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Assessment of Groundwater Quality in S.A.S Nagar District, Punjab, India, using the Water Quality Index and GIS

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***Abstract:** The main objective of this study is to assess the groundwater quality and interpret ate them using Geographic Information System (GIS). Ground water samples were collected from different location from tube wells, bore wells and handpumps. Then physicochemical parameters analysed include pH, total dissolved solids (TDS), total hardness (TH), Na^+, K^+, Ca^+, Mg^+, Cl^- and SO_4^{2-}. The TDS in groundwater is relatively high in the north western part of the area and it is low in the eastern part of the study area. Spatial variation maps of pH, TDS, TH, Na^+, K^+, Ca^+, Mg^+, Cl^- and SO_4^{2-}. have been created using the Inverse Distance Weighted (IDW) method in a GIS environment. From the WQI assessment, the quality of water is predominantly 'good' to 'excellent' categories, suggesting that groundwater from the S.A.S Nagar is suitable for drinking purposes. Having a immense information of groundwater quality of the areas, decision makers can plan better for the maintenance and operation of groundwater resources.*

***Keywords:** Geographic information system, Groundwater quality, WQI, Geo-spatial data, Spatial Variation, S.A.S Nagar India.*

I. INTRODUCTION

Quality of groundwater has been recognized as a deciding factor in the continuous development of a nation, as maintenance of ecology and establishment of industries are dependent on it (Malassa et al., 2013; Ravindra et al., 2016). Groundwater assets are dynamic in nature and influenced by such factors as the development of water system exercises, industrialization and urbanization, consequently checking and saving this significant asset is basic (Chatterjee et al., 2009). The chemical composition of groundwater significantly depends on the composition of bedrocks, their dissolution, contribution from nearby aquifers, percolation rate of the surface soil and anthropogenic activities being executed at the surface (Malassa et al., 2013; Ravindra et al., 2016). Further, agricultural activities, such as, using fertilizers and spraying pesticides in the fields, modify the chemical composition of the groundwater (Mor et al., 2019). Therefore, it is important to regularly observe the groundwater. With a motive of sustaining the groundwater quality, regular monitoring of groundwater has been performed in various cities of the world such as, China (Li and Qian, 2018), USA (Hudak, 2010), and India (Chidambaram et al., 2014).

Punjab is an agribusiness prevailing state and a significant part of the water system needs are met by groundwater assets. Long term precipitation information show that the decrease in precipitation has been 40–50 % during the most recent two decades (PHRED 2014). Unregulated growth and the Urbanisation of the population of the S.A.S Nagar district have altered the terrain. Net zone planted in the locale is 750 sq.km, which establish about 73% of the absolute region. Water system in the region is for the most part by methods for tube wells. The area irrigated under tube wells constitutes about 67% of the gross irrigated area (Saigal., 2013). Conditions are worse in mid-latitude regions, where many studies have emphasized the need for urgent groundwater decontamination and preservation (Li and Qian, 2018; Zhang et al., 2018). Among the various arid and semi-arid countries, sustainable use of groundwater is of crucial importance, especially in India. Large population in India depends on groundwater for fulfilling their daily purpose needs (Zhang et al., 2018). Increased stress due to industrialization, quality of India's groundwater is being compromised in various regions such as, North India: Delhi (Adhikary et al., 2009), Uttar Pradesh (Singh et al., 2006); South India: Karnataka (Ravikumar et al., 2011), Tamil Nadu (Vasanthavigar et al., 2010); West India: Jaipur, Rajasthan (Tank and Chandel, 2010); Middle India: Maharashtra (Patil et al., 2017). These studies have analysed the point data of physicochemical characteristics, which are primary deciding factors, for establishing the suitability of groundwater. These studies reported that industrialization and agricultural activities have degraded the quality of groundwater (Ravindra and Mor, 2019b; Mor et al., 2006a, 2006b; 2009, 2016b; Mondal et al., 2010).

Groundwater acts as the major source of fresh water in S.A.S Nagar, Punjab, India. An occasional checking of water quality is fundamental to comprehend the quality degradation and furthermore to design the remedial measures to control further harm. Many locations in the nearby states of S.A.S Nagar, i.e., Haryana, Delhi and Uttar Pradesh have also been reported to have a poor quality of groundwater (Tank and Chandel, 2010; Adhikary et al., 2009; Singh et al., 2006; Ravindra et al., 2019). However, there are no detailed studies conducted in S.A.S Nagar district of Punjab. There are limited studies which made use of remote sensing tools such as geographical information system (GIS). Spatial interpolation performed using GIS help us to better understand the quality of groundwater in S.A.S Nagar District. Therefore, in this study, a comprehensive physicochemical analysis of S.A.S Nagar District groundwater was performed. Variations in physicochemical parameters were assessed using geo-statistical techniques to identify the possible sources of contamination. Regular monitoring of groundwater will help authorities to plan preventive measures to reduce the public health risks.

II. MATERIALS AND METHODS

A. Study area

S.A.S Nagar district is located in the eastern part of the Punjab state, India and lies between North latitudes of 30°21’00” and 30°56’00” and East longitudes of 76°30’00” and 76°55’00” covering a geographic ambience of 1189 sq.km. The total population of the district is 9,86,147. The decennial growth rate (2001-2011) of population in the district is 30.02% (Saigal., 2013).

