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Assessment of Groundwater quality- A case study of a groundwater recharge project in Vehari Pakistan

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Abstract

The study presents the physiochemical analysis of water samples collected under project, "Recharge of Aquifer for Groundwater Management in Punjab. The samples were analyzed in Engineering Material and Quality Control Laboratory of Irrigation Research Institute and standard procedure has been adopted in this regard for finding out required results of the water samples. The paper contains the results of different activities carried out in field and laboratory which include collection of water samples from field and analysis in laboratory. Study compares the results of samples collected and analyzed in 2019 and have been repeated again in 2021 for comparison purpose. From the analysis result it has been found that shallow water quality in the study area is better than deep water quality and surface water quality is better than groundwater quality. Same trend is observed in 2021. In 2019 quality of water was better than in 2021. This shows that quality of water is being deteriorated with the passage of time. Therefore, some management interventions are recommended including and managed aquifer recharge project to divert flood water to replenish the aquifer as well as improvement of groundwater quality.

Keywords: Groundwater Quality, Old Mailsi Canal, Vehari, Punjab, Pakistan Head Islam.

I. INTRODUCTION

In the present scenario of depleting groundwater reservoir due to excessive extraction of groundwater, the Government of the Punjab Irrigation Department has taken the initiative of launching the study to managed aquifer recharge (MAR) project to replenish the depleted aquifer based on a feasibility study carried out by Water and Power Development Authority (WAPDA, 2009). The increasing demand for water has increased global awareness towards the use of artificial recharge to augment groundwater aquifers having the right geology to create, in effect, underground dams (Zakir-Hassan *et al.*, 2025). MAR or simply called artificial recharge is a process by which excess surface water is directed into the ground – either by spreading on the surface by using recharge wells, or by altering natural conditions to increase infiltration – to replenish an aquifer (Zakir-Hassan, Punthakey, *et al.*, 2022). It refers to the movement of water through man-made systems from the surface of the earth to underground water-bearing strata where it may be stored for future use. The recharge of groundwater aquifer is necessary for controlling/minimizing depletion of groundwater reservoir due to excessive extraction of groundwater (Sherif *et al.*, 2023).

At present groundwater use in Punjab is unsustainable both in qualitative as well as quantitative aspects (IRI, 2013, 2019; Zakir-Hassan *et al.*, 2021). This critical situation needs to be addressed for the future of our next generation and country's economic growth. Realizing the intensity of the problem, the Physics Wing of Irrigation Research Institute (IRI) of Punjab Irrigation Department (PID) has been assigned a project, "Recharge of Aquifer for Groundwater Management in Punjab". For this purpose, Old Mailsi Canal was proposed where surplus river water during flood season (June to August) from head regulator of the canal at Islam Headwork on Sutlej river is to be utilized for overcoming the current scenario through

managed aquifer recharge (IRI, 2019). Groundwater quality in the project area has been assessed to establish the pre-project conditions. Quality of groundwater plays a vital role for sustainable development, management and use of this natural resource (IRI, 2009). It has been further established and observed that there is adequate potential for storage of groundwater in the underlying aquifer (Zakir-Hassan *et al.*, 2024).

2. METHODOLOGY

2.1 Description of study Area

The study area lies on the Sutlej River near Islam Headworks at 29°54'15.86" N latitude and 72°32'56.04" E longitude (Figure 1). The nearest town in the project site is Ludden (District Vehari) in South Punjab region of Pakistan. According to the Irrigation Department (PID 1992), the area is flat with an average slope of about one foot per mile in the south west direction. The project area is facing shortage of surface water. The groundwater levels are declining in the area at a rate more than 2 feet per year (Zakir-Hassan, Allan, *et al.*, 2023). Area is food basket and source of livelihood for the tiny farming communities. The agriculture of the area is facing shortage of irrigation water supplies due to falling groundwater levels and non-perennial canal irrigation supplies(Zakir-Hassan, Akhtar, *et al.*, 2023).

