Advances in Bioresearch
Adv. Biores., Vol 14 (6) November 2023: 352-361
©2023 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.14.6.352361

Advances in Bioresearch

ORIGINAL ARTICLE

Impact of Urbanization on Ground Water Quality of Solan District of Himachal Pradesh

Jyotsana Pandit[1,3]*, Anish Kumar Sharma[2] and S. K. Bhardwaj[3]
[1,2]School of Sciences, P P Savani University, Surat 394125, India;
[3]Department of Environmental Science, Dr. Y.S Parmar University of Horticulture and Forestry, Nauni, Solan 173 230, India
*Email: Jyotsana Pandit: jyotsna.pandit@ppsu.ac.in

ABSTRACT

The present investigation is carried out to assess ground water quality of urban areas of Solan District was assessed using the water quality index (WQI). In order to accomplish this objective, water samples were taken from five different urban areas during the summer and winter seasons. These samples were then analysed for various major physicochemical parameters, such as pH, EC, turbidity, TDS, BOD, COD, DO, As, Cr, Zn, Pb, and Cd, to determine whether or not the water was suitable for drinking and various other household uses. In groundwater pH, EC, turbidity, TDS, BOD, COD, DO were found in the range of 6.99-7.45, 0.221-0.394 dS m^{-1}*,2.46-5.07 NTU, 80.46-200.39 mg* l^{-1}*, 0.95-1.51 mg* l^{-1}*, 51.41-98.39 mg* l^{-1}*, 6.55-7.34 mg* l^{-1} *consequently. Trace elements Pb, Cr, Zn, As, Cd, were found in the range of 0.002-0.009 mg* l^{-1}*, 0.015-0.033 mg* l^{-1}*, 0.12-0.33 mg* l^{-1}*, 0.004- 0.012 mg* l^{-1} *and 0.001-0.00 mg* l^{-1} *respectively. All water quality parameters were within the permissible limits. WQI of ground sources ranged from 19 to 49. According to the findings of the study, urbanization in the district has begun having an effect on ground water sources. As a result, regular quality monitoring is required, and the implementation of such monitoring is essential for the urbanization to be sustainable. In order to improve people's health and keep it in good condition for future generations, we need more stringent rules and guidelines.*

Keywords: *Urbanization, Heavy metals, Seasonal variation, Water quality index*

Received 25.09.2023 Revised 08.10.2023 Accepted 26.11.2023

How to cite this article:
Jyotsana P, Anish K S and S. K. Bhardwaj. Impact of Urbanization on Ground Water Quality of Solan District of Himachal Pradesh. Adv. Biores., Vol 12 (6) November 2023: 352-361.

INTRODUCTION

The global urban population increased by approximately 3.6 billion between the years 1950 and 2018, with another 2.3 billion people expected to move into cities by the year 2050 [1]. The process of urbanization is an evolving one that involves a lot of different aspects [2]. The rapid phase of urbanization causes a variety of different environmental problems and different kinds of pollution, and it is sensitive to the accumulation of heavy metal contamination in both spatial and temporal aspects. This sensitivity arises as a result of the evolution of both time and technology. The expansion of cities and economies has a significant impact on the amount of pollution released into the environment as a result of the discharge of wastewater, which typically consists of pollutants, most notably toxic heavy metals [3, 4]. As a consequence of this, the accumulation of pollutants in river sediments and other water sources acts as a sink for pollutant pollution [5, 6] .

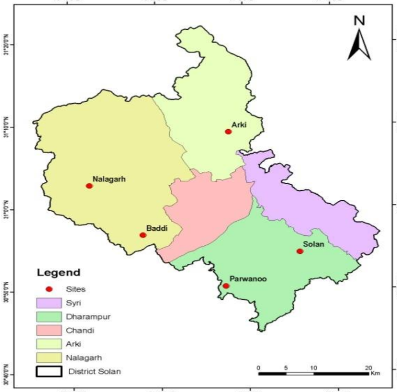
Emerging as a topic of concern on a global scale is the potential threat that is posed by environmental pollution and the degradation of a variety of environmental matrices. The overexploitation of natural resources to meet the demands of an unsustainable pattern of global development has made it more vulnerable to deficiencies. This vulnerability is due to the fact that natural resources are being used to meet global development demands. The presence of heavy metals in the environment is associated with an increased risk of various health problems for organisms, both living and non-living [7]. Instead of being found in surface bodies of water like lakes and rivers, the vast majority of the world's liquid freshwater is stored in underground aquifers. Aquifers are the primary source of base flow water for rivers when there is insufficient precipitation. The urban populations of developing countries are dependent on groundwater for their economic and social well-being. Groundwater is essential. To satisfy the requirements of their residential, municipal, industrial, and commercial customers, cities are required to provide water in a number of different ways. And the process of urbanization has always had a variety of effects, both positive and negative, on the quality and quantity of the local aquifer systems. In light of the fact that urbanization causes shifts in the hydrological cycle, it is essential to investigate how urbanization affects the water resources of the surrounding area, in particular the amount of readily accessible groundwater source there is in the neighbourhood [8]. Both nonpoint and point sources can be found in urban environments, each contributing to the overall contamination. Leaking underground storage facilities and other random accidental spills of organic or inorganic contaminants are examples of point sources that affect the quality of ground water [9]. The rapid expansion of urban areas has two primary effects on ground water resources, including the following: effects on the natural recharge of aquifers as a result of the sealing of ground with concrete; pollution of ground water as a result of leakage from drainage; and industrial waste and effluents. Both of these effects can be attributed to the rapid growth of urban areas [10]. The effect that urbanization has on the groundwater regime of a particular urban area is contingent not only on its geographical location but also on the economic standing of the city or even the country as a whole [11]. The goal of this article is to make the readers aware of the changes that take place in ground water quality as a result of urbanization. This is done so that appropriate planning can be done in advance to combat any negative effects, if they occur. The current investigation is an attempt to study the impact that urbanization has on the quality of the groundwater in various urban areas of Solan District, which is a district in Himachal Pradesh that is experiencing rapid population growth.