B. Hydrogeology of the study area

The Ghaggar River and its feeders structure the characteristic framework on Derabassi block of the locale. While north-eastern part is drained by Siswan Nadi, Jainti Devi Ki Rao and Patiali Rao, which rise up out of the Siwalik Hills. While Jainti Devi Ki Rao and Patiali Rao drains in NE-SW direction and joins the Ghaggar River (Saigal., 2013). The atmosphere of S.A.S region can be delegated subtropical rainstorm. The typical yearly precipitation of the locale is 1061 mm which is unevenly conveyed over the territory in 49 days. The south west storm contributes about 80% of yearly precipitation. The zone can be extensively gathered into two relying on its geomorphic highlights as alluvial fan and alluvial fields. Alluvial fans are stored by slope deluges with a wavy plain as opposed to a precarious incline. Adjoining the alluvial fan are the alluvial fields which frames a piece of enormous Indo-Gangetic Quaternary bowl involves thick sand and silty sand layers interbedded with residue and earth beds (Saigal., 2013). The significant soil sort of the region is weakly solonized tropical arid brown soils.

C. Sampling and Measurement

A total of 88 representative water samples were collected from 11selected location from hand pumps, bore wells, tube wells of different depths and covering different parts of the district from month November 2019 to February 2020 (22 Sample per month). Depth from which samples were drawn out, varied from 10 ft to 1200 ft. Sample locations are shown in Fig. 1. The water samples were strained utilizing 0.45-µm-pore-size membrane filters and put away in polyethylene bottles that were at first washed with nitric acid and flushed completely with distilled water. Bottles were suitably labelled and transferred to the laboratory and kept below $4^{o}C$, till the completion of physicochemical analysis. The various physicochemical parameters analysed include pH, total dissolved solids (TDS), total hardness (TH), Na^{+}, K^{+}, Ca^{+}, Mg^{+}, Cl^{-} and SO_4^{2-}. During field visits, pH was estimated on site using portable equipment. The anions Cl^{-} and SO_4^{2-} and cations Na^{+}, K^{+}, Ca^{+} and Mg^{+} were measured by ion chromatograph at the Punjab Engineering College (Deemed to be University), Chandigarh, following the protocol prescribed by the American Public Health Association (APHA, 2005).

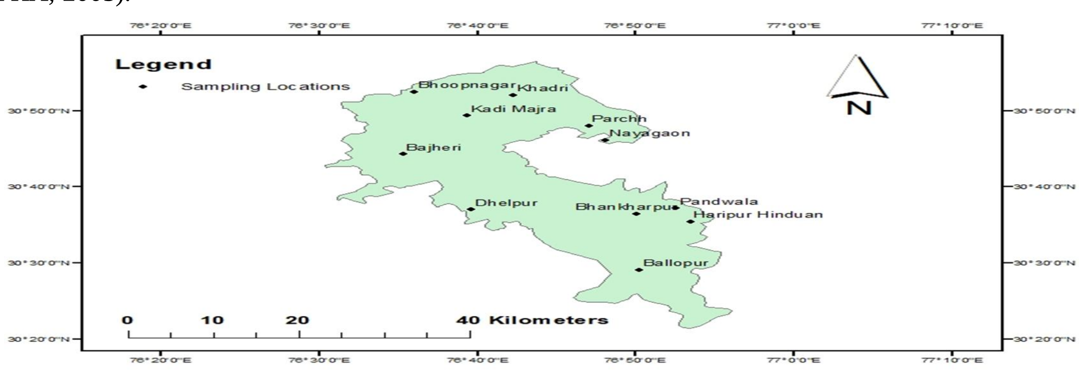
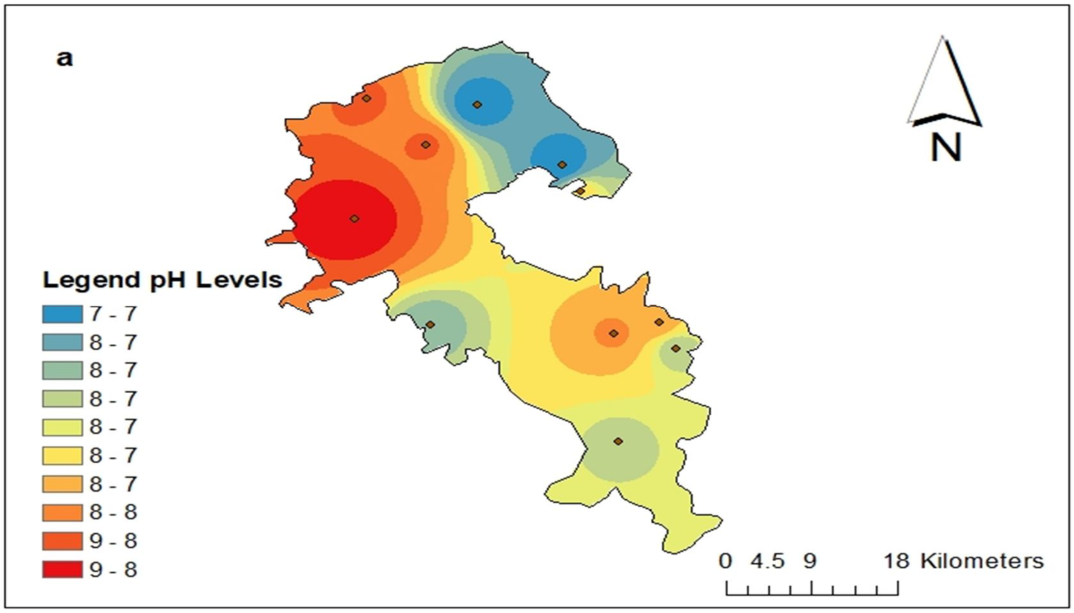
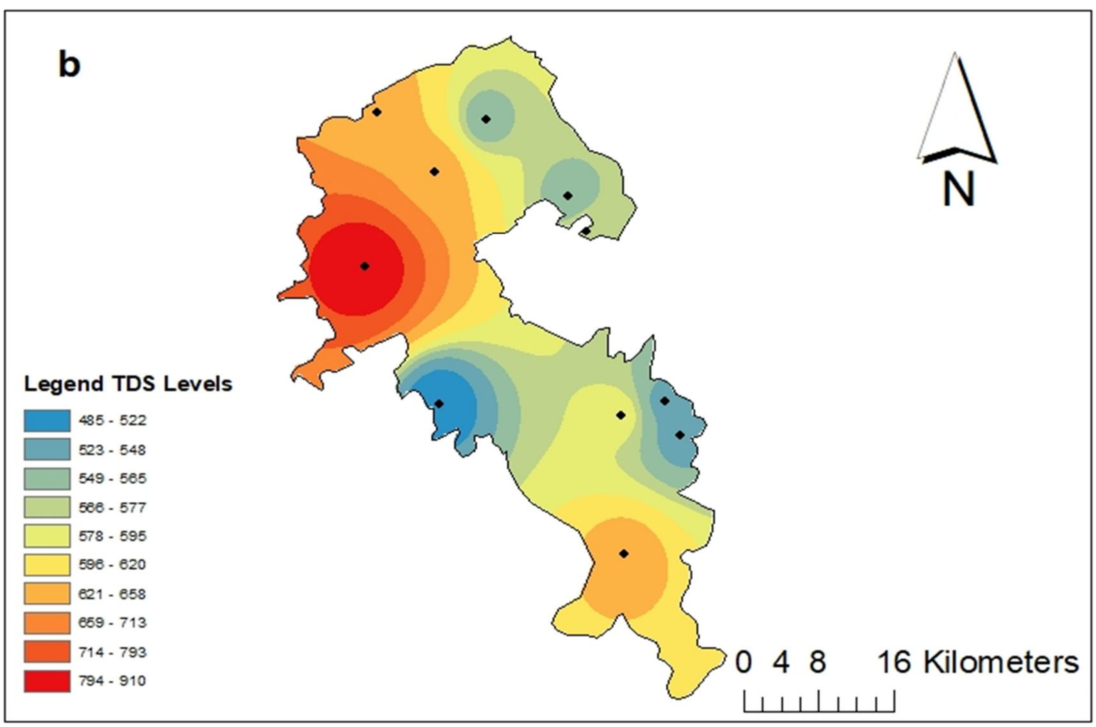


