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A Study and Evaluation of Groundwater Quality and Heavy Metal Contamination in Bathinda district of Punjab, India

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ABSTRACT

This study investigates the groundwater quality and determination of heavy metals in the groundwater of Bathinda district of Punjab. The groundwater quality was evaluated using water samples collected from 15 locations of Bathinda district during July 2022. The samples were analysed for the parameters pH, Temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Salinity, Chloride, Calcium and Heavy metals content such as Cadmium, Chromium, Lead, Nickel, Iron. The results of the above analysis suggested that in the majority of locations EC, TDS, TH and Pb were found to be above the acceptable range as prescribed by the Bureau of Indian Standards (BIS) for drinking purposes. TDS and TH levels were found to exceed the acceptable limit given by BIS in 93.3% of the samples. Cd, Cr, Ni levels were found to be below the permissible limit of BIS. Statistical analysis for heavy metals showed asymmetrical distribution in the studied area. High concentration of Lead and Iron warrants to identify and investigate the natural and anthropogenic sources that are responsible for heavy metal distribution in groundwater. Therefore, it can be concluded from the study that the groundwater quality of Bathinda district is majorly contaminated with Lead and Iron. Overall, the groundwater quality is found to be unsatisfactory and long-term use of such water for human consumption could trigger serious threat to human health.

Key words: *Groundwater contamination, Heavy metals, Water quality, Punjab*

Introduction

Water is an important constituent of the ecosystem that supports all forms of plant and animal life on the earth. There are two principle natural sources from which it is generally obtained; Surface water such as streams, rivers, freshwater lakes etc. and ground water such as well water, borewell water (McMurry and Fay, 2004; Mendie, 2005) India supports more than 16% of world's population with only 4% of world's fresh water resources (Singh 2003). The total amount of fresh water available on Earth in liquid form is 10.7 M km^3 (Oudtshoorn, 1997). The Indian economy is predominantly based on agriculture and hence the optimum quantity of water availability at the right place is imperative to ever increasing farm needs.

Due to inefficiency of surface water to meet the water needs and its regular contamination, the citizens at global level are encouraged to become more dependent on groundwater resources for various purposes like industrial, agricultural, commercial and domestic needs, which have led to overexploitation of groundwater over past few years. The various anthropogenic activities such as excessive use of agrochemicals, addition of pollutants from industrial area, and seepage of domestic wastewater from landfill sites have led to significant contamination of groundwater resources and hence adversely affected the quality of ground-water making it unfit for human use. Most of these factors are related to industrialization and urbanization. The major source of groundwater and surface water pollution is disposal of untreated and partially treated effluents directly into the surface water bodies leading to serious water contamination, threatening the quality of surface and ground water resources. Utilization of water from these sources specially for the purpose of drinking can be hazardous to human health due to the presence of various toxic elements such as As, Pb, Zn, Cd and other heavy metals (Vodela *et al*., 1997). Heavy metals are of particular concern among the wide range of contaminants in groundwater because of their strong toxicity even at low concentrations (Marcovecchio *et al*., 2007). Therefore the groundwater quality is of primary importance to live a healthy life and also for the development of the economy of any country.

Heavy metals is a general collective term which refers to the group of elements having atomic density greater than 4 g/cm^3. The occurrence of heavy metals in groundwater comes from both natural and anthropogenic sources. The natural sources include weathering of rocks, settling of airborne dust, decomposition of living matter and volcanism extruded products whereas anthropogenic sources include draining of sewerage, mineral and mining processing, industrial and domestic effluents (Reiners *et al.*, 1975; Pawar *et al.*, 2014; Mukate *et al.*, 2015; Wagh *et al*., 2016). According to various studies conducted it has been proved that heavy metal pollution in water resources is occurring through various ways including the disposal of untreated industrial waste, overuse of pesticides and fertilizers, waste dumping sites and acid mine drainage (Kale *et al*., 2010; Bhuiyan *et al.*, 2010; Belkhiri *et al.*, 2017; Panaskar *et al.*, 2014). In small quantities the heavy metals are considered essential for the normal functioning and metabolism of the human body but in excess can be deleterious to the human health. Heavy metals are not easily degradable (biologically or chemically) therefore have a tendency to accumulate in the biological system and hence pose a threat to human well being.

