

**“Evaluation of ground water quality and its
effects on soil properties in Morar block of
Gwalior”**

THESIS



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by

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2022

CERTIFICATE – I

*This is to certify that the thesis entitled “**Evaluation of ground water quality and effects on soil properties in Morar block of Gwalior**” submitted in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE in Soil Science and Agricultural Chemistry** of **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** is a record of the bona-fide research work carried out by **Mr. ASHOK SINGH, ID No. 20111303** under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of the investigation has been acknowledged by the scholar.

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Place: Gwalior

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LIST OF ABBREVIATIONS

<	:	Less than
>	:	More than
%	:	Percent
$^{\circ}\text{C}$:	Degree Celsius
B.D	:	Bulk density
CV	:	Coefficient of variance
Cm	:	Centimetre
dS m^{-1}	:	Deci simon per meter
EDTA	:	Ethylene diamine tetra acetic acid
ESP	:	Exchangeable sodium percentage
EC	:	Electrical Conductivity
<i>et al.</i>	:	Co-workers/ Other workers
e.g.,	:	For example,
etc.	:	And similar other things" or "and so on."
Fig.	:	Figure
ha	:	Hectare
i.e.	:	That is
Kg ha^{-1}	:	Kilogram per hectare
mg kg^{-1}	:	Milligram per kilogram
Mg	:	Milligram
mg g^{-1}	:	Milligram per gram
Me L^{-1}	:	Milliequivalent per litre

M	:	Moderate
m ha	:	million hectares
No.	:	Number
OC	:	Organic Carbon
P.D.	:	Particle density
pH_i	:	pH in irrigation water
RSC	:	Residual sodium carbonate
SD	:	Standard deviation
SAR	:	Sodium adsorption ratio
USDA	:	United State Department of Agriculture
USSL	:	United State Salinity Laboratory
Viz.	:	Videlicet – That is
V_s	:	Very slight
WHC	:	Water holding capacity



**DEDICATED TO MY
LOVABLE PARENTS**

Chapter-I

Introduction

Water is one of the most important natural resources for sustaining life, and it is anticipated to become critically short in the next decades as a result of rising demand, rapid population growth, and the country's increasing economy. Water resources must be measured in terms of flow rates due to their dynamic and renewable nature, as well as the ongoing requirement for their exploitation. As a result, the value of water has been recognized, and a greater emphasis has been placed on its efficient use and management. Agriculture, hydropower generation, animal production, industrial operations, forestry, fisheries, navigation, and recreational activities all rely heavily on the country's surface and groundwater resources. Unplanned management, massive industrial and agricultural development, and the discharge of untreated public sewage water, agricultural runoff, and other human and animal wastes into rivers, lakes, reservoirs, and other water bodies are continuously degrading the water quality and biotic resources of these bodies (Venkatesan, 2007; Elmaci *et al.*, 2008). The health of lakes, as well as their biological diversity, is linked to the health of nearly every component of the ecosystem (Indira and Sivaji, 2006; Krishnan *et al.*, 2007; Siddamallayya and Pratima, 2008). Human anthropogenic activities are the primary cause of nutrient increases such as phosphates, chlorides, and calcium, which eventually lead to eutrophication (Chukwu and Odunzeh, 2006; Shekhar *et al.*, 2008).

The trophic status of water bodies is influenced by their location and topography. Chlorophyll concentration, phosphorus, nitrogen load, and transparency have all been used to determine a lake's trophic state. The total weight of biomass in a specific water body at the time of measurement is the trophic condition. Nutrients play a crucial function in freshwater bodies because their excessive influx causes eutrophication. The lush growth of macrophytic flora is also a sign of a water body's trophic state. The current study focuses on the physio-chemical properties of water in the area of Gwalior. The primary goal

of water analysis is to identify the quality of irrigation water and its effects on the soil and, ultimately, the plants grown.

The presence and quantity of micro and macro nutrients, trace elements, alkalinity, acidity, hardness, and the number of suspended particles is all used to assess irrigation water quality. Poor-quality irrigation water has a negative impact on soil quality and crop yield. Plants get their nutrients, water, and support from the earth. The ability of the soil to provide sufficient amounts of water and nutrients, which is governed by its properties, determines its suitability as a medium for plant growth. As a result, soil property study in relation to plant growth has become a significant part of agriculture.