MATERIAL AND METHODS

Study area

The current study was carried out in the urban areas of Solan District in Himachal Pradesh, between the North latitude of 30°44'53" and 31°22'01" and the East longitude of 76°36'10" to 77°15'14". The district is a "gateway" of the state, sharing an interstate boundary with Haryana and Punjab in the south and west, respectively. It is divided into four sub-divisions: Arki, Kandaghat, Nalagarh, and Solan. The rapidly growing district has a total geographical area of 1936 km^2 and a population of 5,80,320 (ref 12), which is expected to grow to 8,06,645 by 2023. The physical environment of the District is rapidly changing as a result of the forces of urbanization and commercialization, and multi-story culture has gained traction over the years.

The district is an industrial hub of the state with migrant population dynamics. Furthermore, many small and medium-sized businesses have emerged and developed throughout the district. Due to migration of rural population to cities in search of jobs and better facilities such as education, the district has recently experienced the highest level of urbanization (18.26%) after Shimla. Currently, the district's urban areas (Arki, Baddi, Nalagarh, Parwanoo, and Solan) house approximately 17.7% of the state's population. Solan and Baddi are classified as class III towns. On the basis of urbanization, Nalagarh, Parwanoo, and Arki are classified as class IV, V, and VI towns, respectively.To investigate the effects of urbanization on ground water quality, five urban areas were chosen : Arki, Baddi, Parwanoo, Nalagarh, and Solan. In the case of water quality, ten treatment combinations (2x5) were replicated three times in randomized block design. To assess seasonal variations, two seasons were chosen: summer (May-June) and winter (December-January).



Water sampling

In the academic year 2018-2019, random samples of water were taken from ground water sources in each urban area during the summer and winter months, respectively, for the purpose of collecting data. In accordance with the standard operating procedure, hand pumps, bore wells, and tube wells were used to collect ground water samples, which were then placed in acid-washed one-liter plastic bottles [13]. After pumping water from the hand pump for five to seven minutes, during which time the temperature was allowed to stabilize, ground water samples were collected. The samples that were collected were correctly labelled, transported to the laboratory, and immediately analyzed for pH, EC, TDS, BOD, COD, and Turbidity. The remaining samples were kept in the refrigerator at a temperature of 4^{0}C s until they could be examined further.

Water analysis

The ground water sources were assessed for following parameters.

pH: The pH of the water was determined using a microprocessor based pH meter (Model 1013 of EIA make) and was expressed in the scale of 0-14.

EC: The electrical conductivity of the water was measured using microprocessor based conductivity/ TDS meter (Model -1601 of EIA make), and expressed in dS cm^{-1}.

TDS: The solid substances of the size of < 0.001 mm present in the water were measured with microprocessor based conductivity / TDS meter (Model- 1601 of EIA make) and expressed in mg l^{-1}.

Turbidity: It was measured by digital turbidity meter (Model- 331 of EIA make) and expressed in NTU (Nephelometric Turbidity Unit).

BOD: The BOD Oxi-direct system (aqualytic make) was used to calculate BOD. The pH of the samples was initially adjusted between 6.5 and 7.5.The sample was mixed in a BOD bottle with 5-6 drops of nitrification inhibitor (ATH). The BOD bottle had a gasket, 3–4 drops of KOH solution, and sensors. BOD bottles were loaded into the system and incubated at 200^{0}C for five days. After 5 days, mg l^{-1} readings were taken.

COD: The COD was calculated by oxidizing a water sample with a hot sulphuric acid solution of potassium chromate and a silver sulphate catalyst. The water samples were digested for 120 minutes at 148^{0}C in a preheated thermo reactor (TR 320). Chloride is masked with mercury sulphate in the system, and the concentration of chromium ions is determined photometrically using a spectroquant pharo 300 (Merck make) instrument and expressed as mg l^{-1}.

DO: The DO of the samples was measured by DO meter of Mark make and expressed in mg l^{-1}. The DO content of water is influenced by water temperature salinity and pressure

Heavy metals (As, Cd, Cr, Hg, Pb and Zn): The water samples were first filtered by Whatman's filter paper (No. 1). The heavy metals were estimated using Inductively Coupled Plasma Emission Spectrometer (ICAP-6300 Duo) and expressed as mg l^{-1}.

PERMISSIBLE LIMITS

The physical and chemical parameters of potable water were discussed by comparing with the BIS and WHO standards as mentioned in Table 1 .

