ISSN: 0973-4929, Vol. 14, No. (1) 2019, Pg. 159-169

Current World Environment

www.cwejournal.org

Suitability Assessment of Sirsa River Water for Irrigation in Shiwalik Foothills of North Western Himalaya

BHARDWAJ S.K., SHARMA R. and AGGARWAL R.K.*

Department of Environmental Science, Dr YSP University of Horticulture and Forestry, Nauni-173230, Solan, India

Abstract

Sirsa river runs through the central part of the Baddi Barotiwala Nalagarh (BBN) industrial region in district Solan of Himachal Pradesh. The water of this river is used for irrigating agricultural fields by the farmers. The increased industrial and urbanization activities in the valley are being pointed out as the cause of river water pollution by the farmers and other habitations in the region. Therefore, such reports prompted the study to assess the river water suitability for irrigation commitments. Thus, Sirsa river water quality was assessed during the year 2018 by taking seven sampling sites as treatments which were replicated six times. To assess the suitability of Sirsa river water for irrigation purposes, various quality parameters such as pH, Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC), Permeability Index (PI), Kelly's Ratio (KR), Magnesium Hazard (Mg. Haz.)and Chloro-Alkaline Index (CAI) were determined. In the Sirsa river water pH, EC, RSC, SSP, SAR, PI, KR, Mg Hazand CAI were found in the range of 6.64-7.55, 129.50-719.67 μS/cm, -5.27 -2.18 meq/l, 13.49-49.44%, 0.41-4.00%, 28.20-57.89%, 2.94-21.24%, 14.97-37.83% and 0.04-0.58%, respectively. All the factors were within the safe range for irrigation purposes except KR values. The high KR values above unity pointed out towards sodicity hazard of water which, therefore can-not be used for irrigation purposes.

Article History

Received: 02 March 2019
Accepted: 25 April 2019

Keywords

Industrial activities;
Irrigation;
KR;
Mg Haz.CAI;
PI;
Pollution;
RSC;
SAR;
SSP;
SurfaceWater.

Introduction

Rivers are a much-valued feature of the natural ecosystem as these perform numerous vital functions. However, owing to its indiscriminate utilization due to the population explosion and various developmental activities, this vital resource is now under tremendous pressure. Additionally, meeting of diverse water necessities for irrigation, human and

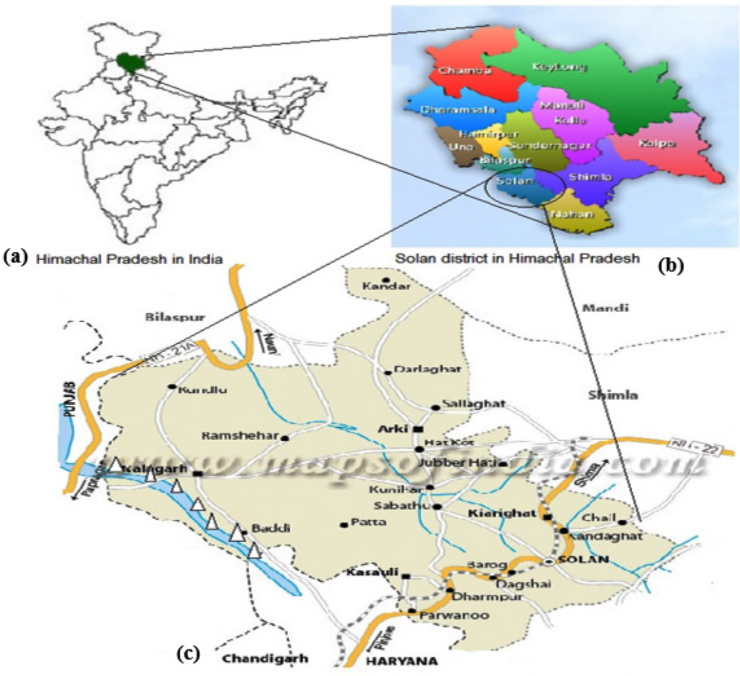
CONTACT Aggarwal R.K. rajeev1792@rediffmail.com Department of Environmental Science, Dr YSP University of Horticulture and Forestry, Nauni-173230, Solan, India.

Doi: http://dx.doi.org/10.12944/CWE.14.1.15

industrial consumption has become a challenge. Further, the rapidly expanding industrialization and urbanization has also exhausted the accessible water resources and the water quality has alsodegraded.[1,2] The factors like basin's lithology, atmospheric and climatic conditions and anthropogenic activities have also been reported to influence water quality.[3,4] Generally, industrial waste waters both non-treated or ill-treated often get mixed with house-hold sewage enter into the surface water bodies where they get dissolved or lie suspended in water deteriorating its quality and causing pollution.[5,6,7]

Irrigation is one of the most vital uses of river water for agrarian resolves and its suitability is determined by estimating the concentration and constitution of dissolved components. In developing countries, waste water is usually used for irrigation as an alternative to the limited fresh water resources because of its accessibility and availability of nutrients.[8,9] However, such water may contain many contaminants and can obstruct the basic purpose of irrigation. These contaminants maybe further taken up by the crops and other biotic forms which can eventually harm human health and the environment creating a greater threat to bio-cycle.[10] Therefore, it has now become essential to evaluate the water quality before applying it for irrigation.

