VOLUME 22 | NUMBER 01 | JULY 2022
https://ejournal.worldconference.id/index.php/neutron
E-ISSN: 2685-3272 | P-ISSN 1412-0860

Assessment of Groundwater Quality using Water Quality Index, and Geo-Spatial Tools

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Abstract

Groundwater is considered a significant component of valuable freshwater resources for the living beings living in the arid and semi-arid regions of Pakistan, factors such as climate change, landfill deposits, application of fertilizers and pesticides on agricultural lands, leakages from septic tanks, industrial effluents, and urbanization jeopardizing the groundwater quality that makes its timely assessment necessary for human survival to protect people from water-borne diseases. This research study was carried out to analyze the 13 physicochemical parameters in the 38 groundwater samples that were taken from nearby different locations of Akram, Pinyari, and Phuleli canal within the jurisdiction of district Hyderabad. 26 samples were taken from hand pumps, electric motors and 12 samples were taken from tube wells to investigate the variability in groundwater quality. The water quality index and kelly's ratio, magnesium hazard, residual sodium carbonate, sodium absorption ratio, soluble sodium percentage, and permeability index were used to assess the suitability of groundwater for drinking, and agricultural purposes. The result of the study revealed that alkalinity, bicarbonates, carbonates, magnesium, PH, potassium, and sodium were within the permissible limit of WHO Standards in all the samples, while the concentration of calcium was crossing the permissible limit only in one sample. Moreover, the availability of Chloride (Cl) was found in 16 samples that were above the limit ranges from 274.9 to 2549, High concentration of EC was found in 14 samples than the permissible limit having values from 2212 to 8360 (P26), and Total Hardness (TH) were found only in 6 samples slightly high from the permissible limit ranges from 509 to 651, and TDS were present in excessive amounts than the allowable limit from 1100 to 4180 mg/l (P26) in 10 samples. Considering the Water Quality Index (WQI) it was observed that 8 sample falls in the good category, 2 samples in the poor category, 11 samples in the very poor category, and 17 samples in the unsuitable category of water quality.

Keywords:
Agricultural, Akram Wah, Drinking, GIS, Groundwater, Hyderabad, Phuleli Canal, Physicochemical Parameters, Pinyari Canal, Water Quality, WQI,.

1. Introduction

Groundwater is considered an natural vital resource on the earth that is utilized by living beings for agricultural, domestic, drinking, and industrial purposes (Shahab et al., 2018). Fresh Groundwater is an essential resource available on the earth that every human being is utilizing for agricultural, drinking, domestic as well as industrial purposes. In a country like Pakistan, the occurrence of rainfall patterns is uneven due to its arid, and semi-arid climatic nature also the less availability of surface water has enforced to increase the dependence on groundwater. In Sindh, only 10% of the area, fresh groundwater is available (Alamgir et al., 2016).

In Pakistan, Hyderabad is ranked 2nd among the largest cities in Sindh Province. The shift of people from rural-based to urban-based areas, lack of proper sewer systems, and effluents discharged from the industrial sector in the city have triggered groundwater contamination (Silva et al., 2021).