Table 1. Permissible limit of water quality parameters for drinking and domestic purpose

Sr. No.	Parameters	BIS	WHO
1	Ph	6.5-8.5	8.2-8.8
2	EC (dS m^{-1})	----------------	1.5
3	TDS (mg l^{-1})	2000	500
4	Turbidity(NTU)	10	<1.5
5	BOD (mg l^{-1})	5	----------------
6	COD (mg l^{-1})	250	----------------
7	DO (mg l^{-1})	6	----------------
8	As (mg l^{-1})	0.05	0.05
9	Cr (mg l^{-1})	0.05	0.05
10	Cd (mg l^{-1})	0.003	0.005
11	Hg (mg l^{-1})	0.001	0.006
12	Pb (mg l^{-1})	0.01	0.05
13	Zn (mg l^{-1})	15	5

Source: (Ref 14 and 15)

WATER QUALITY INDEX

The weighted arithmetic water quality index method [16] has been used for calculation of WQI of the water sources. The calculation of WQI was made by using the following equation:

$$\mathbf{WQI = \Sigma\, Q_i W_i / \Sigma W_i}$$

The quality rating scale (Q_i) for each parameter is calculated by using this expression:

$$\mathbf{Q_i = 100[(V_i - V_0 / S_i - V_0)]}$$

(let there be i water quality parameters and quality rating (Q_i) corresponding to ith parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value).

Where:

V_i = estimated concentration of i^{th} parameter in the analyzed water

V_0 = the ideal value of i^{th} parameter in pure water

V_0= 0 (except pH =7.0 and Dissolved Oxygen = 14.6 mg l^{-1})

S_i= recommended standard value of i^{th} parameter

The unit weight (W_i) for each water quality parameter is calculated by using the following formula:

$$\mathbf{W_i = K/S_i}$$

Where K= proportionality constant and is calculated by using the following equation:

$$\mathbf{K = 1 / \Sigma[1/S_i]}$$

The rating of water quality according to this WQI is given in Table 2.

Table 2: WQI values suitable for human consumption

WQI value	Rating of water quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for human consumption

RESULTS AND DISCUSSION

pH:

According to Table 3, the pH of ground water in various urban areas fell within the acceptable BIS limits of 6.99 to 7.45. When the data from both years were analyzed together, a pattern emerged regarding the pH of the ground water that was consistent with that seen in the data from each individual year. It goes Arki (7.45) > Nalagarh (7.15) > Solan (7.11) > Parwanoo (7.00) > Baddi (6.99). The values of Parwanoo and Baddi were found to be at par with each other. Dumping of domestic/organic waste and the subsequent percolation of domestic effluents into underground wate may account for Baddi's low pH, as suggested by the research of Badmus *et al.* [17]. The ground water's pH also changed significantly with the seasons. pH levels ranged from a high of 7.29 in the summer to a low of 6.99 in the winter. Since ground water volume decreases and evaporation rises in the summer due to high atmospheric temperature, it's possible that ion concentrations rise, leading to the highest pH of the year. Sawane *et al.* [18] and Khan *et al* [19] both outlined similar findings.

Electrical conductivity

It was found that EC varies widely across cities (Table 3). According to Table 3, the EC of ground water in different urban areas fell between 0.221 and 0.394 dS m^{-1}, well below the BIS-mandated maximum of 1.5 dS m^{-1}. In terms of ground water EC, the average effect of both years, as indicated by pooled data, showed a trend nearly identical to that of individual years, in the order of: Baddi (0.394 dS m^{-1}) > Parwanoo (0.378 dS m^{-1}) > Solan (0.257 dS m^{-1}) > Nalagarh (0.234 dS m^{-1}) > Arki (0.221 dS m^{-1}). Nalagarh and Arki have statistically equivalent water EC values. Paul and Sen (2012) speculate that entrapment, ground water recharge, and mineral solubilization from soils may all contribute to Baddi's high EC. The EC of wells and springs varied greatly with the seasons. An EC of 0.311 dS m^{-1} was recorded during the summer months, while an EC of 0.283 dS m^{-1} was recorded during the winter months. Higher conductivity in the summer due to an increase in salt concentration due to evaporation is consistent with previous studies by Reddy [20] and Solanki and Acharya [21].

Turbidity

Table 3 showed that the turbidity of ground water in different urban areas was between 2.46 and 5.07 NTU, well below the 10 NTU threshold set by BIS. The analysis of the combined data from the two years showed the following hierarchy of urban areas' effects on ground water turbidity: Baddi (5.07 NTU) > Parwanoo (3.86 NTU) > Nalagarh (3.11 NTU) > Solan (2.89 NTU) > Arki (2.46 NTU). The values of Baddi and Nalagarh were found to be at par with each other. The increased turbidity in Baddi could be a result of soil erosion caused by nearby construction. In addition, ground runoff may have been amplified due to the area's compactness, leading to water body silting. These results agree with those found by Polkowska *et al* [22] . The turbidity of underground water supplies was also greatly affected by the changing of the seasons. The turbidity peaked in the summer at 3.73 NTU and dropped to its lowest in the winter at 3.23 NTU. The results are consistent with those found by Garg *et al.* [23], who found that turbidity in ground water rises during the summer due to rapid growth and increased activity in algae and microfauna.

