (179). Eliminating the bio- availability of heavy metals has many advantages over excavation. One way of stabilizing heavy metals is adding the chemicals which help in the formation of salts either insoluble or not easily absorbed by plants/animals. This method is called in-situ fixation or stabilization. This process does not interrupt the environment or generate hazardous waste, in turn the compound so found are less toxic. The heavy metals may remain in the soil but in a less harmful or bio- available form. (265). This method is relatively more useful. Still all over the world large number of sites remains contaminated due to expensive technologies available. To overcome this problem newer technologies which are cost effective and eco-friendly are now developed and widely used.

Phyto-remediation consists of mitigating pollutant concentrations in contaminated soils, water or air, with plants able to contain, degrade or eliminate metals, pesticides, solvents, explosives, radio nuclides crude oil and its derivatives and various other contaminants from the media (137). Phyto-remediation of metals is a cost effective 'green technology' based on the use of specially selected metal accumulating plants. Phyto-remediation is considered as an innovative, economical and environmentally compatible solution for remediation of heavy metal contaminated sites (145, 252). Heavy metals may bound or accumulated by particular plants which may increase or decrease the mobility and prevent the leaching of heavy metals into ground water. Growing plants/weeds can help to reduce heavy metal pollution (80, 192, 194, 195, 197).

Various sub-processes of phyto-remediation include -

(i) Phyto-extraction by phyto-accumulator is a technique in which heavy metal hyper-accumulator plants like *Avena strigosa, Crotalaria Juncea and Aspergillus* are used (244, 245). High biomass, metal accumulating plants and appropriate soil amendments are used to transport and concentrate metals from the soil into above ground shoots which are harvested with conventional agricultural methods.

(ii) Phyto-stabilization reduces the mobility of harmful substances in the environment by limiting the leaching thus stabilizing pollutants and rendering them harmless.

(iii) Phyto-transformation is chemical modification of environmental substances as a result of plant metabolism resulting in their inactivation, degradation or immobilization.

(iv) Phyto-stimulation enhances the soil microbial activity for the degradation of contaminants, specially by organisms associated with roots, it involves aquatic plants supporting microbial degraders also thus called as rhizoshere degradation as well.

(v) Phyto-volatalization involves the use of plants mitigating the pollution by extracting volatile metals from the soil/water and volatilizing them through the foliage.

(vi) Rhizofilteration is filtering water through a mass of roots to remove toxic substances. The pollutants remain absorbed or adsorbed to the roots (176).

Plants suitable for phyto-remediation must possess certain characteristics: tolerance to the prevailing contaminant, having profuse root system, a high biomass production [fast growth with large biomass), easy handling and established agricultural practice (Phenotypes suitable for easy harvest, treatment and disposal), and the plant species should preferably be indigenous to the region (67).

Natural processes are often slow to restore ecosystems without the intervention of human beings and may take centuries or longer (220, 246). Selectivity may encourage the establishment of metal tolerant plant species near or on the contaminated sites, though natural immigration of such species may be slow. According to Bradshaw A, “There are genuine difficulties in appropriate species reaching particular sites, especially if the dispersal mechanism of the seeds is poor unless they already occur in the immediate vicinity.” Thus taking use of this selected plant species can often be planted to ensure prompt treatment.

Various plant species playing important role in phyto-remediation are Indian mustard, willow, sunflower, poplars, alfalfa, algae, water hyacinth, fibrous root grass (*Sorghum*) etc. The metals most commonly phyto-remediated are lead, cadmium, cobalt, chromium, Nickel, Radioactive isotopes of uranium, strontium and some organic compounds as well (51, 106). Metal bioavailability depends not only on the chemical properties of the metal but also on the various physico-chemical parameters of the soil like soil pH, electrical conductivity, organic content, clay fraction, etc. All these factors are responsible for the binding ability of metals to soil. Investigation of plants to uptake heavy metals from different kinds of soil profiles varied (82, 233).

The tested plant species were grouped by their capability of heavy metal uptake and sensitivity to high metal pollution (16, 205, 277).

(i) Accumulator and tolerant species e.g. Maize (Zn) or Willow (Cd, Zn), accumulator and moderately sensitive species e.g. Rape (Cd, Zn) or Sorrel (Cd, Cu, Zn), Leek (Cd, Pb, Zn), accumulator and sensitive species eg Black elder (Pb) or Calendula (Zn).

(ii) Moderately accumulator and tolerant species e.g. Orache and Golden rod, moderately accumulator and moderately sensitive species: e.g. Amaranthus, sensitive species e.g. Trigonella.

(iii) Non-accumulator and tolerant species e.g. Horseradish or Ryegrass and sensitive species e.g. Robinia or Maple.

Phyto-remediation is an advantageous technique over the traditional *in-situ* and *ex-situ* processes; as it is cost effective, more over the plants can be easily monitored to ensure proper growth; and the valuable metals can be reclaimed and reused through phyto-remediation. This prevents erosion and preservation of the topsoil. However this technique is slow; require large area, only specific plants with specific characteristics can be used. Higher concentration might be toxic to the plant which can fail the whole technique.

Depending on various researches and findings some recommendations and suggestions for minimization/remediation of heavy metal polluted soil and to sustain the quality of surface soil for further use in and around Kota city of Rajasthan (India) are as follows:

In urban and rural planning or development care should be taken for the environmental aspects and land area should be categorized properly as residential/commercial/industrial or agricultural. Distances recommended should strictly be maintained in between these areas, as distance between the pollution resources and the receiver play an important role.

Location of Industries/development projects should be decided as per the guidelines given by the Ministry of Environment and Forest (MOEF), Central Pollution Control Board (CPCB) and State Pollution Control Board (SPCB). Discharge of effluents from various industries should be under strict vigilance and discharger bodies should not be given liberty but taken as a punishable crime. Risk due to mismanaged storage, handing, and transportation of chemicals, materials and products can affect the soil quality. Discharges from domestic and commercial areas need to be properly controlled. Similarly the solid waste should have proper disposal plan in rural and urban areas i.e. Sewage Treatment Plants (STP).

Automobile workshops should be away from the city and the agricultural areas. Washing of automobiles in rivers or nearby water bodies should be strictly banned.

Various chemical products used in our daily life and agricultural practices are also a major source of soil poisoning. Farmers should be motivated to minimize the use of hazardous chemicals and adopt bio farming, alternate cropping methods, use of compost and manures should be encouraged. Regarding the safety and performance of fertilizers and pesticides, there must be complete quality control by government or authentic agencies. Information regarding the manufacturer, the constituents, grade of material and cautions should be clearly indicated on each pack of pesticides/fertilizers. Farmers should be encouraged for balanced fertilization which includes applications of all essential plant nutrients, judicious use of chemical fertilizers along with other sources of plant nutrients such as organic manures and bio-fertilizers. Farmers should also be educated and encouraged for the use of compost, green manure as soil humus improves the biological and physicochemical properties of soil. Guidelines to the user about the quantity, dilutions, application details and requirements for better performance should be provided with each pack of product. The information about critical ingredients used in the formulation and their effects on the health of human beings and live stock should be provided on the label.

Consumers and small scale industries can minimize the load of pollutants by reformulation of products, modifying the procedures, recovering recycling and reuse of waste products. Time to time dialogue between manufacturers, users, environmentalists and medical/health officers is a must. People belonging to rural or urban areas should be educated to take care of their environment so that they become aware and are able to analyze the problem of ecological imbalance. The knowledge and training that motivate and enable the individual to participate in the societal endeavor to protect the environment and conserve its resources are necessary. Mass communication and media plays an important role in spreading awareness among people about the eco-toxicity of the pollutants. It is the responsibility of the user or the polluter to protect the environment or shall be liable to pay the penalty. Environmental courts should be set up to deal with the cases of violations of environmental laws.

Fiscal incentives can be given for research and development, introduction of clean technologies, recycle and reuse of waste. Pollution abatement policy should focus upon the promotion of clean and green technologies.

Environmental considerations should be incorporated into each and every development plan. As Kota city is expanding, greater cooperation and coordination among Government, various agencies and public is necessary for implementation of Environment Management Plan (EMP). Plant covers, grasses, shrubs and useful trees should be planted on roadsides. Plants and trees helpful for phyto-remediation are better options for the exposed sites. The conditions of the soil and environment pollution are still under control in the studied area but people have to be educated or made aware of the adverse consequences of pollution. Thus awareness and adopting suitable technologies can have a check on poisoning of soil due to heavy metals before it becomes challenging. Monitoring and quality check of the surface soil should be done by the authentic agencies time to time.

BIBLIOGRAPHY

1. Abdel Sabour M F, Mortvedt J J and Kelose J J, Cadmium-Zinc interactions in plants and extractable Cadmium and Zinc fractions in soil, *Soil Sci*., **145**, 424-431, **1988**.
2. Adah C A, Abah J, Ubwa S T and Ekele S, Soil availability and uptake of some heavy metals by three staple vegetables commonly cultivated along the south bank of river Benue Makurdi, Nigeria, *Int. J. Environ. Bioenergy*, **8(2)**, 56-67, **2013**.
3. Adil-ud-Din, Mohammad A I, Abdul Reheem, Hussain Ullah, Ahmed I, Waseem A, Ullah R and Azar Ul Haq Ali Shah, Assessment of heavy metals in Onion and Potato in imported and local variety of Pakistan and Afganistan, *Life Sci. J.*, **10(10s)**, 198-204, **2013**.
4. Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological Profile for Zinc and Cobalt, US Department of Health and Human Service, 205-88-0608, **(1994a)**.
5. Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological profile for Nickel and Iron, US Department of Health and Human Services, Public Health Service, 205-88-0608 **(1994b)**.
6. Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological Profile for Cadmium and Nickel, US Department of Health and Human Services, Public Health Service, 205-95-0606, **(1999a)**.
7. Agency for Toxic Substances and Disease Registry (ATSDR), Toxicological Profile for Lead, US Department of Health and Human Services, 205-93-0606, **(1999b)**.
8. Agyarko K, Darteh E and Berlinger B, Metal levels in some refuse dump soils and plants in Ghana, *Plant Soil Environ*., **56 (5)**, 244-251, **2010**.
9. Alissa E M and Ferns G A, Heavy metal poisoning and cardiovascular disease, *J. Toxicol.*, **2011**, 21 pages, **2011**.
10. Al-Jassir M S, Shaker A and Khaliq M A, Deposition of heavy metals on green leafy vegetables sold on road sides of Riyadh city, Saudi Arabia, *Bull. Environ. Contam. Toxicol*., **75**, 1020-1027, **2005**.