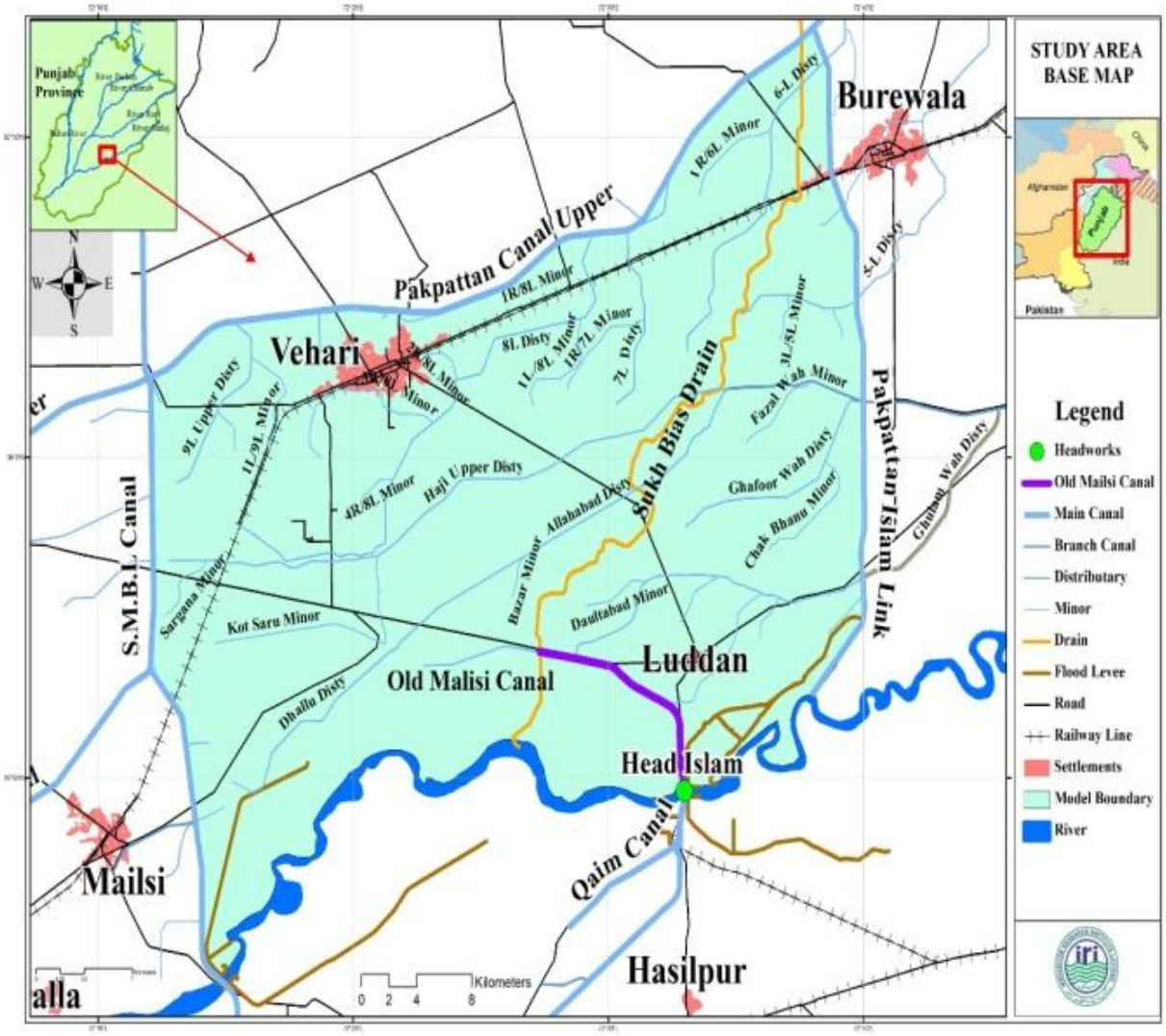

Figure1: Map of study area showing major features

2.2 Sample collection

Water sampling points were specified in the vicinity of Old Mailsi Canal for observing the quality status of ground water and water samples were collected accordingly. This area falls in Bari Doab. Water samples from selected points were collected and shifted to lab for analysis (Figure 2). All the samples were collected separately into a pre-cleaned high-density 500ml polyethylene sampling bottles. These were carefully labeled and immediately transported to the laboratory in a cool ice chest for analysis (Zakir-Hassan, Shabir, *et al.*, 2022).

Figure 2: Sampling and on-site testing of water samples

2.3 Lab Analysis

The physiochemical parameters measured include pH, Electrical Conductivity, total dissolved solids (TDS), Turbidity, Carbonates, Bicarbonates, Chlorides, Calcium, Magnesium, Sodium, Potassium, Hardness, pH was measured with the help of HANNA Model HI 8424. E.C, TDS and Dissolved Oxygen (DO) were measured in situ with the help of Lovibond Senso Direct 150 meter. Turbidity was measured with Lovibond TurbiDirect in situ. In the laboratory, Carbonates, Bicarbonates, Chlorides, Calcium, Magnesium, Sodium, Potassium, Hardness, were determined using standard laboratory protocols described by (APHA, 2021) (Table 1).

Table 1: Methods of analysis of different parameters of water quality(APHA, 2021; Trivedy & Goel, 1986)

Name of parameter	Instrument used for Determination	Method used	Method Reference
pH	pH meter	-	APHA 2021
Electrical Conductivity	E.C meter	-	Trivedi and Goel (1986)
TDS	TDS meter	-	Trivedi and Goel (1986)
Chloride	Burette	Titration	APHA 2021
Sodium	Flame Photometer	Calibration	APHA 2021
Potassium	Flame Photometer	Calibration	APHA 2021
Calcium	Burette	Titration	Trivedi and Goel (1986)
Magnesium	Burette	Difference	Trivedi and Goel (1986)
Hardness	Burette	Titration	Trivedi and Goel (1986)

2.4 Suitability of Groundwater for Irrigation

Water quality for irrigation is very important and different elements have significant effect on crop and soil health and subsequently leach down to the groundwater. Some most important parameters were calculated as given below.

Residual Sodium Carbonate (RSC)

It is used to predict the additional sodium hazard associated with CaCO3 precipitation and is another alternative measure of the sodium contents in relation with calcium and magnesium (Adimalla, 2020; Hopkins *et al.*, 2007). This can be calculated as:

$$RSC = (CO3\ 2- + HCO3\ -) - (Ca2+ + Mg2+)$$

where, all concentrations are in milliequivalent per liter (meq/l)

Sodium Adsorption Ratio (SAR)

Sodium adsorption ratio (SAR) is an easily measured property that gives information on the comparative concentrations of sodium, calcium and magnesium (Adimalla, 2020; Hopkins *et al.*, 2007). The SAR can be calculated as:

$$SAR = [Na+] \sqrt{[Ca+++\ Mg++]/2}$$

where [Na+], [Ca2+], and [Mg2+] are the concentrations in meq/l of sodium, calcium, and magnesium ions in the water sample.

3. RESULTS AND DISCUSSION

3.1 Deep water samples collected in 2019

Chemical analysis indicated that turbidity of deep water samples ranged from 9.5NTU to 15.3NTU. pH values of samples were in the range from 6.8 to 7.5. Electrical Conductivity ranged from 599µs/cm to 3200µs/cm. Total Dissolve Solids (TDS) of deep water samples ranged from 299 ppm to 1600 ppm. Dissolve oxygen values ranged from 2.3% to 5.5 %.Carbonate values of deep water samples were found out to be Nil while bicarbonate values of deep water samples ranged from 0.6me/l to 9.3me/l. Chloride values of deep water samples ranged from 0.5me/l to 12.7me/l. Sodium values ranged from 2.30me/l to 10.56me/l. Calcium value ranged from 0.5me/l to 12.5 me/l. Magnesium value ranged from 1.1me/l to 13.3lme/l. Total Hardness value of deep water samples ranged from 125 to 1075 mg/l. SAR values of deep water ranged from 1.61 to 3.22. RSC values were found out to be Nil for all samples (Table 2).

