CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Groundwater resource has significant role in achieving the food security and increasing the food production. Groundwater occurs in a range of climatic conditions, geographic zones and in different lithological set ups and usually requires little or no treatment. Groundwater both qualitatively and quantitatively is a vital resource and is under a great threat. Its continuous use and demand has made the groundwater management burning issue today. Further being a monsoon dependent country, hence most of the time groundwater supply fulfills our water requirement. The situation becomes more critical in that parts of our country where water utilization is high due to irrigational activities. A large amount of the world’s irrigation, agriculture and number of industries are dependent on groundwater. However, the continuous rising demand for water in India, mostly for irrigation, drinking and industrial use lead to problems of over exploitation of these resources. Groundwater is 20% of the world resource of fresh water and used by irrigation, for domestic purposes and industries (Usha et.al., 2011). It is an important component of the water resource system. 85 percent of India’s rural domestic water needs and 50 percent of urban water requirements and more than the 50 percent of irrigation requirements are met by the groundwater resources.

Groundwater is also considered as the most resilient source of the drinking water (Lapworth et.al., 2017). The main limiting factors for obtaining and using of groundwater are the lack of precise data on aquifers such as storativity, depth and contamination status. This shortage of information has hampered groundwater protection and development. But in view of the increasing urbanisation, population and uncontrolled pollution, there is an urgent need to protect and manage these shrinking groundwater resources judiciously and efficiently to ensure its sustainable utilization.

India experienced both green revolution and famine, while on one hand the green revolution led to a decrease in hunger pangs of millions of people whereas on
the other hand it has led to emergence of different environmental problems. In the post green revolution period, the rapid increase in use of the groundwater resources mainly for irrigation contributed to the agriculture and for the economic development of the country. Sustainable development of the groundwater resources have posed different challenges in the recent decades. While declining water levels are the main concern in our country, coupled with poor under surface drainage, the intensive irrigation in some specific canal command regions, have created problems of groundwater salinity and water logging which makes the soils unproductive and contaminated. Human well-being system and ecosystem health in different locations have been seriously affected by the changes in the global water balance caused mainly by anthropogenic pressures. This situation will be analysed as rapidly growing urban centres put heavy pressure on the local groundwater resources. This increasing demand for groundwater is fulfilled mainly by the sub-surface water abstraction which deteriorates both the groundwater quality as well as quantity.

There is wide gap between the water needs and availability for different uses. This calls for urgency of groundwater resource development and conservation of new technologies to enhance the utilizable groundwater resource potential and actually develop its source for our existence and it caters the need of public both in rural and urban areas. With the growing requirements for the diverse purposes and during the course of development, groundwater resources has been both depleted and polluted. In the absence of any groundwater rules, regulations and legislation unabated increase in groundwater exploitation during green revolution results in over exploitation of the resource. Man through a variety of modern technologies and man made activities is dramatically changing the characteristics of groundwater resources systems. Various activities like power generation, intense agriculture, chemical and other industries are the major sources of the groundwater contamination. The most important types of groundwater contamination are urban pollution due to seepage of septic tank effluents, municipal landfills, agricultural pollution due to excessive continuous use of the fertilizers, pesticides and industrial pollution due to seepage of effluents. Microbial contamination of groundwater may be due to presence of the biodegradable organic matter in water discharges from domestic and industrial effluents.
Punjab state is one such state where groundwater level as well as quantity and quality is deteriorating very fast and only 25 blocks out of 141 falls in the safe category, but most of the blocks in this category too have saline water. Punjab state is basically an agriculture dominant, where intensity of cultivating crops in a year is quite high. This Punjab state stands 3rd after Andhra Pradesh and Uttar Pradesh in total consumption of the pesticides. Also the consumption of plant nutrients is highest (158.9 kg/ha) in this state of our country. Much of the irrigation is dependent on groundwater resources and out of the total 138 blocks of Punjab, 84 blocks are categorized as over-exploited as far as groundwater resources are concerned. Most of these blocks are in central plains of the Punjab state. 94% of sown area in Punjab state is irrigated, 61.6% is irrigated by the tubewells and remaining 38.4% by the canals.

Punjab is only state in our country which is suffering from the unique, serious and harmful environmental problems. U concentration in groundwater of Punjab has been rising as well as spreading at faster rate. The study conducted by Health department of Punjab has been reported that Uranium content found is above 50% as per the permissible limit given by WHO in most of districts of Punjab. U in groundwater issue in the state is baffling as there is no Uranium mine in Punjab state. One theory is that U may come from Iraq where US army uses Uranium in its warheads, other theory suspects contamination of air which may be cause by U-laden winds from Afghanistan, whereas on other hand, many experts feel groundwater contamination is due to toxic scrap which is dumped into the state’s Sutlej and Beas rivers which may be cause for Uranium contamination. It could also be originated from thermal power plants as “Coal, used in these thermal plants is known to have the radioactive material like Uranium”. But there are some agencies and researchers who warn against this type of the speculation and theories. “Punjab state is already suffering from cocktail of the pesticides”. The most important type of groundwater contamination in Moga District is mainly due to uncontrolled use of the pesticides and fertilizers which causes contamination in groundwater. The broad range of contamination sources is one of the main factors which contribute for the complexity of the groundwater quality and its contamination (Agarwal, 2005).

Groundwater is the main critical input for the production of different crops. Amidst unreliable and inefficient public tubewells and canal irrigation systems, Indian
Government has encouraged the private investment in the groundwater extraction by various provisions such as subsidized credit availability and the Punjab State Government added to it by providing free power supply. The attractive returns received from the policy support and from new technology triggered farmers to invest in large amount in the groundwater development making it a principal irrigation source in the Punjab. Due to injudicious use of this valuable natural groundwater resource, Punjab state has emerged as an substantial case of groundwater overexploitation with 72 percent higher groundwater removal than sustainability. Depleting the groundwater resources not only put heavy financial burden on farmers but also disrupt ecological balance, and also creates socio-economic inequalities in distribution. Some studies have analysed the socio-economic consequences of exhausting groundwater resources in the Punjab state at micro level and similar studies have identified many reasons for the emerging groundwater crisis. This studies have explained the institutional, hydrological and policy related measures for improving the groundwater sustainability in the parts of Punjab state. Among different approaches groundwater pricing and regulation of the energy supply is discussed as an effective way for the management of groundwater resources in our country.

Scientists have also detected Aluminum in groundwater in few districts of Punjab where the groundwater resources are already U and Arsenic contaminated. Punjab governmnet has decided to source drinking water from the canal networks in Barnala and Moga districts where presence of toxic heavy metals in the sub-soil water is rampant. In some parts, Reverse Osmosis systems were installed for the removal of toxic metals. The situation of groundwater contamination in Punjab state is really very bad, so we need more scientific studies for understanding implications on health of local people who consume this U contaminated water. Therefore, we must know about source of U's presence which may be very unaccountable and unusual. No exhaustive study on U contamination in groundwater of Punjab has been undertaken.

The Southwest Punjab is facing problems like salt water encroachment, water-logging, salinity and groundwater pollution, which are the consequences of intensive agricultural and irrigation practices (Sharma et.al., 2016a, 2016b, 2016c). Groundwater scarcity has become an increasingly significant problem mainly in the semi-arid and arid parts of India, where the median annual precipitation is less than
the value of 500 mm (Keesari et al., 2014). Groundwater quantity and quality studies become unavoidable since its poor and bad quality may badly affect its users (Prasanna et al., 2010). The quality of the groundwater resources depends upon the overall relative amount of different chemical constituents which are present in the groundwater (Ghosh et al., 2011). Chopra and Krishan (2014) have estimated that about 47% of groundwater is not fit for agricultural and drinking purposes due to high amount of salinity. According to World Health Organization safe drinking water is the basic necessity for the health, development and wellbeing of mankind (WHO, 2003). Today Groundwater has become much vulnerable to contamination due to industrialization and population explosion. Groundwater can be contaminated through varieties of chemical substances released near or at the soil surface from non point and point sources (Gautam et al., 2013). Some substances found naturally in soils or rocks such as manganese, iron, fluorides, arsenic, chlorides, sulfates or radio nuclides can become dissolved in groundwater (Chilton, 1996). Groundwater chemistry depends on the different geochemical processes taking place as well as on chemistry of recharged water in the subsurface (Rajmohan and Elango, 2004). The hydrogeochemical processes and complexities of groundwater flow system are temporally and spatially different depending on local scale, chemical characteristics of aquifer and geology of area. Two chief sources of ions which control the groundwater chemistry are anthropogenic activities and weathering (Garcia, et al., 2001).