11. Al-Lahham O, El-Assi N M and Fayyad M, Impact of treated waste water irrigation on quality, attributes and contamination of Tomato fruit, *Agric. Water Manage.*, **61(1)**, 51-62, **2003**.

12. Al-Lahham O, El-Assi N M and Fayyad M, Translocation of heavy metals to Tomato fruits irrigated with waste water, *Sci. Hortic*., **113(3)**, 250-254, **2007**.

13. Alloway B J, Cadmium , Heavy Metals in Soil, John Wiley and Sons, Inc., New York, 100-124, **(1990)**.

14. Alpaslan B and Yukselen M A , Remediation of Lead contaminated soils by stabilization/solidification , *Water, Air and Soil Pollut.*, **133 (1-4)**, 253-263, **2002**.

15. Angle S J, Baker A J M, Whiting S N and Chaney R L, Soil moisture effects on uptake of metals by Thalaspi, Asyssum and Berkheye, *Plant Soil*, **256 (2)** 325-332, **2003**.

16. Anton A and Mathe Gasper G, Factors affecting heavy metal uptake in plant selected for phytoremediation, *Z. Naturforschung*, **60**, 244-246, **2005**.

17. Antonious G F and Snyder J C, Accumulation of heavy metals in plants and potential phyto-remediation of Lead by Potato (*Solanum tuberosum L.*), *J. Environ. Sci. Health, part A*, **42**, 811-816, **2007**.

18. Arora M, Bala K, Rani S, Rani A, Kaur B and Mittal N, Heavy metal accumulation in vegetables irrigated with different water sources, *Food Chem*., **111(4)**, 811-815, **2008**.

19. Asdeo A and Loonker S, A comparative analysis of trace metals in vegetables, *Res. J. Environ. Toxicol*., **5(2)**, 125-132, **2011**.

20. Atayese M O, Eigbadon A I, Oluwa K A and Adesodun J K, Heavy metal contamination of Amaranthus grown along major highways in Lagos, Nigeria, *Afr. Crop Sci. J.*, **16(4)**, 225-235, **2008**.

21. Awasthi S K, Prevention of Food Adulteration Act No. 37 of 1954. Central and State rules as amended for 1999, third ed., Ashoka Law House, New Delhi, **(2000)**.

22. Ayodele J T and Oluyomi C D, Grass contamination by trace metals from road traffic, *J. Environ. Chem. Ecotoxicol*., **3(3)**, 60-67, **2011**.

23. Azizian A, Amin S, Maftoun M, Emam Y and Noshadi N, Response of Lettuce to Cd enriched water and irrigation frequencies, *Afr. J. Environ. Sci. Technol*., **5(10)**, 884-893, **2011**.

24. Bagdatlioglu N, Nergiz C ,and Ergonul P G, Heavy metal level in leafy vegetables and some selected fruits, *J. Verbr. Lebensm.*, **5**, 421-428, **2010**.

25. Bahemuka T E and Mubofu E B, Heavy metals in edible green vegetables grown along the sites of the Sinza and Msimbazi rivers in Dar-es-Salaam, Tanzania, *Food Chem.*, **66(1)**, 63-66, **1999**.

26. Baker D E, Anacher M C and Leach R M, Sewage sludge as a source of Cadmium in soil-plant-animal systems, *Environ. Health Perspectives*, **28**, 45-49, **(1979)**.

27. Bansal O P, Competitive adsorption of heavy metals by soils of Aligarh district, *Int. J. Chem. Sci*., **7(2)**, 1439-1446, **2009**.

28. Barthel J and Edwards S, Metal Treatment Technologies , *L.L.C.*, 12441 W. 49th Ave., Suite 3, Wheat Ridge Co 80033, (303), 456- 6977.

29. Behbahaninia A and Mirbagheri S A, Investigation of heavy metals uptake by vegetables crops from metal contaminated soil, World Academy of Science, *Eng. Technol*., **43**, 556-58, **2008**.

30. Benton J and Jones J R, Laboratory guide for conducting soil tests and plant analysis, CRC press, NW corporate BVLD, Boca Raton, Florida, **2000**.

31. Bigdeli M and Seilse Pour M, Investigation of metals accumulation in some vegetables irrigated with waste water in Shahre Rey Iran and toxicological implications, *Am-Eur. J. Agric. Environ. Sci.*, **4(1)**, 86-92, **2008**.

32. Bingham F T, Bioavailability of Cd to food crops in relation to heavy metal content of sludge-amended soil, *Environ. Health Perspect.*, **28**, 39-43, **1979**.

33. Brallier S, Harrison R B, Henry C L and Dongsen X, Liming effects on the availability of Cd, Cu, Ni and Zn in a soil amended with sewage sludge 16 yrs previously, *Water Air and Soil Pollut.*, **86**, 195-206, **1996**.

34. Brar S, Henderson D, Schenck J and Zimmerman E A, Iron accumulation in the substantia nigra of patients with Alzheimer disease and Parkinsonism, *Arch. Neurol*., **66(3)**, 371-374, **2009**.

35. Brewer G J, Iron and Copper toxicity in diseases of ageing, particularly Atherosclerosis and Alzheimer's disease, *Exp. Biol. Med. (Maywood)*, **232(2)**, 323-325, 2007.

36. Brewer G J, Copper toxicity in the general population, *Elin. Neurophysiol*., **121(4)**, 459-460, **2010**.

37. Bu-Olayan A H and Thomas B V, Trace metals sequestration in desert plants of Kuwait, *Res. J. Chem. Environ.*, **13 (3)** , 33-38, **2009**.

38. Cang L, Wang Y J, Zhou D M and Dong Y H, Heavy metal pollution in poultry and livestock feeds and manures under intensive farming in Jiangsu Province, China, *J. Environ. Sci. (China)*, **16(3)**, 371-374, **2004**.

39. Casarett L J and Doull J, Toxicology in the basic science of poisons, Fifth Edition edited by Curtis D K, McGraw-Hill, New York, 715, **2005**.

40. Chang A C, Page A L, Lund L J, Warneke J E, Nelson C O and Yosef B B, Municipal sludges and utility ashes and their effects on soils in inorganic contaminants in the Vadose zone, *Ecological studies*, Springer-Verlag, Berlin, **74**, 125-139, **1989**.

41. Chapman H D, Methods of analysis for soils, plants and waters, University of California, *Div. Agric. Sci.*, **1961**.

42. Chapman S L, Fly ash as a fertilizer and lime sources in Arkansas, *Arkansas Acad. Sci. Proc*., **28**, 20-22, **1984**.

43. Chen T B, Zheng Y M, Lei M, Huang Z C, Wu H T, Chen H, Fan K K, Yu K, Wu B X and Tian Q Z, Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China, *Chemosphere*, **60**, 542-551, **2005**.

44. Cheraghi M, Lorestani B, Merrikhpour H and Rouniasi N, Heavy metal risk assessment for Potatoes grown in over used phosphate fertilized soils, *Environ. Monit. Assess.*, **185(2)**, 1825-1831, **2013**.
45. Chimbira C and Moyo D Z, The effect of single and mixed treatments of Lead and Cadmium on soil bioavailability and yield of *Brassica napus* irrigated with sewage effluent, A potential human risk, *Afr. J. Agric. Res.*, **4(4)**, 359-364, **2009**.
46. Chojnacka K, Chojnacki A, Gorecka H and Gorecki H, Bioavailability of heavy metals from polluted soils to plants, *Sci. Total Environ.*, **337(1-3)**, 175-182, **2005**.
47. Chopra A K, and Pathak C, Bioaccumulation and translocation efficiency of heavy metals in vegetables grown on long term waste water irrigated soil near Bindal river, Dehradun, *Agric. Res.*, **1(2)**, 157-164, **2012**.
48. Chove B E, Ballequ W R, and Chove L M, Copper and Lead levels in two popular leafy vegetables grown around Morogoro Municipality, Tanzania, *Tanzania Health Res. Bull*., **8(1)**, 37-40, **2006**.
49. Christiana Omono M A and Samuel K, Investigation of heavy metal levels in road side agriculture soil and plant samples in Adogo, Nigeria, *Academic J. Environ. Sci.*, **1(2)**, 31-35, **2013**.
50. Codex Alimentarius Commission, Food addictives and contaminants, Joint FAO/WHO Food standards programs, ALNORM 01/12 A, 1-289, **2001**.
51. Comis D, Green Remediation, *J. Soil water Conservn.*, **51**, 184-187, **1996**.
52. Cui Y J, Zhu Y G, Zhai R H, Chen D Y, Huang Y Z, Qiu Y and Liang J Z, Transfer of metals from soil to vegetables in an area near a smelter in Nanning, China, *Environ. Int*., **30**, 785-791, **2004**.
53. Cummings J H, Beatty E R, Kingman S M, Bingham S A and Englyst H N, Digestion and physiological properties of resistant starch in the human large bowel, *Br. J. Nutr.,* **75(5)**, 733-747, **1996**.

54. Dahmani-Muller H, Oort F V, Ge Lie B and Balbane M, Strategies of heavy metals uptake by three plant species growing near a metal smelter, *Environ. Pollut.*, **109 (2)**, 231-238, **2000**.

55. Datta S P, Biswas D R, Saharan N, Ghosh S K and Rattan R K, Effect of long term application of sewage effluents on organic carbon, bio-available phosphorous, potassium and heavy metals by crops, *J. Indian Soc. Soil Sci*., **48**, 836-839, **2000**.

56. Davies B E, Inter-relationships between soil properties and the uptake of Cd, Cu, Pb, Zn from contaminated soils by Radish, *Water, Air and Soil Pollut*., **63(3-4)**, 331-342, **1989**.

57. Davies B E, Cadmium, in Heavy metals in soil, edited by Alloway B J, Blackie, Glasgow, John Wiley and Sons, New York, **100**, **1990**.

