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IMPACT OF IRRIGATION WATER QUALITY ON SOIL PROPERTIES AND NUTRIENT STATUS OF MURAR BLOCK OF GWALIOR, MADHYA PRADESH, INDIA

Ashok Singh[1], Akhilesh Singh[2], Bhadoria S.S.[2], Shashi S. Yadav[2] and Priyadarshani Arun Khambalkar[2]*
[1]Programme Assistant (Lab Tech.) Krishi Vigyan Kendra Jalore-II Agriculture University Jodhpur, Rajasthan, India
[2] Rajmata Vijaya Raje Scindiya Krishi Vishwa Vidyalaya, Gwalior MP, 474002, India
*Corresponding author E-mail: murlipriya245@gmail.com
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ABSTRACT

The quality of irrigation water greatly affects soil health, nutrients, and fertility. This study examined the impact of different irrigation sources on soil in Murar block, Gwalior district. Soil samples were collected from three depths (0–15, 15–30, and 30–60 cm) of tube well and sewage water irrigated fields for analysis of soil properties and fertility status. The results stated that sewage water irrigation had a clear effect on soil properties i.e. lower bulk density, particle density and higher porosity % due to organic matter enrichment, whereas slightly higher pH and EC recorded in tube well-irrigated soils. Higher organic carbon, nitrogen (200–333 $kgha^{-1}$), phosphorus (18–23 $kgha^{-1}$), and potassium (254–306 $kgha^{-1}$) with important cations and anions, such as Ca^{2+}, Mg^{2+}, HCO_3^-, and Cl^-, were increased under sewage irrigation. As a result, the soil fertility index was higher in sewage-irrigated soils than that of the soil irrigated with tube well. The study shows that sewage water can enrich soils, but careful management is needed to avoid salt problems and maintain soil health. These findings are useful for farmers and planners to manage irrigation and soil fertility in semi-arid regions like Murar block of Gwalior. Overall, this study highlights the significant differences in soil properties affected by the quality of irrigation water that used during the cropping season.
Keywords **:** Irrigation water quality, soil fertility, nutrients, organic carbon, NPK, Murar block, Gwalior.

Introduction

Water is one of the most essential natural resources for sustaining life, and it is expected to become critically scarce in the coming decades due to rising demand, rapid population growth, and the increasing economy. It is important to measure water resources in terms of flow rates because of their dynamic and renewable nature, along with the ongoing need for sustainable management. Consequently, the value of water has been recognized, leading to a greater emphasis on its efficient use and management. The country's surface and groundwater resources are vital for various sectors, including agriculture, hydropower generation, livestock production, industrial operations, forestry, fisheries, navigation, and recreational activities. However, unplanned management practices, extensive industrial and agricultural development, and the discharge of untreated sewage, agricultural runoff, and other human and animal wastes into rivers, lakes, reservoirs, and other water bodies are continuously degrading the quality of water and the biological resources found within these ecosystems (Venkatesan, 2007; Elmaci *et al*., 2008).

The irrigation generates significant increases in agricultural production, especially in semi-arid areas where water is usually a limiting factor. However, in the long run, the use of low-quality water can cause soil degradation and decrease productivity. The use of medium-to-low quality irrigation water affected soil physical properties, generating infiltration and structural problems (Comino *et al*., 2020). In the agriculture practices the quality of irrigation water influences crop yield, soil properties, and water management in agricultural activities. Applying saline or sodic water, in particular, lowers agricultural production and degrades the physical and chemical characteristics of soil. In contrast using sewage water for irrigation improves soil fertility, but it also raises the amount of heavy metals in the soil. Soil pollution was caused by higher levels of bicarbonates, chlorides, sodium, potassium, and heavy metals in sewage water. In addition to enhancing soil qualities such as organic carbon, accessible N, P, and K status, and perhaps lowering fertilizer costs, the long-term use of sewage water for crop irrigation contaminates the soil and crop by introducing heavy metals (Ingole *et al*., 2023). The current study examines the effects of use of different source of wastewater and tubewell water for irrigation on soil properties and soil characteristics.