Table 3 Seasonal variation in pH, EC and Turbidity in urban ground water

Parameters	pH			EC (dS m^{-1})			Turbidity (NTU)			TDS (mg l^{-1})		
Seasons / Urban areas	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean
Arki	7.59	7.31	**7.45**	0.239	0.203	**0.221**	2.78	2.13	**2.46**	98.98	61.94	**80.46**
Baddi	6.92	7.05	**6.99**	0.398	0.390	**0.394**	5.31	4.84	**5.07**	204.22	196.57	**200.39**
Nalagarh	7.32	6.97	**7.15**	0.227	0.240	**0.234**	3.24	2.99	**3.11**	120.83	125.17	**123.00**
Parwanoo	7.21	6.79	**7.00**	0.415	0.341	**0.378**	4.22	3.51	**3.86**	167.34	119.97	**143.66**
Solan	7.39	6.83	**7.11**	0.274	0.239	**0.257**	3.11	2.68	**2.89**	114.08	89.02	**101.55**
Mean	**7.29**	**6.99**		**0.311**	**0.283**		**3.73**	**3.23**		**141.09**	**118.53**	

Table 4 Seasonal variation in BOD, COD and DO in urban ground water

Parameters	BOD (mg l^{-1})			COD (mg l^{-1})			DO (mg l^{-1})		
Seasons / Urban areas	Summer	Winter	Mean	Summer	Winter	Mean	Summer	Winter	Mean
Arki	1.02	0.88	**0.95**	52.10	50.72	**51.41**	6.83	7.85	**7.34**
Baddi	1.81	1.21	**1.51**	109.20	87.58	**98.39**	6.27	6.83	**6.55**
Nalagarh	1.27	1.29	**1.28**	117.28	71.19	**94.23**	6.96	6.74	**6.85**
Parwanoo	1.46	1.12	**1.29**	92.85	81.83	**87.34**	6.39	7.02	**6.71**
Solan	1.18	0.93	**1.06**	91.29	69.61	**80.45**	7.15	7.40	**7.28**
Mean	**1.35**	**1.09**		**92.54**	**72.18**		**6.72**	**7.17**	

Total Dissolved Solids

Ground water TDS was found to vary widely between urban areas. Table 3 shows that the TDS of ground water in various urban areas fell within the guidelines established by the BIS (2000 mg l^{-1}) and the WHO (500 mg l^{-1}). The combined data showed a similar pattern in ground water TDS to that seen in each individual year, in the following sequence: From highest to lowest: Baddi (200.39 mg l^{-1}) > Parwanoo (143.66 mg l^{-1}) > Nalagarh (123.00 mg l^{-1}) > Solan (101.55 mg l^{-1}) > Arki (80.46 mg l^{-1}). Increased anthropogenic activities in these land uses, which may have increased the dumping of waste materials and other household waste water effluents, may account for the highest TDS in Baddi, as reported by Khaund *et al*[24]. The TDS of ground water varied greatly depending on the time of year. The TDS peaked in the summer at 141.09 mg l^{-1} and dropped to a low of 118.53 mg l^{-1}in the winter season. Higher TDS in the summer is expected since more water evaporates when temperatures are higher, as found by Tripathi and Pandey [25] and Sharma [26].

Biological oxygen demand

According to Table 4, the ground water BOD in different urban areas ranged from 0.95 to 1.51 mg l^{-1}, which was within the permissible limit of mg l^{-1}as prescribed by BIS. The analysis of both years' pooled data revealed that different urban areas have a significant impact on ground water BOD in the following order: Baddi (1.51 mg l^{-1}) > Parwanoo (1.29 mg l^{-1}) > Nalagarh (1.28 mg l^{-1}) > Solan (1.06 mg l^{-1}) > Arki

(0.95 mg l^{-1}). The values of Arki and Solan were found to be statistically at par with each other. According to Trivedi and Goel [27], the highest BOD levels in Baddi can be attributed to the enrichment of water sources with untreated domestic and industrial effluents, soaps, and detergents. The seasons also had a significant impact on the BOD of ground water sources. The summer season had the highest BOD of 1.35 mg l^{-1}, while the winter season had the lowest of 1.09 mg l^{-1}. Summer BOD levels may be attributed to high microbial activity, as determined by Kaur and Kaur [28] and Maya *et al.* [29]. It was discovered that the interaction of urban areas and seasons had a significant impact on ground water BOD.

Chemical Oxygen demand

The COD of ground water sources was found to vary significantly across urban areas (Table 4). The examination of the data presented in Table 4 revealed that the ground water COD in various urban areas ranged from 51.41 to 98.39 mg l^{-1}, which was within the BIS permissible limit of 250 mg l^{-1}. The analysis of both years' pooled data revealed that different urban areas have a significant impact on ground water COD in the following order: Baddi (98.39 mg l^{-1}) > Nalagarh (94.23 mg l^{-1}) > Parwanoo (87.34 mg l^{-1}) > Solan (80.45 mg l^{-1}) > Arki (51.41 mg l^{-1}). The COD of Baddi, Nalagarh and Parwanoo was statistically at par with each other. Higher COD levels in Baddi, Nalagarh, and Parwanoo could be attributed to organic and inorganic content leaching into water. Shaik and Mandre [30] discovered similar outcomes. The seasons had a significant impact on the COD of ground water sources. Summer had the highest COD of 92.54 mg l^{-1}, while winter had the lowest of 72.18 mg l^{-1}. The results are in conformity with the findings of Fokmare and Musaddiq[31] and Nag *et al.* [32] who revealed highest COD in summer season due to prevailing high temperature and low rain.