Punjab is currently facing serious groundwater quality issues due to its contamination by several toxic metals (Shrivastava, 2015; Dhillon and Dhillon 2016; Kumar *et al.,* 2016, 2018). Numerous studies have indicated nitrogen fertilizers (Shivran *et al.*, 2006; Kumar *et al*. 2006; Bishnoi and Arora, 2007) and pesticides (Subba Rao, 2002; Naik *et al.*, 2009) are the primary cause of groundwater contamination. Other modeling based research identifies that surface contaminants are the major threat to groundwater in Punjab (Kumar *et al.*, 2015; Kumar *et al.,* 2016). The people of Punjab have high dependency on groundwater for drinking, domestic,and particularly for irrigation and industrial purposes. Punjab particularly, the south-west region has emerged as the epicenter of many dreadful diseases and is currently known as Cancer capital of India; owing to very high cancer cases (108 cases per lakh people as compared to national average of 80 per lakh) (DHFW 2012; Sharma and Singh 2016). About three decades ago, farmers in south west Punjab including Bathinda shifted cropping sequence from cotton-wheat to rice-wheat because of the high returns in the rice-wheat cropping system. As the cultivation of rice requires puddling and flooding the fields with water resulting in increase in extraction of groundwater. Hence the uncontrolled and unsustainable extraction of groundwater without recharge of aquifers has affected the quality of groundwater (CGWB, 2001; Rajmohan and Elango, 2005). The level of the water table lowered greatly due to this excessive removal of groundwater and infiltration of small quantities of contaminants resulted in high extent of pollution. A study conducted on few southern districts of Punjab revealed that the groundwater resources of this region are not suitable for drinking purposes. (Kaur *et al.,* 2017). There is continuous extraction of groundwater in the Bathinda district of Punjab to meet the demand for water supply and irrigation due to insufficient surface water present as no river flows through the district.

Various Studies on Heavy Metal Pollution of Ground-Water

An exclusive study on heavy metals was conducted by Sekhon *et al.* (2013) in the Patiala district of Punjab using Graphite furnace. The drinking water was detected with heavy metals such as Cadmium, Chromium, Nickel, Lead, Selenium. Average value of Nickel was found to be above the permissible limit prescribed by WHO. This study examined preliminary data for the development of a framework for sustainable groundwater development and management in that area. These findings could serve as a valuable lesson for other districts in Punjab, such as Ludhiana and Jalandhar, which have a high concentration of dyeing industries. It could help them comprehend the possible risks to their groundwater resources.

A study conducted by Hossain (2006) has shed light on the alarming levels of arsenic contamination in drinking water in Bangladesh, as most of the districts recorded concentrations exceeding the acceptable limit of 10 μgl^{-1}l and a significant number had levels beyond 50 μgl^{-1}. This poses a serious threat to public health as long-term exposure to arsenic can result in various health issues such as skin lesions, cancer, and cardiovascular diseases. The situation is further worsened by the practice of using contaminated groundwater for irrigating paddy rice, which is the main staple food of the population. This leads to an accumulation of arsenic in the soil, making it unsuitable for agriculture and subsequently causing the arsenic to be absorbed by the rice plants. Recent studies have shown that a considerable percentage of the arsenic present in rice and vegetables is inorganic, thereby emphasizing the severity of the issue.

Buragohain *et al.* (2010) investigated the seasonal variation of lead, arsenic, cadmium, and aluminum contamination in groundwater in Dhemaji district of Assam, India. Using Atomic Absorption Spectrometer, they analyzed samples collected from 20 different sites during both dry and wet seasons. The presence of these heavy metals in high concentration in groundwater can have adverse effects on human health. The study revealed varying levels of metal contamination and established the extensive nature of the problem in the area. This information is crucial for understanding the levels of heavy metal contamination and their variations in different localities of the Dhemaji district.

Aims and Objectives of the Study

To determine the suitability of groundwater for various purposes, it is essential to evaluate the heavy metal concentrations in the study area and compare them with the guidelines recommended by the Bureau of Indian Standards (BIS, 2012).

Thus, the present study aims to evaluate the groundwater quality and investigate the distribution of heavy metals obtained from Bathinda sited along various water channels in Punjab. The suitability of the findings of the work can provide valuable insights into the potential risks posed to groundwater resources as a result of the discharge of industrial waste into surface water channels or rivers.