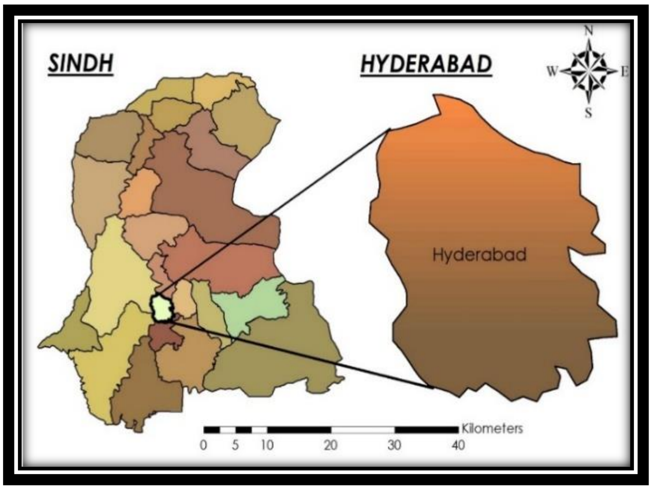
Since this natural resource is dynamic, its contamination may spread in time and space which needs to be assessed . Due to the variable nature of groundwater, its contamination may spread over time, and space necessitates immediate assessment to protect this vital resource from contamination (Talib et al., 2019). Around 70-80% of all human diseases are caused by contaminated water(Maity et al., 2020). In rural areas majority of people still totally rely on untreated groundwater, it is vital to find a solution because safe access to drinking water is a fundamental human right (Raza et al., 2017). The formation of balanced socioeconomic development is based on the quantity, quality, and safe accessibility of water resources, and its optimal use cannot be maintained without an evaluation of its quality. In 1965, Horton established the water quality index (WQI), and later on, Brown 1972 made some improvements to it, further modifications were performed by a Scottish Scientist Deininger in 1975 at the Scottish development department (Singh et al., 2022). The WQI is a mathematical equation that was developed to simplify the communication of information to all stakeholders by converting a significant amount of water quality data into a single number. Various research studies were conducted by researchers, some of them are discussed below;

(Singh et al., 2022) determined the groundwater quality using WQI and GIS applications in 89 small villages. Twelve water quality parameters were selected for the study area. Results revealed that the WQI ranged from 71 to 447, result also identified 68% of the groundwater of the study area had poor water quality while the remaining 32% is considered as good quality water that is allowable to consume. Fluoride, TDS, and pH were found to be excessive amounts than the allowable limit. The study also establishes that a higher number of the population is still consuming the water, despite the fact it is highly vulnerable and is prone to many water-borne diseases.

(Qureshi et al., 2021) conducted the research study in Tandojam city of Sindh, in which groundwater quality parameters of 30 samples were analyzed. The results of the study revealed the availability of alkalinity, chloride, EC, nitrate, pH, TDS, TH, turbidity, and sulfate in most of the samples in a higher concentration than the permissible guidelines. (Lanjwani et al., 2020) analyzed the parameters of groundwater quality of Larkana, Sindh. The result concluded that 12 samples among 25 samples were considered as not suitable for drinking purposes due to the high presence of chloride, EC, fluoride, and TDS. (Solangi et al., 2019) have evaluated the quality of groundwater in the sujawal district in the province of Sindh, a total of 94 samples were taken through different locations of the study area. Results of the study revealed that 77.66% of samples were poor to very poor quality, 13.8% of samples were considered unsuitable for drinking purposes while the remaining 8.51% of samples were of excellent to good quality based on the water quality index (WQI) and synthetic pollution index (SPI) indicated that 45.83% of samples were slight to moderately polluted, 20% of samples were highly polluted while 18% were suitable and 16% were considered as unsuitable. The authors also revealed that the quality of most groundwater samples exceeded the permissible limit prescribed by WHO and suggest that using that water may have a high risk and can cause several diseases.

2. Methodology

2.1. Study Area



NEUTRON
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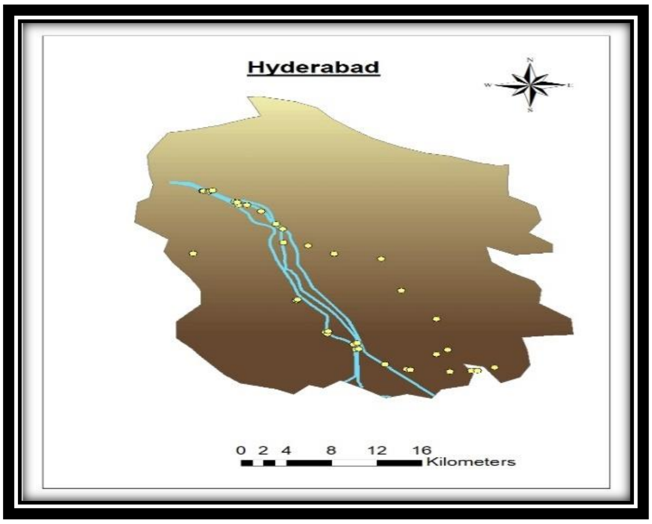

Figure 1. shows the map of the study area of Hyderabad district.