58. Davies B E, Lead, in Heavy metals in soil, edited by Alloway B J, Blackie, Glasgow, John Wiley and Sons, New York, **177-196**, **1990**.

59. Dheri G S, Brar M S and Malhi S S, Heavy metal concentration of sewage contaminated water and its impact on underground water, soil and crop plants in Alluvial soils of North-Western India, *Commun. Soil Sci. Plant Anal*., **38(9-10)**, 1353-1370, **2007**.

60. Di Salvatore M, Carratu G and Carafa A M, Assessment of heavy metal transfer from a moderately polluted soil into the edible parts of vegetables, *J. Food Agric.Environ*., **7(2)**, 683-688, **2009**.

61. Dogheim S M, Ashraf E L M M, Alla S A G, Khorshid M A and Fahmy S M, Pesticides and heavy metal levels in Egyptian leafy vegetables and some aromatic medicinal plants, *Food Addit. Contam*., **21(4)**, 323-330, **2004**.

62. Dunbar K R, McLaughlin M J, and Reid R J, The uptake and partitioning of Cadmium in two cultivars of Potato (*Solanum tuberosum L.*), *J. Exp. Bot.*, **54(381)** ,349-354, **2003**.

63. Elbagermi M A, Edwards H G M and Alajtal A I, Monitoring of heavy metal content in fruits and vegetables collected from production and market sites in the Misurata area of Libya, *ISRN Anal. Chem.*, **2012**, 1-5, **2012.** Article ID 827645

64. Ellen G, Van I W and Tolsma K, Heavy metals in vegetables grown in the Netherlands and in domestic and imported fruits, *Int. Z. Lebensm Unters Forsch*, **190**, 34-39, **1990**.
65. Ellis K J, Vartsky D and Cohn S H, In vivo monitoring of heavy metals in man; Cadmium and Mercury, *Neurotoxicol*., **4(3)**, 164-168, **1983**.
66. Engvall J and Perk J, Prevalence of hypertension among Cadmium exposed workers, *Arch. Environ. Health*, **40(3)**, 185-190, **1985**.
67. Ensley Burt D, "Rationale for the use of phytoremediation" in Phytoremediation of Toxic Metals-using plants to clean up the environment, John Wiley and Sons, **2000**.
68. Eshun K and He Q, Aloevera: a valuable ingredient for the food, pharmaceutical and cosmetic industries- a review, *Crit. Rev. Food. Sci. Nutr*., **44(2)**, 91-96, **2004**.
69. Essiett U A, Effiong G S, Ogbemudia F O and Bruno E I, Heavy metal concentrations in plants growing in crude oil contaminated soil in Akwa Ibom state, south-eastern Nigeria, *Afr. J. Pharm. Pharmacol*., **4(7)**, 465-470, **2010**.
70. European Commission Decision of 12 October, 2006 amending, for the purposes of adapting to technical progress, the Annex to Directive 2002/95/EC of the European Parliament and of the council as regards exemptions for applications of Lead and Cadmium as notified under document number C, 2006, 4790.
71. Farooq M, Anwar F and Rashid V, Appraisal of heavy metal contents in different vegetables grown in the vicinity of an industrial area, *Pak. J. Bot.*, **40(5)**, 2099-2106, **2008**.
72. Federal Environmental Protection Agency (FEPA), Principles of Environmental Chemistry, Metro Prints Ltd., Port Harcourt, Nigeria, **1998**.
73. Federal Register/vol 65, NO 8/ Wednesday, January 12, 2000/ Rules and Regulations, 1976, **2000**.
74. Feleafel M N and Mirdal Z M, Hazards and effects of pollution by Lead on vegetable crops, *J. Agric. Environ. Ethics*, **26(3)**, 547-567, **2013**.

75. Flemming C A and Trevors J T, Copper toxicity and chemistry in the environment ; a review, *Water Air and Soil pollut*., **44(1-2)**, 143-158, **1989**.

76. Flemotomou E, Molyviatis T and Zabetakis I, The effect of trace elements accumulation on the levels of secondary metabolites and antioxidant activity in Carrots, Onions and Potatoes, *Sci. Res*., **2(10)**, 1071-1076, **2011**.

77. Fosmire G J, Zinc toxicity, *Am. J. Clin. Nutr*., **51(2)**, 225-227, **1990**.

78. Fytianos K, Katsianis G, Triantafyllou P and Zachariadis G, Accumulation of heavy metals in vegetables grown in an industrial area in relation to soil, *Bull. Environ. Contam. Toxicol*., **67(3)**, 423-430, **2001**.

79. Gerster H , The potential role of Lycopene for human health, *J. Am. Coll. Nutr.*, **16(2)**, 109-126, **1997**.

80. Ghosh M and Singh S P, A comparative study of Cadmium phytoextraction by accumulator and weed species, *Environ. Pollut*., **133(2)**, 365-371, **2005**.

81. Ghosh R, Xalxo R, Gope M C, Mishra S, Kumari B and Ghosh M, Estimation of heavy metals in locally available vegetables collected from road side market sites of different areas of Ranchi city, *PHARMBIT*, **23** and **24(1-2)**, 68-73, **2011**.

82. Golia E E, Dimirkou A and Mitsios I K, Influence of soil parameters on heavy metals accumulation by vegetables grown in agricultural soil of different soil orders, *Bull. Environ. Contam. Toxicol.*, **81(1)**, 80-84, **2008**.

83. Gupta M K, Srivastava R K and Singh A K, Bench scale treatability studies of contaminated soil using soil washing technique, *E-J of chem*., **7(1)**, 73-80, **2010**.

84. Gupta N, Khan D K and Santra S C, Heavy metal accumulation in vegetables grown in a long term waste water irrigated agricultural land of tropical India, *Environ. Monit. Assess*, **184(11)**, 6673-82, **2012**.

85. Gupta N, Khan D K and Santra S C, An assessment of heavy metal contamination in vegetables grown in waste water irrigated areas of

Titagarh, West Bengal, India, *Bull. Environ. Contam. Toxicol.*, **80**, 115-118, **2008**.

86. Gupta S and Jain R, Impact of sewage water on physico-chemical characteristics of soil of Bikaner city, *Asian J. of chem.*, **15(3and4)**, 1284-1290, **2003**.

87. Gupta S, Satpati S, Nayek S and Garai D, Effect of wastewater irrigation on vegetables in relation to bio-accumulation of heavy metals and bio-chemical changes, *Environ. Monit. Assess.*, **165(1-4)**, 169-177, **2010.**

88. Gupta U C and Gupta S C, Trace element toxicity relation SWPS to crop production and livestock and human health. Implications for management, *Commun. Soil Sci. Plant Anal.*, **29(11-14)**, 1491-1522, **1998.**

89. Hai-Ning Y U, Zun-Chen W, Sheng-Rong S and Wel-Guang S, Effects of Capsaicin and its analogs on the growth of gastric cancer cells and their structure activity relationships in vitro, *Food Sci. Technol. Res.*, **19(5)**, 865-873, **2013**.

90. Hardiyanto and De Guzman C C, Identification of Lead and Cadmium levels in white Cabbage (*Brassica rapa L.*), soil and irrigation water of urban agricultural sites in Philippines, *Indonesian J. of Agric. Sci*., **9(1)**, 1-6, **2008**.

91. Hashmi D R, Khan F A, Shaikh G H and Usmani T H, Determination of trace metals in the vegetables procured from the markets of Karachi city by Atomic Absorption Spectrophotometer, *J.Chem. Soc. Pak.*, **27(4)**, 353-357, **2005**.

92. Hashmi D R, Ismail S and Shaikh G H, Assessment of the level of trace metals in commonly edible vegetables locally available in the markets of Karachi city, *Pak. J. Bot.*, **39(3)**, 747-751, **2007**.

93. Hayes A W, Principles and Methods of Toxicology, Philadelphia, CRC Press, 858-861, **2007**.

94. He Z L, Zhang M K , Calvert D V, Stoffela P J , Yang X E and Yu S , Transport of heavy metals in surface run off from vegetable and citrus fields, *Soil Sci. Soc. Am.*, **68**, 1662-1669, **2004**.

95. Henningsen P F, Urushadze T, Steffens D, Ralandadze B and Narimanidze E, Uptake of heavy metals of food crops from highly polluted Chernozen Tbilisi, Eastern Georgia, *Agron. Res.*, **8(1)**, 781-795, **2010**.

96. Holmgren G G S, Meyer M W and Chaney R L, Cd, Pb, Zn, Cu and Ni in agricultural soils of the United States of America, *J. Environ. Qual.*, 22, 335-348, 1993.

97. Hoppe M, Hulthen L and Hallberg L, The relative bioavailability in humans of elemental iron powders for use in food fortification, *Eur. J. Nutr*., **45(1)**, 37-44, **2005**.

98. Hylla S, Gostner A, Dusel G, Anger H, Bartram H P, Christi S U, Kasper H and Scheppach W, Effects of resistant starch on the colon in healthy volunteers possible implication for cancer prevention, *Am. J. Clin. Nutr.*, **67(1)**, 136-142, **1998**.

99. ICP Forest Manual, Part-IIIa, Soil Sampling and Analysis, **1998**.

100. Igwegbe A O, Belhaj H M, Hassan T M and Gibali A S, Effect of a highways traffic on the level of Lead and Cadmium in fruits and vegetables grown along the roadsides, *J. Food Saf.*, **13(1)**, 7-18, **1992**.

101. Inoti K J, Fanuel K, George O and Paul O, Assessment of heavy metal concentrations in urban grown vegetables in Thika town, Kenya, *Afr. J. Food Sci*., **6(3)**, 41-46, **2012**.

102. Intawongse M and Dean J R, Uptake of heavy metals by vegetable plants grown on contaminated soil and their bioavailability in the human gastrointestinal tract, Food Additives and Contaminants, **23**, 36-48, **2006**.

103. Islam E U, Yang X E, He Z L and Mahmood Q, Assessing potential dietary toxicity of heavy metals in selected vegetables and food crops, *J. Zhejiang Univ. Sci. B*, **8(1)**, 1-13, **2007**.

104. Ismail B S, Farihah K and Khairiah J, Bioaccumulation of heavy metals in vegetables from selected agricultural areas, *Bull. Environ. Contam. Toxicol.*, **74(2)**, 320-327, **2005**.