Nalagarh valley representing the southernmost expanse of Solan district in Himachal Pradesh (HP); comprises Baddi, Barotiwala and Nalagarh (BBN) region which has witnessed reckless industrial development in the recent past.[11] Sirsa river is the main river that originates near Kalka, enters HP in district Solan flowing through sub-shivalik hills before, it unites with river Sutlej at Chak Dehra near Ghanauli.Currently, itis facing tremendous pressuredue to the random development of numerous large and small scale industries besides profuse urban areas all over its catchment area.[12,13] Additionally, there are several streams namely Chikninadi, Phulanadi, Rattanadi, Baladnadi and Surajpurchao; heavily loaded industrial and domestic effluents which join Sirsa river further contributing towards the water quality deterioration.[14,15] The composition of the discharge in all the streams joining Sirsa river have been noticed to vary



Water sampling locations along river Sirsa in BBN region of Solan district

Fig. 1: Location Map of the Study Area

(Source: Google maps)

seasonally and has reported to contain heavy load of effluents during rainy season.[16] The water of the river is primarily used for irrigation by the local inhabitants; along with other domestic and industrial applications. Therefore, the present investigation was conducted to assess the suitability of Sirsa river water for irrigation purposes.

Material and Methods

Baddi, Barotiwala, Nalagarh (BBN) area is a rapidly growing industrial township which has developed as a major industrial hub in Solan district of HP.It lies within 30° 57′N; 76° 22′E and the geological structure of the region embraces Shiwalik formations. The soils of this hilly terrain are majorly neutral whereas its texture varies from sandy loam to clay loam. Except the areas having vegetation cover, soil depth is usually shallow. The major part of the Sirsa river basin is covered by alluvium soil varying from 10-20 cm in thickness and is mostly granular with Holocene and Pre-Holocene deposits. In the upper and middle parts of the river basin; alternate beds of clay, pebbles, gravel are dominating whereas in the downstream part of basin sediments get finer to become clay.[16] The area which is irrigated with the river water, is majorly used for the cultivation of vegetable crops (pea, tomato, brinjal, capsicum, beans, cabbage, cauliflower, bhindi), sub-tropical fruits, cereals (maize, rice, wheat, barley), pulses and oil seed crops.[17]

Sirsa river is one of the major perennial tributaries of Sutlej and it flows south-westerly in the area to join Sutlej 10 km before the commencement of Ropar (Fig. 1 a, b and c). Since Sirsa river is flowing through various urban and industrial areas and its water is used for irrigation in the region, therefore, in order to evaluate the water quality for irrigation purposes; detailed survey of the river catchment area was conducted and the entire river stretch of 29 km flowing along the BBN region was divided into six parts (Fig. 1c). The entry point of river into the industrial hub was considered as control. At each stretch, six water samples were taken from the centre of the river which were considered as replications. Accordingly, seven sampling sites were considered as treatments which were replicated six times. In total, 42 water samples were collected across the flow of Sirsa river in January 2018 and were further subjected to physicochemical analysis using standard methods. All the analytical chemicals, reagentsand glassware used in this study were purchased from CHD Pvt. Ltd. (New Delhi), Merck Life Sciences Pvt. Ltd., Fisher Scientific, Hi-Media laboratories Pvt Ltd.and Borosil laboratories Pvt. Ltd. (Mumbai).

Water Sampling and Laboratory Analysis

Bulk samples were collected in pre-washed plastic bottles at depths ranging from 15-30 cm in the water body. At the time of sampling, bottles were carefully rinsed two to three times with water to be sampledThe samples were stored in an ice box, transported to the laboratory and analysed for parameters within 24 h using standard methods (APHA, 2012). Water pH and Electrical Conductivity were estimated using pH meter (ESICO Model-1013) and EC meter (ESICO Model-160), respectively. Water samples were passed through Whatman No. 42 filter paper and further used for the estimation of ions namely Na^+, K^+, Mg^{2+}, Ca^{2+}, CO_3^{2-}, HCO_3^-, Cl^-. The elements like Na+ and K+were estimated using Flame Photometer (ESICO Model-1382). To estimate Ca^{2+} in water, an alcoholic-alkaline solution was made to react with calcium ions which further modified glyoxal-bis(2-hydroxyanil) to form a red-violet complex.In case of determination of Cl- ions, these were made to react with mercury(II) thiocyanate to form slightly dissociated mercury(II) chloride and the thiocyanate released in the process in turn reacted with iron(III) thiocyanate. For estimation of Mg^{2+} ions, these ions were made to react with phthalein purple in neutral solution to form a violet dye. All the coloured complex formations were determined photometrically by using Spectroquant® Pharo 300(Merc make). CO_3^{2-} and HCO_3^- were estimated by titration method using standard H_2SO_4 with phenolphthalein and methyl orange as an indicator.[18,19]