Material and Methods

Location and Climate

The study was conducted in years 2021-22 under Morar block of Gwalior district, which was situated at 26°14'15" N to 78°13'50" E in the North part of the Gwalior district, Madhya Pradesh (India); to study the effect of irrigation with different water sources (tube well and wastewater) on soil physical and chemical soil. The climate of the study area was semi-arid, with average summer maximum temperature is 45ºC, and winter minimum temperature lies to 2ºC.

Soil Sampling Ninety composite soil samples from 0-15,15-30, 30-45 cm soil depth respectively were collected from GPS located irrigated field of 10 villages under Morar block of Gwalior District.

Laboratory analysis: The research methods involved analysis of air-dried, sieved (2 mm) soil sample in labs for selected parameters. Soil bulk density (BD) was determined by the core method and particle density (PD) by the pycnometer method, while percent porosity was computed from BD and PD (Blake & Hartge, 1986). The chemical properties i.e. Soil pH and EC were determined in 1:2.5 soil–water suspension (Jackson, 1973), and organic carbon by Walkley and Black's method (1934). Available N was estimated by alkaline $KMnO_4$ method (Subbiah & Asija, 1956), P by Olsen's bicarbonate extraction (Olsen *et al*., 1954), and K by ammonium acetate extraction using a flame photometer (Jackson, 1973). Exchangeable Ca^{2+} and Mg^{2+} were determined by EDTA titration, while Na^{+} and K^{+} by flame photometry. Carbonates and bicarbonates were estimated by acid titration (Piper, 1966), chloride by argentometric titration (Richards, 1954), and sulphate turbidimetrically (Chesnin & Yien, 1950). The fertility index (FI) was computed using the categorization of low, medium, and high nutrient status following the method of Parker *et al.* (1951) as modified by Ramamoorthy & Bajaj (1969). For statistical analysis, mean, standard deviation, and coefficient of variation were computed for soil parameters with standard procedures (Gomez & Gomez, 1984; Panse & Sukhatme, 1985).

Study Area

The GPS location of soil sampling sits of Morar Block of Gwalior District (Table 1).

Table 1 : GPS location with sample code of soil samples collected

S.No.	Village name	Soil Sample Code	GPS location	Source of water (Tube- well/sewage)
1	Mohanpur	F1	N 26° 12' 37" E 78° 14' 11"	Tube well
		F2	N 26° 12' 39" E 78° 14' 09"	Tube well
		F3	N 26° 12' 40" E 78° 14' 12"	Tube well
2	Sonsa	F1	N 26° 10' 12" E 78° 16' 50"	Tube well
		F2	N 26° 10' 14" E 78° 16' 47"	Tube well
		F3	N 26° 10' 10" E 78° 16' 48"	Tube well
3	Tankoli	F1	N 26° 10' 12" E 78° 16' 50"	Tube well
		F2	N 26° 10' 14" E 78° 16'46"	Tube well
		F3	N 26° 10' 9" E 78° 16' 52"	Tube well
4	Baderafutker	F1	N 26° 08' 50" E 78° 23' 40"	Tube well
		F2	N 26° 08' 49" E 78° 23' 39"	Tube well
		F3	N 26° 08' 45" E 78° 23' 39"	Tube well
5	Laxmangarh	F1	N 26° 09' 44" E 78° 23' 37"	Tube well
		F2	N 26° 09' 46" E 78° 23' 35"	Tube well
		F3	N 26° 09' 48" E 78° 23' 33"	Tube well
6	Maharajpura	F1	N 26° 17' 10" E 78° 12' 59"	Tube well
		F2	N 26° 17' 08" E 78° 12' 64"	Tube well
		F3	N 26° 17' 12" E 78° 12' 62"	Tube well

7	**Rora**	F1	N 26° 07' 30" E 78° 15' 45"	Tube well
		F2	N 26° 07' 32" E 78° 15' 47"	Tube well
		F3	N 26° 07' 28" E 78° 15' 42"	Tube well
8	**Sunarpuramafi**	F1	N 26° 16' 38" E 78° 22' 54"	Tube well
		F2	N 26° 16' 40" E 78° 22' 56"	Tube well
		F3	N 26° 16' 36" E 78° 22' 52"	Tube well
9	**Jalalpur**	F1	N 26° 15' 44" E 78° 14' 51"	Sewage
		F2	N 26° 15' 45" E 78° 14' 53"	Sewage
		F3	N 26° 15' 43" E 78° 14' 54"	Sewage
10	**Jamahar**	F1	N 26° 16' 25"E 78° 10' 23"	Sewage
		F2	N 26° 16' 23" E 78° 10' 19"	Sewage
		F3	N 26° 16' 27" E 78° 10' 25"	Sewage