Uranium is natural, ubiquitous and radioactive element. It is a silver coloured heavy metal and is a natural occurring element which is also widespread in the nature present in all types of soils, rocks, plants and also in sea water. U is also soluble in its aqueous solutions in the hexavalent form (U⁶⁺). U is the heaviest element found in the notable amount on the earth naturally. According to UNSCEAR, the concentration of Uranium of soil is 300 μg/kg to 11.7 mg/kg. Significant concentration of U occur in some minerals such as uraninite in U rich ores and phosphate rock deposits. Table 1.1 enlists the Uranium content in different rock types based on data from different oceanic and continental island sites. The ²³⁸U isotope is most abundant in nature followed by significantly low quantities of ²³⁵U and ²³⁴U. The majority of natural U radioactivity may be due to U isotopes ²³⁸U and ²³⁴U. It occurs in five oxidation states but only 2 oxidation states (+4, +6) of U are considered stable enough and have
importance in practical (ATSDR, 1999). In soil, U is mostly present in +6 oxidation state as \( \text{UO}_2^{2+} \) uranyl cation (Ebbs et. al., 1998). The Uranium mobility in soil depends upon pH of soil solution (Choi and Park, 2005). There are few regions in the world which have High background radiation areas (HBRA’s) due to the geochemical effects and local geology which results in increased level of terrestrial radiation (Bennett, 1997).

**Table 1.1 Uranium content in different Rock types**

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Name of the rock (Uranium in ppm)</th>
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<tbody>
<tr>
<td><strong>Igneous</strong></td>
<td>Granites, Grano-diorites, Rhyolites (2.2-6.1)</td>
</tr>
<tr>
<td></td>
<td>Gabbros (0.8)</td>
</tr>
<tr>
<td></td>
<td>Basalt (0.1-1.0)</td>
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<tr>
<td><strong>Sedimentary</strong></td>
<td>Shale’s (black) (3-1250)</td>
</tr>
<tr>
<td></td>
<td>Bauxite (11.4)</td>
</tr>
<tr>
<td></td>
<td>Phosphates (50-300)</td>
</tr>
<tr>
<td></td>
<td>Peat (1-12)</td>
</tr>
<tr>
<td><strong>Metamorphic</strong></td>
<td>Granulites (4.9)</td>
</tr>
<tr>
<td></td>
<td>Slate (2.7)</td>
</tr>
<tr>
<td></td>
<td>Schist (2.5)</td>
</tr>
<tr>
<td></td>
<td>Gneiss (2.0)</td>
</tr>
<tr>
<td></td>
<td>Phyllite (1.9)</td>
</tr>
</tbody>
</table>

(Source: Ivanovich and Harmon, 1982)

The Moga District is in southwest part of Punjab state where maximum content of Uranium in groundwater have been reported by various agencies and researchers. The sediments of this area contains recent, terrace gravels and river boulders which are loosely packed in clay-sand matrix with the occurrence of thin Kankar beds. These sediments owe their origin to a combination of number of geological agents. Rivers of the Himalaya have played a major role, since the rise of the mountain chain during the period extending from Miocene to Pleistocene. These sediments are divided into two parts, Newer alluvium and Older alluvium. The Newer alluvium are called Bet in Punjab, is mostly confined to neighbourhood of river channels and are of Upper Pleistocene to Recent age. The Older alluvium consist of reddish to pale brown coloured layers of clay and kankar is found in these sediments. The Older alluvium is from Middle to Upper Pleistocene age. The geology of the study area is mainly alluvial deposits and forms fluvial delta. The alluvial deposits of Punjab occur in the tectonic basin wherein the sediments have been transported from adjoining areas comprising of Shivaliks, metamorphic rocks and
granites. There is a need to construct or built up entire palaeo fluvial system and sedimentation history of Punjab alluvial deposits so as to delineate the occurrence of U and other related radio isotopes in these fluvial deposits. 95% of the cultivated area of the Punjab is irrigated. In the Punjab state, the total annual water availability is 31.30 lac hectare meter. There is a demand of 43.70 lac hectare meter to meet the present requirement of the Punjab state. The demand of 12.40 lac hectare meter is met by over exploitation of groundwater. These kinds of practices are leading to depletion of groundwater by 1 meter per year in main regions of Punjab. In this scenario the contamination of U in the alluvial formations needs a thorough investigation in order to identify the source and migration behavior of U.

The weathering of granitic rocks dissolves U which finally goes into the groundwater and the granitic rocks which form the basement for overlying sediments in this area. Though granites contain U which occur in minerals or mineralized zones but Punjab state alluvium is deposited by rivers Sutlej, Ghaggar, Beas and Ravi. The other source may be Phosphatic fertilizers which are known to contain U concentration 20 to 300 mg/kg. Such fertilizers are extensively used in the Moga district. It shows that high concentration of U observed in groundwater of shallow aquifer could be because of the use of such fertilizers in the area. Leaching and illuviation are two processes, which dissolved solutes and mineral matter and moved downward through the soil profile which get concentrated in the discrete zones of soil. Hence, radioactive contaminants which depend on chemical properties which accumulate in drinking water are main levels of concern. Groundwater systems are at risk to this contamination and are required for extensive monitoring and evaluation for the radioactive contamination to make ensure about the quality of drinking water.

The high exposure to higher levels of U is major concern for health of people (Orloff, 2004) because of hazardous nature of U and internal exposure, (Lawrie, 2000). The heavy metals and U accumulate in human organs and show progressive rising toxic actions notably, ingestion of Uranium and heavy metals which may continuously increase risk of cancer, genetic problems, kidney damage and cardiovascular diseases. The experiment evidence suggest that reproductive and respiratory system are mainly affected by Uranium exposure (ASTDR, 1999). Uranium has radiological and chemical toxicity which target two most important
organs, lungs and kidneys (WHO, 2008). The renal effects of U in drinking water shows that U exposure is associated with altered proximal tubulus function without threshold which depicts that low Uranium concentration of drinking water may cause nephrotoxic impact (Kurttio et al., 2002). Groundwater samples having U concentration above 30 micrograms/l (as prescribed by WHO) and 60 micrograms/l as prescribed by AERB is unfit for drinking purpose. U is absorbed into the blood which is retained and carried in body tissues and organs. Once U got absorbed in blood, it forms soluble complexes with the bicarbonate, citrates and proteins (Stevens et al., 1980 and Cooper et al., 1982). It is reported that the interaction between groundwater, soil and U is very much complicated, sensitive to soil and its physico chemical properties. Therefore, the estimation of U in groundwater may be substantial both for the health risk assessment, hydro geochemical prospection and for mitigation processes. Hence, the need of assessment of Uranium concentration in drinking water is very much significant. The periodic monitoring of groundwater is essential to understand the groundwater quality degradation and also to plan some suitable remedial measures to control further damage in this area. Therefore hydrochemical investigation was carried out in Moga district to understand the scenario of groundwater chemistry, to assess the effect of the groundwater resources and to identify the processes which impact the groundwater quality. Thus, for sustainable development of groundwater resources precise appraisal of hydrogeology and geochemistry and other varied quantitative assessment of groundwater are required. An attempt has been made to discuss statement of the problem, location of the research area and entail a comprehensive account of climate, physiographic, drainage, rainfall, groundwater resources, agriculture and economy of the Moga district under study. The review of the literature, objectives, and scope of the study are also taken up in sequel.