On the basis of estimated concentrations of the abovementioned ions, irrigation suitability of Sirsa river water was determined by evaluating critical parameters such as Residual Sodium carbonate (RSC), Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Permeability Index (PI), Kelley's Ratio (KR), Magnesium Hazard (Mg Haz.) and Chloro-alkaline index (CAI) using the standard formulae given in Table 1. In order to determine the utility of river water for irrigation based on various parameters was ascertained according to the classifications suggested by several authors as given in Table 3. Ionic concentrations were expressed as mg/l and further conversion into milli equivalent/l (meq/l) was followed afterwards. The quality of the data obtained in the study was verified through careful standardization, blank measurements in the respective procedure and samples in triplicates. The data obtained from the analysis of water samples was subjected to statistical analysis using one-way SPSS 11.0 software. Microsoft Excel 2010 was used for the calculations and data analysis.

Results and Discussion

pH

The Sirsa river water pH values were found to be in the range of 6.64-7.55 with a mean ± SD of 7.15±0.05 (Table 2) indicating that the water was in normal range. The water pH was within the prescribed standard limits of 6.5-8.5.[26] However, significant variations were noticed in river water pH values which followed an increasing trend as river flows down from control site towards the last point along-side the industrial activities (Table 2). The addition of industrial and domestic effluents resulting in increased photosynthetic algal activities that consume all the dissolved carbon dioxide leading to decrease in the concentration of free CO_2 thereby decreasing the acid formation which might have ultimately increased the water pH.[27,28] The results are in line with Rana *et al.* (2016)[29] who have also describe driver water pH varying from 6.01-7.53 in Solan district in HP while studying the various land

Table1: Standard formulae to calculate the water quality parameters

S. No.	Parameter	Calculation	Reference
1	RSC	$(HCO_3^- + CO_3^{2-}) – (Ca^{2+} + Mg^{2+})$	[19]
2	SSP	$[Na^+ + K^+ / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)]$ *100	[20]
3	SAR	$Na^+ / (Ca^{2+} + Mg^{2+} / 2)^{1/2}$	[21]
4	PI	$[Na^+ +(HCO_3^-)^{1/2} / (Ca^{2+} + Mg^{2+} + Na^+)]$ *100	[22]
5	KR	$Na^+ / (Ca^{2+} + Mg^{2+})$	[23]
6	Mg. Haz.	$(Mg^{2+}$ *100)/($Ca^{2+} + Mg^{2+})$	[24]
7	CAI-I	$[Cl^- - (Na^+ + K^+)] / Cl^-$	[25]

Table 2: Status of Sirsa river water quality parameters assigned for irrigation usage

Treatments	pH	EC (µS/cm)	RSC (meq/l)	SSP (%)	SAR (meq/l)	KR (%)	Mg Haz. (%)
T1	6.64	129.50	-2.61	13.49	0.41	3.26	14.97
T2	6.78	179.83	-3.21	13.53	0.46	3.17	25.59
T3	6.80	283.83	-3.52	15.14	0.48	2.94	25.98
T4	7.33	420.50	-5.27	32.73	2.01	10.35	37.83
T5	7.33	508.67	-3.65	43.24	3.08	16.40	26.03
T6	7.51	612.50	-4.13	45.49	3.61	18.14	30.19
T7	7.55	719.67	-2.18	49.44	4.00	21.24	17.65
Range	6.64-7.55	129.50-719.67	(-)5.27-(-)2.18	13.49-49.44	0.41-4.00	2.94-21.24	14.97-37.83
CD	0.11	3.00	0.15	0.62	0.04	0.22	0.21
Mean ± SD	7.15 ± 0.05	407.79 ± 1.03	-3.51 ± 0.05	30.44 ± 0.05	2.01 ± 0.02	10.79 ± 0.08	25.46 ± 0.07
Min	6.75	132.50	-8.79	14.12	0.45	3.48	15.17
Max	7.44	716.67	1.33	50.07	3.97	21.02	37.63

uses in the region. Similar range of the pH values for river water have also been recorded by various authors affirming it safe for use in agriculture.[30,7]

Electrical Conductivity (EC)

Electrical conductivity evaluates the electric current carrying capacity of water based on the concentration of dissolved ions and has been assigned as an important criterion for assessing the appropriateness of water for its use in irrigation. The river water EC values ranged between 129-720 µS/cm (Table 2) which were well below the standards permissible limits of 1500µS/cm prescribed by BIS. All the river water samples were found to be under safe and moderately safe class, thus may be considered fit for irrigation purposes (Table 3).