Study Area

Bathinda district spans over an area of 3,367 km^2 and is located between 29°33′ and 30°36′N latitude and 74°38′ and 75°46′E longitude. The district's climate is primarily influenced by the Western Himalayas to the north and Thar Desert to the south and southwest, resulting in a semi-arid and hot climate that is typically dry except during rainy months. The district's geology is characterized by an alluvial complex of Quaternary period origin, formed by the ancestral tributaries of the Indus River system, including the ancient Satluj River (GSI 1976).

The alluvial sediments in the area are primarily composed of alternating beds of fine to medium sand, silt, and clay, typically overlaid with a thin layer of unstratified loam containing organic matter. Calcium carbonate concretions and nodules, known as kankar, are associated with fine-grained alluvium, occurring as massive, nodular, and granular beds below the water table. The aquifer system in the area is composed of Quaternary alluvial sediments consisting of fine to medium-grained sand or sand and kankar with an admixture of clay. The aquifers' dominant basic cations are Ca^{2+} and Mg^{2+}, and the distribution of calcium carbonate suggests different degrees of carbonate leaching (Sharma *et al.,* 1998)

The soils in the area are primarily composed of primary quartz, with other minerals such as muscovite, plagioclase and alkali feldspars, amphibole, biotite, anhydrite (gypsum), and chlorite, present in the sand and silt fractions. The clay fraction of the soils contains minerals such as illite, chlorite, and kaolinite. (Sidhu and Gilkes, 1977; Rajkumar *et al.,* 2010). The aquifers in the area belong to the vast aquifer system of the Indo-Gangetic alluvial plains (Thomas *et al.,* 1995).

Two modern thermal colony power plants are located in Bathinda namely Guru Nanak Dev Thermal Colony Plant in the city and Guru Hargobind Thermal Colony Plant at Lehra Mohabbat. In both the thermal power plants, water is the only and main source for generating electricity. Bathinda is also home to Fertilizer Plant, i.e. National Fertilizer Limited (NFL), Ambuja Cement Indusrty and

Bathinda Chemicals, a large oil refinery. These thermal power plants and industrial activities have led to continuous degradation of the Groundwater quality and use of various fertilizers and pesticides has also affected the soil quality of the nearby fields.

Hydrogeology

The Bathinda district is situated on the Indus alluvium of the Quaternary era and contains a multi-aquifer system with thick sandy aquifer zones and thin clay layers. The area has both confined and unconfined aquifers (CGWB Report 2007; Gupta and Thakur, 1989). All the aquifers are shallow and vary from 8 to 30 m. Rainfall in the area has a mean annual value of 408 mm (2004-2008), with the majority falling between June and September during the south-west monsoon period, accounting for about 77.1% of the total rainfall.

Materials and Methods

During the month of June 2022, 15 groundwater samples were collected from different sources such as tubewells, handpumps and borewells. The samples were collected from agricultural fields, residences and public places (e.g. Schools, petrol pumps). The standard procedure was followed for collecting groundwater samples. Water samples were collected in clean polyethylene bottles of 1 L capacity rinsed with HNO_3. At the time of sampling, bottles were thoroughly washed 2-3 times with groundwater to be sampled. In case of borewells the water samples were collected after pumping for 10 mins.

This was done to remove stagnant groundwater and to stabilize the electrical conductivity. Hand gloves were worn before handling of sampling bottles to delineate any kind of contamination. The bottles were tightly capped and properly labelled. The samples collected for heavy metal analysis were acidified with conc. HNO_3 (pH<2) to avoid adsorption on the walls of the sampling bottle. The water samples were immediately preserved in icebox after collection till they were transported to the laboratory and were stored at 4°C until used for further analysis. Various physico-chemical parameters and tech-