Overall chemical analysis results showed that 73 % samples were fit for irrigation except sample Nos. DWS2, DWS 6, DWS 19, DWS 20, DWS 21, DWS 24, DWS 26 which were unfit (27 %) according to Punjab Irrigation Department Standards for irrigation water (Figure 3).

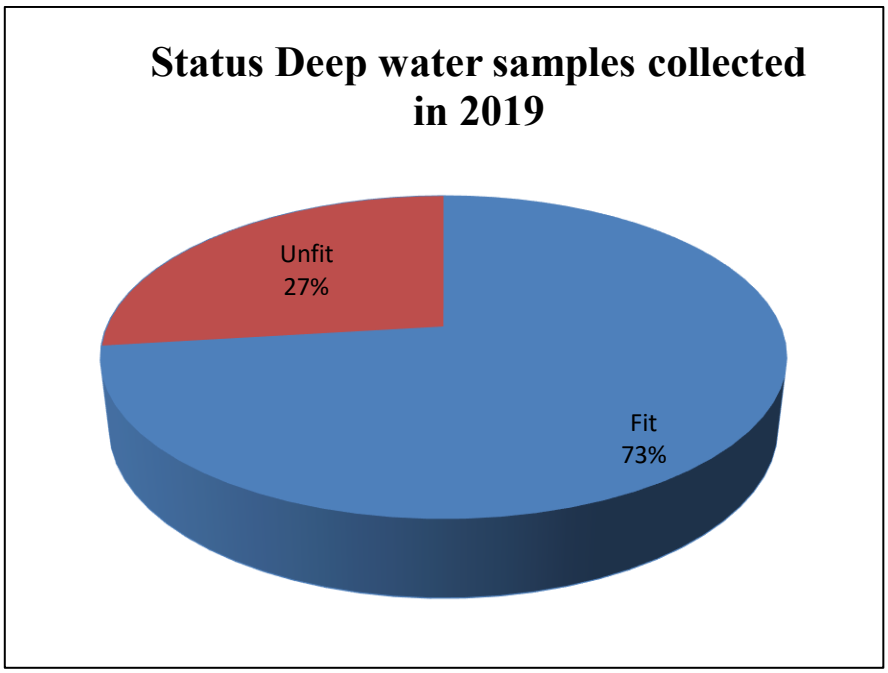

Figure 3: Status of deep water samples collected in 2019

3.2 Shallow Water Samples Collected in 2019

Turbidity of shallow water samples ranged from 9.8NTU to 13.0NTU. pH of shallow water samples ranged from 6.9 to 7.0. Electrical Conductivity of shallow water samples ranged from 807µs/cm to 2120µs/cm. Total Dissolve Solids (TDS) of shallow water samples ranged from 403 ppm to1060 ppm. Dissolve oxygen ranged from 3.2% to 5.0 %. Carbonate values of shallow water samples were found out to be Nil. Bicarbonate values ranged from 2.7me/l to 7.2me/l. Chloride value of shallow water samples ranged from 1.8me/l to 9.8me/l. Sodium value of shallow water ranged from 3.47me/l to 6.34me/l. Calcium value ranged from 1.5me/l to 10.3me/l while magnesium value ranged from 1.1me/l to 7.2me/l. Total Hardness value of samples ranged from 130 to 875mg/l. SAR values of shallow water ranged from 1.94 to 3.27 While RSC value was Nil for shallow water samples (Table 3).

Analysis results showed that 67% samples were fit for irrigation except samples no. SWS 3 and SWS 6 which were unfit (33%) according to Punjab Irrigation Department Standards for irrigation (Figure 4).