1.2 REVIEW OF LITERATURE
1.2.1 Water Quality Issues and Concerns

- Groundwater qualities in Sub-Saharan Africa and around the world are increasingly being hampered negatively by man made activities and anthropogenic sources analysed by Li et al., (2017). Contaminating sources such as demographic dynamics ignorance, human settlement developments,
advanced agricultural production, industrial activities, improper watershed and waste management are the major threat that compromise groundwater quantity and quality. Lapworth et al., (2017) reported that in many peri urban and urban centres in Africa groundwater are being put under considerable pressure from pollution loading.

The optimum management of groundwater resources requires proper governance arrangements from regional level to national scale. During the study author understand the socioeconomic and biophysical drivers of the groundwater resources are necessary for environmental challenges and agro-economic conditions (Kuper et al., 2016). In groundwater resources based irrigation in Tunisia region, government identifies the groundwater plays central role for sustaining the rising farm incomes and rural communities and also ensure food security. The economic development of Tunisia region has been based on groundwater resources which follow adoption of drilling and pumping technology, digging of wells and establishment of agroindustry (Mekki and Ghazouani, 2016). The development carried out in this area by the farmers without planning and monitoring the resources. Behind positive side of system which is based on depletion of the groundwater resources and this type of development results in rising pressure on groundwater resources and continous declining of the water tables.

Vandeberg et al., (2015) worked out the spatial assessment of Lake Alice National Wild Life Refugee of groundwater quality in the vicinity and results highlighted that the high concentrations of phosphorus, nitrate and E.coli from the upstream sources are likely to impose greatest potential effect on Alice Refugee Lake. Liu et al., (2015) carried out a study on characterizing heavy metal which are build up on urban surfaces road and its effects on reuse storm water and found that heavy metals which were build-up on urban roads were from moderate to highly polluted levels. Cadmium, Copper, Nickel and Zinc were mainly from anthropogenic activities.

Kanzari et al., (2012) conducted the study on simulation of water and salts dynamics in Bouharzle (Central Tunisia) and found that rainfall events allowed the leaching of the accumulated salts in the top soil which promoted
their burying in the depth and a continuous leaching in the deeper layer which may increase groundwater contamination. Edmunds (2012) represents the continent-wide maps of the Africa aquifer storage and the potential borehole yield which is based on extensive review of publications, maps and data.

- Pfister et al., (2011) found that groundwater consumption in future, impact of global agriculture and its effects. Their results suggested that mitigating environmental impacts require fundamental changes in the international cooperation and agricultural systems, by producing crops where it is most environmentally efficient. Vinson et al., (2011) conducted a study on groundwater salinity and its effects for sustainable RO desalination process in coastal regions of North Carolina area, USA. This study evaluates the chemical composition groundwater salinity and noted the changes in salinity from Atlantic coast that is used for the RO desalination processes.

- Siebe and Cifuentes (1995) worked out in Central Mexico on environment impact of irrigation from wastewater, the measurement carried study on the soil fertility suggested that distribution of nitrogen loss presents potential risk to health of public which is triggered by the higher nitrate concentration of groundwater. There was proof of the rising prevalence of the parasitic infections in agricultural workers and their family members which were exposed to untreated waste water irrigation.

- The chemistry of groundwater is controlled by many processes and also depends upon the minerals which are present in the geological formations can be used for understanding hydrogeological processes and other mechanisms which control groundwater quality as per study conducted by Zuane (1990). The area of Punjab state is agricultural dominant region which makes it prone to over exploitation of the groundwater and usage of pesticides and fertilizers for enhancing the productivity of crops.

- The temporal variations of the drinking water quality was analysed by Tirkey et al., (2017) in Ranchi city, Jharkhand. Geometric DWQ Indices were increased during pre-monsoon season due to lesser contamination and lesser ionic contribution in the groundwater. On the other side, increasing
concentrations of health related parameters such as fluoride, lead and chromium have decreased the drinking water quality index scores during monsoon period. The chromium and lead values were higher during monsoon period. The domestic sewage, anthropogenic activities and groundwater run-off may be the sources for the presence of chromium and lead which may also be due to infiltration through the soil of large amounts of chromium received from groundwater released by industries.

- The groundwater resources are being over-exploited in many parts of our country. This scenario is clearly depicted in the human influenced alluvial aquifers of the Punjab state which is due to the exponential rising demand for industrial activities, irrigation necessities and domestic usage. Keesari et al., (2016) reported that contamination in groundwater quality in many parts of Punjab state may be due to inorganic and organic contaminants. The Southwest Punjab is facing problems like groundwater pollution, water-logging, salt water encroachment and salinity, which are the consequences of intensive agricultural and irrigation practices (Sharma et al., 2016a, 2016b, 2016c).

- Ramachandra et al., (2015) conducted study on the urbanization and its effects in Delhi from space and studied spatio-temporal patterns and its indicators. In this study the data from four decades was used for understanding the land use and land cover. Results of landscape matrices indicated that urban centers were highly gathered, while outer areas and buffer zones were on verge of aggregating patches of urban centres. It has been suggested that in order to make ensure that groundwater recharge, the government authorities are required to maintain the minimum vegetation cover in the study area, from recharge by units of rain water harvesting and percolation pits. Sidhu et al., (2015) studied the temporal variation and heavy metal values in the urban groundwater flow giving special emphasis on the irrigation utility Chandigarh for appraisal of the irrigation water quality index (IWQI). The results showed that IWQI ranged from 70-85 for both the sampling seasons, thus the value falling under the ‘Low restriction’ category for irrigation purposes. Water of this category should be used in the soils with light texture or moderate
permeability and should be avoided in soils with high clay. Chandigarh area witnessed the heavy textured soil and water which was used for irrigation purpose and was potentially leading to the sodicity problem. The metal concentration in the samples taken from the study area showed the trend of Fe>Ni>Mn>Cd thus showed a severe drop in the water quality.

- Roy and Shah (2002) conducted study in Northern part of Gujarat and found that most of the districts of Punjab and Haryana in which the groundwater exploitation exceeds the normal recharge. In some districts of Haryana and Punjab, Karnal, Jind, Mahendragarh in Haryana, Jalandhar, Sangrur and Kapurthala in Punjab are in category of the low potential high use. They depicted that over exploitation leads to the problems like salinization and pollution of fresh groundwater resources.

- Sharma (2000) depicted that in some regions of Punjab, the value of fluoride in the groundwater is above permissible limit 1.5 mg/l. In this study, roof water harvesting is desirable as there may be shortage of groundwater resources. Rainwater is free from dissolved solids and it does not contain any harmful substances such as fluoride and other parameters.

- Singh, G. (1999) has described the geology and geomorphology of Bathinda and Sangrur districts. The study identified seven major phases of fluvial action designated as F1 to F7 with intervening six arid phases A1 to A6. He also opined that these sediments were deposited in shallow basins in the low energy condition comprising water, lacustrine and dry aeolian phases. A paleoclimate fluctuated from semi arid to tropical where rainy seasons were intervened by long dry spells.


- Singh, K.P. (1996) studied the temporal changes in chemical quality of the groundwater of Ludhiana, Punjab, India and he also compared the results from
1983 to 1992. This study indicated that groundwater samples which contain cyanide have increased because it cannot be absorbed and remain in hydrogeological environment and other trace elements which do not show any important change.

- Malik and Banerji (1981) have related the high nitrate content of groundwater with use of fertilizers. He opined that main source of high nitrates in the groundwater is possibly from nitrogen rich fertilizers and mentioned that there is need to work out the desirable quantity of fertilizers that should be used for particular crop in particular area and to educate and aware the farmers on this aspect.