Results and Discussion

Ionic composition of tube well and sewage water

The ionic composition of tube well and sewage water of Morar block, Gwalior, revealed marked differences in the concentration of major cations and anions (Table 2). Variability was relatively lower, reflecting uniform sewage inputs. Overall, sewage water exhibited higher concentrations of Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, and SO_4^{2-} compared with tube well water, largely due to anthropogenic effluents. Bicarbonate dominance in both sources highlights carbonate weathering and organic matter decomposition, while elevated chloride and sulphate in sewage water indicate domestic contamination. These findings suggest that while tube well water shows natural variability, sewage water poses higher risks of salinity and alkalinity, requiring treatment before agricultural or domestic use (Abanyie *et al.*, 2023; Rao *et al.* 2021).

Table 2: Ionic composition of tube well and sewage water

Parameter	**Ionic composition tube well water (me L^{-1})**							
	Cations (me L^{-1})				**Anions (me L^{-1})**			
	Ca^{++}	**Mg^{++}**	**Na^+**	**K^+**	**CO_3^{2-}**	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**
Range	0.17-4.36	0.05-1.24	1.18-5.98	0.02-0.09	0.08-0.66	1.11-4.91	0.28-3.11	0.10-0.90
Mean	2.51	0.40	3.02	0.06	0.36	3.34	1.82	0.36
SD	1.15	0.30	1.52	0.02	0.14	1.04	0.73	0.23
CV (%)	45.87	74.00	50.23	30.69	37.35	31.04	40.38	62.38
	Ionic composition sewage water (me L^{-1}) of							
	Ca^{++}	**Mg^{++}**	**Na^+**	**K^+**	**CO_3^{2-}**	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**
Range	2.73-5.39	0.19-1.79	1.34-4.34	0.10-0.20	0.37-0.44	2.27-4.78	1.58-2.78	0.90-1.30
Mean	3.95	0.88	2.70	0.15	0.40	3.79	2.26	1.12
SD	1.03	0.64	1.44	0.04	0.03	1.08	0.49	0.13
CV (%)	26.06	73.22	53.49	28.18	06.70	28.62	21.92	11.90

Influence on soil Physical Properties of soil

The effect of irrigation sources on soil physical properties (Table 3) was reported slightly lower bulk density (1.22–1.33 g cm^{-3}) with mean values of 1.28–1.29 g cm^{-3} in sewage water irrigation. Particle density was relatively stable under both irrigation sources. Slightly higher values under sewage irrigation may be attributed to suspended solids and mineral enrichment. Porosity showed more pronounced variation. Tube well irrigation recorded porosity from 40.51–57.49%, while sewage irrigation-maintained porosity between 49.61–53.16%. Higher and more uniform porosity under sewage water reflects improved pore space and aeration. Overall, sewage irrigation reduced bulk density, enhanced porosity, and maintained stable particle density, thereby improving soil structure and supporting sustainable soil productivity. Similar results are also reported by Outhman, 2016 and Surajit *et al.*, 2015.

Table 3: Influence of irrigation sources on soil Physical Properties

Tube well water									
Particulars	**Bulk density**			**Particle density**			**Porosity (%)**		
Depth (Cm)	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Range	1.24-1.42	1.22-1.41	1.21-1.40	2.56-2.72	2.43-2.87	2.37-2.77	44.53-54.41	40.51-55.64	42.39-57.49
MEAN	1.33	1.32	1.31	2.65	2.62	2.54	49.69	47.73	49.65
SD	0.06	0.06	0.06	0.04	0.15	0.14	2.95	5.12	5.06
CV %	4.40	4.60	4.60	1.52	5.63	5.37	5.93	10.73	10.19
Sewage water									
Range	1.25-1.33	1.22-1.33	1.26-1.30	2.56-2.66	2.61-2.69	2.52-2.61	49.61-51.92	48.65-51.59	50.19-53.16
MEAN	1.28	1.29	1.28	2.60	2.66	2.58	50.61	50.20	51.81
SD	0.03	0.04	0.01	0.03	0.03	0.03	0.88	1.03	0.98
CV %	2.29	2.89	1.06	1.30	1.05	1.26	1.75	2.06	1.89