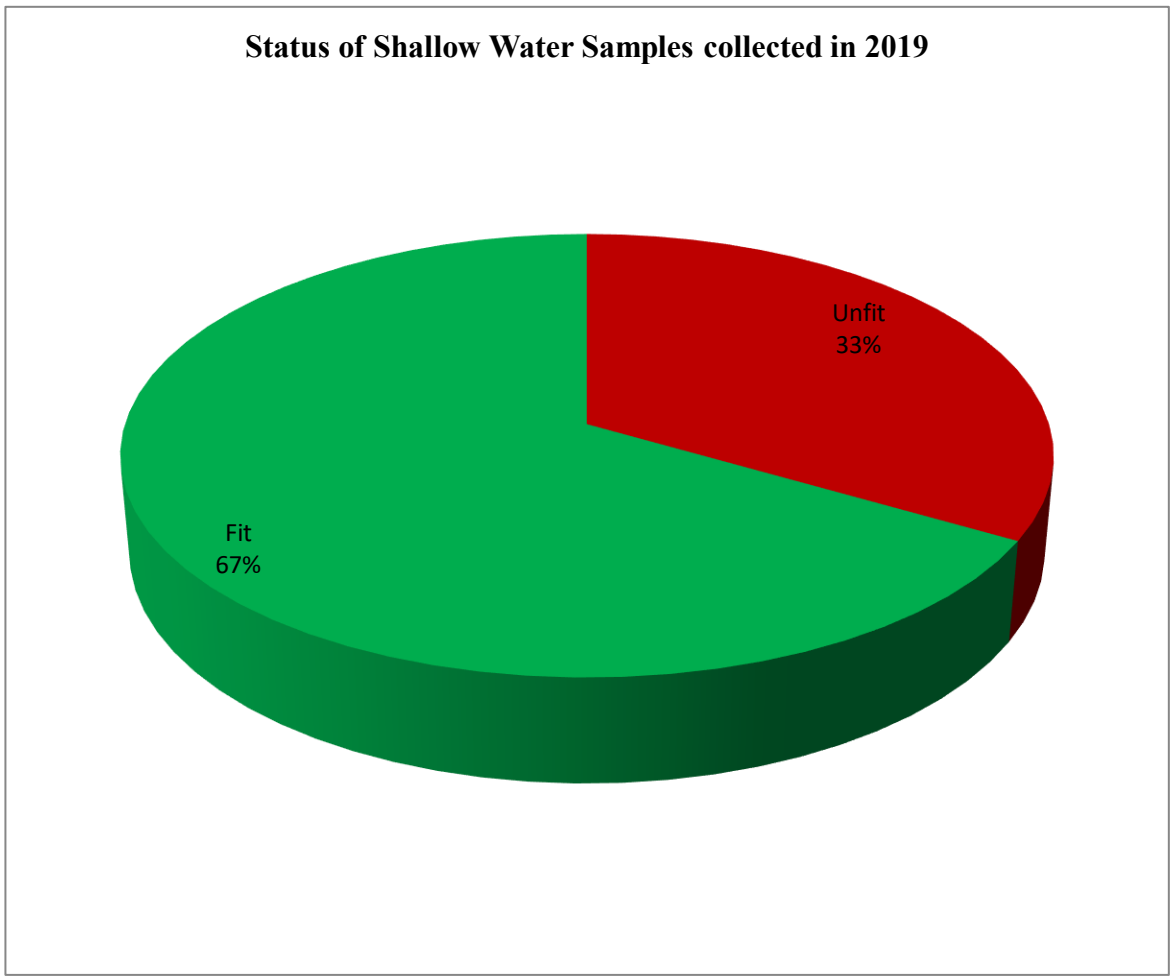

Figure 4: Status of shallow water samples collected in 2019

3.3 Surface water samples collected in 2019

Turbidity of surface water samples ranged from 8.5NTU to 10.0NTU. pH of surface water samples ranged from 7.0 to 7.3. Electrical Conductivity of surface water samples ranged from 382µs/cm to 891µs/cm. Total Dissolve Solids (TDS) of surface water samples ranged from 191 ppm to 446 ppm. Dissolve oxygen ranged from 3.5% to 4.0 %. Carbonate values of surface water samples were found out to be Nil. Bicarbonate value of surface water samples ranged from 1.0me/l to 4.5me/l. Chloride value of surface water samples ranged from 0.7me/l to 2.1me/l. Sodium value of surface water ranged from 0.61me/l to 0.76me/l. Calcium values ranged from 0.5me/l to 1.5me/l. Magnesium values ranged from 1.5me/l to 3.0me/l. Total Hardness values of surface water samples ranged from 115 to 275mg/l. SAR values of surface water ranged from 0.53 to 0.67 (Table 4).

Analysis results showed that 100 % of surface water samples were fit for irrigation according to Punjab Irrigation Department Standards for irrigation (Figure 5).