- Balakrishnan et.al., (1979) carried out studies of Himalayan foothills of Punjab and Himachal Pradesh and the geological correlation with the nearby adjoining regions of Punjab plains. There is a major fault down thrown towards the hills, affecting the basement. Refraction velocity distribution in the plains brings out that the lower Siwalik section, which is very thin, pinches out against a line passing through Gurdaspur and a point between Adampur and Jalandhar. Dharamshala formation is mostly absent in the plains. In the Hoshiarpur-Pathankot region the sediments may be resting on a Precambrian basement.

- Singh et.al., (1977) has studied the sodium hazard and salinity of groundwater of the Bathinda district. This study revealed that groundwater in this region contains a high concentration of salts and their long term use may result in the build up of salinity in the soil and groundwater to an extent that growth of the crops is severely inhibited.

- Bajwa et.al., (1975) divided the Punjab state into five hydro-chemical zones based on the quality rating and gave the first approximation of groundwater quality map of Punjab state. According to him, around 40% groundwater of the state varies from marginal fit to unfit for various usages.

- Awasthi (1969) has studied the influence of submerged Aravali Ridge on the groundwater conditions in Punjab. He also opined that water logging in the state is related to the main geological factors responsible in the lithological
difference within the alluvium itself and the meteorological conditions of the area.

1.2.2 Uranium in Groundwater Concerns and Issues

- Uranium isotope analysis is a tool to understand the different sources, flow paths, mixing patterns in the groundwater systems, aquifer characterization, tracing their evolution and pollution studies. Bonotto (2017) studied activity ratio from spas of southeastern Brazil and found that water sources are mainly from reduced environments. Large scale changes in Uranium and bicarbonate in the groundwater of irrigated regions of western part of US was assessed by Burow et al., (2017).

- A study was carried out by Berk and Fu (2016) on geogenic U mobilisation by nitrate input into aquifers. Nitrate is recognized to change U solubility by oxidative dissolution of reduced U(IV) minerals and a similar study on natural U contamination in major US aquifers linking with nitrate was carried out by Nolan and Weber (2015).

- Berisha and Goessler (2013) determined the natural elemental concentrations in drinking water samples of Kosovo’s territory with (ICPMS). The results showed that 98.8% of the samples which were analyzed had Uranium concentration higher than the 0.01 µg /l which was limit. The U concentrations till 166 µg/l were observed with average value of 5 µg/l. 2.6% of drinking water samples exceed the WHO maximum limit of 30 µg/l, so there is very less risk of U exposure by drinking water. Shomar et al., (2013) conducted study on Uranium in soils of Qatar area, around 409 soil samples were collected throughout Qatar for investigating that whether there is some detectable trace of depleted Uranium (DU). The results depicted that there was no linkage between the distribution, occurrence of U concentrations and isotopic ratios of the Uranium.

- Stalder et al., (2012) conducted survey of U in the drinking water of Swiss and reported that the higher concentrations of U in groundwater was mainly in alpine areas which can be due to the geology of bedrock. Water sources from different locations were analysed for various elements such as Si, V, Mn, Li, Co, Cu, Ni, Zn, Sr, Sb, Cd, Pb and Uranium. There was no correlation of U
with other elements mainly heavy metals. U content ranged considerably from below detection limit to almost 100 µg/l.

- The case study was carried out by Jurgens et.al., (2010) in California on the effects of groundwater development of U and reported that there was strong correlation between U and bicarbonate and U was leached from shallow sediments by high values of bicarbonate water. Most of the groundwater samples with high U concentration were saturated with calcite, whereas on other hand groundwater samples which having low U concentration was mostly undersaturated. This result indicated that the higher value of U content in the study area was mainly associated with shallow groundwater. The study also illustrated effects of irrigation which supported the agriculture and groundwater development in the groundwater quality in many arid regions of world.

- A comprehensive work was carried out by McCall et.al., (2009) to find the major sources of higher U concentrations in Clarks area of Nebraska drinking water sources. Direct push methods were mainly applied for obtaining the hydraulic profiling tool logs and were also used for understanding the hydrostratigraphy of different parts of aquifer. This investigation observed that Direct Push methods can be used as tools for investigating the unconsolidated aquifer. The groundwater chemistry variations and U distribution in the aquifer were monitored and found that Uranium can also be oxidized as well as dissolved in the groundwater even under low oxygen environment and reducing conditions. Hence, this study showed that presence of carbonate can increase the solubility of U upto 1000 times when it was compared with groundwater which is carbonate free.

- A survey on rivers, springs and wells was conducted by Alirezazadeh and Garshasbi (2003) in Iran and reported the concentration values of Uranium in the tubewells varied from 1 to 10 µg/L, whereas 95% of cities had Uranium concentration in wells at less than 4.70. Surface water showed U concentration which varied from 0.75 to 2.58 µg/L. Daily intake of Uranium in drinking water was estimated in the range from 2 to 21 µg/d, with average value of 5.44 µg/d. Tubewells are the major source of supplying the drinking water in majority of cities in this study area.
Kevin et al., (2002) conducted study on the multiple influences of the nitrate with U solubility during the bioremediation process of U contaminated sediments from the U contaminated area in New Mexico. He demonstrated that the nitrate can also influence Uranium in the Uranium contaminated environment by different mechanisms. The results reported that nitrate should be removed, because nitrate reducers compete metal reducers but also, because in the presence of nitrate Uranium (IV) produced will be reoxidized to Uranium (VI).

Gordon (1992) found link between ore bodies and biosphere Uranium content at six different location of Canada. Generally, U content in soils which was collected from ore body varied from 3-7 mg/kg and in soil horizon ‘A’ horizon, U concentration varied from 0.4-6 mg/kg with average value 1.6 mg/kg which is known for the natural occurrences of Uranium. The transfer coefficients were revealed by him as ratio of maximum concentration which was determined for the soil and groundwater of U ore bodies in British Columbia. The Soil and groundwater Concentration values of 4,588 and 1,507 were revealed for Blizzard and Ontario deposit. The IAEA has monitored the isotopes in precipitation worldwide. The isotopic compositions of δ¹⁸O and δD in precipitation are the most sensitive tracers which are applied for studying the natural circulation of water and movement of groundwater as per study conducted by Turner et al., (1992). Meteoric processes which change the isotopic composition of the groundwater isotopic composition in a way that the precipitation in the particular environment also has characteristic as that of stable isotope.

The U isotopic disequilibrium in the groundwater was studied by Osmond et al., (1983). This study showed that U⁴⁺ is immobile but oxidising and groundwaters which bear carbonates, U⁶⁺ is much more conservative and mobile. This intervening α-decay also causes the displacement of recoil and radioactive disequilibrium between the 2 isotopes and this study also exposed that number of aquifers also display isotopic patterns and ore deposits which were consistent with disequilibrium model.
Fyfe and Brown (1979) undertook a detailed study on the geochemical cycle of Uranium and stated that U transport and accumulation in the sediments which may be dominantly biochemical. U in mantle and rates of U addition and subduction return flow are above the subduction zones, erosion of Uranium and granites were also discussed. The problem of U distribution in mantle during the evolution of Earth is unresolved and the main models of the crustal evolution suggest that early depletion, continual depletion which was followed by the slow replenishment and constant mantle composition seems to be unlikely.

The Uranium contamination of drinking water was widely observed in southwest parts of the Punjab state (Rishi et al., 2017). Similar studies for U contamination was carried out by (Gomez et al., 2006 and Rana et al., 2016).

Sharma and Singh (2016) observed that bicarbonate derived mainly from root respiration and irrigation water enhances the leaching of the U bound in the sediments, mostly favourable in arid climate. Drinking water with high Uranium concentration possesses risk to chemical toxicity. Radiological and chemical toxicity risk study was carried by Bajwa et al., 2015.