2.2. Collection of Geo-Referenced Groundwater Samples

38 samples were collected along the canals through hand pumps, electric motors, and tube wells in 1-liter polyethylene bottles. Before collection of samples, bottles were properly washed (first with tap water, then with detergent, and rinsed with distilled water for removal of any contamination. While collecting GW samples, the depth of groundwater and GPS coordinates were also recorded. Water samples were collected after the purging process. The purging of a 30 ft depth dug well needs 30 strokes of a hand pump. Standard SoPs were followed for the collection of water samples and their transportation to USPCAS-W.

2.3. Assessment, and Characterization of the Groundwater Quality for Drinking, and Agricultural Purposes

The samples were assessed and analyzed for the below-listed parameters and water quality was characterized and categorized as per WHO standards.

Table 1. Shows the Physicochemical Parameters Analyzed in the Groundwater Samples.

Alkanity	Chloride (Cl)	Potassium (K)
Bicarbonates(HCO3)	Electrical Conductivity (Ec)	Power of Hydrogen (PH)
Carbonates (CO3)	Hardness	Sodium (Na)
Calium (Ca)	Magnesium (Mg)	Total Dissolved Solids (TDS)

2.4. Evaluation of the Suitability of Groundwater Based on the Following Equation for Drinking and Irrigation Purposes

$$\mathrm{WQI} = \sum \mathrm{Wi} \times \mathrm{Qi} \quad (1)$$

$$\mathrm{SP} = \frac{(\mathrm{Sodium}+\mathrm{Potassium})}{(\mathrm{Calcium}+\mathrm{Magnesium}+\mathrm{Sodium}+\mathrm{Potassium})} \times 100 \quad (2)$$

$$SAR = \frac{\mathrm{Sodium}}{\sqrt{(\mathrm{Calcium}+\mathrm{Magnisium})/2}} \quad (3)$$

$$\mathrm{RSC} = \mathrm{Bicarbonate} + \mathrm{Carbonate} - (\mathrm{Calcium} + \mathrm{Magnesium}) \quad (4)$$

$$MH = \frac{Magnesium}{Calcium+Magnesium} \times 100 \quad (5)$$

$$\mathrm{PI} = \frac{\mathrm{Sodium}+\sqrt{\mathrm{Bicarbonate}}}{\mathrm{Calcium}+\mathrm{Magnesium}} \times 100 \quad (6)$$

$$\mathrm{R} = \frac{\mathrm{Sodium}}{\mathrm{calcium}+\mathrm{Magnesium}} \quad (7)$$

Table 2. Shows the Different Indices Used to Analyze the Suitability of Groundwater Samples.

Parameters	Ranges	Water Classes
SAR	<10	Excellent
	10-18	Good
	18-26	Fair
	>26	Poor
RSC	<1.25	Safe
	>1.25	Unsuitable

SSP	<20	Excellent
	20-40	Good
	40-60	Permissible
	60-80	Doubtful
	>80	Unsuitable
KR	<1	Safe
	>1	Unsuitable
MH	<50	Good
	>50	Unsuitable
PI	<25	Good
	25-75	Suitable
	>75	Unsuitable

2.5. Preparation of Groundwater Quality Maps and Infer Guidelines Regarding the Water Quality Status in District Hyderabad

GIS maps of each of the water quality parameters were prepared using the Interpolation Inverse Distance Weighted (IDW) method in ArcGIS 10.8 through these maps, a conclusion about the water quality of the Hyderabad district was drawn.

3. Results and Discussion

Groundwater suitability for drinking and irrigation purposes is based on the water quality index and irrigation indices. The results and discussion are made as follows.