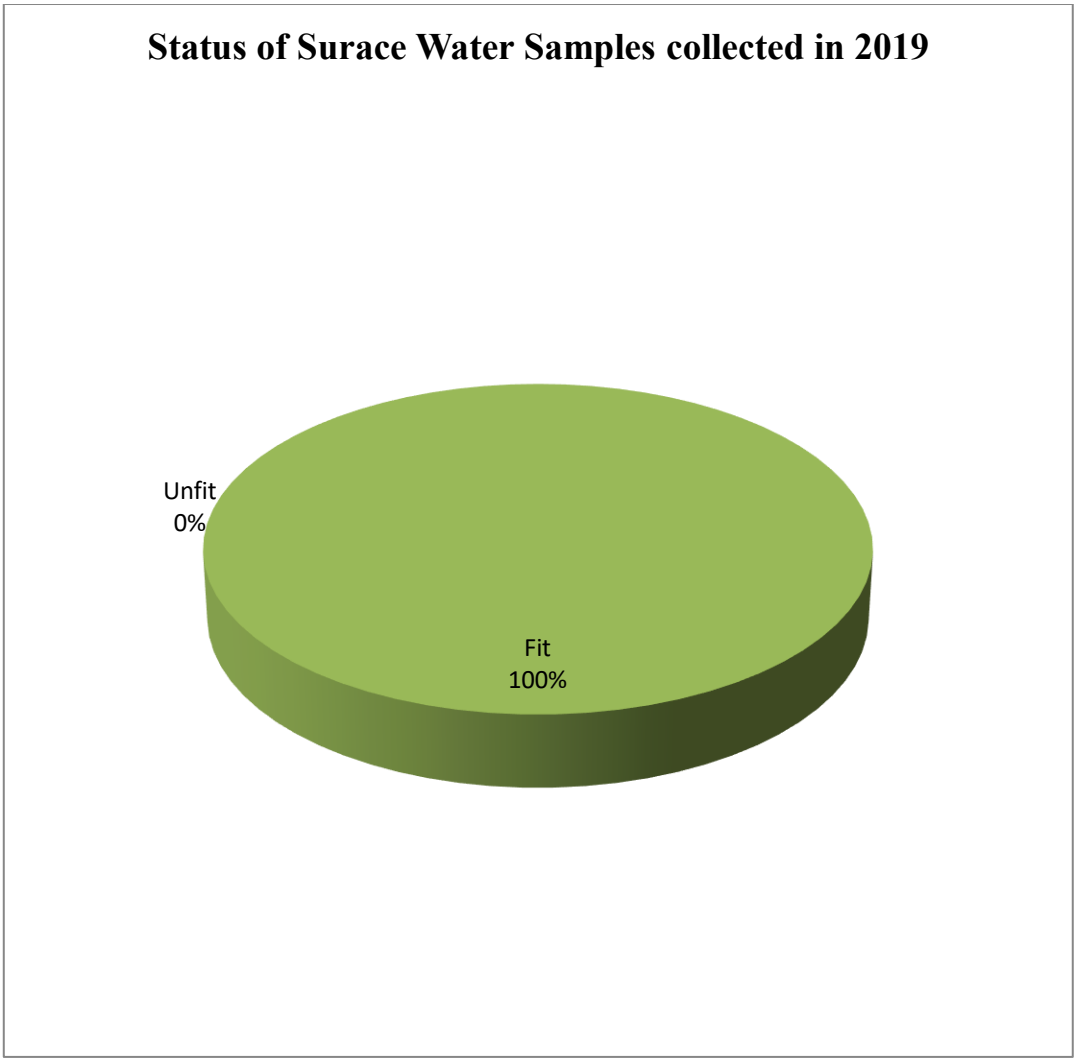

Figure 5: Status of surface water samples collected in 2019

3.4 Physiochemical analysis of deep water samples collected in 2021

Turbidity of deep water samples ranged from 1.2NTU to 12.3NTU.pH of deep water samples ranged from 7.10 to 7.54. Electrical Conductivity of deep water samples ranged from 766 µs/cm to 5170µs/cm. Total Dissolve Solids (TDS) of deep water samples ranged from 383 ppm to 2585 ppm. Carbonate values of deep water samples were found out to be Nil. Bicarbonate values of deep water samples ranged from 1.0me/l to 4.5me/l. Chloride values of deep water samples ranged from 1 to 4.0 me/l. Sodium values of deep water ranged from 2.2me/l to 16.0me/l .Calcium values ranged from 0.5me/l to 3.5me/l. Magnesium values ranged from 1.0me/l to 5.3me/l. Total Hardness s of deep water samples ranged from 90 to 335 mg/l. SAR values of deep water ranged from 1.94 to 8.95 (Table 5).

Analysis results showed that 81% samples were fit for irrigation except samples no. DWS30, DWS33, DWS41and DWS 42 which were unfit (19%) according to Punjab Irrigation Department Standards for irrigation (Figure 6).

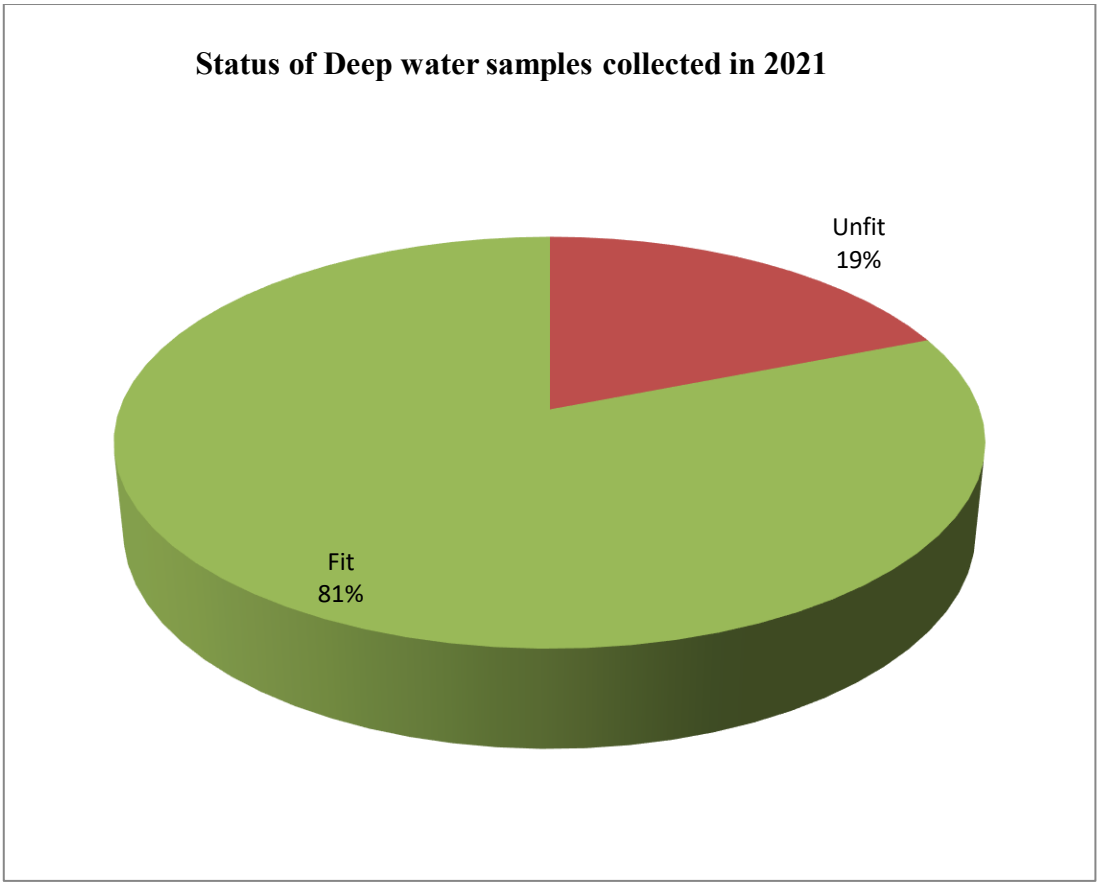

Figure 6: Status of deep water samples collected in 2021

3.5 Surface water samples collected in 2021

Turbidity of surface water samples ranged from 11.2NTU to 11.5NTU. pH of surface water samples ranged from 7.01 to 7.23. Electrical Conductivity of surface water samples ranged from 369µs/cm to 2035µs/cm. Total Dissolve Solids (TDS) of surface water samples ranged from 184 ppm to 1017 ppm. Carbonate values of surface water samples were found out to be Nil. Bicarbonate values of surface water samples ranged from 0.7me/l to 2.1me/l. Chloride values of surface water samples ranged from 0.6me/l to 4.3me/l. Sodium values of surface water ranged from 1.2me/l to 8.5me/l. Calcium values ranged from 0.5me/l to 1.4me/l. Magnesium values ranged from 0.5me/l to 1.4me/l. Total Hardness values of surface water samples ranged from 85 to 135mg/l. SAR values of surface water ranged from 1.23 to 7.29 (Table 6).

Analysis results showed that 67% of samples were fit and 33% samples were unfit for irrigation according to Punjab Irrigation Department Standards for irrigation water (Figure 7).