105. Izadiyar M H and Yargholi B, Study of Cadmium absorption and accumulation in different parts of four forages, *Am-Eur. J. Agric. Environ. Sci.*, **9(3)**, 231-238, **2010**.

106. Jadia C D and Fulekar M H, Phytotoxicity and remediation of heavy metals by fibrous root grass (*Sorghum*), *J. Appl. Biosci.*, **10**, 491-499, **2008**.

107. Jafarian Dehkordi A and Alehashem M, Heavy metal contamination of vegetables in Isfahan, Iran, *Res. Pharm. Sci.*, **8(1)**, 51-58, **2013**.

108. Jankaite A, Baltrenas P and Kazlauskiene A, Heavy metal concentrations in road side soils of Lithuania's highways, *Geologija*, **50(64)**, 237-245, **2008**.

109. Jarup L, Hazards of heavy metal contamination, *Brit. Med. Bull.*, **68(1)**, 167-182, **2010**.

110. Jarup L, Health effects of Cadmium exposure: a review of the literature and risk estimate, *Scandinav. J. work. Environ. Health*, **24**, 11-51, **1998.**

111. Jassir M S, Shaker A and Khaliq M A, Deposition of heavy metals on green leafy vegetables sold on road sides of Riyadh city, Saudi Arabia, *Bull. Environ. Contam. Toxicol.*, **75(5)**, 1020-1027, **2005**.

112. John M K, Cadmium uptake by eight food crops as influenced by various soil levels of Cadmium, *Environ. Pollut.*, **4**, 7-15, **1973**.

113. Joint FAO/WHO Expert committee on Food Additives, Summary and conclusions, in 53rd meeting, Rome, June 1-10, 1999.

114. Joint FAO/WHO food standard programme, Codex Alimentarious Commission. Doc No. Cx FAC 96 codex general standard for contaminants and toxins in foods, **1996**.

115. Jolly Y N, Islam A and Akbar S, Transfer of metals from soil to vegetables and possible health risk assessment, Springer plus, **2**, 385, 1-8, **2013**.

116. Jorhem L and Sundstroem B, Levels of Lead, Cadmium, Zinc, Copper, Nickel, Chromium, Manganese and Cobalt in foods on the Swedish market, *J. Food Comp. Anal.*, **6**, 223-241, **1993**.

117. Kabata Pendias A and Pendias H, Trace elements in soils and plants, CRC Press, Boca Raton, **1984**.

118. Kachenko A G and Singh B, Heavy metals contamination in vegetables grown in urban and metal smelter contaminated sites in Australia, *Water, Air and Soil Pollut.*, **169**, 101-123, **2006**.

119. Kalra Y, Methods for plant Analysis, CRC Press, NW Corporate BVLO, Boca Raton, Florida, LLC, **2000**.

120. Kapoor N and Tiwari P, Effect of heavy metal poisoning during pregnancy, *Int. Res. J. Environ. Sci.*, **2 (1)**, 88-92, **2013**.

121. Kapungwe E M, Heavy metal contaminated water, soils and crops in periurban wastewater irrigation farming in Mufulira and Kafue towns in Zambia, *J. Geogr. Geol.*, **5(2)**, 55-72, **2013**.

122. Kene D R, Lanjewar S A, Ingole B M and Chjaphale S D, Effect of application of Fly ash on Physico chemical properties of soil, *J. Soils Crops*, **1**, 11-18, **1991**.

123. Khairiah J I, Yin H Y, Ibrahim N K, Wee W A, Aminah A S, Maino A A, Zalifah M K, and Giber K G, Bioavailability of Chromium in vegetables of selected agricultural areas of Malaysia, *Pak. J. Biol. Sci.*, **5(4)**, 471-473, **2002**.

124. Khairiah T, Zalifah M K, Yin Y H and Aminath A, The uptake of heavy metals by fruit type vegetables, grown in selected agricultural areas, *Pak. J. Biol. Sci.*, **7(2)**, 1438-1442, **2004**.

125. Khan A K, Chakzai A, Bazai Z A and Kayani S A, Accumulation of heavy metals by Lettuce (*Lactuca sativa L.*) irrigated with different levels of wastewater of Quetta city, *Pak. J. Bot.*, **43(6)**, 953-2960, **2011**.

126. Khan S, Cao Q, Zheng Y M, Huang Y Z and Zhu Y G, Health risk of heavy metals in contaminated soils and food crops irrigated with waste water in Beijing, China, *Environ. Pollut.*, **152(3)**, 686-692, **2008**.

127. Khan S, Farooq R, Shahabaz S, Khan M A and Sadique M, Health risk assessment of heavy metals for population via consumption of vegetables, *World App. Sci. J.*, **6(12)**, 1602-1606, **2009**.

128. Khanam D, Rahman S H, Islam M S, Ahsan M A, Shaha B and Akbor M A, Seasonal implication of heavy metal contamination of surface water around Dhaka Export Processing Zone (DEPZ), Savar, Bangladesh, Jahangirnagar, *Univ. J. Sci.,* **34(2)**, 21-35, **2011**.

129. Kihampa C, Mwegoha W J S and Shemdoe R S, Heavy metal concentrations in vegetables grown in the vicinity of the closed dumpsite, *Int. J. Environ. Sci.*, **2(2)**, 889-895, **2011**.

130. Kisku G C, Barman S C and Bhargava S K, Contamination of soil and plants with potentially toxic elements irrigated with mixed industrial effluent and its impact on the environment, *Water Air Soil Pollut.,* **120**, 121-137, **2000**.

131. Kloke A, Sauerback D R and Vetter H, Changing metal cycles and human health, Edited by Nriagu J O, Springer-Verlag, Berlin, **1984**.

132. Krishna A K, and Govil P K, Soil Contamination due to heavy metals from an industrial area of Surat, Gujarat, Western India, *Environ. Monit. Assess*., **124(1-3)**, 263-275, **2007**.

133. Kuboi T, Noguchi A and Yazaki J, Family dependent Cadmium accumulation characteristics in higher plants, *Plants Soil*, **92**, 405 -415, **1986**.

134. Kumar N, Soni H and Kumar R N, Characterization of heavy metals in vegetables using ICPA, *JASEM*, **11(3)**, 75-79, **2007**.

135. Lacatusu R and Lacatusu A R, Vegetables and fruit quality within heavy metal polluted areas in Romania, *Carpth. J. Earth Environ. Sci.,* **3(2)**, 115-129, **2008**.

136. Ladwani K D, Ladwandi K D, Manik V S and Ramteke D S, Impact of domestic wastewater irrigation on soil properties and crop yield, *Int. J. Sci. Res. Publ.*, **2(10)**, 1-7, **2012**.

137. Lambert M, Leven B A and Green R M, New methods of cleaning up heavy metals in soils and water, Innovative solutions to an environmental problem, *Environ. Sci. Technol.*, Briefs for citizens, Kansas State University, 101, Ward Hall, Manhattan, KS 66506

138. Langer werff J V, Uptake of Cadmium, Lead and Zinc by Radish from soil and air, *Soil Sci.*, **3**, 129-133, **1971**.

139. Levy J, Bosin E, Feldman B, Giat Y, Minister A, Danilenko M and Sharoni Y, Lycopene is a more potent inhibitor of human cancer cell proliferation than either alpha-carotene or beta-carotene, *Nutr. Cancer*, **2493**, 257-266, **1997**.

140. Li N Y , Li Z A, Zhuang P, Zou B and Mc Bride M, Cadmium uptake from soil by Maize with intercrops, *Water, Air and Soil Pollut.*, **199**, 45-56, **2009**.

141. Lippard S J and Berg J M, Principles of Bioinorganic Chemistry, Mill Valley ,California, University Science Books, **1994**.

142. Liu Y W, Han C H and Lee M H, Patatin, the tuber storage protein of Potato (*Solanum tuberosum L.*), exhibits antioxidant activity in vitro, *J. Agric. Food Chem.*, **51(15)**, 4389-4393, **2003**.

143. Lokeshappa B, Shivpuri K, Tripathi V and Dikshit A K, Assessment of toxic metals in agricultural produce, *Food Public Health*, **2(1)**, 24-29, **2012**.

144. Lokeshwari H and Chandrappa G T, Impact of heavy metal contamination of Bellandur lake on soil and cultivated vegetation, *Current Sci.*, **91(5)**, 622-27, **2006**.

145. Lombi E, Zhao F J, Dunham S J and Mc Grath S P, Phytoremediation of heavy metal contaminated soils, natural hyper accumulation versus chemically enhanced phytoextraction, *J. Environ. Qual.*, **30(6)**, 1919-1926, **2001**.

146. Low P A, Opfer-Gehrking T L, Dyck P J, Litchy W J and O’Brien P C, Double blind placebo controlled study of the application of Capsaicin cream in chronic distal painful polyneuropathy, *Pain*, **62(2)**, 163-168, **1995**.

147. Luilo G B and Othman C C, Lead pollution in urban roadside environments of Dar-es-Salaam city, Tanzania, *J. Sc*i., **32(2)**, 61-68, **2006**.

148. Lune P and Zwart K B, Cadmium uptake by crops from subsoil, *Plant Soil*, **189**, 231-237, **1997**.

149. Lyngby J E, Brix H and Schierup H H, Absorption and translocation of Zinc in Eelgrass (*Zostera marina L.*), *J. Exp. Mar. Biol. Ecol.*, **58**, 259-270, **1982**.

150. Mahakulkar A S, Gupta R R and Nandeswar S N, Bioaccumulation of heavy metal toxicity in the vegetables of Mahalgaon, Nagpur, Maharashtra, India, *Curr. World Environ*., **8(3)**,463-468,**2013**.

151. Mahdavi E S, Determination of Pb, Ni, Hg, Cr, Cd in edible vegetables in the south west of Tehran province with Atomic Absorption, *Res. J. Environ. Sci.*, **3(3)**, 339-344, **2009**.

152. Mahmood A and Malik R N, Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, *Pakistan, Arabian J. Chem*., **7(1)**, 91-99, **2014**.

153. Maleki A and Zarasvand M A, Heavy metals in selected edible vegetables and estimation of their daily intake in Sanandaj, Iran, *Southeast Asian J. Trop. Med. Public Health*, **39(2)**, 335-340, **2008**.