The management of problematic soil and the use of effective fertilisation processes are made easier with knowledge of soil attributes. Madhya Pradesh's natural soil, water, climate, and agrobiodiversity are all diversified. Agricultural production systems have been developed to meet the needs of a growing human population for food, fibre, and feed at the expense of the natural ecosystem, and factor productivity has been steadily declining in recent years. This is an indication that the current agricultural production system is ineffective. Soil resources are quickly depleting as a result of pollution and nutritional deficiencies, making it harder to carry out the core functions of complete life maintenance. Large swaths of fertile land in canal-irrigated areas are affected by soil salinity. Agriculture is no longer viable as a result of the sodicity and water logging.

According to the NBSS&LUP, Nagpur is home to 57.7% of India's degraded lands (187.7 MH). Water erosion affects 148.9 million hectares (79.3%), wind erosion 13.5 million hectares (7.2%), chemical degradation 3.78 million hectares (7.3%), and physical degradation 3.8 million hectares (7.3%). (1939, ISSS). A to fulfil the escalating demands of an expanding population. Unscientific management of soil and water resources, without systematic and long-term management of natural resources, particularly soil and water, is critical for agricultural and national economic development. In this setting, soil productivity is critical for strengthening agricultural expansion regard for long-term

sustainability, has had a negative impact on agriculture's rate of growth and productivity. As a result, there has been significant resource deterioration as well as substantial environmental problems. Over use and haphazard management of finite resources without respect for long-term viability have resulted in a variety of soil degradations that pose a threat to soil productivity and food security.

Given the foregoing factors, a thorough and well-planned investigation of the soil and irrigation water of this tract is required. The research will also aid with fertilizer.

Therefore, the proposed study "**Evaluation of ground water quality and its effects on soil properties in Morar block of Gwalior.**" has been proposed to investigate objectives listed below

Research Objectives-

1. To evaluate the irrigation water quality of Morar block of Gwalior district.
2. To evaluate the effect of irrigation water quality on soil properties.
3. To find out the inter- connection between quality characteristics of ground water and some selected soil properties.

Chapter-II

Review of Literature

The review of literature provides the abstract of research carried out in India and abroad related to present investigation entitled “**Evaluation of ground water quality and its effects on soil properties in Morar block of Gwalior**” conducted at Department of Soil Science and Agricultural Chemistry, College of Agriculture, RVSKVV, Gwalior. The reviews of research studies that have demonstrated spatial variability of water and soil properties and various methods/approaches that have been used to analyze spatial variability and then deals methodology for developing nutrient management. The review of literatures in this chapter are presented under following heads.

2.1 Quality of irrigation water

2.1.1 Salinity

2.1.2 Sodicity

2.1.3 Alkalinity

2.2 Effect of irrigation water on soil properties

2.3 Physical properties of soil

2.4 Fertility status

2.4.1 Physico-chemical properties of soils

2.4.2 Status and spatial distribution of macronutrients in soils

2.4.3 Organic carbon, Available N, P, K

2.1 Quality of irrigation water

Irrigation water contains dissolved elements in the form of cations and anions in general. The quality of irrigation water is determined by the concentration and composition of these dissolved elements. Water with a high proportion of divalent cations ($\text{Ca}^{2+} + \text{Mg}^{2+}$) over sodium (Na^+) and a lower concentration of carbonate and bicarbonate ions is considered to be of superior quality.

Kishor (2003) reported that the SAR and RSC values of irrigation waters of Rajgarh tehsil of Churu district ranged between 6.0 to 39.9(m.moles /l)^{1/2} and negative to 6.7 meL⁻¹, respectively. About 77 and 21 per cent water samples showed RSC <2.5 and 2.5–5.0 meL⁻¹, respectively.

Singh *et al.* (2006) investigated the quality of soil and ground water samples collected from 60 tube wells distributed at 60 sites of non-command area of Degana tehsil, Nagaur district, Rajasthan, India. Electrical conductivity (EC), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) of ground water samples varied from 1.25 to 9.66 dSm⁻¹, 6.3 to 35.2 and nil to 10.0 meL⁻¹, respectively. The water was mostly Na-Mg-Ca type with dominance of chlorides followed by carbonate + bicarbonates. Only 8.3 per cent of the water samples are of good quality. Approximately 16.7, 41.7, 5.0, 5.0 and 23.3 per cent water samples fell under marginally saline, high SAR saline, marginally alkaline, alkaline and highly alkaline, respectively.