Tripathi et al., (2013) conducted study for U concentration and activity ratios of U isotopes to represents geochemical conditions of groundwater in Malwa region of Punjab state. The main reason for higher U variation in activity ratios and levels from the secular equilibrium conditions and this study also reported Uranium concentration in the groundwater samples varied from 13.9 to 172.8 µg/l with the average value of 72 µg/l which is high than national as well as international guideline. Moreover, groundwater in this study area has been classified as the oxidized aquifer on the normal U content strata increased the U content strata on basis of U concentration. The $^{238}$U, $^{235}$U and $^{234}$U isotopic U concentration in the groundwater samples ranged from 89 to 1534, 4 to 68 and 76 to 1386 mBq/l.

As per the study carried out by Alrakabi et al., (2012) the concentrations of Uranium, Bromine and Sr elements were found higher in different shallow groundwater samples which were collected from the hand pumps in different villages. They also exhibited correlation with the total salt content and
elemental Uranium concentration of groundwater samples and canal water in the Bathinda district of Punjab which have been investigated by using the X-ray fluorescence, technique.

- A study was carried out by Kansal et.al., (2011) to assess U concentration in groundwater samples which were taken from hand pumps from different parts from Western parts of Haryana using the fission track registration technique. U concentration in groundwater for whole of area varied from 6 μg/l to 43 μg/l with median value of 19 μg/l in study area. These reported high values of Uranium may be due to the fact that this study area is known for having high gamma radiations in which the main contributor to dose rates being U and thorium. The groundwater samples from different locations such as Baliyal, Bhiwani and Tusham area depicted values higher than recommended safe limit 30 μg/l and higher Uranium content in groundwater samples may be due to radioactive rich granites of Tusham Hills in Bhiwani district of Haryana state.

- An investigation was carried out by Chamberlain (2009) and his study reported that the major cause of groundwater contamination and soil in the Malwa area of Punjab state was the fly ash that originate from the coal burnt in the thermal power plants which also contains higher level of U and ash as this region has the state's two largest coal-fired thermal power plants.

- Babu et.al., (2008) estimated that U concentration varied between 0.3 to 1442 μg/l. On the basis of this study, it was found the recharge area was located in the northern side and discharge area in the southern side of Kolar district, Karnataka. Thus the groundwater flows from the north to south direction in this area which shows diffusion gradient that run from the north to south direction. Hence, this was observed that the origin of U was from granite strata and there was diffusion trend which was observed in the course of flow-path in the groundwater of this area.

- Rani and Singh (2006) determined U concentration in groundwater in Punjab and Himachal Pradesh. They found concentration of Uranium, 1.39 ±0.96 to 98.25 ± 2.06 ppb in Punjab with mean of 19.94 ± 0.87 ppb. Kochhar et.al., (2006) reported high values of Uranium and radon along with chromium, lead,
arsenic which were more than the permissible limits in groundwater of South West parts of Punjab state.

- The U estimation in drinking water samples were collected from some areas of the Amritsar District was conducted by Singh et.al., (2003) employing fission track technique and found that Uranium concentration in drinking water samples varied from 3 to 45 µg/l. Hence positive correlation of nitrate, chloride, conductance, sodium, potassium, magnesium, total dissolved solids and calcium with U concentration has been found and this study also showed that U has much more greater affinity for the chloride and nitrate ions, so the determination of U and studying their correlation will be significant.

- Lee et.al., (2001) monitored concentrations and activity ratio of U isotopes in the groundwater which was measured for study and were variable which depend upon the location of the sampling sites. The results also suggested that most of the U isotopes in the groundwater exist as the dissolved U which also form complexe with the carbonate ion such as $(\text{UO}_2(\text{CO}_3)_2^2-)$. The U concentration isotopes depends upon the U solubility of groundwater and geological characteristics of aquifer and $^{238}\text{U}$ concentration in groundwater of hot spring region was found to be high than those in the other areas which can be due to the fast and quick material exchange between the groundwater and other rocks like U, shales and granite. The U activity ratio have tendency to decrease with the rising concentration of U and this study also suggested that isotopic data can be used for investigaing movement and history of resources of the groundwater.

- Singh, G. (1992) has given the account of Quaternary geological studies in regions of Faridkot and Bathinda districts. He discussed the various aeolian deposits, fluvial and geomorphological landforms. Based on the shallow subsurface information, the top part of the older alluvium has been classified into 7 subdivisions. The aeolian deposits have been classified into 3 subdivisions namely Older/ Stabilized dunes (“O” dunes), Semi Consolidated dunes (“SC” dunes) and Newer dunes (“N” dunes). The study indicated a southward shifting of river Ghaggar. The palaeowind directions and the morphological features indicate that dunes in Punjab are northern extension of
the Thar desert, but their formation could possibly involve reworking of local fluvial sediments.

- According to Krishna, Brahamam and Kochhar (1989) the Aravali-Delhi strike turns northwest from Tusham and further the gravity data shows that Tusham lies on triple gravity junction and considerable portion of gravity low is caused by arcuate granitic intrusion (240 km long and 6 km wide). There is trifurcation of gravity trend from Tusham marked by the extension of Aravali basement towards Himalayas in the form of Delhi-Moradabad ridge in eastward direction, Delhi-Hardwar ridge and Delhi- Lahore ridge in northwest direction. Aravali–Delhi ridge is quite shallow in southern side becoming deeper on the northwestern side. This is well exposed by the presence of pre-Cambrian rocks immediately below the alluvium at depths of 242 m and 533 m in exploratory boreholes drilled at Phulka (Haryana) and Khialiwala (Punjab) respectively.

- Mathur and Evans (1964) on the basis of the exploratory drilling by ONGC revealed occurrence of granite at 700 meter depth near Zira (Ferozepur). On the basis of groundwater exploration studies in Harike-Fazilka tract (Ferozepur district), the occurrence of reddish sandstone and reddish brown clay at 330 meter depth probably of Siwalik Supergroup was encountered.

1.2.3 Issues related to Heavy metals and Uranium in Soils and Food chain

- As per the study conducted by Dheri *et al.*, (2007) on the heavy metal values of water contamination with sewage and its related effects on soil and plant crops of alluvial soils in northwest India which indicated that accumulation of toxic heavy metals in soils and its uptake by the plant crops which pose high potential risk for the toxicity of plants and entry into food chain.

- A study was undertaken by Mehra *et al.*, (2007) to find the estimated and the average effective dose from the analysis of $^{232}$Th, $^{40}$K and $^{226}$Ra in soil samples of Punjab state. They also analyzed the soil samples from 30 different locations in Malwa belt and estimated $^{226}$R, $^{232}$Th and $^{40}$K. They also opined that soil was safe as far as radiation hazard was concerned and it can be used for the construction material and there was no radiation hazard.
The quality of effluents of Hattar Industrial estate in Pakistan was studied by Sial et al., (2006) and found that quality of effluents from Hattar Industries that heavy metals which persists in soil that can be leached into groundwater and adsorbed in soil particles. Human exposure to heavy metals through ingestion of the contaminated food and uptake of the drinking water can result in the accumulation of animals, plants and humans. They monitored a range of biological and physico-chemical properties of soil and also studied the chemical quality of industrial effluents which receive polluted effluents for identification and chemical analysis of plants which grow on soils receiving effluent as well as microbial characterization of soil and also for irrigation purpose.

Punjab Pollution Control Board, Patiala (2004) published a report on effect of contaminants in wastewater on vegetables and soil, a case study has been conducted to ascertain the effect of various pollutants present in the drains which are carrying sewage from various localities and industrial effluents of different industries situated in Chandigarh and Mohali area and identified alarming level of heavy metals in the wastewater which was utilized by the farmers in the surrounding villages to irrigate their field. Pathogens were also found in most of root vegetables.

Bohn et al., (2001) gave comprehensive and up-to-date coverage of the basics of soil chemistry. They provided the safe limits for the nutrients of soil. They established that the crops grow rapidly when the soil contains enough calcium. Ca maintains pH of the soil which is neutral for plants and micro-organisms survival. It was also assessed that 5-15 percent of exchangeable sodium has inhibitory effect on groundwater movement. In the presence of high sodium, plants spend much more energy on water intake due to the higher osmotic pressure which results in less potential for the plant growth.