154. Manthri S, Sravanthi K C and Sidagonde S, Anthelmintic activity of Tomato leaf extract, *J. of Phytology*, **3(3)**, 15-17, **2011**.

155. Mapanda F, Mangwayana E N, Nyamangara J and Giller K E, The effect of long term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe, *Agric., Ecosystems Environ.*, **107**,151-165, **2005.**

156. Mason L, Moore R A, Derry S, Edwards J E and Mc Quay J H, Systematic review of topical Capsaicin for the treatment of chronic pain, *BMJ*, **328(7446)**: 991, **2004**.

157. Menon M, Hermle S, Gunthardt-Goerg M S and Schulin R, Effect of heavy metal soil pollution and acid rain on growth and water use efficiency of a young model forest eco-system, *Plant Soil*, **297**, 171-183, **2007**.

158. Michael J S, Gerrit H V, Thornton I and Makuch Z, Mercury, Cadmium, Lead in Handbook for sustainable Heavy metals, Policy and Regulation, Springer, **2001**.

159. Miller C E, Turk L M and Forth H D, Fundamentals of soil science, John Wiley and Sons, **1987.**

160. Mingorance M D, Valdes B and Oliva Rossini S, Strategies of heavy metal uptake by plants growing under industrial emission, *Environ. Int.*, **33(4)**, 514-520, **2007**.

161. Mohammed N K and Khamis F O, Assessment of Heavy metal contamination in vegetables consumed in Zanzibars, *Sci. Res.*, **4(8)**, 588-594, **2012**.

162. Mosley Y Y I and Omar Abed El-Hakeem Almagrabi, Heavy metal accumulation in some vegetables irrigated with treated waste water, *Int. J. Green Herbal Chem*., **12(1)**, 81-90, **2013**.

163. Mwegoha W J S and Kihampa C, Heavy metal contamination in agricultural soils and water in Dar-es-Salaam city, Tanzania, *Afr. J. Environ. Sci. Technol*., **4(11)**, 763-769, **2010**.

164. Nabulo G, Black C R and Young S O, Trace metal uptake by tropical vegetables grown on soil amended with urban sewage sludge, *Environ. Pollut*., **159(2)**, 368-376, **2011**.

165. Nabulo G, Oryem O H and Diamond M, Assessment of Lead, Cadmium and Zinc contamination of roadside soils, surface films and vegetables in Kampala city, Uganda, *Environ. Res*., **101(1)**, 42-52, **2006**.

166. Nahum A, Hirsch K, Danilenko M, Watts C K, Prall O W, Levy J and Sharoni Y, Lycopene inhibition of cell cycle progression in breast and endometrial cancer cells associated with reduction in cyclin D levels and retention of P 27 (Kip 1) in the cyclin E-Cd K_2 complexes, *Oncogene*, **20(26)**, 3428-3436, **2001**.

167. Narin I , Tuzen M , Sari H and Soylak M, Heavy metal content of Potato and Corn chips from Turkey, *Bull. Environ. Cont. Toxicol*., **74(6)**, 1072-1077, **2005**.

168. Naser H M , Sultana S ,Mahmud Nashiruddin, Gomes R and Noor S , Heavy metal levels in vegetables with growth stage and plant species variation, *Bangladesh J. Agri. Res*., **36(4)**, 563-574, **2011**.

169. Nath K, Saini S and Sharma Y K, Chromium in tannery industry effluent and its effect on plant metabolism and growth, *J. Environ. Biol*., **26(2)**, 197-204, **2005.**

170. Needleman H L, Schell A, Bellinger D, Leviton A and Allred E N, The long term effects of exposure to low doses of Lead in childhood. An 11 year follow-up report, *New Engl. J. Med*., **322 (2)**, 83-88, 1990.

171. Ni W Z, Yang X E and Long X X, Differences of Cadmium absorption and accumulation in selected vegetable crops, *J. Environ. Sci*., (China), **14(3)**, 399-405, **2002**.

172. Nicholson F A, Chambers B J, Williams J R and Unwin R J, Heavy metal contents of livestock feeds and animal manures in England and Wales, *Bioresour. Technol*., **70(1)**, 23-31, **1999**.

173. Nirmal Kumar J I, Soni H, Kumar N R and Bhatt I, Hyperaccumulation and mobility of heavy metals in vegetable crops in India, *J. Agric. Environ*., **10**, 34-45, **2009**.

174. Nirmal Kumar J I, Soni H and Kumar R N, Characterization of heavy metals in vegetables using Inductive Coupled Plasma Analyser (ICPA), *J. Appl. Sci. Environ. Manage*., **11(3)**, 75-79, **2007**.

175. Nogawa K, Kobayashi E, Okubo Y and Suwazono Y, Environmental Cadmium exposure, adverse effects and preventive measures in Japan, *Biometals*, **17(5)**, 581-587, **2004**.

176. Nouri J, Khorasani N, Lorestani B, Karami M, Hassani A H and Yousefi N, Accumulation of heavy metals in soil and uptake by plant species with phytoremediation potential, *Environ. Earth Sci*., **59**, 315-323, **2009**.

177. Nwajei G E, Okwagi P, Nwajei R I and Obi-Iyeke G E, Analytical assessment of trace elements in soils, Tomato leaves and fruits in the vicinity of paint Industry, Nigeria, *Res. J. Recent Sci*., **1(4)**, 22-26, **2012**.

178. Olajire A A and Ayodele E T, Study of atmospheric pollution levels by trace elements analysis of tree barks and leaves, *Bull. Chem. Soc. Ethop*., **17(1)**, 11-17, **2003**.

179. Oliver D P, Hannam K G, Tiller N S, Willhelm R H, Merry R H and Cozens G D, The effect of Zinc fertilization on Cadmium concentration in Wheat grain, *J. Environ. Qual.*, **23**, 705-711, **1994**.

180. Oliver D P, Tiller K G, Alston A M, Cozens G D and Merry R M, Effects of soil pH and applied Cadmium on Cadmium concentration in Wheat grain, *Aust. J. Soil Res*., **36(4)**, 571-584, **1998**.

181. Osma E, Serin M, Leblebici Z and Aksoy A, Heavy metal accumulation in some vegetables and soils in Istanbul, *EKOLOJI*, **21(82)**, 1-8, **2012**.

182. Othman O C , Heavy metals in green vegetables and soil from vegetable gardens in Das-es-Salaam, Tanzania, *Tanzania J. Sci*., **27**, 37-48, **2001**.

183. Oyedele D J, Gasu M B and Awotoye O O, Changes in soil properties and plant uptake of heavy metals on selected municipal solid waste dump sites in ile-lfe, Nigeria, *Afr. J. Environ. Sci. Technol*., **3(5)**, 107-115, **2008**.

184. Page A L, Bingham F T and Nelson C, Cadmium absorption and growth of various plant species as influenced by solution Cadmium concentration, *J. Environ. Qual*., **1(3)**, 288-291, **1972**.

185. Papa S, Eerullo L, Monaco A D, Bartoli G and Fioretto A, Trace elements in fruit and vegetable, *Int. J. Environ. Qual*., **2**, 79-83, **2009**.

186. Parashar P and Prasad F M, Study of Heavy metal accumulation in sewage irrigated vegetables in different region of Agra district, India, *Open J. Soil Sci*., **3**, 1-8, **2013.**

187. Parekh P P, Khwaja H A, Khan A R, Naqvi R R, Malik A, Khan K and Hussain G, Lead content of petrol and diesel and its assessment in an urban environment, *Environ. Monit. Assess*., **74(3)**, 255-262, **2002**.

188. Parveen Z, Khuhro M I and Rafiq N, Market basket survey for Lead, Cadmium, Copper, Chromium, Nickel and Zinc in fruits and vegetables, *Bull. Environ. Contam. Toxicol*., **71(6)**, 1260-1264, **2003**.

189. Paz-Ferreiro J, Lu H, Fu S, Mendez A and Gasco G, Use of phytoremediation and biochar to remediate heavy metal polluted soils; a review, *Soil Earth*, **5**, 65-75, **2014**.

190. Pourang, Nima, Noori and Azam S, Assessment of metals in fourteen species of vegetables and crops cultivated in a suburban area using multivariate analysis, *Toxicol. Environ. Chem*., **94(4)**, 694-712, **2012**.

191. Prabu P C, Impact of heavy metal contamination of Akaki river of Ethiopia on soil and metal toxicity on cultivated vegetable crops, *EJEAFChe*, **8(9)**, 818-827, **2009**.

192. Puschenreiter M, Horak O, Friesl W and Hart W, Low cost agricultural measures to reduce heavy metal transfer into the food chain; a review, *Plant Soil Environ*., **51(1)**, 1-11, **2005**.

193. Raben A, Taqliabue A, Christensen N J, Madsen J, Holst J J and Astrup A, Resistant starch: The effect on postprandial Glycemia, hormonal response and satiety, *Am. J. Clin. Nutr*., **60(4)**, 544-551, **1994**.

194. Radwan M A, and Salama A K, Market basket Survey for some heavy metals in Egyptian fruits and vegetables, *Food Chem. Toxicol*., **44**, 1273-1278, **2006**.

195. Ramezani Z, Aghel N and Amirabedin N, Determination of Pb and Cd in Garlic herb (*Allium sativum*) planted in Gilan and Khuzestan provinces using Graphite Furnace Atomic Absorption Spectrophotometer, Jundishapur , *J. Nat. Pharma. Prod*., **7(2)**, 41-44, **2012**.

196. Rana L, Dhankhar R and Chhikara S, Soil characteristics affected by long term application of sewage waste water, *Int. J. Environ. Res*., **4(3)**, 513-518, **2010**.

197. Rangnekar S S, Sahu S K, Pandit G G and Gaikwad V B, Study of uptake of Pb and Cd by three nutritionaly important Indian vegetables grown in artificially contaminated soils of Mumbai, India, *Int. Res. J. Environ. Sci*., **2(9)**, 1-5, **2013**.

198. Rapant S, Dietzova Z and Cicmanova S, Environmental and health risk assessment in abandoned mining areas, Zlata Idka, *Slovakia*, **51(3)**, 387-397, **2006**.