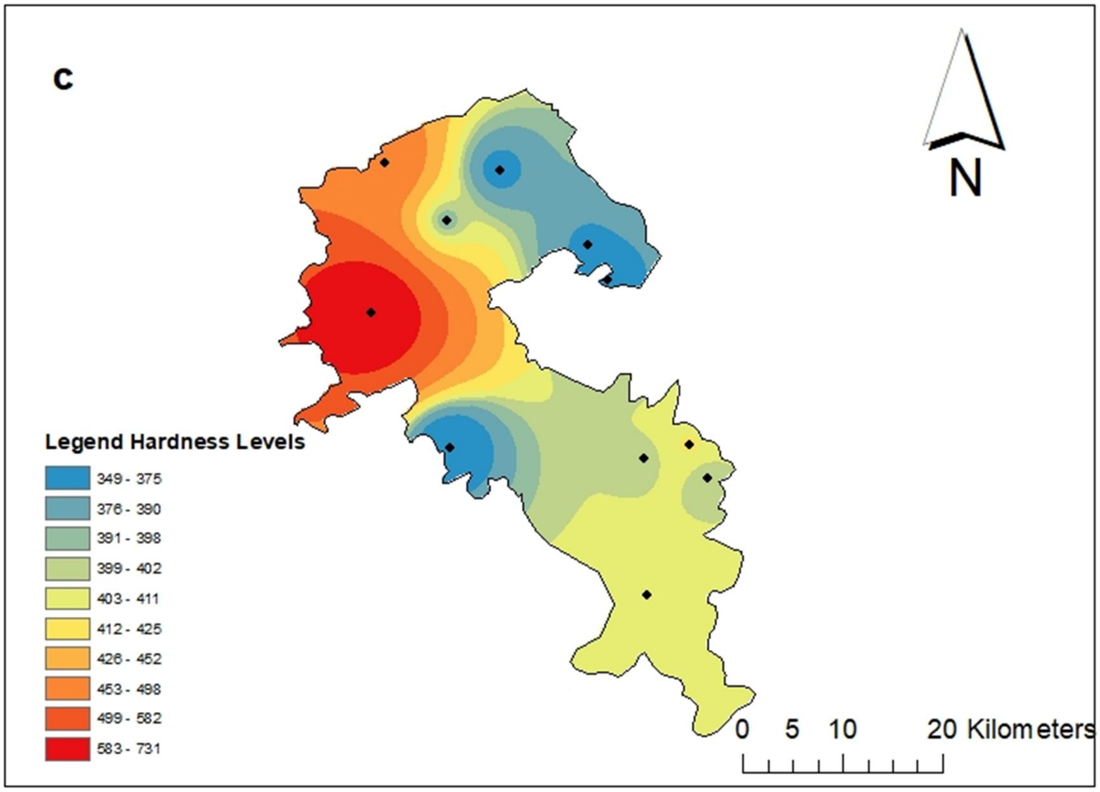
Fig.1 Map of the S.A.S Nagar district and the sampling locations