Table no. 03, shows the presence of physicochemical concentration in groundwater samples.

NEUTRON
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ID	Alkal.	HCO_3 (mg/l)	CO_3 (mg/l)	Ca (mg/l)	Cl (mg/l)	EC µs/cm	TH (mg/l)	Mg (mg/l)	K (mg/l)	PH	Na (mg/l)	TDS
P1	5	5	0	47.03.00	119.09.00	1072	326.07.00	50.09.00	12.02	07.17	97.01.00	536
P2	5	5	0	44.04.00	159.09.00	1252	265.03.00	37.07.00	04.07	07.21	75.05.00	626
P3	5	5	0	46.07.00	49.09.00	575	165	12	06.04	07.24	26.02.00	288
P4	5	5	0	141.01.00	379.08.00	2212	650.03.00	81.07.00	16.06	07.46	163.01.00	1106
P5	5	5	0	144.09.00	469.08.00	2620	649.02.00	95	05.08	07.31	205.06.00	1309
P6	02.05	02.05	0	96.01.00	349.08.00	2400	491.09.00	61.06.00	05.08	07.29	135.03.00	1200
P7	5	5	0	54	99.09.00	1374	293	38.06.00	10.06	07.13	75.06.00	687
P8	02.05	02.05	0	96.02.00	224.09.00	962	376	33.04.00	06.05	07.26	77.02.00	480
P9	5	5	0	51.07.00	799.07.00	4120	292	39.08.00	05.07	07.51	224	2060
P10	5	5	0	81	174.09.00	1420	380.04.00	43.06.00	06.08	07.29	124.08.00	710
P11	5	5	0	74.07.00	149.09.00	1471	388.06.00	49.04.00	07.04	07.02	158.02.00	735
P12	5	5	0	139.06.00	399.08.00	2260	512.01.00	40.03.00	05.08	07.14	167.05.00	1133
P13	5	5	0	13.06	49.09.00	1094	93.09.00	14.06	02.04	0,3430556	186.08.00	547
P14	5	5	0	70.01.00	199.09.00	850	288.03.00	27.08.00	05.02	07.34	47.02.00	425
P15	5	5	0	72	474.08.00	2790	344.04.00	40.03.00	06.03	07.49	222	1399
P16	02.05	02.05	0	182.07.00	899.07.00	4170	651.09.00	56.08.00	10.07	07.17	214.03.00	2080
P17	02.05	02.05	0	183.06.00	249.09.00	1575	648	54.09.00	11.01	07.19	224.02.00	787
P18	02.05	02.05	0	61.07.00	174.09.00	960	223.09.00	17.02	04.07	07.25	45.06.00	479
P19	5	5	0	62.02.00	174.09.00	1358	256.02.00	24.08.00	04.02	07.35	146.06.00	679
P20	5	5	0	51.02.00	174.09.00	845	180.01.00	12.09	06.01	07.47	69.03.00	423
P21	5	5	0	49.09.00	224.09.00	1210	244.07.00	29.04.00	04.06	07.42	87.05.00	605
P22	5	5	0	50.01.00	324.08.00	1540	225	24.05.00	08.05	07.06	136.05.00	770
P23	5	5	0	32.03.00	99.09.00	653	168.04.00	21.05	04.01	07.49	39.01.00	326
P24	02.05	02.05	0	30.01.00	974.06.00	3880	222.08.00	36	4	07.57	214.01.00	1940
P25	5	5	0	30	649.07.00	3280	223.03.00	36.02.00	03.09	0,3388889	214	1646
P26	02.05	02.05	0	325.03.00	2549.02.00	8370	647.01.00	106.01.00	15.07	0,3597222	213.03.00	4180
P27	5	5	0	85.01.00	49.09.00	998	326.02.00	28	06.08	07.41	133	499
P28	5	5	0	94.05.00	474.08.00	1726	509.03.00	66.08.00	06.05	07.41	90.07.00	864
P29	5	5	0	131.02.00	349.08.00	1962	528.04.00	49.03.00	08.08	07.47	213	979
P30	5	5	0	130	274.09.00	1681	528.02.00	50	08.06	07.51	212.08.00	842
P31	5	5	0	112.09.00	74.09.00	1044	429.04.00	36.03.00	05.03	07.31	80.08.00	522
P32	02.05	02.05	0	43.04.00	449.08.00	1791	238.06.00	31.08.00	06.06	07.51	214.05.00	894
P33	02.05	02.05	0	50.05.00	99.09.00	870	207.09.00	20.01	05.08	07.54	83.01.00	434
P34	5	5	0	49.09.00	74.09.00	673	182	14.02	06.03	07.55	64.06.00	335
P35	5	5	0	61.05.00	274.09.00	1230	305.05.00	37.02.00	09.06	07.33	127.05.00	615
P36	5	5	0	36.08.00	149.09.00	1265	206.02.00	27.09.00	05.08	07.38	98.05.00	632
P37	5	5	0	39.08.00	49.09.00	729	170.07.00	17.05	06.08	07.29	66.05.00	364
P38	5	5	0	89.07.00	124.09.00	937	617.09.00	96	06.08	07.54	212.01.00	468