199. Rehman S U, Use of domestic sewage effluent for sustainable production of vegetables in Kashmir valley, *Int. J. Environ. Waste Manage*., **6(1-2)**, 149-161, **2010**.

200. Salman J D, Sulaiman I D and Abd Al-Raziq S S, Assessment of the levels of trace metals in commonly, edible vegetables and fruits of Baghdad city, Iraq, Ibn AL – Haitham, *J. Pure Appl. Sci*., **24(2)** 171-178, **2011**.

201. Salvatore M D, Carrtu G and Carafa A M, Assessment of heavy metals transfer from a moderately polluted soil to edible parts of vegetables, *J. Food Agric. Environ*., **7(2)**, 683-688, **2009**.

202. Sarsar V, Hardeep, Selwal K K, Tanwar R S, Tyagi P K and Ahuja A, Indian mustard(*Brassica juncea L.*) mediated remediation of Lead, *Int. J. App. Biol. Pharm. Tech.*, **3 (4)**, 1-5, **2012.**

203. Satpathy D and Reddy M V, Phytoextraction of Cd, Pb, Zn, Cu and Mn by Indian mustard (*Brassica juncea L.*) grown on loamy soil amended with heavy metal contaminated municipal solid waste compost, *Appl. Ecol. Environ. Res*., **11(4)**, 661-679, **2013**.

204. Sattar M U, Khan M A, Khalil A A and Amir R M, Mitigation of heavy metals in vegetables through washing with house hold chemicals, *Int. J. Agric. Sci. Res. (IJASR)*, **3(5)**, 1-12, **2013**.

205. Sauerbeck D R, Plant element and soil properties governing uptake and availability of heavy metals derived from sewage sludge, *Water Air and Soil Pollut*., **57-58(1)**, 227-257, **1991**.

206. Schwarz K, Clinical Chemistry and Chemical Toxicology of Metals, Edited by Browed S S, Elsevier, Amsterdam, 135, **1977**.

207. Shafiq-ur-Rehman, Use of domestic sewage effluent for sustainable production of vegetables in Kashmir valley, *Int. J. Environ. Waste Management*, **6(1-2)**, 149-161, **2010**.

208. Sharma Rakesh M S and Raju N S, Correlation of heavy metal contamination with soil properties of industrial areas of Mysore, Karnataka, India by cluster analysis, *Int. Res. J. Environ. Sci*., **2(10)**, 22-27, **2013**.

209. Sharma R K, Agrawal M and Marshall F M, Heavy metals (Cu, Cd, Zn & Pb) contamination of vegetables in urban India: a case study in Varanasi, *Environ. Pollut*., **154**, 254-263, **2008 a**.

210. Sharma R K, Agrawal M and Agrawal S B, Physiological, biochemical and growth responses of Lady's Finger (*Abelmoschus esculentus L.*) plants as affected by Cadmium contaminated soil, *Bull. Environ. Contam. Toxicol*., **84(6)**, 765-770, **2010**.
211. Sharma R K, Agrawal M and Marshall F M, Atmospheric depositions of heavy metals Cd, Pb, Zn, and Cu in Varanasi city, India, *Environ. Monit. Assess*., **142(1-3)**, 269-278, **2008b**.
212. Sharma R K, Agrawal M and Marshall F M, Effects of waste water irrigation on heavy metal accumulation in soil and plants, Paper presented at a National Seminar, Bangalore University, Bangalore, Abst. No.7, P.8, **2004**.
213. Sharma R K, Agrawal M, and Marshall F M, Heavy metals in vegetables collected from production and market sites of a tropical urban area of India, *Food Chem. Toxicol*., **47**, 583-591, **2009**.
214. Sharma R K and Agrawal M, Biological effects of heavy metals; an overview, *J. Environ. Biol. India*, **26(2)**, 301-313, **2005**.
215. Sharma R K, Agrawal M and Marshal F M, Effect of wastewater irrigation on heavy metal accumulation in soil and plants, *Environ. Sci. Technol. India*, **161**, 31 **2008**.
216. Sharma S and Prasad F M, Accumulation of Lead and Cadmium in soil and vegetable crops along major highways in Agra (India), *E-J of Chem*., **7(4)**, 1174-1183, **2010**.
217. Shidfar F, Froqhifar N, Vafa M, Rajab A, Hosseini S, Shidfar S and Gohari M, The effects of Tomato consumption on serum glucose, apolipoprotein B, apolipoprotein A-1, homocysteine and blood pressure in type 2 diabetic patients, *Int. J. Food Sci. Nutr*., **62(3)**, 289-294, **2011**.
218. Shu W S, Xia H P, Zhang Z Q, Lan C Y and Wong MH, Use of Vetivar and three other grasses for revegetation of Pb/Zn, mine tailings, Field experiments, *Int. J. Phytoremediation* , **4 (1)**, 47-57, **2002**.
219. Singh A, Sharma R K, Agrawal M and Marshall F M, Health risk assessment of heavy metals via dietary intake of food stuffs from the

wastewater irrigated site of a dry tropical area of India, *Food Chem. Toxicol*., **48(2)**, 611-619, **2010**.

220. Singh B R and Narwal R P, Plant availability of heavy metals in a sludge treated soil; II metal extractability compared with plant metal uptake, *J. Environ. Qual*., **13**, 344-349, **1984**.

221. Singh J, Rawat K S and Kumar A, Mobility of Cadmium in sewage sludge applied soil and its uptake by Radish (*Raphanus sativus L.*) and Spinach (*Spinacia oleracea L.*), *Int. J. Agric. Food Sci. Technol*., **4(4)**, 291-296, **2013**.

222. Singh K P, Mohan D, Sinha S and Dalwani R, Impact assessment of treated/untreated wastewater toxicants discharged by sewage treatment plants on health, agricultural and environmental quality in wastewater disposal area, *Chemosphere*, **55(2)**, 227-255, **2004**.

223. Singh P K, Deshbhratar P B and Ramtake D S, Effects of sewage waste water irrigation on soil properties, crop yield and environment, *Agric. Water Manage*., **103**, 100-104, **2012**.

224. Singh R, Gautam N, Mishra A and Gupta R, Heavy metals and living systems : An overview, *Indian J. Pharmacol.*, **43 (3)**, 246-253, **2011**.

225. Singh R, Singh D P, Kumar N, Bhargava S K and Barman S C, Accumulation and translocation of heavy metals in soil and plants from fly ash contaminated area, *J. Environ. Biol*., **31(4)**, 421-430, **2010.**

226. Singh R P and Agrawal M, Potential benefits and risks of land application of sewage sludge, *Waste Management*, **28(2)** , 347 -358, **2008**.

227. Singh S and Kumar M, Heavy metal load of soil, water and vegetables in periurban Delhi, *Environ. Monit. Assess*., **120(1-3)**, 79-91, **2006**.

228. Singh V P , Toxic Metals and Environmental Issue, Sarup & Sons, New Delhi, 277-284, **2005**.

229. Singh V P, Metal Toxicity and Tolerance in Plants and Animals, Sarup & Sons, **2006**.

230. Sinha S, Gupta A K, Bhatt K, Pandey K, Rai U N and Singh K P, Distribution of metals in the edible plants grown at Jajmau, Kanpur

(India) receiving treated tannery waste water: relation with Physico-chemical properties of the soil, *Environ. Monit. Assess*., **115**, 1-22, **2006**.

231. Smolders E, Cadmium uptake by plants, *Int. J. Occup. Med. Environ. Health*, **14(2)**, 177-183, **2001**.

232. Sobukola O P, Adoniran O M, Odedairo A A and Kajihausa O E, Heavy metal level of some fruits and leafy vegetables from selected markets in Lagos, Nigeria, *Afr. J. Food Sci*., **492**, 389-393, **2010**.

233. Somasundaram J, Krishnasamy R, Mahimairaja S and Savithri P, Dynamics of Lead in different soil conditions, *J. Environ. Sci. & Eng*., **48(2)**, 123-128, **2006**.

234. Srivastav R, Mathur S K, Srivastava M, Dass S and Prakash S, Bricks reveal recent history of heavy metal pollution in soil around North Indian city, *Sci. Total Environ.*, **209 (1)**, 41-46, **1998**.

235. Srivastava K P and Singh V K, Impact of Air pollution on pH of soil of Saran, Bihar, India, *Res. J. Recent Sci*., **1(4)**, 9-13, **2012**.

236. Surh Y J and Lee S S, Capsiacin, a double edged sword: toxicity, metabolism and chemopreventive potential, *Life Sci*., **56(22)**, 1845-1855, **1995**.

237. Tagipur H and Mosajeri, Heavy Metals in the vegetables collected from production sites, *Health promotion perspect.*, **3(2)**, 185-193, **2013**.

238. Tang J C, Zhu W, Kookana R and Katayama A, Characteristics of Biochar and its application in remediation of contaminated soil, *J. Biosci. Bioeng.* ,**116 (6)**, 653-659, **2013**.

239. Tripathi A and Misra D R, A study of physico-chemical properties and heavy metals in contaminated soils of municipal waste dumpsites at Allahabad, India, *Int. J. Environ. Sci*., **2(4)**, 2024-2033, **2012**.

240. Tripathi R M, Ragunath R and Krishnamurthy T M, Dietary intake of heavy metals in Bombay city, India, *Sci. Total Environ*., **208**, 149-159, **1997**.

241. Tsadilas C D, Soil pH influence on Cadmium uptake by tobacco in high Cadmium exposure, *J. Plant Nut*., **28(8)**, 1167-1178, **2000**.

242. Turkdogan M K, Kilicel F, Kara K, Tuncer I and Uygan I, Heavy metal contamination of vegetables and fruits in the endemic upper gastro intestinal system, *Environ. Toxicol. Pharmacol*., **13(3)**, 175-179, **2003**.

243. Tyler L D and Mc bride M B, Influence of Ca, pH and Humic acid on Cadmium uptake, *Plant Soil*, **64**, 259-262, **1982**.

244. Uraguchi S, Watanabe I, Yoshitomi A, Kiyono M and Kuno K, Characteristics of Cadmium accumulation and tolerance in novel Cadmium accumulating crops, *Avena strigosa* and *Crotalaria Juncea*, *J. Exp. Bot*., **57(12)**, 2955-2965, **2006**.