Yoshida et al., (2000) during study on U concentration $^{235}\text{U}/^{238}\text{U}$ ratio in plant and soil samples which were collected around U conversion building near JCO campus of Japan found that highest values of $^{235}\text{U}/^{238}\text{U}$ atom ratio are found in soil and plant samples which were found near U conversion building which also propose that contamination seems connected to building. In this study,
they examined that soils and plants were contaminated during critical accident and surrounding environment of the building was contaminated with enriched Uranium which was released during common operations of the building.

1.3 NEED AND SIGNIFICANCE OF THE STUDY

From the above review of literature, it may be concluded that the environmental pollution and ecological degradation because of unplanned industrialization became an important issue of international concern in 21st century, in terms of depleting the natural resources and generating huge amounts of waste and extensive use of fertilizers and pesticides that lead to groundwater contamination. Based upon the hypothetical and scientific approaches reviewed from the literature survey and commensurate with the nature of problems associated with groundwater contamination in the study area, this will help in the proper management of natural resources, groundwater in conjunction with land area irrigated by the groundwater.

South-western part of Punjab has predominantly agrarian culture and irrigation has been the main stay of their economy, prosperity and development. Therefore, the main occupation of major area of population of the Moga district is “agriculture” and major sources of irrigation are tubewells, wells, pumping sets and canals. During ‘Green Revolution’ this district has achieved new heights in agriculture production mainly due to introduction of high yielding wheat varieties and introduction of paddy as the second major crop which has put a great strain on groundwater resource since most of irrigational needs are met with the groundwater resource as “Indian Agriculture is a victim of its own success especially Green revolution”. The irrigational spacing of tubewells has led to further decline in water level. This may be due to the rapid change in cropping patterns and installation of larger number of tubewells which led to drying of dug wells due to steep decline in groundwater levels. Increasing over exploitation of the groundwater for irrigation purposes has resulted in decline in water level tables and there is threat of the salinization and soil sodification due to excessive use of bad quality of the groundwater.

Uranium has been reported by various agencies and researchers in parts of district Moga and adjoining areas of Southwest Punjab. This study is an attempt to systematically quantify the U concentration in groundwater, soil and vegetables at micro-level. It also aims at working out the linkage between the U concentration in
soil and water and the food chain especially, in the root vegetables which were grown in study area. The agricultural practices in this part of the state are becoming environmentally unsustainable. Therefore, groundwater in the study area needs to be carefully managed and sustainably if its use has to be maintained for the future generations. Proper management, planning, monitoring and awareness is required so as to avoid the serious degradation of the environment and groundwater quality.

1.4 OBJECTIVES OF STUDY

The broad objective of this study is to estimate the U concentration in the groundwater samples and to find its linkage with food chain in parts of district Moga, Punjab. To commensurate with the nature of problems associated with U concentration in groundwater in the area of concern, ever increasing demand of water for manifold uses and procuring safe water for drinking (human and livestock) and irrigation, following objectives were defined for the present investigations:

- To understand the occurrence of groundwater and its behavior in relation to geological conditions in the research area.
- To demarcate the U contaminated zones with respect to groundwater and soil in the Moga District.
- To evaluate physico-chemical characteristics of groundwater and soil and evaluate its effect on food chain especially, the root vegetables.
- Critical evaluation of groundwater suitability for drinking and agricultural purposes.
- Collecting and synthesizing past and current scientific work to re-examine important technical and behavioral relationships related to groundwater in the study area.
- To suggest the suitable remedial management practices to control the further degradation of groundwater.

1.5 GENERAL DESCRIPTION OF MOGA DISTRICT

1.5.1 History of Moga District

Initially Moga was the part of Ferozepur district. Later, on August 7th 1972, Moga tehsil became a part of Faridkot district. In the year 1995, Moga tehsil along with Bagha Purana tehsil clubbed together to form a new district Moga. It is a municipality as well as city in the Punjab state. The Moga district being 17th district on the map of Punjab was found on 24th of November 1995. In past, Brar
communities lived in Moga. They generally called themselves ‘Sindhu Brars’. Another prominent community, who lived there were ‘Gils’ an important section of Jats. The Gils says that they came from Raja of the Rajputs who ruled at the place Garhmathela. The “Gil” name was explained by story by effect that Raja had no child from Rajputni wives and then he married the Jat women, she born son. Then other wives of the Raja became jealous of her and exposed the newly born baby in marshy spot of jungle. Hence infant was found by the king’s minister as co incidence and was called Gil, from area where he was found the “Gil” which means the moisture.

The Wadan Gils (totally there are twelve sections among the Gils) settled in beginning of 17th century in south and western parts of this district. Brars attacked them and took these all places, hence the Gils were further driven in northern parts of the area. Then they established themselves around Chal, Chhirak and Moga which are at present now and Peace was finally established by marriage of daughter of Brars Sangar to one of their “Gils”. This alliance also helped in raising the Brars considerably in the social scale. After the marriage, the daughter of Sangar gave birth to two male children, ‘Moga’ and ‘Vega’. The district was named Moga in the remembrance of the great ‘Moga’, who was a man of great importance among the Wadan Gils.

1.5.2 Location of Study Area

The Punjab state is located in the northwestern part of our country, India. It lies in western component from Great Northern Plains i.e. the Sutlej-Ganga plains of India. It extends from 29°30'- 32°32' North latitude and from 75°55'-76°50' East longitude. The total area of State has been grouped under 5 administrative divisions, Jalandhar, Faridkot, Ferozepur, Patiala and Roopnagar. The state comprises of 22 districts, 77 subdivisions and 141 blocks. The average elevation of this region is 300 m from sea level. Moga is located at 30°8' N to 75°17' E . It has an elevation of 217 meters (711ft). The district is surrounded by the Sangrur distrcit in South direction, Jalandhar district on North side, Ludhiana district on East side and Faridkot and Ferozepur on West direction. This study area spreads over the area of 2230 km², which is 4.42% of Punjab State. Fig. 1.1 shows the location of the Moga District.
1.5.3 Demography

As per the data census 2011, Moga urban population is 159,897, which shows that females were 75,089 and males population was 84,808. In Moga district, Males constitute 54 percent of population and females constitute about 46%. The literacy rate of this area is 81.42%. From the total Moga population as per 2011 census, only
22.8% of population lives in the urban areas of district and in total 227,246 people lives in urban regions. The Sex Ratio in urban areas of Moga district is 890. Similarly the child sex ratio in this area was 853 and population of children (0-6) in urban areas was 24,722. The average literacy rate of Moga district is 78.95 percent.

1.5.4 Soil

The Soil of this area is alluvial which is formed of sediments from Shivalik hills and Himalayas brought and laid down by the rivers from Indus system. The hills of Moga district contains rock-phosphate deposits and other rocks and minerals which are are known to contain higher Uranium concentration ranging from 300 to 3900 Bq/kg (Roessler et.al., 1979). The large-scale collection of radium and Uranium from hills which occurs by Himalayan river are the main source of radioactivity in the plains. From Geomorphologically view point, this area is vast stretch of the recent and old alluvium of Quaternary age which was modified by orogenic processes which are associated with fluviatile action. Table 1.2 below shows the U concentration in Fertilizers.