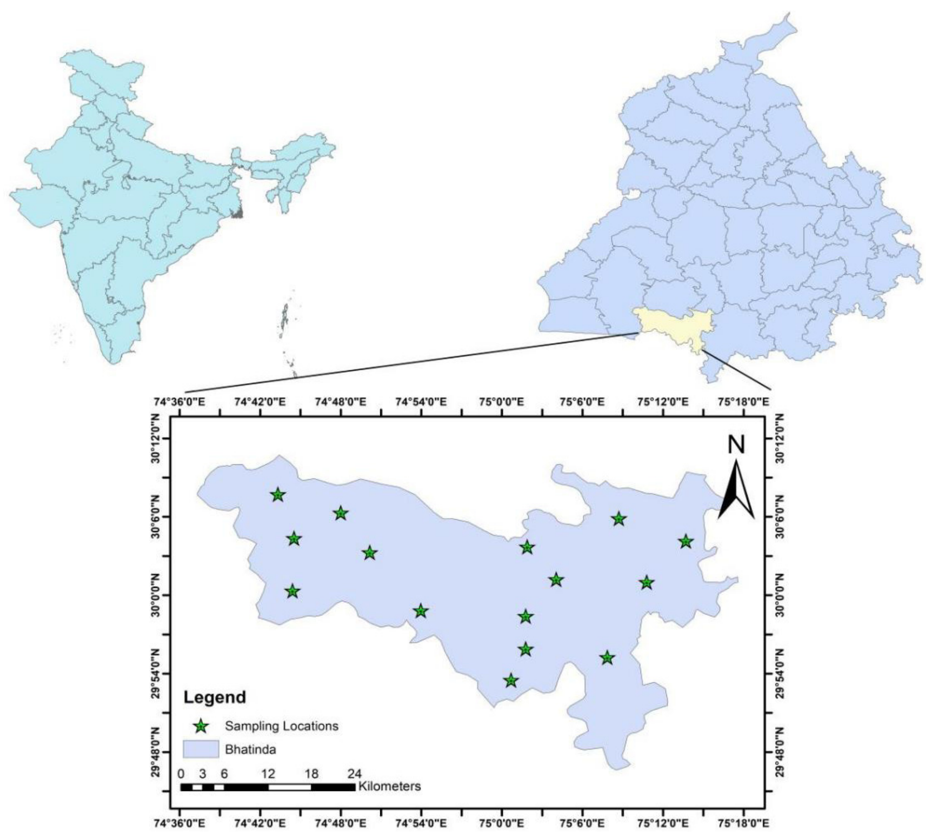

Fig. 1. Showing Groundwater sampling locations of Bathinda district, Punjab.

niques for their analysis are given in the Table 2 and 3.

Results and Discussion

Groundwater quality can be affected by various natural and manmade factors that can alter its chemical composition. Geogenic sources such as geological formations, soil, rocks can release minerals, salts, and trace elements into the water which can influence the quality of groundwater. Various contaminants including heavy metals, pesticides and organic compounds can be introduced into groundwater as a result of anthropogenic activities such as sewage disposal, agricultural and industrial activities. As the various physico-chemical parameters are an important indicator of water qualityand can provide insights into the sources and behavior of various chemical and toxic elements in groundwater, their analysis is essential for identifying the potential risks to human health and environment.

The groundwater samples showed no color, odor and turbidity. Physical parameters such as pH, Temperature, Total dissolved solids, Salinity, Electrical conductivity were analyzed along with chemical parameters such as Calcium, Magnesium, Phosphate and heavy metals such as Lead, Chromium, Cadmium, Nickel and Iron. Table 4 displays the guidelines for drinking water quality, WHO and BIS (2012) standards.

Physical Parameters

Odor: As prescribed by the BIS drinking standards, all the groundwater samples exhibited no odor.

pH: 6.5-8.5 is the desirable pH range necessary for drinking water. The pH value of water samples showed spatial difference among different sampling locations in the study area and ranged from minimum 6.30 and maximum 7.40. In majority of sampling sites, the pH was within the permissible limit for drinking water as prescribed by WHO(6.5-8.5) except in site 2(6.35), site 9(6.30) and site 10(6.45). The pH of most of the water samples was found to be less than 7 which shows that water is slightly

Table 1. Showing the sampling locations, source and type of water.

