Chapter - 1

INTRODUCTION

"In a world of plenty, no one, not a single person, should go hungry. But almost 1 billion still do not have enough to eat. I want to see an end to hunger everywhere within my lifetime." ***– Ban Ki-moon, United Nations Secretary-General***

Food is the fundamental physiological necessity for existence of life on earth. Social and economic security is also jeopardized without food security. Efficient working of human mind also depends on the nourishment acquired through food. Population explosion, advent of urbanization, crunch of resources, changes in social outlook and improper distribution of food have elicited a situation where every one in nine people i.e. about 795 million people on earth are deprived of sufficient food (FAO *et al*., 2015). Developing countries are worst hit in terms of hunger and malnourishment. Global Hunger Index (GHI) of 2013 reported India to be at 63rd rank out of 78 countries with worst hunger conditions (Biswas and Tortajada, 2014). The situation is expected to worsen in future as the total population is projected to reach 1.45 billion by 2028 and will further rise exponentially to 1.7 billion by 2050. Millennium Development Goals (MDGs) as framed by United Nations in 2000 have achieved slight success in combating food dearth. Recent assessment report indicates that by the target year 2015 the chronically hungry population of world has reduced to 12.9% from 23.3% in 1990-92 (FAO *et al*., 2015).

Food availability is reliant on the crop yield, directly or indirectly. Apart from natural (climate change and natural disasters) and social factors, the issues responsible for less per capita crop production are declining land availability and water crisis (FAO, 2009; Raja *et al*., 2015). Globally, per capita availability of arable land has decreased drastically from 0.45 ha (approx.) in 1960 to 0.25 ha (approx.) in 2009 (Bruinsma, 2009). Decline in fresh water availability due to increased demand, injudicious use and climate change has also affected the per capita agricultural yield. It is documented that 70% of fresh water is used for irrigation (Bruinsma, 2009). To eradicate hunger, efforts are being made to intensify crop yield by increasing resource availability. To address the issue of declining land availability and for the expansion of agricultural land, cultivation of crops is being carried out even at contaminated sites. In many parts of world especially in developing countries food crops are grown in the vicinity of highly polluting industries, wastewater drains, mining sites, etc. (Zhao *et al*., 2007; Hu and Ding, 2009). Water scarcity issues are managed by the use of wastewater for irrigation. Continuous use of wastewater for irrigation deteriorates the quality of soil, as a result of buildup of contaminants. Crop productivity is definitely increased by such practices but detrimental effects of contaminants are witnessed on the entire ecosystem. Soil gets degraded in terms of microbial flora, fertility and other physico-chemical aspects triggering the stress responses in plants growing on such soil. The food crops grown on a contaminated site can be harmful at all trophic levels of food chain due to microbial infestation, higher dose of toxins and heavy metal accumulation (Khan *et al*., 2008; Ahmad *et al*., 2013).

Heavy metals are of major concern among all the pollutants owing to global reports documenting high content in food crops and toxicological effects to plants and animals (Järup, 2003; Dorne *et al*., 2011). These are toxic metals and are defined as elements having density higher than 3.5 g/cm^3 (Duffus, 2002; Appenroth, 2010). They exist in earth's crust and are released to ambient environment through various biogeochemical processes but the concentration of these metals increase much beyond the background level due to anthropogenic activities. Soil acts as ultimate sink of these metals as a result of interaction with other abiotic and biotic components. Heavy metals from air and water reach the soil matrix either by deposition from air or percolation from water leading to transfer of metals in food chain due to accumulation by plants.

Soil quality is assessed through determination of physicochemical parameters, heavy metal content and genotoxicity (Cotelle *et al*., 1999). Estimation of content of heavy metals in food crops growing on polluted sites gives an idea about the possible transfer of heavy metals to food chain. Though, traces of some metals are required for the physiological metabolism of living organisms but the higher concentrations of these metals exhibit many toxicological responses (Järup, 2003; Inoue, 2013). Metals like cadmium and lead are identified as potential carcinogens by the USEPA. Also, other metals like copper, chromium, arsenic and mercury are reported to be toxic at higher concentrations (Orisakwe *et al*., 2012a, 2012b; Inoue, 2013; Saha and Zaman, 2013). Risk associated with heavy metals in food crops is estimated by calculating hazard quotient i.e., concentration of exposure through intake with food to reference oral dose. If the value of hazard quotient is more than 1, the food crop is considered hazardous for human consumption, (US EPA, 1989). Hazard quotient of many crops across the world is reported to be beyond safe limits thus questioning the safety of food crops (Yang *et al*., 2011; Chang *et al*., 2014; Cherfi *et al*., 2014). The recent efforts to increase the global food production have ignored the safety aspects of food instigating rise in number of cancer cases, neurological disorders and impairment of vital organs (Nagajyoti *et al*., 2010).