Dissolved Oxygen

The data presented in Table 4 revealed that the ground water DO in various urban areas ranged from 6.55 to 7.34 mg l^{-1}, which was within the BIS permissible limits. The analysis of pooled data from both years revealed a similar trend to that of individual years in different urban areas, in the following order: Arki (7.34 mg l^{-1}) > Solan (7.28 mg l^{-1}) > Nalagarh (6.85 mg l^{-1}) > Parwanoo (6.71 mg l^{-1}) > Baddi (6.55 mg l^{-1}). Arki's and Solan's values were statistically at par with each other. Maximum DO in Arki ground water sources may be attributed to minimal anthropogenic activities that did not disrupt the natural cleaning processes of water. The seasons had a significant impact on the DO of ground water sources as well. The highest DO was 7.17 mg l^{-1} in the winter, while the lowest was 6.72 mg l^{-1} in the summer. The findings are consistent with the findings of Gayatri *et al.* [33], who stated that at high temperatures during the summer, water's oxygen holding capacity decreases and thus DO decreases, whereas at low temperatures during the winter, oxygen remains dissolved in water, increasing its DO contents. Furthermore, they stated that during the summer, reduced water volume and accelerated microbe growth in higher temperatures are responsible for increased degradation of organic matter, which eventually depleted the DO concentration. The seasons also had a significant impact on the DO of ground water sources.

Lead

The examination of the data presented in Table 5 revealed that the Pb concentration in ground water ranged from 0.002 to 0.009 mg l^{-1}, which was within the permissible limit of (0.01 mg l^{-1}) as prescribed by BIS and WHO. The average effect of both years, as indicated by pooled data, showed a similar trend to that of individual years in terms of ground water Pb, which followed the following order: Baddi (0.009 mg l^{-1}) > Parwanoo (0.007 mg l^{-1}) > Solan (0.006 mg l^{-1}) > Nalagarh (0.004 mg l^{-1}) > Arki (0.002 mg l^{-1}). The water Pb of Baddi, Parwanoo and Solan was found to be statistically at par with each other. The higher Pb concentrations in Baddi, Parwanoo, and Solan may be attributed to excessive industrialization/urbanization, as well as the disposal of effluents from the area's numerous metal, plastic, and glass industries, landfill leachates, and ultimately diffusing through the soil solution into groundwater. The findings are consistent with those of Nair *et al.* [34] and Devi [35]. The seasons also had a significant impact on the Pb content of ground water sources. Summer had the highest Pb concentration of 0.007 mg l^{-1}, while winter had the lowest concentration of 0.004 mg l^{-1}. The findings are consistent with the findings of Ghannam *et al.* [35], who discovered higher concentrations of Pb in summer as a result of increased bioaccumulation due to metal concentrations caused by reduced water level.

Table 5 Seasonal variations in Pb, Cr, and Zn in urban ground water

Parameters	**Pb (mg l^{-1})**			**Cr (mg l^{-1})**			**Zn (mg l^{-1})**		
Seasons / Urban areas	**Summer**	**Winter**	**Mean**	**Summer**	**Winter**	**Mean**	**Summer**	**Winter**	**Mean**
Arki	0.003	0.001	**0.002**	0.014	0.016	**0.015**	0.12	0.13	**0.12**
Baddi	0.010	0.007	**0.009**	0.026	0.019	**0.022**	0.22	0.16	**0.19**
Nalagarh	0.005	0.002	**0.004**	0.027	0.020	**0.023**	0.37	0.29	**0.33**
Parwanoo	0.009	0.004	**0.007**	0.034	0.032	**0.033**	0.28	0.21	**0.25**
Solan	0.006	0.005	**0.006**	0.025	0.014	**0.019**	0.17	0.14	**0.15**
Mean	**0.007**	**0.004**		**0.025**	**0.020**		**0.23**	**0.18**	

Table 6 Seasonal variation in As and Cd in urban ground water

Parameters	**As (mg l^{-1})**			**Cd (mg l^{-1})**		
Seasons / Urban areas	**Summer**	**Winter**	**Mean**	**Summer**	**Winter**	**Mean**
Arki	0.004	0.003	**0.004**	0.002	0.001	**0.001**
Baddi	0.013	0.009	**0.011**	0.007	0.002	**0.005**
Nalagarh	0.004	0.002	**0.003**	0.001	0.005	**0.003**
Parwanoo	0.013	0.010	**0.012**	0.006	0.002	**0.004**
Solan	0.008	0.005	**0.007**	0.005	0.002	**0.004**
Mean	**0.008**	**0.006**		**0.004**	**0.002**	

Chromium

The Cr content of ground water sources was found to vary significantly across urban areas. According to Table 5, the ground water Cr in different urban areas ranged from 0.015 to 0.033 mg l^{-1}, which was within the permissible limit of 0.05 mg l-1 as prescribed by BIS and WHO. The average effect of both years, as indicated by pooled data, showed a nearly identical trend to that of individual years in terms of ground water Cr, which followed the order: Parwanoo (0.033 mg l^{-1}) > Nalagarh (0.023 mg l^{-1}) > Baddi (0.022 mg l^{-1}) > Solan (0.019 mg l^{-1}) > Arki (0.015 mg l^{-1}). The water Cr of Baddi and Nalagarh was found to be statistically at par with each other. The highest Cr content in Baddi and Nalagarh may be attributed to waste discharge from electro-coating, paint and dye, fabric manufacturing, and pharmaceutical industries, or to sewage addition, as Singh *et al.*[36] discovered. The seasons also has a significant influence on the ground of water. The summer season had the highest Cr of 0.025 mg l^{-1}, while the winter season had the lowest of 0.020 mg l^{-1}. The findings are consistent with those of Ahmad *et al.* [37] and Shanbehzadeh *et al.* [38], who found higher Cr during the summer months due to high ground water evaporation followed by high temperature.