Prasad *et al.* (2007) carried out the ground water quality survey to categorize underground irrigation waters of Mahboob Nagar district, Andhra Pradesh for irrigation suitability. A total of 1131 water samples were collected from 64 mandals during the year 2001, 2002 and 2003. Depth of water in the bore/open wells varied from 3 m to 60 m. Electrical conductivity of water samples varied from 0.3 to 8.5 dSm⁻¹, while the pH ranges from 6.3 to 9.4. Soluble carbonate, bicarbonates and RSC of these waters varied from nil to 11.2, 0.2 to 17.0 and nil to 16.1 meL⁻¹, respectively, while SAR varied from 0.1 to 27.1 (m mole L⁻¹)^{1/2}. Sodidity was more prevalent than salinity in the study area.

Shahid *et al.* (2008) reported that maximum number of underground water samples of Juana block in district Jind had EC between 1 and 2 dSm⁻¹. Sodium was the dominant cation followed by calcium and magnesium.

Tailor and Chandel (2010) assessed the physico-chemical parameters of ground water samples of Malpura block of Tonk district, Rajasthan (India). Ground water samples from hand pumps and tube wells of 15 sampling stations were analyzed during pre-monsoon (March-June, 2009) with the help of standard methods. The USSL diagram illustrates that most of the ground

water samples fall in the field of C_4S_4 (very high salinity hazard and very high alkalinity hazard) and C_3S_1 (high salinity hazard and low alkalinity hazard) classes.

Mahadevaswamy (2011) studied on quality of ground water of Nanjangud taluk, Mysore district of Karnataka. Water quality parameters of water samples were analyzed and results of analysis have been used to suggest models for predicting water quality. Based on water samples collected and analyzed from 50 locations, the hydrogeochemical facies in the area are found to be dominated by sodium-bicarbonate type.

Agarwal *et al.* (2013) studied hydro-chemical characteristics of ground water around Raiser district Bikaner to evaluate the suitability of water for irrigation and domestic uses. Ground water sample of twenty-four key wells of the study area were collected and analyzed for physico-chemical parameters. According to US Salinity Laboratory Diagram, almost 50 per cent water samples are lying under C_4S_2 , C_4S_3 and C_4S_4 category which indicates very high salinity and medium to very high SAR values indicating that these water samples are not suitable for irrigation purpose.

Rajput and Polara (2012) reported that well/tube well waters of Bhavnagar district (Gujrat) are poor in quality. Almost half of the samples of well/tube well waters from cultivated fields were saline (EC 0.75 dSm^{-1} and above). This is an indicated potential development of saline soils in Bhavnagar district.

Muhammad *et al.* (2013) collected 296 water samples from Layyah tehsil of and categorized according to the suitability criteria of water quality evaluation. Results showed that, 95 unfit water samples had electrical conductivity higher than permissible limit (*i.e.*, $>1250 \mu\text{S cm}^{-1}$), 12 samples were found with high SAR (*i.e.*, $>10 \text{ (mmol L}^{-1}\text{)}$), and 47 samples had high RSC (*i.e.*, $>2.5 \text{ me L}^{-1}$). Direct use of unfit irrigation water not only causes severe salinity/sodicity problems in soil but also depress plant growth to alarming level depending upon the extent of dissolved salts.

Narsimha *et al.* (2013) collected 18 groundwater samples from Hanmakonda area, Warangal district, (Andhra Pradesh) and analyzed for

various physical and chemical parameters. Majority of the samples (78 per cent) belong to C₃-S₁ water class, indicating water with high salinity and low sodium.

Singh *et al.* (2021) study that the groundwater quality in rural areas of Ujjain District of Madhya Pradesh, India, in order to check its suitability for drinking purpose, water quality analysis was done at seven time points during the two study years in six villages of Ujjain District, Central India. A total of 868 groundwater samples from 124 households were collected, and standard analytical methods were employed for analysis. Overall groundwater quality of the area is good and qualified for drinking. However, occurrence of high number of dissolved solids (> 800 mg/L) and hardness (>400 mg/L) is the issue of concern, as long-term use of such water might result in variety of health ailments, such as kidney stones and atopic dermatitis in children.

Sachin *et al.* (2021) reported was made to assess the ground water quality of different villages in Chikkamagalur block of Chikkamagalur district in Karnataka using various water quality parameters. The values of pH ranged from 6.3 to 8.0, while EC ranged from 0.10 to 1.10 dS m⁻¹. Sodium and potassium content in the irrigation water ranged from 0.13 to 3.83 and 0.10 to 5.12 meq L⁻¹, respectively. The Ca and mg content which indicate the hardness of the water and are the important cations was recorded between 0.60 and 5.85 meq L⁻¹. Chloride concentration varied from 4.40 to 11.2 meq L⁻¹, while bicarbonate ranged from 0.4 to 8.8 meq L⁻¹. Based on irrigation water quality index (IWQI), it was found that 87.5% of the water samples of the study area were poor in quality and slightly unsustainable for irrigation, while 8.3% was very poor and only 4.2% was good in quality for irrigation.