Table 3: Water classificationfor irrigation suitability based on severalparameters

Class	Range	Suitability for irrigation
A.EC (µS/cm) (Source: CGWB and CPCB, 2000)[32]		
1	Below 250	Safe
2	250-750 (moderately saline)	Moderately Safe
3	750-2250 (medium to highly saline)	Permissible
4	2250-4000 (high salinity)	Safe with permeable soils and moderate leaching
5	4000-6000 (very high salinity)	Doubtful
6	Above 6000 (excessive salinity)	Unsuitable
B.RSC (Source: Eaton, 1950; USDA, 2008)[19,35]		
1	<1.25	Safe
2	1.25-2.5	Moderate
3	>2.5	Unsuitable
C.SSP (Source: Wilcox, 1955)[36]		
1	<20	Excellent
2	20-40	Good
3	40-60	Permissible
4	60-80	Doubtful
5	80-100	Unsuitable
D.SAR (Source: USSL, 1954)[37]		
1	<10	Excellent
2	10-18	Good
3	18-26	Doubtful
4	>26	Unsuitable
E.PI (Source: Doneen, 1962)[22]		
1	>75%	Very Good
2	25-75%	Good
3	<25%	Unsuitable
F.KR (Kelly, 1963)[23]		
1	<1	Very Good
2	1-2	Marginal
3	>2	Poor

Although significant variations were observed in water EC values which followed an accumulative trend towards the last point of the river along-side the industrial activities signifying the greater impacts of direct disposal of untreated industrial and domestic effluents in the river. The increase in the EC values towards the lower section of the river along-side the industrial hub can be ascertained to the addition of the inorganic dissolved solids such as calcium, chloride, aluminium, nitrate, sulphate, iron, magnesium, and sodium ions and organic compounds such as oils, alcohols, phenols, and sugars from the domestic and industrial wastes into the river.[31] According to the classification of water based on EC for irrigation purposes given by CGWB and CPCB (2000),[32] river water samples were under saline to moderate saline class (Table 3). Generally, water with an EC value below 750 µS/cm is regarded assuitable for irrigation.[33] High EC reduces the plants osmotic activity and thus hinders water and nutrients absorption from the soil. Hence, irrigation water with high EC values can affect crop yield potential as amount of water present in the soil for its use by the plants decreases dramatically with increased EC.[34] Herojeet *et al.*(2016)[15] have also reported EC values in the range of 250-2000 µS/cm for Sirsa river water samples classifying them under good and permissible class reflecting their use as safe for irrigation purposes. Sharma *et al.* (2014)[3] have stated EC values in the range of 283-760 µS/cm for river water samples in limestone mining areas of district Solan in HP and all samples were reported to be well within permissible limits therefore suitable for irrigational purposes. Haritash *et al.* (2016)[5] have described EC values ranging from 38-170 µS/cmin thewater samples gathered from river Ganga located at Rishikesh in Uttarakhand asserting its secure use in irrigation for agriculture. Similar range of EC values for the surface water 455.00-618.50µS/cmhave also reported in the Solan district of HP as an impact of various land uses in the region.[29]

Residual Sodium Carbonate (RSC)

Residual Sodium Carbonate is an index to assess the quality of irrigation by comparing the concentrations of Ca^{2+} and Mg^{2+} to HCO_3^- and CO_3^{2-}. It also determines the precipitation of Ca^{2+} and Mg^{2+} as carbonates in the soil leading toa relative upsurge in Na^+. Consequently, fixationof Na^+ in the soil causes dissolution of organic matter to leave a black spoton the surface post-drying.[15] The RSC values of Sirsa river water ranged between (-)5.27-(-)2.18 meq/lexhibiting significant variations as the river passes through the industrial region however; no specific trend was observed (Table 2). Sirsa river water was found to have RSC values below 1.25 meq/l (Table 3) and according to the recognized guidelines for water quality classification[19,35] it was under safe category for its use in irrigation (Table 3). The negative RSC values observed in the river water can be ascribed to the addition of the various inorganic dissolved solids such as calcium, chloride, aluminium, nitrate, sulphate, iron, magnesium, and sodium ions etc. from the domestic and industrial wastes into the water body. Many authors have also reported negative RSC values for surface water to consider it safe use in agriculture through irrigation.[5,15,38,39]

Soluble Sodium Percentage (SSP)