Sample No	Location	Source of GW	Type of water
1	Hargobind School	Borewell	Groundwater
2	Bus Stand	Handpump	Groundwater
3	Akal Academy (School)	Borewell	Groundwater
4	St. Xavier School	Borewell	Groundwater
5	Road, Jajjal	Handpump	Groundwater
6	B.D.O Office	Handpump	Groundwater
7	Bus Stand, Maur	Handpump	Groundwater
8	Home, Kot Shamir	Borewell	Groundwater
9	Malakana	Borewell	Groundwater
10	Peer, Bhagu	Handpump	Groundwater
11	Tungwali	Handpump	Groundwater
12	Khet, Lehra Khana	Tubewell	Groundwater
13	College	Borewell	Groundwater
14	Shop, Maur	Borewell	Groundwater
15	Home, Giana	Borewell	Groundwater

Table 2. Showing the physical parameter analyzed and methods used

Sample No	Parameters	Name of the Instrument/ Method used	Remarks
1	Odor	Physiological sense	Analysis on the spot
2	pH	Multiparameter	Analysis on the spot
3	Temperature	Multiparameter	Analysis on the spot and in lab
4	TotalDissolved Solids	Multiparameter	Analysis on the spot and in lab
5	Total Hardness	EDTA Titration	Analysis in the Lab
6	EC	Multiparameter	Analysis on the spot
7	Salinity	Multiparameter	Analysis on the spot

acidic.

Temperature: The temperature of water samples in the study area fluctuated between minimum value of 27.7°C (Site 10) to maximum 36.6°C (Site 6). The efficiency of water treatment units can be significantly affected by the temperature of water. At lower temperatures, the viscosity of water increases which can diminish the settling efficiency of the solids present in water due to greater resistance offered by high viscosity during particle settling. Consequently, the settling unit efficiency in removing solids from water reduces. Also, the high viscosity can increase the resistance in filtration units, causing drop in pressure which can ultimately lower the flow rate of water through filters and decrease the filtration efficacy in removing contaminants (Arcadio and Gregoria, 2003).

Electrical Conductivity: Water's electrical conductivity is a measure of its ability to conduct an electrical current and is closely associated with the concentration of ionized substances in the water. The levels of electrical conductivity in water are influenced by factors such as temperature, total dissolved solids (TDS), and organic compounds, which can impact the concentration of ions in the water. The EC was recorded in range of minimum 640 to maximum 5110 μScm^{-1}. Results showed that all the values of EC are beyond permissible limits as prescribed by BIS standard value of 300 μScm^{-1}(BIS, 2012). The high EC in groundwater shows mechanisms like water circulation, cation exchange and surface infiltration etc.

Total Dissolved Solids: There is a positive correlation between fluctuations in the electrical conductivity and the concentration of total dissolved solids (TDS) in water, which are commonly used as indicators of water pollution (Jayalakshmi, 2011). The value of Total Dissolved Solids for different sampling sites ranged between 455-3630 mgl^{-1} with maximum at site 15. The permissible limit of TDS for drinking water is 500 mgl^{-1} (WHO,2004). Results indicated that TDS in majority of water samples is above the permissible limit as prescribed by WHO (2004).

Table 3. Table showing the chemical parameters analyzed and methods used

Sample No	Parameters	Name of the Instrument/Method used	Remarks
1	Chloride	Silver nitrate Method	Analysis done in the lab.
2	Calcium	EDTA Titration	Analysis done in the lab
3	Lead	AAS	Analysis done in the lab
4	Chromium	AAS	Analysis done in the lab
5	Cadmium	AAS	Analysis done in the lab
6	Nickel	AAS	Analysis done in the lab
7	Iron	AAS	Analysis done in the lab

Table 4. Table showing the guidelines for drinking water

Parameters	WHO Standard	Indian Standard	EPA Guidelines
Color	-	5-10 Hazen units	-
Odor	Unobjectionable	Unobjectionable	-
Temperature. (°C)	-	-	-
pH	6.5-8.5	6.5-8.5, 6.5-9.5	6.5-9.5
Electrical Conductivity (µS/cm)	300us/cm	300us/cm	2500us/cm
Total Dissolved Solids (mg/l)	500-1000	500-1000	-
Total Hardness (mg/l)	-	200-600	-
Salinity (mg/l)	-	>1200	-
Chlorides (mg/l)	200-600 mg/l	250-1000 mg/l	250 mg/l
Calcium (mg/l)	-	75-200 mg/l	-
Cadmium (mg/l)	-	0.003 mg/l	-
Chromium (mg/l)	-	0.05 mg/l	-
Lead (mg/l)	-	0.05 mg/l	-
Nickel (mg/l)	-	0.02 mg/l	-
Iron (mg/l)	-	0.3 mg/l	-