Zinc

The data in Table 5 revealed that ground water Zn levels in various urban areas ranged from 0.12 to 0.33 mg l^{-1}, which was within the permissible limits set by the BIS and WHO (15 mg l^{-1} and 5 mg l^{-1}). The average effect of both years, as indicated by pooled data, showed a nearly identical trend to that of individual years in terms of ground water Zn, which followed the order: : Nalagarh (0.33 mg l^{-1}) > Parwanoo (0.25 mg l^{-1}) > Baddi (0.19 mg l^{-1}) > Solan (0.15 mg l^{-1}) > Arki (0.12 mg l^{-1}). According to Devi [39], higher ground water Zn in Nalagarh may be due to the addition of untreated wastes from rapidly expanding regions with dense populations, industrial establishments, and landfill leachates. The seasons of the year also exerted significant influence on Zn of ground water sources. The highest Zn concentration was 0.23 mg l^{-1} in the summer, while the lowest was 0.18 mg l^{-1} in the winter. The findings are consistent with those of Umeh [40] and Oguzie [41], who discovered higher Zn concentrations during the summer season as a result of reduced volume associated with higher evaporation rate caused by higher water temperature.

Arsenic

The data presented in Table 6 revealed that the As in ground water ranged from 0.004 to 0.012 mg l^{-1}, which was within the permissible limit of 0.05 mg l^{-1} as prescribed by BIS and WHO. The average effect of both years, as indicated by pooled data, showed a nearly identical trend to that of individual years in terms of ground water As in the following order: Parwanoo (0.012 mg l^{-1}) > Baddi (0.011 mg l^{-1}) > Solan (0.007 mg l^{-1}) > Arki (0.004 mg l^{-1}) > Nalagarh (0.003 mg l^{-1}). The presence of high levels of As in Baddi may be due to anthropogenic activities such as mining, the combustion of fossil fuels, and the addition of industrial effluents. Similar results have been reported by Hussain *et al.* [42]. The seasons also had a significant impact on the As of ground water sources. The summer season had the highest As of 0.008 mg l^{-1}, while the winter season had the lowest of 0.006 mg l^{-1}. The findings are consistent with those of to Durowoju *et al*. [43].

Cadmium

The Cd content of ground water sources was found to vary significantly across urban areas. According to the data presented in Table 6, the ground water Cd in different urban areas ranged from 0.001 mg l^{-1} to 0.005 mg l^{-1}, which was within the WHO permissible limit of (0.005 mg l^{-1}). The average effect of both years, as indicated by pooled data, showed a nearly identical trend to that of individual years in terms of ground water Cd. Baddi had the highest Cd concentration of 0.005 mg l^{-1}, followed by statistically par values of Parwanoo (0.004 mg l^{-1}), Solan (0.004 mg l^{-1}) and Nalagarh (0.003 mg l^{-1}). Arki had the lowest Cd concentration of 0.001 mg l^{-1}. The addition of wastes from various industries, Cd-stabilized plastics, Ni-Cd batteries, or unprocessed effluents from sewage treatment plants may be responsible for the highest Cd levels in Baddi [44]. The seasons also had a significant impact on the Cd of ground water sources. Summer had the highest Cd concentration of 0.004 mg l^{-1}, while winter had the lowest concentration of 0.002 mg l^{-1}. According to Abdel *et al.* [45] the higher Cd concentration in summer ground water is likely due to leaching of a small amount of Cd bound within soil material due to warmer temperatures and a faster rate of chemical weathering.

Water quality index

The WQI of ground sources in different urban areas were found to exhibit significant variations. The data presented in Table 7 revealed that the WQI of ground sources ranged from 19 to 49. The ground water of Baddi was found to have highest value of water quality index (49) followed by Parwanoo (41), Nalagarh (36), Solan (29) and Arki (19). The ground water quality of Baddi, Parwanoo, Nalagarh and Solan was rated as good, and excellent in case of Arki. The highest WQI in Baddi may be attributed to the area's rapid industrialization and various anthropogenic activities that may have resulted in seepage / leaching of contaminants in ground sources, as delineated by Thakur *et al.* [46].

Table 7 Water quality index of surface and ground sources of urban areas

Sources / Urban areas	Ground water
Arki	19
Baddi	49
Nalagarh	36
Parwanoo	41
Solan	29

WQI value of 0-25, 26-50, 51-75, 76-100 and greater than 100 is rated as excellent, good, poor, very poor and unfit for human consumption

CONCLUSION

The research concluded that the ground water quality in the region has already started to decline as a result of urbanization. Some trace elements have been detected in the ground water sources, though they are well within permissible limits. Ground water must be protected from further contamination by maintaining and enhancing the sewage network and water supply system. It is important to prevent waste of precious drinking water due to leaks. Any plan to increase groundwater use must account for the potential of existing aquifers, and withdrawals must be limited to no more than the mean annual total recharge rate. For similar urban areas around the world, this paper will inform city planners and administrators of the effects of urbanization on the ground water regime in urban areas of solan district where the infrastructure developments are not in conformity with the rapid growth in population. Poor water quality of surface water sources in the district is caused by improper sewage disposal, unchecked industrial effluents entering the water sources, and possibly the runoff phenomenon and the unprotected nature of natural water sources themselves. This could endanger the local ecosystem and cause health problems for the local population. Consequently, the research showed that the water sources require some treatment prior to usage, and it is crucial to safeguard them from the risks of contamination. Sustainable management of water resources requires consistent and proper implementation of clean technology and environmental measures by industries, as well as strict adherence to regulatory standards for emission and discharges from various sectors.