The permeability of agricultural soils irrigated with water containing excessive amounts of Na^+ ions may reduce drastically and eventually causing deficient inner drainagein the soil. Thus, the water being used for irrigational purposes should have a lower Na^+ concentration. The SSP values of Sirsa river water varied between 13.49-49.44% with a mean ± SD of 30.44±0.05 (Table 2) which was in lower range with a less pronounced effect on water quality for irrigation. The lower SSP values in the study can be credited to the heavy load of various inorganic dissolved solids coming from the domestic and industrial wastes into the water body. According to the standard classification, all the samples were found to be under excellent category for irrigation (Table 3). Haritash *et al.*(2016)[5] have observed SSP values in the range of 9.71–25.54% for Ganga river water in Rishikesh, Uttarakhand depicting it suitable for irrigation. Herojeet *et al.* (2016)[15] have estimated SSP values in the range of 5.36- 68.33% for Sirsa river water in Solan district of HP whereas Sharma *et al.* (2016)[3] have noted SSP values between 3.33-8.88% for surface water samples in limestone mining areas of district Solan showing its suitability for irrigation commitments.

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio is commonly used criterion for estimating the sodium hazard associated with an irrigation water supply.[39] Water infiltration lessens due to high sodium relative to the calcium and magnesium contents and this condition is referred as "sodicity". Sodicity further causes swelling and dissemination of soil clays, surface crusting and pore choking along-with a decrease in the downward movement of water through the soil. Consequently, inspite of pooling of water on the soil surface after irrigation, actively growing plants roots do not get sufficient water.[34] Higher values can affect the soil overall permeability by causing damages to its structure resulting in compact and impervious nature.[20,40,41,15] SAR quantifies sodicity in terms of the relative concentration of Na^+ to the sum of Ca^{2+} and Mg^{2+} ions in water. The SAR values of Sirsa river water ranged between 0.41-4.01 meq/l (Table 2).

The U.S. Salinity Laboratory, (1954)[37] has given water classification on the basis of SAR values in relation to irrigation and all the samples were found to be excellent for the same target (Table 3). However, uninterrupted use of water having low SAR levels from 1 to10 in irrigation may cause sodium hazard to sensitive crops.[42] Herojeet *et al.*(2016)[15] reported SAR values in the range of 0.27-4.02 meq/l for Sirsa river water samples which have been classified as excellent for irrigation purposes. Haritash *et al.* (2016)[5] estimated SAR values between 0.24-0.43 meq/l in the water samples collected from Ganga river in flowing through Rishikesh in Uttarakhand stating its safe use in irrigation for agriculture. Sheriff and Hussain (2017)[39] have reported water samples collected from Noyyal River at Tiruppur, Tamilnadu, India under excellent category based on SAR classification, which can be used for irrigation purposes.

Table 4: Status of Sirsa river water quality indices assigned for irrigation purposes

Treatments	PI (%)	CAI (%)
T_1	34.22	0.58
T_2	30.26	0.50
T_3	28.20	0.49
T_4	41.46	0.28
T_5	51.90	0.14
T_6	53.35	0.04
T_7	57.89	0.19
Range	28.20-57.89	0.04-0.58
CD	0.82	0.03
Mean±SD	42.47±0.28	0.32±0.02
Min	29.02	0.06
Max	57.07	0.55

Kelley's Ratio (KR)

Kelly's ratio is an important parameter used in the assessment of water quality for irrigation based on the Na^+, Ca^{2+} and Mg^{2+} ion concentrations in the water. As per standard classification, water with a KR value higher than unity is considered non-suitable for irrigation.[23] During the present investigation, KR ranged from 2.94-21.[24] with mean ± SD value of 10.79±0.08 (Table 2). All samples fell under Class III as shown in Table 3 which indicated the unsuitability of water for irrigation. Such higher values of KR can be ascribed to the presence of excessive Na^+ ions in the river water due to the addition of waste waters from several industries. This may be credited to the direct disposal of domestic and industrial waste waters into the river leading to increased concentrations of the different ions in the water. Higher KR values for the surface water have also been reported in the literature suggesting unsafe nature of water for irrigation.[38,5,25]

Magnesium Hazard (Mg Haz.)

It is well established fact that the higher levels of Mg^{2+} in water support an advanced production of transferrable Na^+ in irrigated soils which not only deteriorates soil structure but also has adverse effect on the crop yield affecting overall production.[24,43] Water with Mg Haz. less than 50% is appraised fit for irrigation.[44] The Mg Haz. values of Sirsa river water ranged from 14.97-37.83% with mean ± SD value of 25.46±0.07 (Table 2) and thus, river water was considered safe for its use in agriculture through irrigation. Several authors have described Mg Haz. values well below standard accepted limits of 50% suggesting safe use of water in irrigation.[5,25,45] In a recent study, all shallow tube well and pond water samples exceeded Mg Haz. value of 50% whereas river water samples (71.42%) had shown lower MAR values within 50%.[38]

Permeability Index (PI)