Total Hardness: The ion exchanges in aquifer and calcareous rocks dissolution causes high TH in groundwater. If consumed for a short period of time, the high TH do not cause any serious health hazard in humans but can have effect on water supply system. It can cause corrosion in boilers in Industrial supplies and if used for a long time in crop irrigation can also have an adverse impact onsoil quality. The acceptable limit for TH as prescribed by BIS standard is 200 mgl^{-1}. Nearly all the samples except one were found to have TH above the acceptable limit. The minimum concentration was found to be 200 mgl^{-1} and the maximum concentration recorded was 548 mgl^{-1}.

Salinity: Salinity at different groundwater sites lies between 328 (minimum)-7090 mgl^{-1} (maximum). Salinity>1200 mgl^{-1} is regarded as unacceptable for drinking water. Increased groundwater salinity is related with higher concentration of various elements such as Sodium, Fluoride, Sulphate, Boron, and Arsenic.

Chemical Parameters

Chloride: The groundwater showed natural presence of Chlorine in varying concentrations. Prescribed limit for chlorine in drinking water is 250-1000 mgl^{-1}(BIS 2012). The chloride was found to be in range 39-369 mgl^{-1} in the study region. Sedimentary rocks and rock salt deposits are the major sources of chloride in groundwater but industrial and sewage effluents, and agricultural run off are among the other sources which also contribute through infiltration in groundwater (Chapman, 1996). Most of the samples except few are well within the acceptable limit prescribed for drinking water by BIS. The reason might be mixing of industrial effluents in sewage which leads to release of high amounts of organic and inorganic ions like chlorides can be attributed for high concentration of chlorides in groundwater.

Calcium: The desired limit for Calcium in drinking water is 75 mgl^{-1} (BIS, 2012). Minimum value of Calcium in water was found to be 12.82 mgl^{-1} and maximum of 105.8 mgl^{-1}. Most of the groundwater samples demonstrated acceptable levels of Ca^{2+} for drinking purposes. The presence of Ca^{2+} in groundwater is primarily attributed to the dissolution of Ca-rich minerals within the aquifer. Calcium compounds typically maintain stability in water; however, factors such as temperature and pressure changes can lead to a reduction in Ca^{2+} ions within the groundwater (Chapman, 1996). The elevated concentration of both Ca^{2+} and Mg^{2+} contributes to water hardness, which can impose limitations on the usability of groundwater for irrigation purposes.

Cadmium: Cadmium because of its nature and its several anthropogenic sources mainly application in industrial fields is said to be omnipresent. As per BIS guidelines, the maximum allowable limit for Cadmium is 0.003 mgl^{-1}. Cadmium is found to be below detectable limit (BDL) in most of the water samples except 3 samples showing minimum concentration which was beyond detection and maximum concentration of 0.037 mgl^{-1}and not profoundly found in groundwater.

Chromium: Chromium is found naturally in rocks, plants, soil and volcanic dust, and anthropogenic sources of Cr^{6+} in drinking water are discharged from steel and pulp industry and erosion of natural

Table 5. Table showing result of physical Parameters of Ground Water & Comparison with Drinking Water Standard BIS (2012)

S. No.	Parameters	Acceptable limit (BIS 2012)	Permissible limit (BIS 2012)	Minimum	Maximum	Average	% of samples exceeding Acceptable limit(x)	% of samples exceeding Permissible limit(y)
1.	Odor	Unobjectionable	Unobjectionable	Odorless	Odorless	-	-	-
2.	pH	6.5-8.5	-	6.30	7.40	6.81	20(3)	-
3.	Temp.(°C)	-	-	27.7	36.6	-	-	-
4.	EC(µScm^{-1})	300	-	640	5110	2007.53	100(15)	-
5.	TDS(mgl$^{-1)}$	500	2000	455	3630	2104.13	93.3 (14)	20 (3)
6.	T Hardness (mgl$^{-1)}$	200	600	200	548	331.63	93.3(14)	0(0)
7.	Salinity (mgl^{-1})	-	1200	328	7090	1532.66	-	33.33 (5)

deposits of Cr^{3+}(EPA, 2007). Chromium is an important metal used in various processes and products. (Nriagu, 1988). Chromium is also used in alloy manufacturing, paints for corrosion inhibition, wood preservatives, dyes fixatives and as an anti-corrosive in cooking systems and boilers (Cotman *et al.,* 2004). As per BIS standard acceptable limit for Chromium is 0.05 mgl^{-1}. Chromium was found to be present beyond the acceptable limit in two samples and in the remaining samples, chromium was not detected.