Conflict of interest. The authors declare that there is no conflict of interest.

REFERENCES

1. United Nations. World urbanization prospects. (2018).https://population. un.org/wup/.
2. Shimod, V., Vineethkumar, T.K. and Jayapal, G. (2022).Effect of urbanization on heavy metal contamination: a study on major townships of Kannur District in Kerala, India. Bulletin of the National Research Centre.,46(4):1-14.
3. Sin, S.N., Chua, H., Lo, W. and Ng, L.M. (2001).Assessment of heavy metal cations in sediments of Shing Mun River, Hong Kong. Environ Int.,26(5–6):297–301.
4. FengPeng, F., Song, Y.H., Yuan, P., Cui, X. and Qiu, G. (2009).The remediation of heavy metals contaminated sediment. Hazard Mater.,161:633–640
5. Nasehi, F., Hassani, A, H., Monavvari, M., Karbassi, A.R. and Khorasani, N. (2015).Evaluating the metallic pollution of riverine water and sediments: a case study of Aras River. Environ Monit Assess.,185(1):197–203.
6. Rigaud, S., Radakovitch, O., Couture, R.M., Deflandre, B., Cossa, D., Garnier, C. and Garnier, J.M. (2013).Mobility and fluxes of trace elements and nutrients at the sediment–water interface of a lagoon under contrasting water column oxygenation conditions. Appl Geochem.,31:35–51.
7. Santos, I.R., SilvaFilho, E.V., Schaefer, C.E., Albuquerque-Filho, M. R. and Campos, L. S. (2005).Heavy metal contamination in coastal sediments and soils near the Brazilian Antarctic Station, King George Island. Mar Pollut Bull.,50(2):185–194.
8. Wakode. (2018). Impact of urbanization on groundwater recharge and urban water balance for the city of Hyderabad, India. Hemant Balwant Wakode a,n, Klaus Baier a, Ramakar Jha b, Rafig Azzam. International Soil and Water Conservation Research.,6:51–62
9. Jha, R., Singh, V.P. and Vatsa, V. (2008).Analysis of urban development of Haridwar, India, using entropy approach. Journal of Civil Engineering.,12:281–288.
10. Baier, K., Schmitz, K.S., Azzam, R. and Strohschon, R. (2014).Management tools for sustainable ground water protection in mega urban areas-small scale land use and ground water vulnerability analyses in Guangzhou, China. International Journal of Environmental Research.,8:249–262.
11. Vazquez Sune, E., Sanchez Vila, X. and Carrera, J. (2005).Introductory review of specific factors influencing urban groundwater, an emerging branch of hydrogeology, with reference to Barcelona, Spain. Hydrogeology Journal.,13(3):522–533.
12. GOI. (2011).Census of India 2001: Size, Growth and distribution of population in India. Ministry of Home Affairs, New Delhi, India. pp.1-60
13. APHA. (2012).Standard methods for the examination of waste water. Washington DC.p.161
14. Anonymous. (2012).Indian standard 10500 of drinking water specification. Bureau of Indian Standards, New Delhi, India.p.32
15. Kumar, M. and Puri, A. (2012).A review of permissible limits of drinking water. Indian Journal of Occupational and Environmental Medicine.,16:40-44.
16. Balan, I.N., Shivakumar, M. and Kumar, P.M. (2012).An assessment of ground water quality using water quality index in Chennai Tamil Nadu, India. Chronicles of Young Scientists.,3(2):146-150
17. Badmus, B.S., Odewande, A.A., Ayolabi, E.A. and Ayodele, T. (2001).Experimental investigation of leachate contamination on groundwater exploration in basement complex area. Journal of Natural Sciences, Engineering and Technology.,8(1):11-15.
18. Sawane, A.P., Puranik, P.G. and Bhate, A.M. (2006).Impact of industrial pollution on river Irai, district Chandrapur with reference to fluctuation in CO_2 and pH. Journal of Aquatic Biology., 21(1):105-110.
19. Khan, A.A., Nabi, N.G., Dar, S.G., Rashid, A. and Teli, A.R. (2017).Seasonal variations of physico-chemical parameters in Lower Lake of Bhopal. The Pharma Innovation Journal., 6(11):710-714.
20. Reddy, V. (2009).Physico-chemical parameters of Pakhal Lake of Warangal District, Andhra Pradesh, India. Journal of Aquatic Biology.,24(1):1-4.
21. Solanki, R. and Acharya, C.A. (2016).Physico chemical characteristics of ‘Ugat Vaniya Lake’ in Surat City, Gujarat, India. International Journal of Pharmacy and Life Sciences.,7(4):4996-5001.
22. Polkowska, Z., Skarzynska, K., Dubiella, J.A., Staszek, W. and Namiesnik, J. (2007). Evaluation of pollutant loading in the runoff waters from a major urban highway (Gdansk Beltway, Poland).Global Nest Journal.,9:269-275.
23. Garg, V.K., Suthar, S., Singh, S., Sheoran, A., Garima. and Jain S. (2010).Drinking water quality in villages of southwestern Haryana, India: assessing human health risks associated with hydrochemistry. Environmental Geology.,58(1):1329–1340.
24. Khaund, N.J., Phukon, P. and Bhattacharya, K.G. (2012).Physico-chemical studies of surface water quality in the Jia Bharoli river basin, North Brahamputra plain, India. Archives of Applied Science Research.,4(2):1169-1174.
25. Tripathi, A.K and Pandey, S.N. (2009).Water pollution. PH Publishing Corporation, New Delhi. pp.275-276
26. Sharma, A., Ganguly, R. and Gupta, A.K. (2017).Characterization of municipal solid waste in Sundernagar, Himachal Pradesh, India. Research Journal of Pharmaceutical, Biological and Chemical Sciences.,8(1):276.