245. Uzma I S, Sadia G R and Talat A, Bioremediation of Heavy metals using isolates of filamentous fungus Aspergillus fumigates collected from polluted soil of Kasur, Pakistan, *Int. Res. J. Biol. Sci*., **2(12)**, 66-73, **2013**.

246. Vangronsveld J and Cunningham S D, Introduction to the concepts in metal contaminated soils in situ inactivation and phytorestoration, Springer, **1998**.

247. Vanlune P, Zwart K B, Cadmium uptake by crops from the subsoil, *Plant Soil*, **189(2)**, 231-237, **1997**.

248. Varalakshmi L R and Ganeshmurthy A N, Heavy metal contamination of water bodies, soils and vegetables in periurban areas of Bangalore city of India, 19th world congress of soil science, soil solutions for a changing world, **37**, 1-6, **2010**.

249. Vaseghi S, Afyuni M, Shariatmadari H and Moblim, Effects of sewage sludge and soil pH on micronutrient and heavy metal availability, *JWSS, Isfahan Univ. Technol.*, **7(3)**, 95-106, **2003**.

250. Viehweger K, How plants cope with heavy metals, *Botanical Studies*, **55**: 35 , **2014.**

251. Vogel A I, Fourth edition, text book of quantitative inorganic analysis including elementary instrumental analysis, Woolwich Polytechnic, London, S.E. 18, **1939**.

252. Wang Q R, Cui Y S, Liu X M, Dong Y T and Christine P, Soil contamination and plant uptake of heavy metals at polluted sites in China, *J. Environ. Sci. Health*, **38(5)**, 823-238, **2003**.

253. Wang X, Sato T, Xing B and Tao S, Health risks of heavy metals to the general public in Tianjin, China, via consumption of vegetables and fish, *Sci. Total Environ.*, **350 (1-3)**, 28-37, **2005**.

254. Wang X H, Liu Y G, Zeng G M, Zhou C H, Li X, Fan T and Zuo M, Extraction of heavy metals from contaminated soils with EDTA and their redistribution of fractions, *Huan Jing Ke Xue*, **27(5)**, 1008-1012, **2006**.

255. Watson C P and Evans R J, The post mastectomy pain syndrome and topical Capsaicin: a randomized trial, *Pain*, **51(3)**, 375-379, **1992**.

256. Wei B and Yang L, A review of heavy metal contaminations in urban soils, urban road dust and agricultural soils from China, *Microchem. J.*, **94(2)**, 99-107, **2010**.

257. Wei S, Zhou Q and Wang X, Identification of weed plants excluding the uptake of heavy metals, *Environ. Int.*, **31**, 829-834, **2005**.

258. Willard H, Meritt L and Dean J A, Instrumental Methods of Analysis, CBS Publisher, **1986**.

259. Wittig R, Plants as biomonitors in indicators for heavy metals in terestrial environments, VCH, *Weinheim*, 3-28, **1993**.

260. Wong C S C, Li X C, Zhang G, Qi S H and Peng X Z, Atmospheric depositions of heavy metals in the Pearl River Delta, China, *Atmos. Environ.*, **37**, 767-776, **2003**.

261. Wong J W C, Heavy metal contents in vegetables and market garden soils in Hong-Kong, *Environ. Technol.*, **17(4)**, 407-414, **1996**.

262. Wong M H, Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils, *Chemosphere*, **50**, 775-800, **2003**.

263. Wood P, Remediation methods for contaminated sites in contaminated land and its Reclamation, edited by Hester R and Harrison R, The Royal society of chemistry, Cambridge, 47-71, **1997**.

264. Wu S C, Luo Y M, Cheung K C and Wong M H, Influence of bacteria on Pb and Zn speciation mobility and bioavailability in soil : A laboratory study, *Environ. Pollut.*, **144**, 765-773, **2006**.

265. Xian X, Effect of chemical forms of Cadmium Zinc and Lead in polluted soils on their uptake by Cabbage plants, *Plant Soil*, **N3**, 257-264, **1989**.

266. Xu D, Zhou P, Zhan J, Gao Y, Dou C and Sun Q, Assessment of Trace metal bio availability in garden soils and health risks via consumption of vegetables in the vicinity of Tong ling mining area, China, *Ecotoxicol. Environ. Saf*., **90**, 103-111, **2013**.

267. Yadav A, Yadav P K and Shukh D N, Investigation of heavy metal status in soil and vegetables grown in urban area of Allahabad, Uttarpradesh, India, *Int. J. Sci. Res. Publ*., **3(a)**, 1-7, **2013**.

268. Yahaya A H, Saad I A A and Arof A K, The Environmental significance of Cadmium in contaminated soils, *Malays. J. Sci*., **26(1)**, 119-127, **2007.**

269. Yan X, Zhang F, Gao D, Zeng C, Xiang W and Zhang M, Accumulations of heavy metals in road side soils close to Zhaling, Eling and Nam Co Lakes in the Tibetan Plateau, *Int. J. Environ. Res. Public Health*., **10(6)**, 2384-2400, **2013**.

270. Yanqun Z, Yuan L, Jianjun C, Haiyan C, Li O and Schvartz C, Hyperaccumulation of Pb, Zn & Cd in herbaceous grown on Lead, Zinc mining area in Yunnan, China, *Environ. Int*., **31(5)**, 755-762, **2005**.

271. Yargholi B, Azimi A A, Baghvand A, Liaghat A M and Fardi G A, Investigation of Cadmium absorption and accumulation in different parts of some vegetables, *Am.-Eur. J. Agric. Environ. Sci*., **3(3)**, 357-364, **2008**.

272. Yekeen T A and Onifade, Evaluation of Some heavy metals in soils along a major road in Ogbomosho, Southwest Nigeria, *J. Environ. Earth Sci*., **2(8)**, 71-79, **2012**.

273. Yusuf A A, Arowolo T O A and Bambose O, Cadmium, Copper and Nickel levels in vegetables from industrial and residential areas of Lagos city, Nigeria, *Global J. Environ. Sci*., **1(1)**, 1-6, **2002**.

274. Yusuf K A and Oluwole S O, Heavy metal (Cu, Zn, Pb) contamination of vegetables in urban city : A case study in Lagos, *Res. J. Environ. Sci*., **3(3)**, 29-298, **2009**.

275. K ., **5(2)**, 47-52, **2009**.

276. Zamora P W, Jesus J O, Su G S, Ragragio E, Su M L S and Villanueva S, Assessing Lead concentrations in leafy vegetables in selected private

markets in metro Manila, Philippines, *J. Appl. Technol. Environ. Sanit.*, **2(3)**, 175-178, **2012**.

277. Zaprjanova P, Dospatliev L, Angelova V and Ivanov K, Correlation between soil characteristics and Lead and Cadmium content in the above ground biomass of Virginia tobacco, *Environ. Monit. Assess.*, **163(1-4)**, 253-261, **2010**.

278. Zarcinas B A, Ishak C F, Mc Laughlin M J and Cozens G, Heavy metals in soil and crops in south east Asia Peninsular Malaysia, *Environ. Geochem. Health*, **26(4)**, 343-357, **2004**.

279. Zehra S S, Arshad M, Mahmood T and Waheed A, Assessment of heavy metal accumulation and their translocation in plant species, *Afr. J. Biotechnol.*, **8(12)**, 2802-2810, **2009**.

280. Zhang X, Wang H, He L, Lu K, Sarmah A, Li J, Bolan Pei J and Huang H, Using biochar for remediation of soils contaminated with heavy metals and organic pollutants, *Environ. Sci. Pollut. Res. Int.*, **20(12)** 8472-8483, **2013**.

281. Zurera G, Morena R, Salmeron J and Pozo R, Heavy metal uptake from green house border soils for edible vegetables, *J. Sci. Food Agric.*, **49**, 307-314, **1989**.

ANNEXURES

ANNEXURE -1

ABBREVIATIONS

1. **AAS**	:	Atomic Absorption Spectrophotometer
2. **ATSDR**	:	Agency for Toxic Substances and Disease Registry
3. **BIS**	:	Bureau of Indian Standards
4. **CEC**	:	Cation Exchange Capacity
5. **CFA**	:	Coal Fly Ash
6. **CPSC**	:	Consumer Product Safety Commission
7. **DRI**	:	Dietary Reference Intake
8. **DNA**	:	Deoxy Ribo Nucleic Acid
9. **EDTA**	:	Ethylene Diamine Tetra Acetic Acid
10.**EPA**	:	Environmental Protection Agency (U.S.)
11. **FDA**	:	Food and Drug Administration
12. **HR-ICP-MS**	:	High Resolution Inductively Coupled Plasma Mass Spectrometry
13. **ICP-AES**	:	Inductively Coupled Plasma Atomic Emission Spectrophotometry
14. **IPCS**	:	International Programme on Chemical Safety
15. **I**Q	:	Intelligence Quotient
16. **KSTPS**	:	Kota Super Thermal Power Station
17. **MCL**	:	Maximum Contaminant Level

18. **NIOSH**	:	National Institute for Occupational Safety and Health
19. **OSHA**	:	Occupational Safety and Health Administration
20. **PFA**	:	Prevention of Food Adulteration Act
21. **PVC**	:	Poly Vinyl Chloride
22. **RNA**	:	Ribo Nucleic Acid
23. **STP**	:	Sewage Treatment Plant
24. **UIL**	:	Upper Intake Level
25. **WHO**	:	World Health Organization

ANNEXURE – 2

RESEARCH PAPERS PUBLISHED

1. Paper entitled "DETERMINATION OF HEAVY METAL ACCUMULATION IN *Lycopersicum esculentum L.* GROWN ON CONTAMINATED SITES" has been published in the International Journal of Chemical Sciences, 12 (1), 39-44, 2014.

2. Paper entitled "UPTAKE OF HEAVY METALS BY *Capsicum annuum L.* In SELECTED AGRICULTURAL AREAS AROUND KOTA CITY" has been published in the Journal of Chemical Biological and Physical Sciences, Sec D, 4 (4), 3785-3789, 2014.