In World Food Summit (1996), the food security is addressed as a multidimensional approach that focuses on continuous availability, safety, accessibility and nutritional content of food for all individuals (FAO, 2008). International organizations (USEPA, FAO and WHO) are continuously making efforts to develop protocols and standards for the production of safe food. Agricultural organizations are trying to develop the practices to reduce heavy metal uptake in food crops growing on contaminated sites or irrigated with wastewater. Heavy metal uptake by plants is dependent on the bioavailability or mobility of metal ions. Metal-immobilizing amendments when added to soil reduce metal availability by forming stable complexes or by acting as sorbents for the adsorption of metal ions. Improving soil quality with organic or inorganic amendments is a cost effective strategy to prevent the transfer of heavy metals to food chain (Mahar *et al*., 2015).

In India, the agricultural crops are grown along the various wastewater drains like, Yamuna Drain (Delhi) and Tung-Dhab Drain (Amritsar). Also, municipal and sewage water is widely used for the irrigation purposes to meet water scarcity. Depending upon the source of discharge, the wastewater often contains high concentrations of toxic heavy metals.

Amritsar (31.64°N 74.86°E) spread across an area of 2,683 km^2, is known for its cultural heritage. Being part of food bowl state of India, it is amongst major producer of vegetables in the country. The average annual rainfall of Amritsar district is 541.9 mm leading to semi-arid conditions throughout the year (Govt of Punjab, 2016). The average depth of ground water table is 302-450 m and the annual draft from ground water exceeds much more than annual replenishment of groundwater resources in district. (Central Ground Water Board, 2015). To manage the scarcity of water the irrigation in many parts of district is carried out using wastewater. There are mainly two types of industries in the district; electroplating and textile dyeing, most of these industries do not have an upgraded effluent treatment plant and thus discharge the wastewater as untreated or after the primary treatment which thus include many harmful chemicals. Also, the 217 MLD of domestic wastewater is discharged and there is no functional sewage treatment plant to treat the domestic wastewater (Rajya Sabha Secretariat, 2015). Wastewater discarded by industries or municipal drains is generally untreated and even if it is treated, the treatment process adopted is of primary level which doesn’t remove heavy metals (Huibers and Van Lier, 2005; Pedrero *et al*., 2010). The two main drains Tung-Dhab drain or Municipal wastewater drain through the network of sub-drains receives wastewater from industries, household and other commercial areas of Amritsar district. Increase in number of cancer cases and higher frequency of micronuclei (buccal mucosa) was reported in the people residing near these drains (Sambyal *et al*., 2004).

Considering the alarming consequences of cultivation of food crops along the wastewater drains or irrigation with wastewater the present study was planned to achieve following objectives:

- Survey and selection of agricultural fields along Tung-Dhab and Municipal wastewater drains, irrigated with ground water and wastewater, respectively.
- Monitoring of soil samples from selected sites along wastewater drains.
    - Genotoxicity assessment of soil samples from selected sites using *Allium cepa* root chromosomal aberration assay.
    - Physico-chemical analysis i.e. soil texture, alkalinity, pH, nitrates and phosphates, essential elements *viz.* calcium (Ca), magnesium (Mg), sodium (Na), potassium (K) and heavy metals i.e., copper (Cu), cadmium (Cd), chromium (Cr), iron (Fe), manganese (Mn), lead (Pb) and zinc (Zn) of soil samples.
    - Estimation of CHNS content in soil samples.

- Monitoring of vegetable crops along wastewater drains;
- Estimation of heavy metal content viz. copper (Cu), cadmium (Cd), chromium (Cr), iron (Fe), lead (Pb) and zinc (Zn) in vegetable samples collected from these sites.
- Analysis of hazard quotient of vegetables with respect to adults and children.

- Identifying suitable low cost soil amendments which reduce heavy metal uptake by food crops.
    - Selection of metal and vegetable on the basis of content of metal and hazard quotient of different vegetables at various sites.
    - Preliminary screening of suitable amendments.
    - Content of metal in selected vegetable grown on soil having different amendments.
    - Growth parameters: root length, shoot length.
    - CHNS content of vegetable, amendments and soil.
    - Estimation of essential metals chromium (Cr), Cobalt (Co), Manganese (Mn), Iron (Fe) and Zinc (Zn) in vegetable, amendments and soil.
    - Biochemical studies of vegetable grown on soil having different soil amendments
        - ✓ Protein content
        - ✓ Chlorophyll A, Chlorophyll B, Total Chlorophyll.
        - ✓ Carotenoids
        - ✓ Ascorbic Acid