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>Uranium Concentration(µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc Sulphate</td>
<td>0.95</td>
</tr>
<tr>
<td>Urea</td>
<td>0.40</td>
</tr>
<tr>
<td>Ammonium sulphate</td>
<td>0.95</td>
</tr>
<tr>
<td>Potash</td>
<td>0.37</td>
</tr>
<tr>
<td>NPK Complex</td>
<td>0.82</td>
</tr>
</tbody>
</table>

(Source : Brindha et.al., 2011)

The soils which are loamy and have clay content below 10% are found in this study area. They contain smaller quantities of lime but Mg content is very high. They are well supplied with potash as well as phosphoric acid, but quantities which were available were very less. The agriculture in this zone depend upto large extent on the nature of soils which is also influenced by certain climatic factors. The soils of Moga district is fertile and alluvial. Fig. 1.2 shows the physiography and soils in study area.
Fig. 1.2 Physiography and Soils of district Moga

1.5.5 Occupation and Area Distribution

Moga city is economically better as compared to other towns of the Punjab state. The economic development of the District depends upon Agriculture. From employment point of view 79.95% population belongs to rural area and is engaged
with agriculture and allied activities. Area of the villages in the district is about 223040 hectares. Presently, the main economy of the Moga district is established on Sand Mines situated on the River Sutlej which run in Moga District and the river carry sand which settle as the river enter the Moga area.

1.5.6 Agriculture and Cropping Pattern

Agriculture is main occupation of people who live in Moga District, having different types of soil and agro-climate conditions which are quite suitable for the growing of various types of cereals, vegetables, fruits and other crops. Major crops which were grown in this region are Wheat, Paddy, Maize, Barley and Millet. Besides these, potato and a variety of vegetable like green-peas, cauliflower, cabbage, spinach tomatoes, are also grown in the district. The most of the land is un-irrigated and depended upon the rainy season for irrigation. Soil in the district varied from clay to sandy loam. The part of lands which were irrigated and the irrigation facilities are provided by lifting water from shallow streams, dug wells and medium to deep tube wells in the valley area. The agriculture and cropping pattern in Moga area is shown in Table 1.3 below.

Table 1.3 Agriculture and Cropping Pattern in the Study Area

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Statistics</th>
<th>Particulars</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Total Net Sown Area (Hectares)</td>
<td>195247</td>
</tr>
<tr>
<td>2.</td>
<td>Total Area which was Sown more than once (Hectares)</td>
<td>192455</td>
</tr>
<tr>
<td>3.</td>
<td>Total cropped Area (Hectares)</td>
<td>387705</td>
</tr>
<tr>
<td>4.</td>
<td>% of Total irrigated to the Gross Cropped Area</td>
<td>99.99</td>
</tr>
<tr>
<td>5.</td>
<td>% of Net Area which was irrigated to Total Area</td>
<td>100</td>
</tr>
<tr>
<td>6.</td>
<td>% of Net irrigated Area to total Sown Area</td>
<td>89.37</td>
</tr>
<tr>
<td>7.</td>
<td>% of Net Area (irrigated) to Net Area Sown for Wheat</td>
<td>93.21</td>
</tr>
<tr>
<td>8.</td>
<td>% of Net Area irrigated to Net Area Sown for Rice</td>
<td>Nil</td>
</tr>
<tr>
<td>9.</td>
<td>Wheat Production (in Tons)</td>
<td>806</td>
</tr>
<tr>
<td>S. No.</td>
<td>Statistics</td>
<td>Particulars</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>10.</td>
<td>Rice Production (in Tons)</td>
<td>852</td>
</tr>
<tr>
<td>11.</td>
<td>Sugarcane</td>
<td>Nil</td>
</tr>
<tr>
<td>12.</td>
<td>Yield of Wheat (Kg/hectare)</td>
<td>4617</td>
</tr>
<tr>
<td>13.</td>
<td>Yield of Rice (Kg/hectare)</td>
<td>4843</td>
</tr>
<tr>
<td>14.</td>
<td>Intensity of Cropping</td>
<td>198</td>
</tr>
</tbody>
</table>

(Source: District Survey Report, Moga 2016)

1.5.7 Irrigation

The Moga district has area of 383,000 hectares as the gross irrigated area and 198,000 hectare as area which is net irrigated area. Out of total 198,000 hectare, the canals irrigate 6000 hectare of area, which is 3% of irrigated area, whereas 96.97% of net irrigated area is irrigated by tubewells source. The Tubewells are more significant in comparison within the canals as far as percent of the area irrigated by the two methods is taken for consideration. There 65,558 shallow and deep tubewells which were owned by farmers in this district. The district is being extended through the network of canals and Sutlej rivers drains 700 sq.km of area and also drains 42% of area of this district. The annual replenishment of river which depends upon velocity of river, rainy season period and rainfall at different locations of river flow. The main canals of this district which feed the various distributaries, minors and field channels are the Sirhind feeder, Sidhwan Branch and the Abohar canal which irrigate the southern region of Moga district and leave Moga district for irrigating the parts of Bhatinda and Ferozepur districts. The Abohar Branch enters Moga district from village Daodhar at burji and terminates its direction in village Panjgarian Khurd at burji area.

1.5.8 Geomorphology and Climate

Moga has average elevation of 329 metres and is densely populated town which is surrounded by Sutlej stream. Two National Highway N.H.91 and N.H.73. Summer and winter are basically two seasons. The summer season of this district is in the months from April to July and temperature touches 44°C. The winter season is
from November to March month. June is the hottest month and January is the coldest month in this region. The rainfall occurs in month of July. In Moga district, winter rains are mostly experienced during January and February month. The dust storms also occurs in month of the May and June. During monsoon period Moga receive moderate to heavy rainfall. Usually the rain bearing monsoon winds blow from the south-west or south-east direction. This city mostly receives heavy rain from south direction which results in continuous rain, but it mostly receives most of the rain during monsoon season.

1.5.8.1 Rainfall Distribution

The south-west monsoon in this area arrives in the first week of July month and continues till the August Month. 70% of the rainfall in Moga district is mostly received during period from the June to September month and 18 percent of rainfall occurs during period from December to February month. Table 1.4 below shows the annual rainfall of Moga District. The Relative humidity is very high in the morning time which exceed 70% except during the summer season. The humidity in region is comparatively less during afternoons. The driest part of the year is during summer season when the relative humidity in afternoons is 25 percent or less. The Winds are light in the summer season and in early parts of the monsoon season. Winds are light and variable which flow in the direction mostly from the west or north-west during afternoons. In the month of April and May, winds blow mainly from direction between north-west and north-east during the morning period and it also flow in the direction between west and north-east during the afternoon period.

**Table 1.4 Annual Rainfall in Moga District**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Year</th>
<th>Average Annual Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>2011-2012</td>
<td>472.01</td>
</tr>
<tr>
<td>2.</td>
<td>2012-2013</td>
<td>472.1</td>
</tr>
<tr>
<td>3.</td>
<td>2013-2014</td>
<td>218.9</td>
</tr>
<tr>
<td>5.</td>
<td>2015-2016</td>
<td>438.9</td>
</tr>
</tbody>
</table>

(Source: Indian Meteorological Department, 2016)
1.5.9 Physiography

During flood plains of the Sutlej are separated from the upland plain by sharp river-cut bluffs. The sand which dominates in the soil structure of the flood plains, but it diminishes in both quantity and coarseness in the upland plain. The upland plain of this district covers major part of district particularly and elevation varied from 305 metres above sea level from north-east to 213 metres above sea level in south-west with the gradient of 1 metre in 1.6 km. This is the most significant physiographic unit of Moga district. This study area forms parts of Indo Gangetic plains and Sutlej sub basin from the Indus basin. This area is flat with the gentle slope towards the West and Northwest direction. The Sutlej River enters Moga district from the North-East side with boundary of Jalandhar district. It enters from village Kania Khurd and enters the Ferozepur district at village Khana in dharmkot block. The total length of Sutlej River in study area is 27.43 kilometers.