Table 2.1 Classification of irrigation water based on EC, SAR and RSC.

S. No.	Water quality	Symbol	EC (dS m ⁻¹)
A.	Salinity		
1.	Non saline water	C-0	<0.2
2.	Normal water	C-1	0.2-1.5
3.	Low salinity water	C-2	1.5-3.0
4.	Medium salinity water	C-3	3.0-5.0
5.	High salinity water	C-4	5.0-10.0
6.	Very high salinity water	C-5	>10.0
B.	Sodicity		SAR
1.	Non sodicity water	S-0	< 5
2.	Normal water	S-1	5-10
3.	Low sodicity water	S-2	10-20
4.	Medium sodicity water	S-3	20-30
5.	High sodicity water	S-4	30-40
6.	Very high sodicity water	S-5	>40
C.	Alkalinity		RSC (me L⁻¹)
1.	Non-alkaline water	A-0	Negative
2.	Normal water	A-1	0
3.	Low alkalinity water	A-2	<2.5
4.	Medium alkalinity water	A-3	2.5-5.0

5.	High alkalinity water	A-4	5.0-10
6.	Very high alkalinity water	A-5	>10

2.1.1 Salinity

The classification of irrigation water on the basis of EC is based primarily on the development of salinity in the soil to the extent that yields of crops are adversely affected. On the basis of electrical conductivity, the irrigation water may be classified into six salinity classes as proposed by Gupta (1986).

C-0 non-saline waters ($EC < 0.2 \text{ dSm}^{-1}$) may create severe permeability problem in the soil because infiltration rate into the soil is adversely affected due to lack of salts in the water to such an extent that the crop is not adequately supplied with water and yield is reduced.

C-1 Normal water ($EC 0.2-0.5 \text{ dSm}^{-1}$) can be used for irrigation for most crops on most soils with little likelihood that soil salinity will develop.

C-2 Low salinity waters ($EC 1.5-3.0 \text{ dSm}^{-1}$) can be used if a moderate amount of leaching occurs under the current irrigation practices. Most of the crops except sensitive ones can be grown on all soils except very heavy textured soils with impeded drainage.

C-3 Medium salinity waters ($EC 3.0-5.0 \text{ dSm}^{-1}$) can be used on soils provided with good drainage such that leaching fraction (L.F.) is not less than 0.3. Most of the semi-tolerant and tolerant crops can be grown under good management. These waters may have moderate problem on high SAR and RSC.

C-4 High salinity waters ($EC 5.0-10.0 \text{ dSm}^{-1}$) are suitable for irrigation on soils provided with very good drainage such that leaching fraction is always greater than 0.3, so the EC_e does not exceed EC_{iw} . Only salt tolerant crops can be grown under good management. These waters may have the problem of high SAR but no problem due to RSC.

C-5 Very high salinity waters ($EC > 10 \text{ dSm}^{-1}$) are directly not suitable for

irrigation but may be used in conjunction with low salinity waters.

2.1.2 Sodicty

The classification of irrigation waters with respect to sodic hazard on the basis of SAR is based primarily on the increase of exchangeable sodium and its effect on the physical condition of the soil. On the basis of SAR, the irrigation waters may be classified in six classes as proposed by Gupta (1986).

S-O Non-sodic waters (SAR <5) can be used for irrigation on almost all soils for all crops even those sensitive to sodium.

S-1 Normal waters (SAR 5-10) can be used for irrigation on almost all soils with little danger of the development of harmful level of exchangeable sodium for growing all crops except sensitive to sodium.

S-2 Low sodicity waters (SAR 10-20) can be used for crops which are semi-tolerant or tolerant to sodium on almost all soils such that leaching fractions (L.F.) is around 0.3. If there is a presence of gypsum or calcium carbonate in the soil, these waters can be used more successfully.

S-3 Medium sodicity waters (SAR 20-30) can be used only or crops which are tolerant to sodium on soils provided with good drainage such that leaching fractions (L.F.) is always greater than 0.3.

S-4 High sodicity waters (SAR 30-40). These waters are directly not suitable for irrigation but may be used in cycle or in conjunction with low sodicity waters or with the use of amendments such as gypsum.