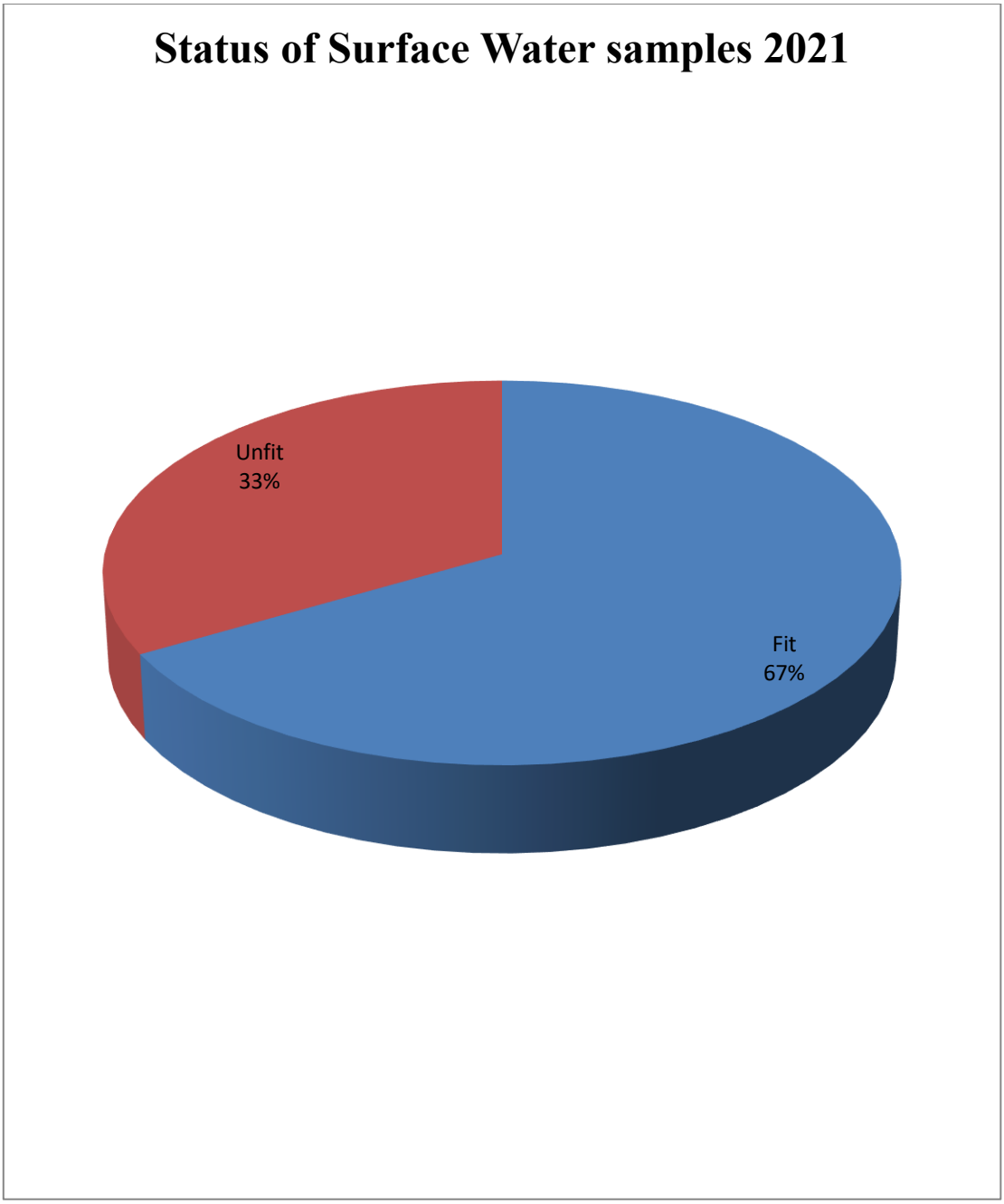

Figure 7: Status of surface water samples collected in 2021

Table 2: Chemical Analysis of Deep water samples collected in 2019

Sr. No.	Description	pH	E.C (µs/cm)	TDS (ppm)	Turbidity (NTU)	DO (%)	CO_3^{2-} (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	Na^+ (me/l)	Ca^{2+} (me/l)	Mg^{2+} (me/l)	Hardness (mg/l)	SAR	RSC
PID irrigation standards			>1500 Unfit	-	-	-	-	-	4.5	-	-	-	-	>10 Unfit	>2.5
1.	DWS 1 Tube well 26-09-19	7.5	1495	747	12.0	2.3	Nil	3.0	7.2	5.86	4.2	5.3	475	2.69	Nil
2.	DWS 2 Tube well 26-09-19	7.3	2190	1095	15.3	3.5	Nil	7.5	4.8	8.13	6.5	8.7	760	2.94	Nil
3.	DWS 3 Tube well 26-09-19	7.3	1021	510	10.7	2.5	Nil	4.0	2.7	3.78	2.8	4.2	350	2.02	Nil
4.	DWS 4 Tube well 26-09-19	7.2	665	332	10.0	2.8	Nil	1.2	2.3	4.30	1.7	2.7	220	2.90	Nil
5.	DWS5	7.2	1185	592	12.8	3.5	Nil	2.3	6.8	6.04	3.5	4.8	415	2.96	Nil

	Tube well 26-09-19														
6.	DWS 6 Tube well 27-09-19	7.2	2160	1080	13.3	4.0	Nil	7.3	8.5	7.26	11.3	8.9	1010	2.28	Nil
7.	DWS 7 Tube well 27-09-19	7.0	1044	522	12.5	4.5	Nil	3.0	3.6	4.26	12.5	4.5	300	2.46	Nil
8.	DWS 8 Tube well 27-09-19	7.0	1051	525	12.0	4.0	Nil	4.0	3.2	4.82	2.0	6.0	400	2.41	Nil
9.	Sample 9 Tube well 27-09-19	7.0	1087	543	11.9	4.2	Nil	3.2	3.9	4.78	2.0	4.4	320	2.67	Nil
10.	DWS 10 Tube well 27-09-19	7.0	602	301	11.0	2.8	Nil	1.8	2.8	2.82	1.7	2.8	225	1.88	Nil
11.	DWS 11 Tube well 28-09-19	7.0	729	364	10.5	2.5	Nil	3.3	3.3	3.04	2.3	1.9	210	2.10	Nil