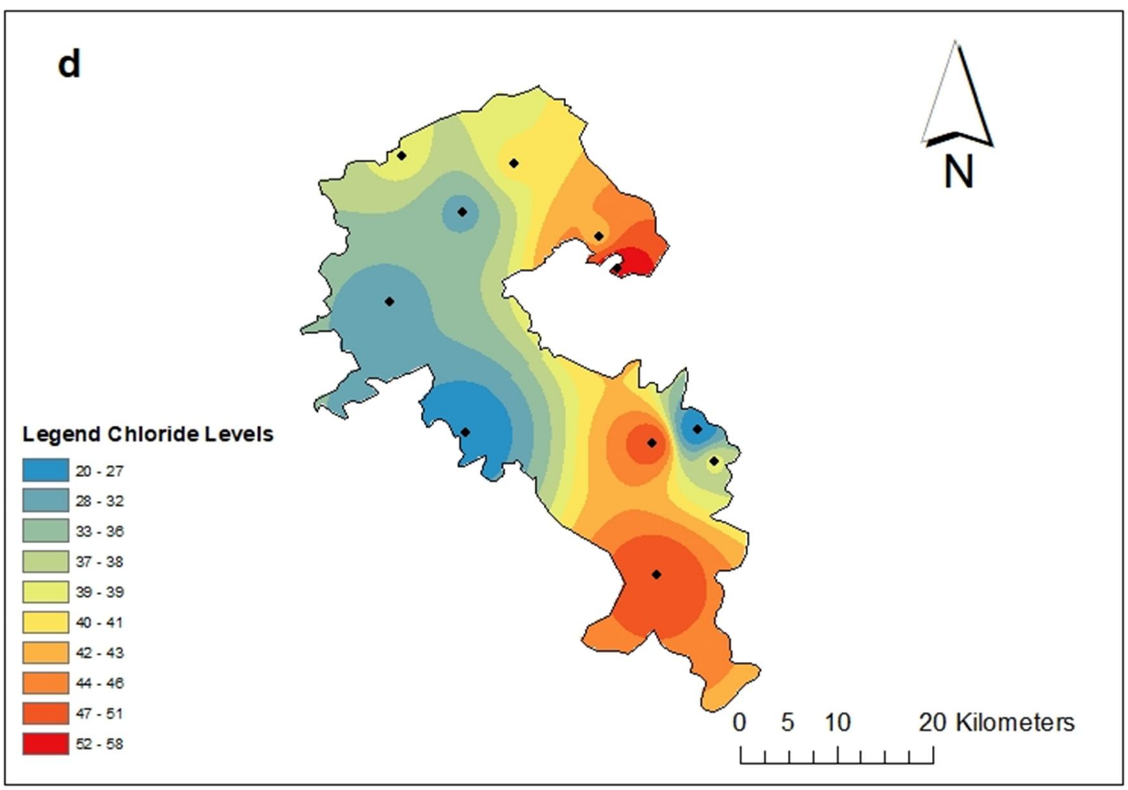
D. GIS Analysis

The classification of Groundwater quality is necessary for an assessment of suitability for domestic, agriculture or industrial uses. The various thematic layers on hardness, pH and ionic concentrations have been generated using Arc GIS 10.3. The extent of groundwater contamination was estimated by comparing each physicochemical parameter with their corresponding permissible limits, as given by World Health Organization (WHO, 2011) and Bureau of Indian Standards (BIS, 2012). Spatial distribution maps for Hardness, pH, TDS, Na^+, K^+, Ca^+, Mg^+, Cl^- and SO_4^{2-}. have been created for S.A.S Nagar District.






c
N
Legend Hardness Levels
349 - 375
376 - 390
391 - 398
399 - 402
403 - 411
412 - 425
426 - 452
453 - 498
499 - 582
583 - 731
0 5 10 20 Kilometers


d
N
Legend Chloride Levels
20 - 27
28 - 32
33 - 36
37 - 38
39 - 39
40 - 41
42 - 43
44 - 46
47 - 51
52 - 58
0 5 10 20 Kilometers