Lead: Lead is found in the environment both naturally and also as a result of anthropogenic activities. The acceptable limit for Lead in drinking water is 0.01 mgl^{-1} and concentration beyond this leads to hazardous effect to human health. This study predicts 100% samples violation in respect to the limit. The regular discharge of industrial effluent in surface water without any proper treatment may be reason for this. In the study area the minimum and maximum concentration of Lead lies between 0.13 mgl^{-1} to 0.92 mgl^{-1}.

Nickel: Nickel is found to be present in groundwater as a result of dissolution from Nickel bearing rocks. Concentration of Nickel in groundwater depends on soil use, pH and depth of sampling. The mobility of Nickel in soil might increase the concentration of Nickel in the groundwater (Kumar *et al.*, 2019). As per BIS2012, the acceptable limit for Nickel in groundwater is 0.02 mgl^{-1}. The minimum concentration of Nickel in groundwater samples was found to be below detectable limit and maximum was 0.049 mgl^{-1}. Nickel was found to be above acceptable limit in three samples while rest of the samples had concentration within desired limits.

Iron: Color change in groundwater is the indication of presence of Iron, and high concentration leads to astringent, bitter taste of the water. Discoloration of clothes, encrusting of supply pipes are some of the hazardous effects that occur due to contamination of Iron (Jain *et al.*, 2010). Iron in the study area showed a range of BDL-1.727 mgl^{-1}. Violation with respect to three samples was recorded and other samples were found to be in concentration below acceptable limit, as recommended by BIS standards.

Conclusion

The findings of the groundwater study carried out indicate that the Bathinda region's groundwater is severely contaminated with respect toheavy metals, total dissolved solids (TDS), and total hardness (TH). The high concentration of TdS renders the water non-potable and reduces the solubility of oxygen, making it unfit for drinking purposes. Furthermore, the groundwater in the Bathinda region contains significant levels of heavy metals, including Lead,Iron and Nickel. The water from nearly all the sampling points is both hard and contaminated, posing immediate health risks to the people residing in the region. These health risks include the potential for cancer, gastrointestinal irritation, and neurological disorders.

The study highlights the significant prevalence of heavy metal contamination in the groundwater. Lead and Iron contamination in groundwater of Bathinda is alarming and needs immediate measures for its mitigation. The research shows the presence of high chemical species which affects the groundwater quality. There is an immediate need to shift towards eco-friendly agricultural models and

Table 6. Table showing the results of Chemical Parameters of Groundwater and comparison with drinking water standards BIS(2012)

S. No.	Parameters	Acceptable limit (BIS 2012)	Permissible limit (BIS 2012)	Minimum	Maximum	% of samples exceeding Acceptable limit(x)	% of samples exceeding Permissible limit (y)
1.	Chloride (mgl^{-1})	250	1000	39	369	20 (3)	0 (0)
2.	Calcium (mgl^{-1})	75	200	12.8	105.8	6.6 (1)	0 (0)
3.	Cadmium (mgl^{-1})	0.003	No relaxation	BDL	0.037	20 (3)	-
4.	Chromium (mgl^{-1})	0.05	No relaxation	BDL	0.057	13.3 (2)	-
5.	Lead (mgl^{-1})	0.01	No relaxation	0.13	0.92	100 (15)	-
6.	Nicke (lmgl^{-1}l)	0.02	No relaxation	BDL	0.049	20 (3)	-
7.	Iron (mgl^{-1})	0.3	No relaxation	BDL	1.72	20 (3)	-

to adopt practices focusing on food security, human health and environment. In summary, the overall quality of the groundwater in the Bathinda region is unsuitable for drinking purposes, emphasizing the need for appropriate treatment techniques to remove these contaminants.

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Declarations

Conflict of intrest: The authors declared that there are no competing or conflicting intrests.
Ethics Approval: This article does not contain any studies with human participants or animals performed by any authors.

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