Sr. No.	Description	pH	E.C (µs/cm)	TDS (ppm)	Turbidity (NTU)	DO (%)	CO_3^{2-} (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	Na (me/l)	Ca^{2+} (me/l)	Mg^{2+} (me/l)	Hardness (mg/l)	SAR	RSC
12.	DWS 12 Tube well 28-09-19	7.0	599	299	10.0	3.0	Nil	0.6	2.9	2.30	1.5	2.0	175	1.74	Nil
13.	DWS 13 Tube well 28-09-19	6.8	904	452	10.5	5.2	Nil	4.8	2.8	3.52	3.5	4.3	390	1.78	Nil
14.	DWS 14 Tube well 28-09-19	6.8	643	321	11.0	5.0	Nil	2.0	0.5	2.56	0.5	2.0	125	2.29	Nil
15.	DWS 15 Tube well 29-09-19	6.9	1105	552	10.4	4.0	Nil	4.2	5.0	4.86	3.8	4.8	430	2.34	Nil
16.	DWS16 Lal Pump 29-09-19	7.0	917	458	10.2	4.2	Nil	2.6	1.8	2.69	1.5	1.1	130	2.36	Nil
17.	DWS 17 Lal Pump 29-09-19	6.9	1147	573	10.0	4.0	Nil	4.8	2.8	4.04	3.5	4.3	390	2.04	Nil
18.	DWS 18 Lal Pump 29-09-19	6.9	1012	506	9.5	4.2	Nil	2.5	4.2	3.47	3.7	4.7	420	1.69	Nil
19.	DWS 19 Lal Pump 29-09-19	7.0	2430	1215	12.0	4.9	Nil	5.7	4.2	7.78	5.8	7.7	675	2.99	Nil
20.	DWS 20 Lal Pump 29-09-19	6.9	3200	1600	14.8	5.5	Nil	9.3	12.7	10.56	8.2	13.3	1075	3.22	Nil

Sr. No.	Description	pH	E.C (µs/cm)	TDS (ppm)	Turbidity (NTU)	DO (%)	CO_3^{2-} (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	Na^+ (me/l)	Ca^{2+} (me/l)	Mg^{2+} (me/l)	Hardness (mg/l)	SAR	RSC
21	DWS 21 Lal Pump 29-09-19	7.0	1514	757	9.5	3.3	Nil	4.4	6.5	4.43	4.8	5.1	495	2.44	Nil
22	DWS 22 Lal Pump 29-09-19	7.0	1131	565	10.4	3.0	Nil	3.4	4.5	4.39	4.0	3.9	395	2.20	Nil
23	DWS 23 Lal Pump 29-09-19	6.8	803	401	10.0	4.4	Nil	2.3	3.6	3.73	4.2	2.6	340	2.02	Nil
24	DWS 24 Lal Pump 29-09-19	7.0	1935	967	14.3	4.5	Nil	6.5	7.7	6.17	6.7	8.5	760	2.23	Nil
25	DWS 25 Lal Pump 29-09-19	7.0	925	462	10.0	3.8	Nil	2.8	4.7	3.13	3.8	3.7	375	1.61	Nil
26	DWS 26 Lal Pump 29-09-19	7.0	1616	808	11.2	4.0	Nil	4.0	7.5	5.0	3.8	5.4	460	2.33	Nil

Table 3: Chemical Analysis of Shallow Water Samples collected in 2019

Sr. No.	Description	pH	E.C (µs/cm)	TDS (ppm)	Turbidity (NTU)	DO (%)	CO_3^{2-} (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	Na^+ (me/l)	Ca^{2+} (me/l)	Mg^{2+} (me/l)	Hardness (mg/l)	SAR	RSC
1.	SWS 1 Hand Pump 29-09-19	6.9	900	450	11.3	4.8	Nil	3.2	2.5	3.69	4.2	3.0	360	1.94	Nil
2.	SWS 2 Hand Pump 29-09-19	7.0	807	403	9.8	4.5	Nil	2.7	1.8	3.73	1.5	1.1	130	3.27	0.1
3.	SWS 3 Hand Pump 29-09-19	7.0	1565	782	10.5	4.5	Nil	2.7	4.3	5.73	3.7	4.7	420	2.80	Nil
4.	SWS 4 Hand Pump 29-09-19	7.0	1243	621	11.0	4.8	Nil	5.0	3.8	3.60	2.8	3.7	325	2.00	Nil
5.	SWS 5 Hand Pump 29-09-19	7.0	920	460	10.2	3.2	Nil	3.8	2.4	3.47	1.7	3.6	265	2.13	Nil
6.	SWS 6 Hand Pump 29-09-19	7.0	2120	1060	13.0	5.0	Nil	7.2	9.8	6.34	10.3	7.2	875	2.14	Nil

Table 4: Chemical Analysis of Surface Water Samples collected in 2019

Sr No.	Description	pH	E.C (µs/cm)	TDS (ppm)	Turbidity (NTU)	DO %	CO_3^{2-} (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	Na^+ (me/l)	Ca^{2+} (me/l)	Mg^{2+} (me/l)	Hardness (mg/l)	SAR	RSC
1.	SRWS 1 Qaim Canal of H/Islam	7.0	400	200	8.8	3.8	Nil	1.2	2.0	0.76	1.0	1.7	135	0.66	Nil
2.	SRWS 2 H/Islam U/S Left side	7.0	390	195	8.5	3.5	Nil	1.3	1.0	0.65	0.8	1.5	115	0.61	Nil
3.	SRWS 3 H/Islam D/S Left side	7.0	382	191	8.6	3.6	Nil	1.0	1.2	0.70	0.5	1.7	110	0.66	Nil
4.	SRWS 4 Bahawal Canal of H/Islam	7.1	408	204	9.5	4.0	Nil	1.5	2.1	0.61	0.9	1.7	130	0.53	Nil
5.	SRWS 5 H/Islam U/S Right side	7.1	412	206	10.0	3.9	Nil	2.2	0.7	0.76	1.0	1.6	130	0.67	Nil
6.	SRWS 6 Qaim Canal Islam Headworks, Sutlj River	7.3	891	446	8.6	3.8	Nil	4.5	1.0	-	1.8	3.7	275	-	Nil
7.	SRWS 7 Head Regulator of old Mailsi Canal	7.3	795	397	8.0	3.5	Nil	3.2	1.5	-	1.5	3.0	225	-	Nil