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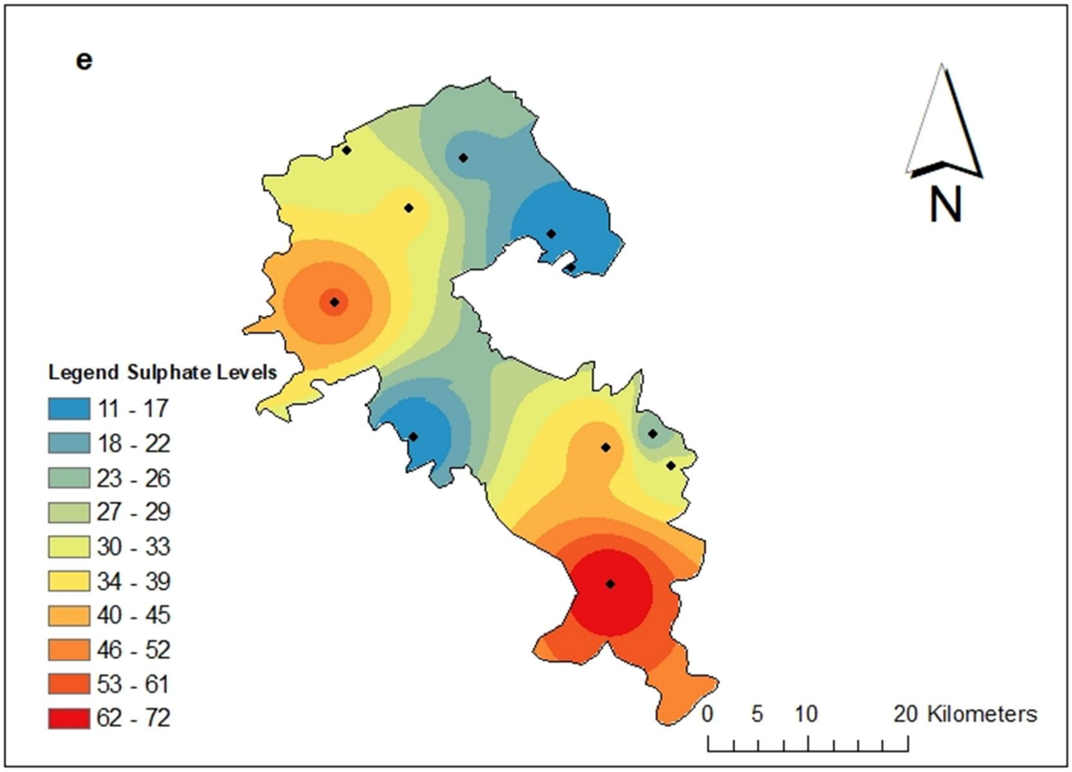