The capability of soil to transmit water and air is one of the most important qualities to consider water out flow depending on its texture and structure and is described as"soil permeability". Permeability index (PI) has been developed as a standard for examining the aptness of water for irrigation. According to the standard classification, water belonging to class I and II with 75% or more of permeability is rendered good for irrigation whereas Class III water with 25% of maximum permeability is contemplated as unfit as presented in Table 3. The PI values of Sirsa river water ranged between 28.20-57.89% with mean ± SD value of 42.47± 0.28 (Table 4). The river water belonged to Class II as shown in Table 3, which indicated its suitability for irrigation. Herojeet *et al.* (2016)[15] have also reported PI values in the range of 22.15-77.15% for Sirsa river water samples under Class I and II and were found to be suitable for irrigation purposes. Haritash *et al.*(2016)[5] described PI values between 25-75% for the Ganga river collected from Rishikesh in Uttarakhand stating its safe use in irrigation for agriculture. Salifu *et al.*(2017)[25] stated that 96.65 and 4.35% of ground water samples collected from the the upper West region of Ghana were under Class I and II, respectively based on PI values which made the water non-suitable for irrigation.

Chloro-Alkaline Index (CAI)

The CAI is based on Cl- ion concentration in water and is commonly used to evaluate the ion exchange reactions occurring between groundwater and its host rock.[46,47] Chloride is avital micronutrient which acts as a cofactor in the water oxidation during photosynthesis. In order to sustain a charge balance during cation transport, it is readily taken up by plants contributing towards cell hydration and turgor maintenance. Chloride also serves to maintain a balance of the positive charge of the soluble cations Na^+, Ca^+, Mg^+, and K^+ in the soil.[48] However, at high concentrations it can cause toxicity and problems in plants such as marginal leaf burn and interveinal chlorosis, reduced yields etc. Positive CAI values indicate occurrence of base-exchange reactions, wherein Ca^{2+} and Mg^{2+} ions existing in water react with clay minerals to discharge Na^+ and K^+ whereas negative CAI values depict chloro-alkaline imbalance or absence.[49,50,25] The CAI values for Sirsa river water ranged between 0.04-0.58% and therefore found suitable for irrigation (Table 4). Sheriff and Hussain (2017)[38] have reported CAI values in the range of -0.153 to 0.726 meq/L for Noyyal river water situated at Tiruppur in Tamilnadu to evaluate its fittingness for irrigation. Kumar *et al.* (2014)[50] quantified positive CAI values in 70% water samples collected from the south Chennai coastal aquifers in Tamil Nadu, India.

Conclusions

The most of the water quality parameters like SAR, SSP, RSC, PI, Mg. Haz. and CAI-I were within the acceptable standard limits for its use in irrigation except Kelly's Ratio (KR) values. The study inferred that the industrial activities have started impacting the Sirsa river water quality as indicated by high Kelly's Ratio values. The high KR values pointed out the sodicity hazard of water which makes it non-suitable to irrigation. However, the continuous disposal of untreated municipal and industrial effluents in the Sirsa river may pose environmental risks and health hazards to the inhabitants and the adjoining agricultural fields. Therefore, before using river water for irrigation, its quality monitoring is necessary as its regular and continuous use for irrigation may influence the soil and plant health. Moreover, the regulatory standards for emission and discharges from different industries should be strictly followed and regular/proper implementation of clean technology and environmental measures by industries should be employed to achieve sustainable management of water resources.

Conflict of interest

There is no conflict of interest for this manuscript.

Acknowledgments

The authors acknowledge the Ministry of Environment Forest and Climate Change (MoEF & CC), Government of India for providing necessary funding to facilitate the research work.

References

1. Kannj I., Achi O. Industrial effluents and their impact on water quality of receiving rivers in Nigeria. *J. Appl. Technol. Env. Sanit.* 2011; 1(1):75-86.
2. Arfanuzzaman M., Rahman A.A. Sustainable water demand management in the face of rapid urbanization and ground water depletion for social–ecological resilience building.

GlobalEco.Conserv. 2017; 10:9-22.