Table 5: Chemical Analysis of Deep Water Samples collected in 2021

Sr. No.	Description	pH	E.C (µs/cm)	TDS (ppm)	Turbidity (NTU)	CO_3^{2-} (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	Na^+ (me/l)	K^+ (me/l)	Ca^{2+} (me/l)	Mg^{2+} (me/l)	Hardness (mg/l)	SAR	RSC
1.	DWS 27 27.05.21	7.24	1060	530	12.1	Nil	1.5	3.0	6.0	2.6	1.0	0.8	90.0	6.32	Nil
2.	DWS 28 27.05.21	7.38	1238	619	11.9	Nil	1.4	2.2	6.5	1.8	3.4	2.1	275	3.90	Nil
3.	DWS 29 27.05.21	7.21	1043	521	11.8	Nil	1.2	3.9	4.1	2.2	3.0	1.8	240	2.63	Nil
4.	DWS 30 27.05.21	7.44	2470	1235	12.0	Nil	4.5	4.0	10.0	3.9	4.4	1.3	285	6.05	Nil
5.	DWS 31 27.05.21	7.51	822	411	12.0	Nil	1.2	2.2	4.5	1.9	2.2	1.0	160	3.54	Nil
6.	DWS 32 26.05.21	7.17	1364	682	11.5	Nil	1.0	2.3	4.8	2.9	2.2	1.6	190	3.53	Nil
7.	DWS 33 26.05.21	7.1	2630	1315	11.8	Nil	2.8	3.5	8.5	3.1	2.8	3.5	315	4.80	Nil
8.	DWS 34 26.05.21	7.51	775	387	11.9	Nil	1.1	1.7	3.5	1.4	1.8	1.9	185	2.57	Nil

9.	DWS 35 26.05.21	7.13	1121	560	12.1	Nil	2.3	2.4	4.9	3.5	3.6	1.2	240	3.17	Nil
10.	DWS 36 25.05.21	7.51	1355	677	12.1	Nil	2.6	2.5	5.4	2.2	4.6	0.9	275	3.25	Nil
11.	DWS 37 25.05.21	7.54	1144	572	12.3	Nil	3.0	2.5	6.5	3.6	2.6	0.9	175	4.96	Nil
12.	DWS 38 27.05.21	7.10	1262	631	12.1	Nil	3.1	2.0	4.1	2.0	4.5	1.2	285	2.42	Nil
13.	DWS 39 27.05.21	7.24	975	487	11.2	Nil	1.5	2.1	5.8	3.4	2.7	0.9	180	4.37	Nil
14.	DWS 40 26.05.21	7.29	766	383	12.1	Nil	1.1	1.2	2.5	1.2	2.5	0.8	165	1.94	Nil
15.	DWS 41 26.05.21	7.26	2110	1055	12.0	Nil	4.2	3.2	12.0	1.9	3.6	1.6	260	7.95	Nil
16.	DWS 42 27.05.21	7.32	5170	2585	12.1	Nil	3.7	3.9	16.0	2.6	5.3	1.4	335	8.95	Nil
17.	DWS 43 27.05.21	7.33	1390	695	11.8	Nil	2.1	1.6	7.3	2.5	2.7	0.9	180	5.41	Nil
18.	DWS 44 27.05.21	7.40	835	417	12.3	Nil	1.2	2.3	2.2	1.1	1.2	0.8	100	2.2	Nil
19.	DWS 45 28.05.21	7.25	1429	714	11.9	Nil	1.6	2.0	6.8	2.3	4.0	1.0	250	4.34	Nil
20.	DWS 46 28.05.21	7.46	966	483	12.0	Nil	1.3	1.6	4.9	1.5	3.0	0.5	175	3.68	Nil
21.	DWS 47 28.05.21	7.28	1047	523	11.6	Nil	1.5	1.7	4.0	2.2	3.2	0.8	200	2.82	Nil

Table 6: Chemical Analysis of Surface Water Samples collected in 2021

Sr. No.	Description	pH	E.C (µs/cm)	TDS (ppm)	Turbidity (NTU)	CO_3^{2-} (me/l)	HCO_3^- (me/l)	Cl^- (me/l)	Na^+ (me/l)	K^+ (me/l)	Ca^{2+} (me/l)	Mg^{2+} (me/l)	Hardness (mg/l)	SAR	RSC
1.	SRWS 10 28.05.21	7.09	411	205	11.4	Nil	0.7	0.6	1.5	1.1	1.2	0.5	85.0	1.62	Nil
2.	SRWS 11 28.05.21	7.01	2035	1017	11.5	Nil	2.1	4.3	8.5	6.1	1.4	1.3	135	7.29	Nil
3.	SRWS 12 River Water	7.23	369	184	11.2	Nil	0.8	0.8	1.2	0.8	1.4	0.5	95.0	1.23	Nil

4. CONCLUSIONS

The overall results of analysis predict that water quality is deteriorating with the passage of time as compared between 2019 and 2021. Deep groundwater quality is deteriorating more as compared to shallow on. Shallow groundwater and surface water consistently indicate better quality. This decline mandates urgent attention and appropriate measures to mitigate further deterioration. Adequate management strategies are essential to ensure sustainable groundwater resources for future generations. MAR project is necessary to mitigate the adverse trends of groundwater quality degradation.

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CONFLICT OF INTEREST:

The authors declare that there is no conflict of interest.
Note: The views expressed in the paper are of the authors and do reflect the responsibility of any organization/department.

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