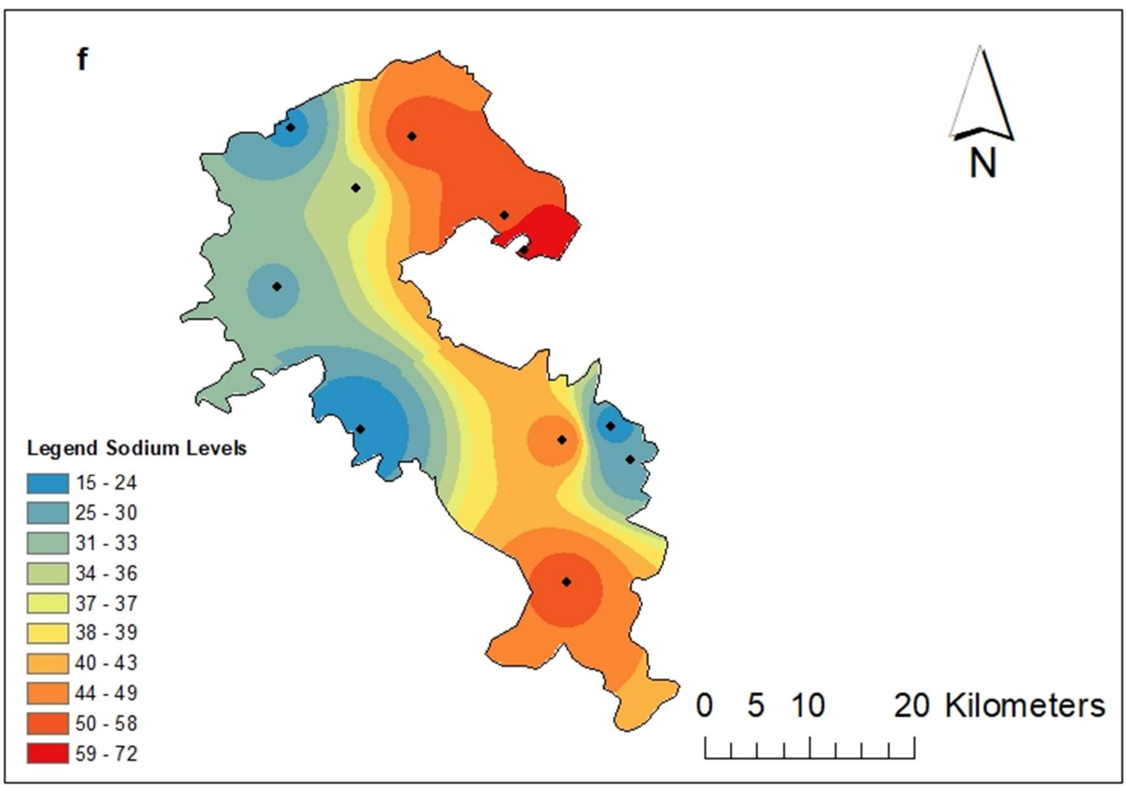
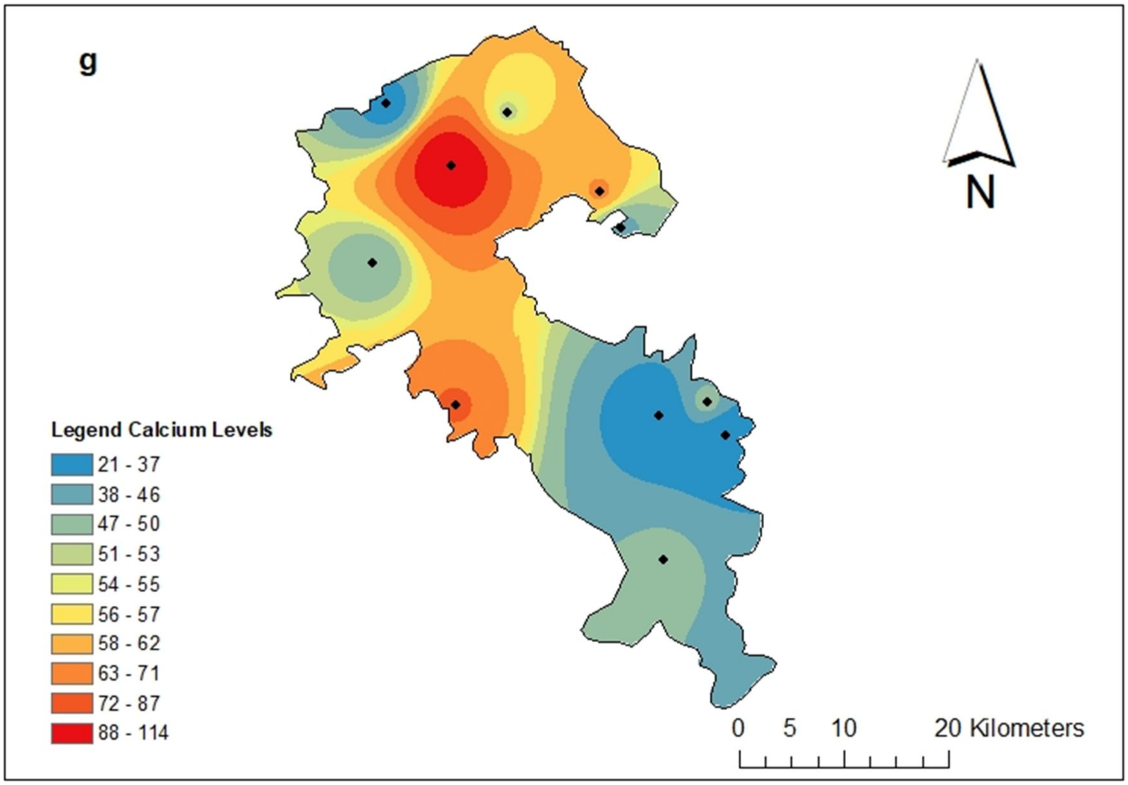
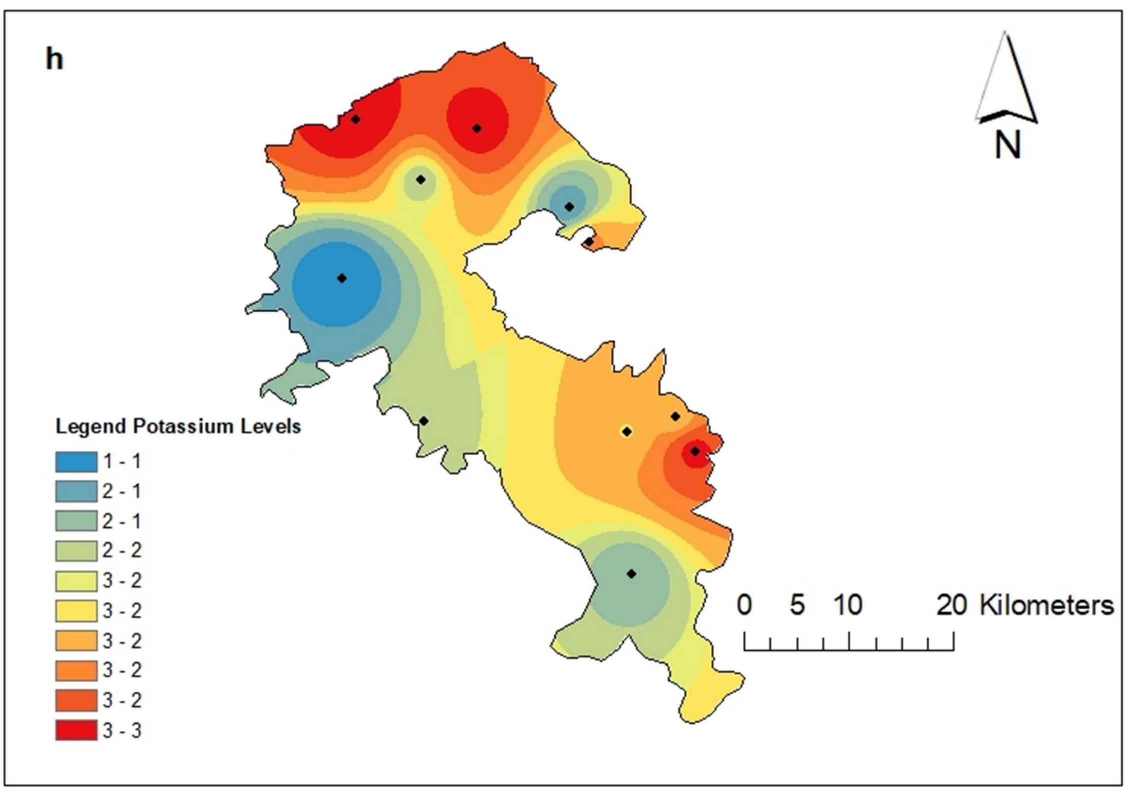