Table 04, shows the obtained values of various indices used for the suitability of groundwater for irrigation purposes.

Sr.No	Sample ID	SSP	SAR	RSC	MH	PI	KR
1	P1	52.7	13.9	-93.2	51.8	101.2	1
2	P2	49.4	11.8	-77.1	45.9	94.6	0.9
3	P3	35.7	4.8	-53.6	20.5	48.4	0.4
4	P4	44.6	15.5	-217.8	36.7	74.2	0.7
5	P5	46.8	18.8	-234.8	39.6	86.7	0.9
6	P6	47.2	15.2	-155.2	39.1	86.8	0.9
7	P7	48.2	11.1	-87.7	41.7	84.1	0.8
8	P8	39.2	9.6	-127.1	25.8	60.8	0.6
9	P9	71.5	33.1	-86.5	43.5	247.3	2.4
10	P10	51.4	15.8	-119.6	35	101.9	1
11	P11	57.2	20.1	-119.1	39.8	129.2	1.3
12	P12	49.1	17.7	-174.9	22.4	94.4	0.9
13	P13	87	49.7	-23.2	51.6	669.6	6.6
14	P14	34.8	6.7	-92.9	28.4	50.5	0.5
15	P15	67	29.6	-107.3	35.9	199.7	2
16	P16	48.4	19.6	-237	23.7	90.1	0.9
17	P17	49.7	20.5	-235.9	23	94.7	0.9
18	P18	38.9	7.3	-76.4	21.8	59.8	0.6
19	P19	63.4	22.2	-82	28.5	171.1	1.7
20	P20	54	12.2	-59.1	20.2	111.5	1.1
21	P21	53.7	13.9	-74.3	37	113.1	1.1
22	P22	66	22.4	-69.6	32.8	186	1.8
23	P23	44.6	7.5	-48.7	40	76.9	0.7
24	P24	76.7	37.2	-63.6	54.4	326.4	3.2
25	P25	76.7	37.2	-61.2	54.7	326.8	3.2
26	P26	34.7	14.5	-428.8	24.6	49.8	0.5
27	P27	55.3	17.7	-108.1	24.7	119.6	1.2
28	P28	37.6	10	-156.3	41.4	57.6	0.6
29	P29	55.1	22.4	-175.5	27.3	119.2	1.2
30	P30	55.1	22.4	-175	27.8	119.4	1.2
31	P31	36.6	9.4	-144.2	24.3	55.7	0.5
32	P32	74.6	35	-72.7	42.3	287.3	2.9
33	P33	55.8	14	-68.1	28.5	120.1	1.2
34	P34	52.5	11.4	-59.1	22.1	104.4	1
35	P35	58.2	18.2	-93.7	37.7	131.6	1.3
36	P36	61.7	17.3	-59.7	43.2	155.7	1.5
37	P37	56.1	12.4	-52.3	30.5	120	1.2
38	P38	54.1	22	-180.8	51.7	115.4	1.1

3.1. GIS Maps of Concentration in the Groundwater of the Study Area

3.1.1. Alkalinity and Bicarbonates

Alkalinity and bicarbonates concentration in all the samples were within the permissible limit with a minimum value of 2.5 mg/l and a maximum of 5 mg/l.