1.5.10 Industrial Scenario

The district sees presence of numerous medium and large scale industries and a supporting network of numerous micro and small industries. The district has five large scale units generating employment in excess of 21,000. Nestle India, Paras Spices and Abohar Power are key industrial entities in the district. Presence of large scale units have resulted in a significant vendor network catering to the bigger players. More investments in the large scale units are expected to happen in the near future which can lead to more vendorization/supplier network. The district also has one cluster devoted to Milk and Milk products complementing the district’s identity as a food and beverage hub. The MSE segment has witnessed decrease of around 1800 units as defunct units which were gradually deregistered. Inspite of this, the MSE segment managed to create additional employment of more than 600 during the period. Employment growth trends in MSME segment are presented in the chart Major Industries

Nestle Moga is one of the biggest private companies in milk business in Punjab. This factory is as food processing Plant of its own kind in North India. Nestle India. Since 1961 Nestlé has operated the Moga Dairy factory in the Punjab, India. The factory produces milk powders, infant products and condensed milk. The annual
fresh milk intake of the Moga factory has risen from less than 12,000 tons to 240,000 tons from 85,000 farmers. In order to achieve this impressive growth Nestlé India has supported a system of sustainable dairy farming. These sustainable methods involve field staff who provide technical assistance to milk suppliers and farmers about animal health, cattle breeding, fodder production and irrigation.

The regular milk payments and sustainable methods over the past decade have improved the livelihoods of tens of thousands of small-scale farmers in the region. They have had a positive social impact on the community and rural economy of Moga as a whole. Nestle’s relationship with India dates back to 1912, when it began trading as The Nestle Anglo-Swiss Condensed Milk Company (Export) Limited, importing and selling finished products in the Indian market. After India’s independence in 1947, the economic policies of the Indian Government emphasized the need for local production. Nestle responded to India’s aspirations by forming a company in India and set up its first factory in 1961 at Moga, Punjab, where the Government wanted Nestle to develop the milk economy. Progress in Moga required the introduction of Nestle’s Agricultural Services to educate, advice and help the farmer in a variety of aspects. From increasing the milk yield of their cows through improved dairy farming methods, to irrigation, scientific crop management practices and helping with the procurement of bank loans.

1.6 GEOLOGY OF MOGA DISTRICT

The great Indo-Gangetic plains are regarded as the major unit of geology in the Indian sub continent and the area under this investigation forms a part of this fertile plain. These plains often referred as Indo-Gangetic trough are tectonically formed in front of Himalayas in north direction and elevated peninsular shield in south direction. This plain though appearing to be one vast stretch embraces several sub basins with an uneven floor with hidden ridges. Based on seismic and borehole data, Rao (1973) divided these plains into five parts from west to east as follows:

- The Indus basin in Pakistan.
- The Punjab basin in Punjab.
- The Ganga basin in U.P. and Bihar.
• The Brahmaputra basin in Assam.
• The Ganga - Brahmaputra basin in Bangladesh and West Bengal.

The Punjab basin follows a NW-SE and ESE and almost EW course in conformity with the trend of Siwaliks hills. Following underground ridges/ basement highs bound this basin:

1. Lahore-Sargodha ridge on the west. This is an Archean basement ridge, which separates the Indus basin from the Punjab state depression on the east.
2. Delhi-Jagadhari ridge on the east. This is a basement high which controls the water divide between the Punjab rivers flowing to west and the Yamuna river (Ganga basin) flowing to east.
3. Aravali-Delhi ridge on the south. This is NW-SE trending broad and gentler regional high. Its highest part is at about 400 m depth passing through Sirsa, Mansa and Faridkot.
4. On northern side, the Siwaliks rocks bound the Punjab basin.

The five evaporites cycles with cumulative thickness about 130.77 meter, occur in Punjab plains, but only three evaporites cycles having cumulative thickness of 50 meter occur below plains of Haryana. Dolomite/dolomitic limestone is of foetid character which probably represents the basin limestone subjected to the bacterial reduction in subphotic zone or was probably deposited in restricted/euxenic environment.

The Geology is one significant factor which control the occurrence and groundwater flow in this area. The unique types of rocks which occur below the surface of earth make different zones of the groundwater potential which vary in different zones. The unique types of rocks which have high permeability and high porosity like sands and boulders have best groundwater potential. The other rock types which have higher porosity, but less permeability, for example clays and silts have very poor groundwater potential. Hence, sands and boulders form the best aquifers whereas the clays along with the silts have very low transmissibility which make poor aquifers. This district was occupied by various geological formations of the Quaternary age which comprise alluvial deposit and this alluvial formation are overlain through the Aeolian sands, except in the region which lies in the proximity of Sutlej River. The distribution of rainfall in this area, geological setting and
geological formations constitute the aquifers which essential controls the hydrogeological framework of Moga district. The geological successions which were encountered in Moga District are shown below in Table 1.5.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>GEOLOGICAL AGE</th>
<th>STRATIGRAPHIC UNITS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td>Upper Pleistocene to Recent</td>
<td>Sand Ridge</td>
<td>Medium to fine grained and buff coloured dunes over the alluvium.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>New Alluvium</td>
<td>Unconsolidated silt, sand and clay and gravel which were deposited on the Sutlej in flood plains.</td>
</tr>
<tr>
<td></td>
<td>From Lower to middle Pleistocene</td>
<td>Old alluvium</td>
<td>Semi consolidated, fine to medium grained clay and sand (brown coloured, very sticky and hard) occasionally found mixed with the Kankar.</td>
</tr>
<tr>
<td>Tertiary</td>
<td></td>
<td>Sandstone and Shale sequences</td>
<td>Reddish maroon and buff coloured</td>
</tr>
<tr>
<td>Achaean</td>
<td></td>
<td>Granites and Gneisses</td>
<td></td>
</tr>
</tbody>
</table>

(Source: CGWB, 2015)

1.7 THESIS OUTLINE

The thesis of six chapters with few appendices is output of research work. The gist of Chapters is discussed as follows.

Chapter 1: Introduction

This deals with the general description of the Moga district, research problem, aims and objectives of the research and the review of literature for the work done. In addition to this Uranium assessment, evolution of groundwater resources, demography, climate, physiography, drainage and geology of the Moga District have obvious implications for the research work carried out for this thesis.

Chapter 2: Hydrogeology and Change in Land use/Land cover in Study Area

The chapter includes hydrogeology, groundwater level, short term and long term fluctuations, groundwater behavior and long term water trend through hydrographs to
estimate the effect on the groundwater resources. The chapter also incorporates the groundwater level behaviour and data regarding lithology of the area. To analyze the spatial changes in the land use and land cover, remote sensing studies were undertaken in the study area from 1990 to 2016 using LandSat images.

Chapter 3: Groundwater Quality Assessment in Study Area with special reference to Uranium Toxicity

This chapter discusses the qualitative aspects of groundwater resource in Moga District. The groundwater quality has been examined in context with drinking and irrigation. Uranium assessment was done for the groundwater samples. Heavy metal distribution analysis was also done. An effort has been made to understand the water type of the Moga district through Piper Trilinear diagram, RSC, SAR, Wilcox, USSL and other parameters have been used to estimate the both drinking and irrigation quality of groundwater in Moga District. In this chapter these factors have been inquired in detail and analyzed for finding the concentration of U in groundwater.

Chapter 4: Soil Quality with respect to Uranium and Heavy metal contamination

This chapter investigates the soil parameters and physico and chemical properties of soils of Moga district. Analysis of soil samples for heavy metals Pb, Cd, Cr, Ni, Zn, Fe, Al and Cu has been discussed in deatail in this chapter. This chapter also incorporates assessment of U in Soils and its linkage with food chain.

Chapter 5: Heavy Metals and Uranium content in Vegetables

It discusses the mobility regarding toxicity of heavy metals from groundwater to food web by heavy metals which accumulate in vegetables which were grown in Moga district and its adjoining areas. The results will create awareness among the public on the safety of consuming vegetables grown in such parts of study area as people living in this contaminated region are at greater risk for health issues.

Chapter 6: Summary and Conclusions

This chapter embodies the summary of the observations and conclusions drawn from various laboratories and field investigations in the study area. In the present examination, the author has attempted to provide a complete assessment of prevailing
environmental problems in the study area. An attempt has been done to provide an overall view of the present situation in the Moga District. Certain recommendations regarding the sustainable growth, proper use of fertilizers and pesticides, use of RO systems are also the content of this chapter.