3. Sharma R., Rishi M.S., Lata R., Herojeet R. Evaluation of surface water quality for irrigation purposes in limestone mining areas of district Solan, Himachal Pradesh, India. *Int. J. Innov. Sci. Eng. Technol.*2014;1(8): 368-375.
4. Reza R., Singh G. Assessment of heavy metal contamination and its indexing approach for river water. *Int. J. Env. Sci. Technol.* 2010; 7(4):785-792.
5. Haritash A.K., Gaur S., Garg S. Assessment of water quality and suitability analysis of river Ganga in Rishikesh, *India. Appl. Water. Sci*. 2016; 6:383-392.
6. Tiwari P. Water quality assessment for drinking and irrigation purpose. *Ind. J.Sci. Res*. 2017; 13(2):140-142.
7. Bhutiani R., Faheem A., Tyagi V., Ram K. Evaluation of water quality of river Malin using water quality index at Najibabad, Bijnor (UP) India. *Environ. Conserv. J.* 2018; 19(1&2):191-201.
8. Keraita B.N., Drechsel P. Agricultural use of untreated urban wastewater in Ghana. In: Scott C.A., Faruqui N.I., Raschid-Sally L. (Eds.). Wastewater use in irrigated agriculture.2004; CABI Publishing, Wallingford, UK, pp. 101–112.
9. Scott C.A., Faruqui N.I., Raschid-Sally L. Wastewater use in irrigated agriculture: management challenges in developing countries. In: Scott C.A., Faruqui N.I., Raschid-Sally L. (Eds.). Wastewater Use in Irrigated Agriculture.2004; CABI Publishing, UK.
10. Qadir M., Wichelns D., Raschid-Sally L., McCornick P.G., Drechsel P., Bahri A., Minhas P.S. The challenges of wastewater irrigation in developing countries. *Agric. Water Manag.* 2010; 97:561-568.
11. Herojeet R.K., Rishi M., Tuli N. Impact of industrialization on groundwater quality: A case study of Nalagarh valley, Himachal Pradesh, India. In: Proceeding of International Conference on Integrated Water, *Wastewater & Isotope Hydrology* 2013; 3:69-75.
12. Government of Himachal Pradesh (GoHP) Economic survey 2010–11. Himachal Pradesh Finance Department, Shimla. http://himachalservices.nic.in/economics/pdf/EconSurveyEng2012_A1b.pdf.
13. Government of India (GoI) Himachal Pradesh development report, state plan division, planning commission. Government of India, 2012; pp 1-18. http://planningcommission.nic.in/plans/stateplan/sdr_hp/sdr_hpch16.pdf.
14. CGWB. Report on the groundwater exploration in the parts of intermontane Sirsa valley, Nalagarh Teshil, Solan District, Himachal Pradesh, Unpub.(1975) pp.1-42.
15. Herojeet R., Rishi M.S., Lata R., Tenzin T., Konchok D. Hydrochemical classification and quality characterization of surface water for irrigation purposes in parts of Sirsa watershed, Nalagarh Valley, Himachal Pradesh, India. SOPAAN-II 2016; 1(1): 37-48.
16. Herojeet R.K., Rishi M.S., Lata R., Konchok D. Quality characterization and pollution source identification of surface water using multivariate statistical techniques, Nalagarh Valley, Himachal Pradesh, India. *Appl Water Sci*. 2017; doi: 10.1007/s13201-017-0600-y.
17. DOA. District Agriculture Plan, Solan H.P. 2009; Vol 11 http://hillagricrepository.co.in/1024/1/87676.pdf
18. Crompton T.R. Carbonate, Bicarbonate and Total Alkalinity. In: Determination of Anions. 1996; Springer, Berlin, Heidelberg.doi: 10.1007/978-3-642-61419-4_8.
19. Eaton E.M. Significance of carbonate in irrigation water. *Soil Sci.*1950;69:123-133.
20. Eaton A.D., Clesceri L.S., Greenberg A.E. Standard methods for the examination of water and wastewater, 19th edn. 1995; APHA, New York.
21. Richards L.A. Diagnosis and improvement of saline alkali soils. In: agriculture, handbook no 60. 1995; US Department of Agriculture, Washington, pp-160.
22. Doneen L.D. The influence of crop and soil on percolating water. In: Proceedings of the Biennial conference on groundwater recharge. 1962; pp 156-163.
23. Kelly W.P. Use of saline irrigation water. *Soil Sci.*1963; 95:355-391.
24. Paliwal K.V. Irrigation with saline water.IARI Monograph no 2 (New series), 1972; New Delhi, pp -198.
25. Salifu M., Aidoo F., Hayford M.S., Adomako D., Asare E. Evaluating the suitability of

groundwater for irrigational purposes in some selected districts of the upper West region of Ghana. *Appl. Water Sci.* 2017; 7:653–662.doi: 10.1007/s13201-015-0277-z.