g
N
Legend Calcium Levels
21 - 37
38 - 46
47 - 50
51 - 53
54 - 55
56 - 57
58 - 62
63 - 71
72 - 87
88 - 114
0 5 10 20 Kilometers


h
N
Legend Potassium Levels
1 - 1
2 - 1
2 - 1
2 - 2
3 - 2
3 - 2
3 - 2
3 - 2
3 - 2
3 - 3
0 5 10 20 Kilometers

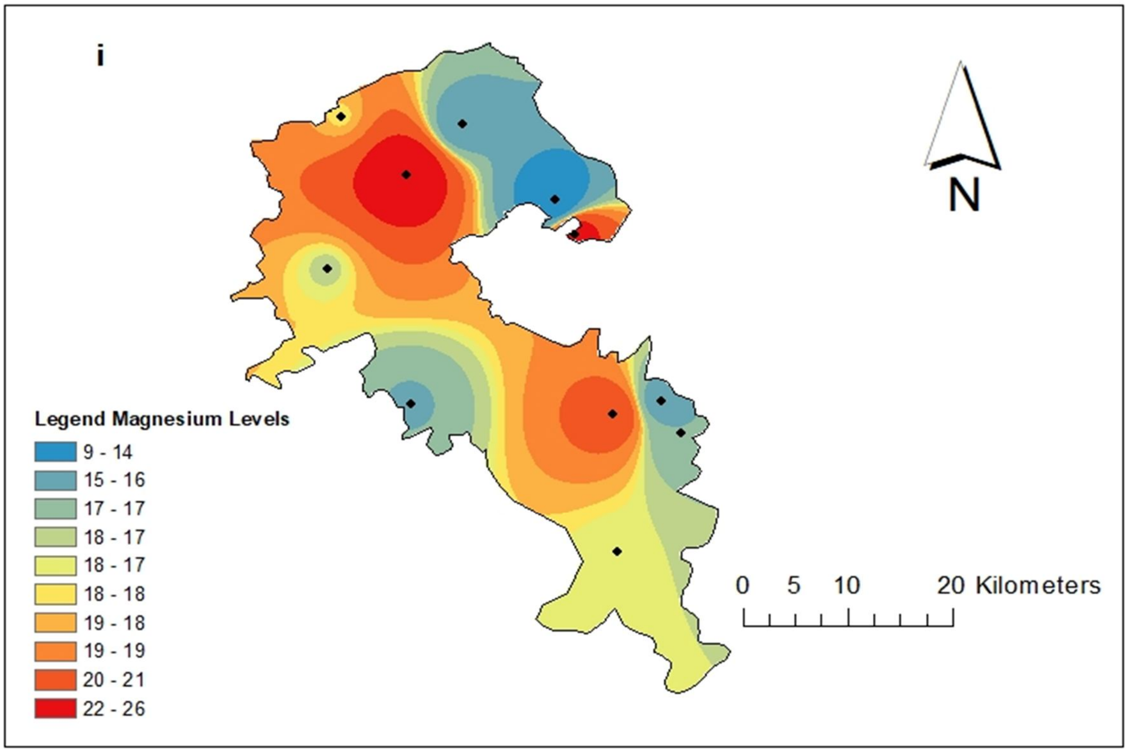


Fig. 3 a Geospatial distribution of pH levels in S.A.S Nagar District. b Geospatial distribution of TDS values in S.A.S Nagar District. c Geospatial distribution of Hardness in S.A.S Nagar District. d Geospatial distribution of chloride ion in S.A.S Nagar District. e Geospatial distribution of sulphate ion in S.A.S Nagar District. f Geospatial distribution of sodium ion in S.A.S Nagar District. g Geospatial distribution of calcium ion in S.A.S Nagar District. h Geospatial distribution of potassium ion in S.A.S Nagar District. i Geospatial distribution of magnesium ion in S.A.S Nagar District.

E. Water Quality Index (WQI)

Among the various indexing approaches, water quality index (WQI) is widely recognized, and user-friendly tool for assessing the drinkability of groundwater (Ketata et al., 2011). WQI could also be utilized in ascertaining the drinkability of groundwater (Gibrilla et al., 2011). The guidelines for drinking purposes as suggested by WHO (2011) have been considered for the count of WQI. In the initial step, every one of the 9 parameters have been assigned a weight (w_i) as indicated by its relative significance in the general nature of water for drinking purposes. In the second step, the relative weight (W_i) is computed from the equation (1).

$$w_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \qquad (1)$$

Where, W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters.

In the third step, the quality rating was calculated using equation (2).

$$q_i = \frac{C_i}{S_j} \times 100 \qquad (2)$$

where q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/L, and S_i is the WHO drinking water standard for every chemical parameter in mg/L.

WQI is finally calculated by summing up the sub-index of each parameter, as shown in equation (3) (Ramakrishnaiah et al., 2009; Sadat-Noori et al., 2014):

$$WQI = \sum SI_i \qquad (3)$$

Where, SI_j is the sub-index of the j^{th} groundwater sample. Subindex was calculated for each groundwater sample, according to equation (4) (Ramakrishnaiah et al., 2009; Sadat-Noori et al., 2014).

$$SI_i = w_i q_i \qquad (4)$$

Where, q_j is the quality rating as calculated in the previous section; and n is the number of physicochemical parameters.