Influence on soil Chemical Properties

The influence of irrigation sources on soil chemical properties (Table 4) reported that, soil pH varied from 7.25 to 8.07 across different depths, indicating slightly alkaline conditions. Electrical conductivity (EC) ranged from 0.17 to 0.80 dS m^{-1}, suggesting moderate salt accumulation in the soil profile. Organic carbon (OC) content varied between 0.15% and 0.45%, with mean values of 0.36–0.41%, reflecting moderate fertility levels, under tube well irrigation. In soils irrigated with sewage water, pH remained relatively stable between. EC values were lower than those under tube well irrigation. Organic carbon was comparatively higher, ranging from 0.22% to 0.47%, with mean values of 0.31–0.42%. Overall, sewage water irrigation improved soil organic carbon compared to tube well water, while tube well irrigation contributed to higher EC, indicating a greater tendency toward salt accumulation. Similar findings were reported by Singh *et al.* (2012), indicating that the use of domestic wastewater along with fertilizers enhanced the chemical properties of the soil more effectively than the application of groundwater with fertilizers.

Table 4: Influence of irrigation sources on soil Chemical Properties

Tube well water									
Particulars	**pH**			**EC (dSm^{-1})**			**Organic Carbon (%)**		
Depth (cm)	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Range	7.25-8.07	7.32-8.15	7.38-8.30	0.17-0.67	0.25-0.68	0.25-0.68	0.19-0.39	0.20-0.41	0.15-0.36
MEAN	7.71	7.69	7.77	0.42	0.46	0.46	0.30	0.29	0.27
SD	0.26	0.27	0.27	0.19	0.15	0.15	0.05	0.05	0.06
CV %	3.39	3.45	3.54	44.01	31.77	31.81	18.01	18.68	21.02
Sewage water									
Range	7.62-7.72	7.56-7.73	7.67-7.77	0.33-0.35	0.36-0.42	0.36-0.42	0.36-0.48	0.24-0.42	0.22-0.36
MEAN	7.67	7.65	7.72	0.34	0.40	0.39	0.40	0.37	0.31
SD	0.05	0.08	0.04	0.01	0.02	0.02	0.05	0.07	0.07
CV %	0.63	1.08	0.58	2.88	6.11	6.07	11.52	17.81	21.55

Influence on soil fertility status

Application of sewage water markedly enhanced soil nutrient availability compared to tube well water. Available nitrogen, in particular, showed a distinct increase in the surface soil layer, with a mean value of 323 •kg •ha^{-1}, as reported by Kharche *et al.* (2011). This indicates that sewage irrigation can substantially improve soil fertility by supplying additional nutrients that are otherwise limited under tube well water. Available Phosphorus also showed notable enhancement. Sewage water recorded mean values of 20, 19.62, and 19.09 kg ha^{-1} across the three depths, which were almost double those under well water (11.68, 11.29, and 11.26 kg ha^{-1}). Lower coefficients of variation (2.37–5.00%) under sewage water suggested more uniform phosphorus distribution compared to tube well water (22.89–24.90%) (Gupta & Yadav, 2015). Available potassium followed a similar pattern, where sewage application resulted in 306, 282, and 254 kg ha^{-1} compared with 263, 280, and 246 kg ha^{-1} under tube well water. The lower CV values (5.06–7.93%) under sewage water further confirmed stable enrichment (Rattan *et al*., 2005). Overall, sewage water irrigation consistently increased available nitrogen, phosphorus, and potassium in the soil profile with reduced variability, demonstrating its superiority over tube well water in enhancing soil fertility (Singh *et al*., 2012 b).