3.1.2. Calcium

In the current study area, the Calcium concentration ranges from 13 to 325 mg/l. Only 1 sample exceeds the permissible limit (200 mg/l).

3.1.3. Carbonate

Carbonate concentration in the study area was within the permissible limit (200 mg/l).

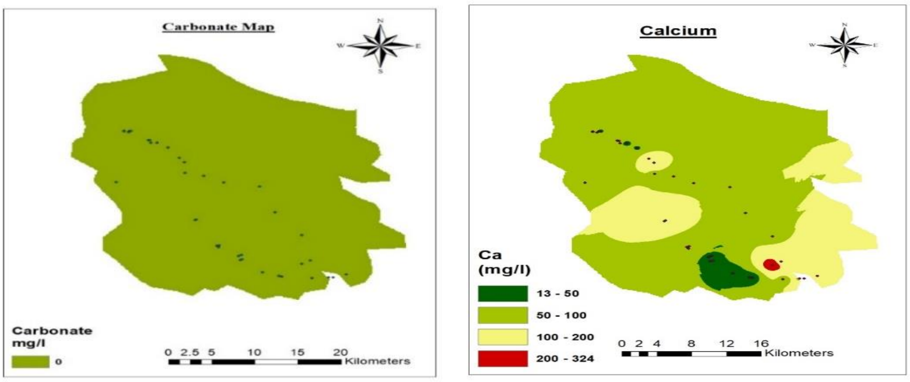

Figure 2 and 3. Show the behavior maps of calcium and carbonate.

3.1.4. Chloride

In the present study, the concentration ranges from 49.9 to 2549 mg/l. 16 samples are above the permissible limit (250 mg/l).

3.1.5. Electrical Conductivity

In the present study, the electrical conductivity varies from 576 to 8360 µS/cm. The results of 14 samples crossed the allowable limits of the WHO standard of 1500 µS/cm.

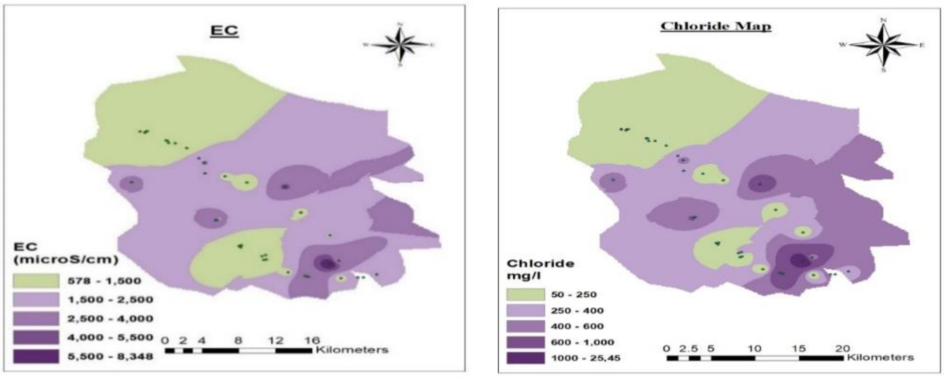

Figure 4 and 5. Show the spatial distribution maps of chloride and electrical conductivity

3.1.6. Hardness

In the current study, area hardness ranges from 94 to 651 mg/l. Only 8 samples contain above the permissible limit (500 mg/l).

