Arable soil supports most of the crop of economic use and chemistry of soil is directly reflected in the composition of plants growing on the soil. Chemical composition of soil, thus, becomes of primary importance for understanding the chemistry of plants and plant products, many of which are consumed as food by human population and livestock.

Chemical composition of soil depends on the nature of parent rock, climate, conditions of weathering etc. In general, sandy soils are rich in oxides of Si, Al and Fe; organic rich soil has relative depletion of other oxides such as Ca and Mg and the calcareous soil is rich in carbonates of Ca and Mg. As most of the common rock-forming minerals in the earth's crust are silicates, it is quite natural to find the abundance of oxides of Si, Al, Fe, Ca, Mg, Na and K in soil, however, many of the silicate minerals contain a large number of minor and trace elements. The trace or minor elements enter the silicate structure by replacing variable amounts of major elements on account of compatibility in ionic radius, charge, electronegativity and co-ordination numbers. For example, Pb, a base metal is diadochic with $K^+$ ($Pb^{2+} = 1.20\text{Å}, K^+ = 1.33\text{Å}$). Hence, even if $Pb$ is not present as sulfide ($PbS$), a certain amount of $Pb$ can be expected in $K$-silicate minerals of soil. Even if a particular soil does not overlie mineralised rocks, supergene enrichment of parent rocks could lead to concentration of a number of trace elements, particularly base metals, in the soil profile. Thus the occurrence and abundance of
individual trace or minor elements in soil would depend on the nature of elemental fractionation in parent rocks, their mobility during weathering and their affinity to form independent compounds during the formation of soil. Igneous rocks constitute 95% of earth's crust, and hence fractionation in the igneous process can largely indicate the likely mode of occurrence of elements in the soil. However, the sedimentary rocks, although constituting only 5% of the crust, are equally important because they form the 95% of the total rocks exposed at the surface.

Stability of minerals play very important role in determining the chemical nature of soil. In general, minerals formed very early during the cooling of the earth are least stable under sedimentary or soil environment, while the ones formed late during the cooling of igneous melt, are more stable. In addition to stability of minerals, an element may become available to soil due to ore deposits in the host rocks. For example, shale is very commonly associated with sulfides and base metal deposits. Similarly, calcareous soils have significant amount of Pb and Zn, as limestones generally contain Pb and Zn. Table 1. summarises some of the trace element analyses for different types of soils of India. Mineralogical variation in parental material is obviously reflected in trace metal variations in the weathered soils.

During the formation of soil profile, elements in the parent materials are redistributed among soil water, weathered material and the unaltered parent rock. In such a
vertical profile, micro-environmental changes take place in terms of ionic potential, pH, oxidation-reduction potential etc. Dissolution-precipitation of some compounds, exchange uptake by clays, chelation by organics, adsorption by colloidal oxides and hydroxides of Fe-Mn etc. are largely responsible for the redistribution of elements. Depending on these mechanisms, metals are removed from one part of the soil profile to the other; and this is important because the soil in the vicinity of plant roots may be deprived of or enriched with those metals present in other parts of the profile. Generally, under mildly oxidising environment, metals such as Cu, Pb and Zn are transferred to the top layers of soil profile, while under slightly reducing environment, the organic chelation becomes more important.

Thus soil will include, in some form or the other, combinations of various elements present in the earth's crust and naturally such combinations will not remain limited only to those elements which are essential for plants, animals and human beings but also those elements will be present which are not required by these organisms. The concentration of various elements will also vary depending upon a very large number of factors and chances are there that elements which are required in small quantities are present high enough to cause contamination. Human interference at various stages with the process of soil formation, bringing out the minerals buried deep under the earth's surface and its subsequent
utilization has also its impact on the chemistry of soil. However, until recently the general concern has been only towards deficiency of micro and macro-nutrients in the arable soil environment. Micro-nutrients are more important this way because their desired concentrations in the soil is very low and once they exceed that level, their role will be as that of contaminants, not only for the plants but also for human and other consumers, in case they are also accumulated in excess by the plants, which is a general manifestation of the presence of excess amounts of elements in the soil.

The list of micronutrients, generally agreed upon, is 172

Zn, Cu, Fe, Mn, Mo, S, Cl, Co, Si, Na, I, F.

With regard to the macro-nutrients the situation is a little different. They are required in quite large quantity and hence their variation although being important will not be as in the case of the micro-nutrients. The tolerance limit is much higher in case of the macro-nutrients.

In addition to the nutrient elements, various other elements are present in the soil depending upon the local conditions. In case such elements can enter the plant roots, these non-essential elements are bound to create problems for the plants. Their concentration will be of secondary importance, because in whatever concentration they are present, they will act only as contaminants. Pb is one of the elements which has to be included in this category.