3. Paper entitled "ASSESSMENT OF HEAVY METALS BIOACCUMULATION IN *Solanum tuberosum L.* CULTIVATED ON ARTIFICIALLY FED MEDIUM" has been published in the Journal of Chemical Biological and Physical Sciences, Sec A, 4 (1), 78-84, 2014.

ANNEXURE-3

PARTICIPATION IN SEMINARS/ SYMPOSIA/ CONFERENCES

1. Actively participated in a four day workshop on Maintenance of Opto-Analytical instruments conducted on January, 17-20, 2011, at JDB Govt. Girls P.G. College, Kota, Raj.

2. Actively participated in a National Conference on Chemical Sciences in New Millennium on January 8th 2012 (NCCSNM-2012) held at Department of Chemistry, Pacific college of basic and applied Sciences, Pacific University, PAHER, Udaipur, Raj.

3. Presented research paper and poster in “National conference on global Environmental changes and disaster management for sustainable life on Earth–A burning issue” held at Maharishi Arvind college of Engineering and Technology, Ranpur, Kota, Raj. on October 21st, 2013.

4. Presented Poster in ‘National Seminar on Pure and Applied Chemical Sciences (current trends and future prospects) in association with Indian Chemical Society, Kolkata, NSPACS -2014 on January 10-11, 2014 organized by Department of Chemistry, Faculty of Science, Jai Narayan Vyas University, Jodhpur, Raj.

SUMMARY

The thesis consists of five distinct chapters:

Chapter I - Introduction and literature reviewed on the subject

This chapter comprises an introductory idea about the studied area, heavy metal pollutants, their sources in the environment and probabilities of their uptake by plants/ vegetables and a report of the literature reviewed on the subject along with the objectives and importance of the study. The chapter includes 186 references.

Chapter II - Methods and methodology

Selection of three vegetables belonging to family *Solanaceae*, widely cultivated and used i.e. *Solanum tuberosum L.* (potato), *Capsicum annuum L.*(chillies) and *Lycopersicum esculentum L.*(tomato). Criteria for their selection, details of standard methods and methodology adopted for sampling process and analysis of the various plant parts, at different stages of maturity and corresponding soils are included in this chapter. The selected vegetables have importance in day to day life in different ways;

Potato - Potato is used as a staple food all over the world besides India. It is a low calorie, high fiber food, rich in vitamin B_6, vitamin K, vitamin C and nutrients viz Mn, P etc. It contains variety of phyto-nutrients, and has antioxidant properties. It protects significantly against cancer and cardio-vascular diseases. It contains various health promoting compounds like carotenoids, flavonoids, caffeic acid and unique tuber storage proteins such as patatin exhibiting activity against free radicals.

Chillies - Also called as a 'wonder spice', consumed all over the world in various forms. They contain an important chemical capsaicin having variety of uses. Capsaicin is a safe and effective topical analgesic agent helpful in relieving various types of pains; it has properties like carminative, stimulant, antispasmodic, astringent, haemostatic and antiseptic. It is good for entire digestive system and increases the effectiveness of other herbs when used with them. Studies have shown that capsaicin in chillies can prohibit proliferation in cancer cells, and possesses chemo protective activity against some chemical carcinogens and mutagens. Pepper spray a form of less lethal weapon used for self defense contains capsaicin extract form chillies .It is suggested as a heart stimulant, antigenotoxic and anticarcinogenic. Also used to beat seasickness, malaria, alcoholism, can also be used for gargle in case of laryngitis.

Tomato - Tomato is widely consumed in raw or cooked form, low calorie, rich sources of antioxidants. Tomato fruit is a familiar vegetable, but its leaves and vines are also used to make medicines. Tomatoes are a rich source of pigment lycopene, thought to play important role in preventing various types of cancers. Lycopene is also a powerful antioxidant. Doctors recommend plenty of tomatoes in the diet for getting rid of stones in kidney or gall bladder. Studies have shown that it is easier for the body to use lycopene that comes from tomato products like tomato pastes, juices etc than from the fresh tomatoes. The antiseptic properties are due to the nicotinic acids present which can fight against viral infections, clogged arteries, stimulate blood flow and can regulate cholesterol levels. They contain anti ageing agents more than fruits. They are also helpful to fight against wrinkles and sunburns.

Since ancient times it has been used to promote healthy and shiny skin adding to natural beauty.

Studies were carried out adopting two different approaches;

1. Samples of plants growing under natural conditions and corresponding soils collected from different probably contaminated cultivation sites around Kota city. Ten sites were chosen around Kota city, Rajasthan. Plant and soil samples were kept classified and marked according to their collection or sampling sources.

2. Samples of plant grown under controlled conditions in artificially contaminated culture media at various levels and corresponding soils/ composts. Five sets of pots were prepared for each plant, each set containing three pots. Different solutions of four concentrations of five metals i.e. Pb, Cd, Zn, Fe and Cu were prepared. After six weeks, we added these solutions of four different concentrations containing metals to four sets of each plant to observe the effects.

One set of pots of each plant was kept untreated which worked as blank. After maturation the sample collection was done as follows.

Potato- Peeled and Unpeeled Potato tubers.

Chillies- Green Chillies and Red Chillies.

Tomato- Leaves, Stems and Fruits.

The soil from the same pot corresponding to the sample collection was done adopting standard methods described in the literature. Plant and soil samples were kept classified and marked according to their collection or sampling source. Plant part samples were thoroughly segregated, washed and dried first in the sunlight and then in the oven at 50-60^0 C temperature for approximately 12 hrs .The dried samples were powdered in an electric grinder using stainless steel jar obtaining fine particles which were sieved through 2 mm mesh. These samples were kept in polyethylene pouches for analysis, soil samples were also dried, powdered and sieved through 8mm mesh and kept in polyethylene pouches for further analysis. To determine heavy metal concentration, a wet digestion method of the dried samples was adopted. A blank digestion solution was made for comparison. For calibration purpose a standard solution for each element under investigation was also prepared.

Heavy metals Pb, Cd, Zn, Fe, and Cu were determined in all plants and soil samples atomic absorption spectrophotometrically, double beam and deuterium back ground correction. Hollow cathode lamps of Pb, Cd, Zn, Fe and Cu were used at specific wave lengths. All samples were run in triplicates.

The chapter includes the figure I indicating location of Kota district on Indian map and figure 2 shows the location of sampling sites around Kota City. This chapter includes 22 references.

Chapter-III- Observations and Results

The chapter includes all observations and results in tabular form for the three consecutive years 2012, 2013 and 2014. This chapter includes one reference with

169 tables showing the results of analysis of the plant parts of three years during which studies were carried out and corresponding soil samples collected from the same site/pot. Data so obtained were compared with standards given by authentic agencies to indicate heavy metal pollution load. Pearson’s correlation coefficients were calculated between different metal concentrations in samples of plant parts, the corresponding soil samples, between different metal concentrations in samples of plant parts and in corresponding soils, as summarized in tabular form. Results obtained reveal a clear dependence of metal concentration in plants on the metal concentrations in corresponding soils. The correlation matrices also show that these concentrations are significantly correlated. Different physicochemical parameters, water holding capacity, porosity, density, pH, conductivity, nitrate, phosphate, potassium, calcium, magnesium and organic matter were determined for different composts. Observations regarding percent uptake, plant growth and quality were also recorded. Similar studies have been carried out for the three successive years 2012, 2013 and 2014.

Chapter- IV Discussion on findings

This chapter is an interpretation part. The range of metal concentrations obtained in plant samples and corresponding soil samples and their correlations are discussed with pollution status of the area, probabilities of uptake by plants keeping in view the geochemical aspects and possible health hazards of metals. This chapter includes 21 references.

Discussion on findings is further divided into two sub section i.e. for randomly sampled plants and for pot experiments;

A. RANDOMLY SAMPLED PLANTS (IN NATURE)

Heavy metals i.e. lead, cadmium, zinc, iron and copper are analyzed in plant samples collected from ten different sites during three consecutive years i.e. 2012, 2013 and 2014 Different uptake patterns were recorded in different plants according to the pollution load of that site and various physicochemical parameters.

The values of water holding capacity, porosity, density, pH, conductivity, nitrate, phosphate, sulphate, potassium calcium, magnesium and organic matter were determined for corresponding soils collected from the sites and it was analyzed that different physicochemical parameters played a significant role in the uptake pattern of heavy metals from soil to the plants.

B. PLANT SAMPLED FROM POT EXPERIMENTS (UNDER CULTIVATION)

Pot experiments were carried out with the three selected plants viz. *Solanum tuberosum L.* (potato), *Capsicum annuum L.* (chillies) and *Lycopersicum esculentum L.* (tomato) and the heavy metals viz. lead, cadmium, zinc, iron and copper. Plant samples and corresponding composts/ soils collected form different pots of different sets were analyzed during three consecutive years i.e. 2012, 2013 and 2014. It revealed that as we increase the concentration of added metal solution in plants, its uptake increases. However the uptake pattern also depends on various physicochemical parameters of the compost/ soil of the corresponding pot from where the plant samples were collected. It is clear from the findings that plants grown in metal contaminated areas have a greater risk of uptaking heavy metals and may cross the permissible limits in particular conditions. It was also observed that the maturity level/ age of plants may be responsible for accumulating concentrations of heavy metals to some extent. Washing and peeling may be helpful to remove heavy metals to some extent. More polluted the soil, more polluted will the plant be.

Pearson's correlation coefficients are calculated among various heavy metals in plants and corresponding soils. Significant correlation found between various metals may be due to anthropogenic activities and natural processes. In pot experiments significant correlations were observed because the solutions of different metals were added in the increasing concentration & thus the uptake in plants increased.

Percent uptake of different heavy metals from soil to the plant also shows that the sites/ pots containing higher concentration of metals are showing higher uptake, thus it is harmful to grow plants in contaminated areas and even a small increase in concentration of metals in the soil can lead to higher uptake. The favorable physicochemical conditions of soil may increase the uptake of heavy metals.

General discussion regarding percent survival, plant growth, quality and yield reveals no considerable change within the studied range.

Chapter V- Remediation, Suggestions and Recommendations

Based on the results and findings some technical remedies, reasonable suggestions and recommendations are given to minimize the heavy metal pollution in the area to sustain soil quality for further use. This chapter includes 51 references.

A Systematic and alphabetized Bibliography and Annexures are given at the end of the thesis.