Table 5: Influence of irrigation sources on soil Fertility Status

Tube well water									
Parameter ($kgha^{-1}$)	**Available nitrogen**			**Available phosphorus**			**Available potassium**		
Depth	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Range	181-294	176-278	157-275	7.78-16.15	7.69-16.16	7.62-16.09	185-360	178-354	168-343
Mean	229	221	209	11.68	11.39	11.26	263	250	242
SD	39.41	33.31	33.26	2.81	2.83	2.58	57.92	53.74	53.85
CV (%)	17.20	15.07	15.87	24.04	24.90	22.89	22.05	21.52	22.25
Sewage water									
Range	296-354	229-278	158-252	19.15-22.10	19.01-20.35	18.15-20.42	269-328	248-308	234-283
Mean	333	252	202	20.53	19.62	19.09	306	282	254
SD	20.20	21.33	34.81	1.16	0.66	0.84	15.49	21.04	20.16
CV (%)	6.07	8.47	17.27	5.64	3.37	4.40	5.06	7.46	7.93

Influence on Soil Fertility Index

The fertility index values obtained under tube well and sewage water irrigation revealed discrete variations in soil quality parameters across different soil depths (0–15, 15–30, and 30–45 cm). Under tube well irrigation, organic carbon (OC) content was found to be medium, nitrogen status low to medium, phosphorus and potassium were in medium range. In contrast, soils irrigated with sewage water showed relatively higher fertility indices, particularly in the surface layer (0–15 cm), where OC, nitrogen, phosphorus, and potassium reached medium to high levels (Figure 1). The fertility index under sewage water irrigation was categorized as medium to high, while under tube well irrigation, it remained medium to low. The improvement in fertility status under sewage irrigation may be attributed to the continuous addition of organic matter, suspended solids, and nutrients present in sewage water, which enriches soil fertility compared to tube well irrigation (Singh *et al.*, 2012a; Yadav *et al.*, 2015). Similar studies have demonstrated that wastewater irrigation not only improves nutrient availability but also increases crop productivity, though with long-term risks of heavy metal accumulation (Gupta *et al.*, 2014; Sharma & Minhas, 2005).

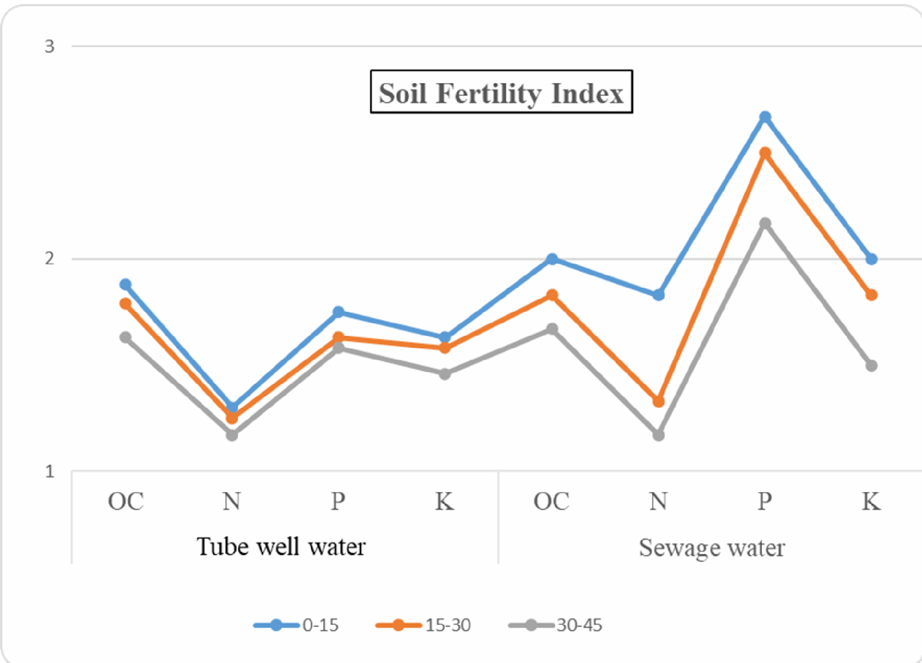

Fig. 1: Comparative Fertility index of Irrigated Soils

Conclusion

Study concluded that sewage water and tube well irrigation alter soil physical properties such as bulk density (BD), particle density (PD), and porosity, while influencing soil chemical parameters also. Variations were observed in pH, electrical conductivity (EC), and organic carbon content under different irrigation sources with respective depth of soil, which subsequently affected the nutrient status and fertility index of the soil. The regular monitoring of water and soil quality is therefore essential for maintaining soil health and ensuring sustainable crop production in the Murar block of Gwalior district.

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