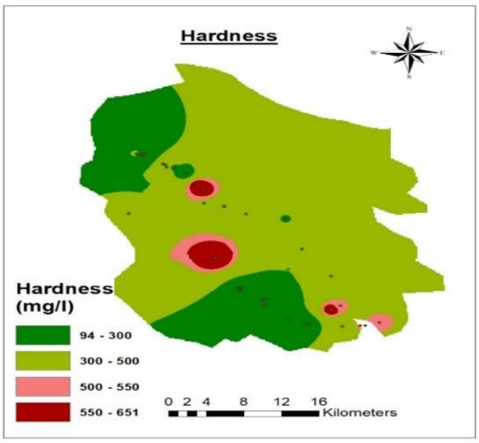

Figure 6, Show the spatial distribution map of hardness

3.1.7. Magnesium

In the study area, the concentration ranges from 12 to 106 mg/l. All sample lies within the permissible limit (150 mg/l). The higher concentration of Magnesium causes the Hardness of water.

3.1.8. pH

In the current study, the pH ranges between 7.13 (minimum) to 7.98 (maximum) with an average value of 7.45, the pH of all the samples was within the permissible limit (6.5–8.5) of WHO.

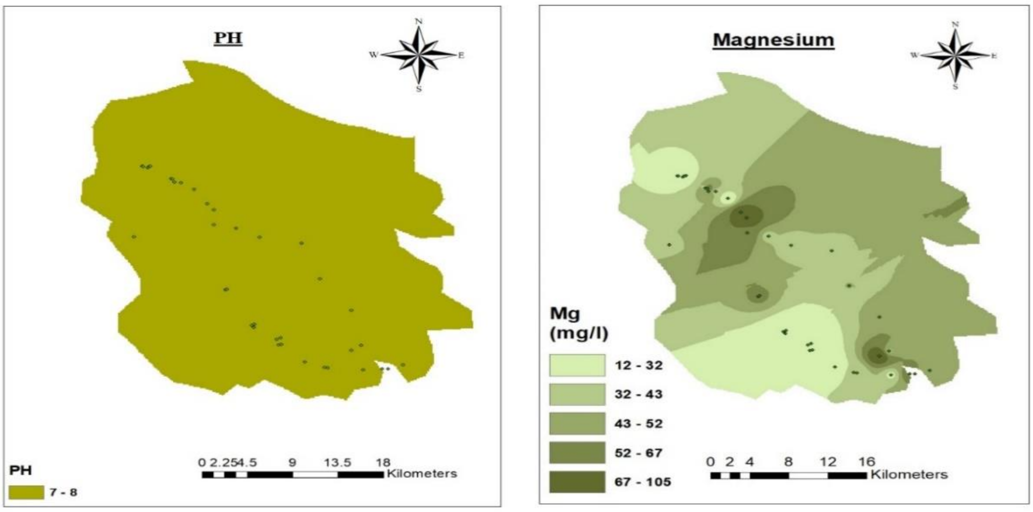

Figure 7 and 8, Show the spatial distribution maps of magnesium and Ph

3.1.9. Potassium

In the present study area, it varies from 2.42 to 16.58 mg/l. Only 2 samples are above the permissible limit which is (12 mg/l).

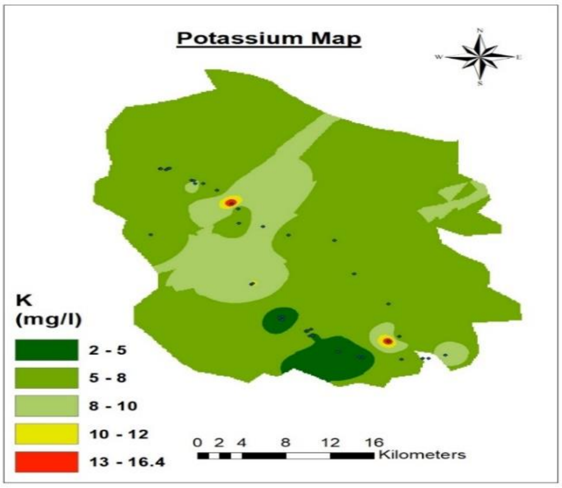

Fig 09, Show the spatial distribution map of Potassium

3.1.10. TDS

TDS in the study area ranged from 288 to 4180 mg/l. 10 samples crossed the allowable limits of the WHO, max permissible limit is 1000 mg/l.