26. Bureau of Indian Standards (BIS). Indian standard drinking water specification (second revision) BIS 10500:2012, New Delhi.
27. Gandaseca S., Rosli N., Ngayop J., Arianto C.I. Status of water quality based on the physico-chemical assessment on river water at wildlife sanctuary Sibuti Mangrove forest, Miri Sarawak. *American J. Environ. Sci.* 2011; 7(3) : 269-275.
28. Gupta N., Pandeya P., Hussain J. Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, *India. Water Sci*. 2017; 31 (1): 11-23.
29. Rana A., Bhardwaj S.K.,Thakur M. Surface water quality and associated aquatic insect fauna under different land-uses in Solan (District Solan), Himachal Pradesh. *Indian J. Ecol*. 2016; 43 (1): 58-64.
30. Bora M., Goswami D.C. Water quality assessment in terms of water quality index (WQI): case study of the Kolong River, Assam, India. *Appl. Water Sci*. 2017; 7:3125-3135.doi:10.1007/s13201-016-0451-y.
31. Al-Badaii F., Othman M.S., Gasim M.B. Water quality assessment of the Semenyih River, Selangor, Malaysia. *J. Chem.* 2013; Article ID 871056, 1-10, http://dx.doi.org/10.1155/2013/871056
32. CGWB and CPCB. Status of ground water quality and pollution aspects in Delhi, India. 2003; http://cpcb.nic.in/gwq-standards.pdf
33. Richards L.A. Diagnosis and improvement of saline alkali soils. In: agriculture, handbook no 60. US Department of Agriculture, Washington,1954, pp 160.
34. Tak H.I., Bakhtiyar Y., Ahmad F., Inam A. Effluent quality parameters for safe use in agriculture. In: Water quality, soil and managing irrigation of crops. Lee TS (Ed.), 2012; ISBN: 978- 953-51-0426-1, InTech, http://www.intechopen.com/books/water-quality-soil-and-managingirrigation-of crops/effluent-quality-parameters-for-safe-use-in-agriculture
35. United States Department of Agriculture (USDA).Assessing water quality for human consumption, agriculture, and aquatic Life Uses, Natural Resources Conservation Service, 2008; Environment Technical Note No. MT1 (Rev. 1).
36. Wilcox L.V. Classification and use of irrigation water. Washington, United States department of agriculture, 1955; Circ. 969.
37. USSL Salinity Laboratory. Diagnosis and improvement of saline and alkaline soils.1954; US Department of Agriculture Handbook, No. 60, 160 p.
38. Shammi M., Karmakar B., Rahman M.M., Islam M.S., Rahman R., Uddin, M.K. Assessment of salinity hazard of irrigation water quality in monsoon season of BatiaghataUpazila, Khulna District, Bangladesh and adaptation strategies. *Pollut*. 2016; 2(2):183-197.
39. Sheriff K.M.M., Hussain A.Z. Evaluation of groundwater quality and its suitability for irrigation use on the bank of Noyyal river at Tiruppur, Tamilnadu, India. *Env.Poll. Prot.* 2017; 2(3):100-111. doi.org/10.22606/epp.2017.2300.
40. Gholami S., Srikantaswamy S. Analysis of agricultural impact on the Cauvery river water around KRS Dam. *World Appl. Sci. J.* 2009; 6(8):1157-1169.
41. Dash A., Das H.K., Mishra B. Hydrogeochemistry and groundwater quality in and around Joda of Keonjhar district, Odisha, India. *Int. J. Env. Sci. Technol.* 2014; 12(2):409-419.
42. Sakthivel R. TDS levels for traditional crops, TDS-resistant crops submitted by India: Water Portal. 2007; International Land Development Consultants, WES, Net India, New Delhi.
43. Joshi D.M., Kumar A., Agrawal N. Assessment of the irrigation water quality of river Ganga in Haridwar district India. *J. Chem.* 2009; 2(2):285-292.
44. Ayers R.S., Wescot D.V. Water quality for agriculture. FAO Irrigation and Drainage, 1985; Paper. 29. FAO, Roma.,174 p.
45. Laze P., Smajl R., Alban I. Assessment of irrigation water quality of Dukagjin basin in Kosvo. *J. Int. Sci. Pub. Agric. Food.* 2016; 4:544-551.
46. Schoeller H. Geochemistry of groundwater. An international guide for research and practice UNESCO, 1967; chapter 15, pp 1–18.

47. Sastri J.C.V. Groundwater chemical quality in river basin. Hydrogeochemicalfacies and hydrogeochemicalmodeling.1994; Lecture notes-Refresher course conducted by school of Earth Science.BharathidasanUniversity. Trichirapalli, Tamilnadu, India.
48. Kafkafi U. Effects of chlorides in effluents used for irrigation on the irrigated crops. *Israel J. Plant Sci.* 2011; 59(2-4):139-146. doi: 10.1560/IJPS.59.2-4.139.
49. Ahamed J.A., Ananthakrishnan S., Loganathan K., Manikandan K. Assessment of groundwater quality for irrigation use in Alathur block, Perambalur district, Tamilnadu, South India. *Appl. Water Sci.* 2013; 33(4):763-771.
50. Kumar K.K., Bharani R., Magesh N.S., Godson P.S., Chandrasekar N. Hydrogeochemistry and groundwater quality appraisal of part of south Chennai coastal aquifers, Tamil Nadu, India using WQI and fuzzy logic method. *Appl. Water Sci.* 2014; 4:341-350.Doi: 10.1007/s13201-013-0148-4.