27. Trivedi, R. K and Goel, P. K. (1986).Chemical and biological method for water pollution studies. Environmental Publications, Karad, India. pp.57-126
28. Kaur, S. and Kaur, J. (2015).Assessment of Seasonal variations in oxygen demanding parameters (DO, BOD, COD) along Sirhind Canal passing through Moga, Punjab, India. International Journal of Innovative Science, Engineering and Technology.,2(5):697-700.
29. Maya, K., Babu, K.N., Pabdmalal, D. and Seralathan, P. (2007).Hydrochemistry and dissolved nutrient flux of two small catchment rivers, south western India. Journal of Chemical Ecology.,23(1):13-27.
30. Shaik, A.M. and Mandre, P.N. (2009).Seasonal study of physico-chemical parameters of drinking water in Khed industrial area. International Research Journal.,2(7):169-172.
31. Fokmare, A. and Musaddiq, M. (2002).A Study of Physico chemical characteristics of Kapsi Lake and purna river water in Akola District of Maharashtra (India). Journal of Ecology and the Natural Environment.,1:261-263.
32. Nag, A.K., Singh, B. and Ghosh, K. (2014).Related to Physico-Chemical Characteristics of Water of Surya Kund a Relgious Pond Located in Gaya Town of Bihar, India. Ultra Chemistry.,10(2):109-116.
33. Gayatri, M.U., Deshbhratar, S.M. and Singh, A.J. (2018).Assessment of the few specific parameters of Satpala Lake at Virar, Thane, Maharashtra. International Journal of Advance Research in Science and Engineering.,7(3):518-525.
34. Nair, I.V., Singh, K., Arumugam, M., Gangadhar, K. and Clarson, D. (2010).Trace metal quality of Meenachil River at Kottayam, Kerala (India) by principal component analysis. World Applied Sciences Journal.,9(10):1100-1107.
35. Ghannam, H.E., Talab, A.S., Jahin, H.S. and Gaber, S.E. (2014).Seasonal variations in physic-chemical parameters and heavy metals in water of El-Bahhr El-Pharaony drain, El-Menoufia Governorate, Egypt. Research Journal of Environmental and Earth Sciences.,6(3): 174-181
36. Singh, H., Pandey, R., Singh, S. K. and Shukla, D.N. (2017).Assessment of heavy metal contamination in the sediment of the River Ghaghara, a major tributary of the River Ganga in Northern India. Applied Water Science.,7(7):4133-4149.
37. Ahmad, M.K., Islam, S., Rahman, M.S., Haque, M.R. and Islam, M.M. (2010).Heavy Metals in Water, Sediment and Some Fishes of Buriganga River, Bangladesh. International Journal of Environmental Research.,4(2):321-332.
38. Shanbehzadeh, S., Dastjerdi, M.V., Hassanzadeh, A. and Kiyanizadeh, T. (2014).Heavy Metals in Water and Sediment: A Case Study of Tembi River. Journal of Environmental and Public Health.,7(1):1-5.
39. Devi, M. (2011).Inventory and estimation of greenhouse gases from waste in Baddi Barotiwala Nalagarh region of district Solan. M.Sc. Thesis. Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, India. pp.54-69
40. Umeh, G.I. (2002).Pollution assessments of Olomoro water bodies using physical, chemical and biological indices: Thesis, University of Benin, Benin City, Nigeria. p. 485
41. Oguzie, F.A. (2003).Heavy metals in water and sediments of the lower Ikpoba River, Benin City, Nigeria. Pakistan Journal of Science and Industrial Research.,46(3):156-160.
42. Hussain, J., Husain, I., Arif, M. and Gupta, N. (2017).Studies on heavy metal contamination in Godavari river basin. Applied Water Science.,7(1):4539-4548.
43. Durowoju, O.S., Odiyo, J.O. and Ekosse, G.I.E. (2016).Variations of Heavy Metals from Geothermal Spring to Surrounding Soil and Mangifera Indica–Siloam Village, Limpopo Province. Sustainability.,8(60):1-12.
44. NPDWRs. (2004).Ground water and Drinking water. USEPA. pp.1-13.
45. Abdel, M.A. and El-Sammak, A.A. (1997).Manmade impact on the geochemistry of the Nile Delta Lakes: A study of metals concentrations in sediments. Water, Air, & Soil Pollution., 97(1):413-429.
46. Thakur, N., Rishi, M. and Sharma, D.A. (2018).Quality of water resources in Kullu Valley in Himachal Himalayas, India: perspective and prognosis. Applied Water Science.,8(1):20-33.

Copyright: © 2023 Author. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.