3.1.11. Sodium

The permissible limit of sodium is 400 mg/l and in the current study area, it varies from 26.16 to 223 mg/l. All samples lie within ranges.

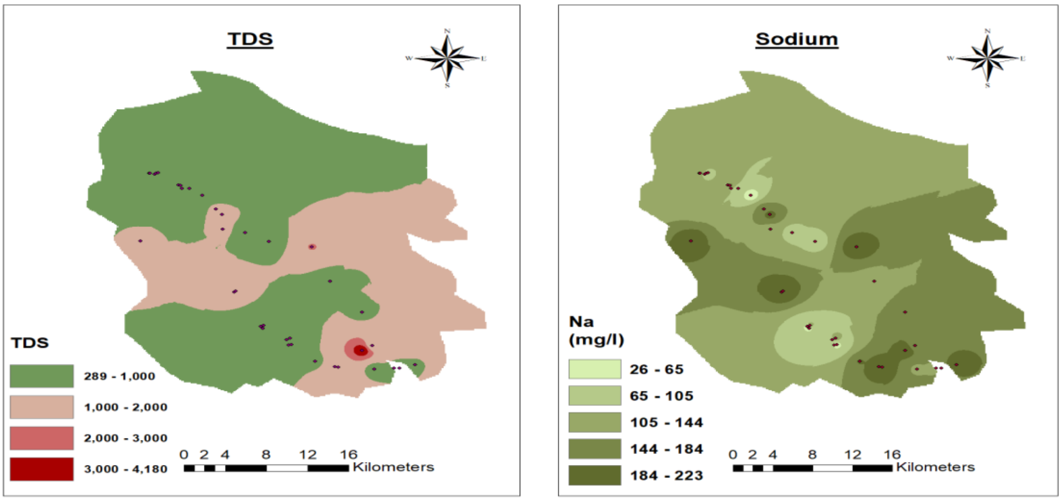

Fig 10 and 11, Show the spatial distribution maps of TDS and Sodium

4. Conclusion

In this research study, 38 groundwater samples were collected from different locations along the Akram, Pinyari, and Phuleli Canals for the assessment of groundwater quality, 12 physicochemical parameters were analyzed, among these 12 physicochemical parameters; alkalinity, bicarbonates, carbonates, magnesium, PH, potassium, and sodium were within the permissible limit of WHO Standards in all the samples, while the concentration of calcium was crossing the permissible limit only in one sample. Moreover, the availability of Chloride (Cl) was found in 16 samples that were above the limit ranges from 274.9 to 2549, High concentration of EC was found in 14 samples than the permissible limit having values from 2212 to 8360 (P26), and Total Hardness (TH) were found only in 6 samples slightly high from the permissible limit ranges from 509 to 651, and TDS were present in excessive amounts than the allowable limit from 1100 to 4180 mg/l (P26) in 10 samples. Considering the Water Quality Index (WQI) it was observed that 8 sample falls in the good category, 2 samples in the poor category, 11 samples in the very poor category, and 17 samples in the unsuitable category of water quality. In the present study, KR values range from 0.4 to 6.5. Out of 38 samples, except 19 samples, others had greater than 1 which means 50% of samples are suitable for irrigation. While SSP of 7 samples was good, 22 samples were permissible, 8 samples had doubtful, and 1 sample had the unsuitable quality of water for irrigation, which means few places are liable to sodium hazard. The MH value in collected samples varies between 20 to 60%. Only 5 samples were unsafe. The SAR values varied from 5 to 50%, In which 7 samples have excellent, 15 samples have good, 10 samples have fair and 6 samples had poor quality for irrigation purposes.

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