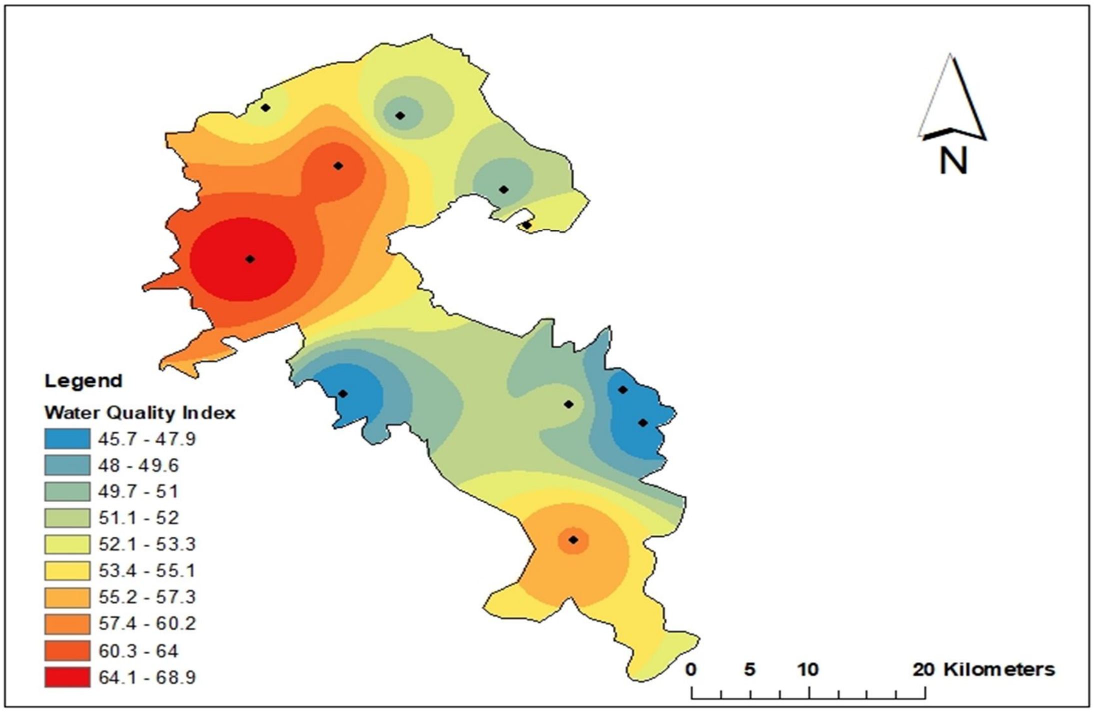


Fig. 4 Water quality index map of the S.A.S Nagar district

Table I. Water quality classification based on WQI value

WQI Value	Water Quality
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking

III. RESULTS AND DISCUSSION

A. pH

The pH of S.A.S Nagar District groundwater ranged between 7.11 - 7.81 with a mean of 7.41. The pH value of district ground water was within permissible limits. Therefore, district groundwater can be used for drinking and irrigation purposes. However, it could alter the reaction mechanism of various ions present in groundwater and minute variations could lead to significant changes in reactions (Muhammad et al., 2010).

B. Total dissolved solids

High TDS is objectionable among consumers as it may cause serious health impacts (WHO, 2011; Mor et al., 2006a). The TDS of S.A.S Nagar District groundwater ranged between 484.6 mg L^{-1} – 910.1 mg L^{-1} with a mean of 604.7 mg L^{-1}. The TDS in groundwater is relatively high in the north western part of the area and it is low in the eastern part of the study area.

C. *Total Hardness*

Calcium and magnesium salts are common constituents of rocks present in earth's crust. Therefore, whenever surface water percolates through the crust, it dissolves salts of Ca^{2+} and Mg^{2+} with it, leading to their enhanced concentration in the groundwater (Ravindra et al., 2019). Total Hardness value ranges from 298 mg L^{-1} to 908 mg L^{-1}. Four samples showed objectionable content of Total Hardness in S.A.S Nagar District groundwater after comparing with the prescribed limits set BIS (2012)

D. Chlorides

Under permissible limits, chloride can help in maintaining the health of kidneys and the nervous system (Cantor Hoover et al., 1987). Chloride concentration in groundwater ranged from 2.5 mg L^{-1} to 77 mg L^{-1} with a mean of 38.3 mg L^{-1}. The chloride content of S.A.S Nagar District groundwater was reported below the permissible limits, as recommended by BIS (2012) and WHO (2011).

E. Sulphates

Sulphate content in the S.A.S Nagar groundwater samples varied from 2.5 mgL^{-1} to 93 mg L^{-1} with a mean of 31.3 mg L^{-1}. The concentration of sulphate in groundwater is relatively high in the south-eastern part of the area and it is low in the north-eastern part of the study area.

F. Sodium and potassium

Sodium and potassium ions are essential elements for the human body, and its regular intake is must for maintaining the salt content in the blood. Consequently, it helps in regulating the water balance of the human body as well (Ravindra et al., 2019). Sodium concentration in groundwater samples ranged from 10.9 mg L^{-1} to 86 mg L^{-1} with a mean of 38.6 mg L^{-1}. Potassium concentration value ranges from 0.1 mg L^{-1} to 3.3 mg L^{-1} with an average of 1.69 mgL^{-1}.

G. Calcium

The concentration of Calcium in groundwater is relatively high in the northern part of the area and it is low in the south-eastern part of the study area. Calcium content in the S.A.S Nagar groundwater samples varied from 12 mgL^{-1} to 145mg L^{-1} with a mean of 51.3 mg L^{-1}. Seven samples showed higher concentration then prescribed acceptable limits by BIS (2012).

H. Magnesium

Magnesium content in the S.A.S Nagar groundwater samples varied from 5 mgL^{-1} to 32mgL^{-1} with a mean of 17.5 mg L^{-1}. Only one sample showed higher concentration i.e. 32mgL^{-1} (Kadi Majra). Spatial variation map shows the concentration of Magnesium in groundwater is relatively high in the northern part of the area and it is low in the south-western part of the study area.

IV. CONCLUSIONS

In this study, Water Quality Index and GIS combined is used to assessed the ground water quality of S.A.S Nagar District, Punjab. Water quality index showed that ground water quality lies in 'excellent' and 'good water' category. Four ground water sample showed higher value of total hardness when compared with BIS (2012). Seven samples showed higher concentration then prescribed acceptable limits by BIS (2012). These higher values can be result of interaction of percolating water with rocks present in the study area. Spatial variation map of WQI can be used to identify the location for drinking water use. With the help of GIS, variation in geochemical parameter of ground water w.r.t space can be monitored. And based on this information better management plan can be formed in future.

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