Cu and Zn, on the other hand, are micro-nutrients and can
be considered as contaminants or pollutants of soil only if they exceed micro-nutrient limits.

Coming back to the crust, we find that the three metals Cu, Pb and Zn constitute, on the average, 32 ppm, 15 ppm and 63 ppm respectively. However, due to local conditions concentration of these elements will vary in the soil from place to place. The factors which will be responsible for such variation will be both natural and anthropogenic. Natural sources of contamination have, however, been playing their role even before human interference came into play. Few of them are weathering of mineral deposits, emissions from volcanoes, vegetation, forest fires, seasalt sprays. However, the chances and scope of soil contamination due to natural sources were quite limited. With the introduction of human interference, chances of metal contamination have increased drastically. The important sources of anthropogenic contamination of soil with respect to these three metals are exploitation of natural reserves, refining and subsequent utilization. These will be dealt in detail in the review portion.

The present work is a study of the impact of base metals on some common vegetable plants under the conditions when they could be considered as contaminants, generally. These three metals are being mined and utilized vigorously in the present days and the chances of soil contamination due to any element is directly related to the quantity mined, refined and utilized. Another important reason for
this choice has been that so far, the two metals Cu and Zn have generally been considered only as micro-nutrients and about the third i.e. Pb the general impression has been that it is not readily absorbed by plants. However, recent studies have refuted such ideas. Many a time the concentration of Cu and Zn have been found to exceed the micro-nutrient limits and Pb has been found to be absorbed quite readily by plants, although it is neither a macronor micro nutrient. In India also these metals are being mined and utilized, hence, chances of soil contamination with these metals is not absent.

In most of the earlier studies the impact of soil metal pollutants have been generally studied only on major agricultural crops. However, on examination of the sites which are mostly liable to be contaminated by base metals, it can be easily concluded that the land is not generally utilized for the cultivation of major agricultural crops alone. The land area around mining and refining sites and other industries, available for cultivation being small and sometimes the unfavourable topography of the mining areas makes them unfit for cultivation of major crops. In addition to these, the readily available consumer markets for vegetables and other minor crops among the worker colonies encourages vegetable plant cultivation. Similar is the situation in and around big and small cities. There too the land is generally utilized for vegetable cropping, generally on account of readily available market in the city for such
commodities. Hence, in the present study the impact of base metal pollutants was studied on some commonly grown vegetable plants. An additional factor for the same was that vegetable crops were found to be commonly grown in kitchen gardens in the cities, industrial and mining townships. Soils of such gardens are always liable to be contaminated by the metals as will be evident later.

In case of major agricultural crops, the part of plant generally consumed by human population is very small, mostly limited to fruits and grains, the leafy parts being sometimes used as cattle fodder. In contrast to that, in case of vegetables in many cases the whole plant is utilized for human consumption. Roots which are, generally, never consumed in case of major crops is very commonly the part which is eaten in case of vegetable plants. Roots are well known for high accumulation of pollutants. Even if we look at the daily consumption figures, the vegetables may even surpass the cereals at places on occasions. So far as their occupying the second place is concerned, there is no doubt about it. One additional point which is not of less importance is that many a vegetables are eaten raw. The root/shoot ratio of vegetable plants is also generally higher than in major crop plants making them superior carriers of pollutants.

There are large number of vegetable plants being cultivated in the areas liable to be contaminated by the base metals. In the present study four different vegetables were chosen: spinach (*Spinacea oleracea*, cultivar. Pusa Jyoti),
ladies finger (*Abelmoschus esculentus* cultivar. Pusa Sawani), radish (*Raphanus sativus* cultivar. Pusa Reshmi) and turnip (*Brassica rapa* cultivar. PTWG). In the first one, the leaves are consumed; in the second, fruit is the part consumed by human population, sometimes the cattle is fed on the leaves; in the third one, root is consumed raw or cooked while the leaf is used as vegetable. In the last one, only the root is generally utilized after cooking, while the leaf part being discarded for cattle feeding. So metal-soil-plant relationship over a complete spectrum of consumable parts could be achieved.

Metals present in the soil as contaminant could interact with plants in two ways. First, by getting accumulated inside the plant body. Second, by interfering with the growth of plants. In the present study, the three metals: Cu, Pb and Zn, were added to soil individually and in combinations and plants were grown. Growth pattern and accumulation of metals were studied at two stages of growth. Simultaneous studies in two mining and refining localities were performed so as to monitor the extent of soil pollution in these areas and its impact on the plants under study. Khetri and Zawar (Rajasthan state, India) were chosen for the study. Former is a place known for copper mining and smelting and the latter is one of the major suppliers of lead and zinc ores. Not only lead and zinc ores are mined at Zawar, concentration of ores is also performed there.