S-5 Very high sodicity waters (SAR > 40). These waters are directly not suitable for irrigation without drastic treatment.

2.1.3 Alkalinity

The alkalinity hazard is based on RSC and primarily caused by the precipitation of Ca^{2+} or Mg^{2+} due to ion pairing with CO_3^{2-} or HCO_3^- increasing residual sodium carbonate as Na_2CO_3 in the soil and increasing SAR/ESP, characterizing it as alkali soil. On the basis of RSC, the irrigation water may be classified in six classes as proposed by Gupta (1986).

A-0 non-alkaline waters (RSC negative) can be used for irrigation on almost all soils for all crops for indefinitely long periods without any problem.

A-1 Normal waters (RSC 0 meL⁻¹) can be used for irrigation on almost all soils for all crops even those were sensitive to carbonates or bicarbonates.

A-2 Low alkalinity waters (RSC < 2.5 meL⁻¹) can be used for irrigation on almost all soils for all crops.

A-3 Medium alkalinity waters (RSC 2.5-5.0 meL⁻¹) can be used for irrigation on almost all soils with little danger of the development of harmful levels of alkali for growing all crops except sensitive to carbonates or bicarbonates.

A-4 High alkalinity waters (RSC 5.0-10.0 meL⁻¹) can be used for irrigation on soils provided with good drainage such that leaching fractions (L.F.) is not less than 0.3 for growing semi tolerant and tolerant crops to sodium. EC should be < 3.0 dSm⁻¹ and < 10 SAR.

A-5 Very high alkalinity waters (RSC > 10.0 me L⁻¹) these waters are directly not suitable for irrigation but may be used in conduction with low alkalinity waters or with the use of amendments like gypsum.

Parhad *et al.* (2018) reported that the calcium carbonate in soils of Sindkheda tehsil of Dhule district ranged from 7.75 to 16.0 per cent with an average of 10.77 per cent. Out of total soil samples, 75 (37.31%) soil samples were high in calcium carbonate content and 126 (62.69%) soil samples in very high category. A highest calcium carbonate was (16.0%) in soil collected from Mandal village (21018.246|N-074034.469|E) and the lowest (7.75%) in soil samples at Bramhane village (21020.572|N074037.220|E). A similar nature of observation for CaCO₃ in soils of Shevgaonn tehsil of Ahmednager District was reported by Dhage *et al.* (2000). Out of total soil samples, 126 (62.69%) soil samples were under very high category. The calcareousness of soils is common feature in soils of arid and semi-arid climate particularly in Vertisols (black soils) due to precipitation of carbonates and bicarbonates under water stress.

2.2 Effect of irrigation water on soil properties

Kanwar and Kanwar (1968) concluded that increase in EC of irrigation water lowered the pH of saturation paste. The decrease in pH values with an increase in salt concentration of irrigation water was also reported by Lal and Lal (1980), Deo and Lal (1982) and Mali (1985). Sharma (1991) observed that pH of soil tended to decrease significantly with the increase in level of EC of irrigation water.

Khandelwal and Lal (1991) investigated that increasing levels of EC of irrigation water increased the EC of soils. Similarly, Lal *et al.* (1998) pointed out that EC of soil was significantly and positively correlated with the EC of irrigation water.

Girdhar (1996) observed that soil pH and ESP increased significantly with the increase in RSC of irrigation water and its adverse effect become additive at high SAR.

Prasad *et al.* (1996) revealed that soil pH increased gradually with increase in RSC of irrigation water.

Ram (1998) reported a highly significant positive correlation between EC of soil and EC of irrigation water.

Sharma and Minhas (1998) observed that pH of silt loam soils increased initially and stabilized after 3 years of irrigation with sodic waters, whereas, sodicity and salinity continued to increase during the experimental period.

Halliwell *et al.* (2001) the effects of wastewater sodium on soil physical properties, particularly with respect to irrigation systems. Fundamental sodicity concepts are examined including sodicity definitions, the effects of sodium on soil properties, a discussion of factors that impede the infiltration rate and hydraulic conductivity, the changes that occur in ionic strength of percolating water in soil, and consideration of the wastewater and soil constituents that modify the effective sodium adsorption ratio. Importantly, the ability for soils to assimilate wastewater over time changes, but these changes are not often considered prior to the planning of such irrigation systems, or after the irrigation systems are operating. The general lack of understanding of sodicity is

in part due to the considerable variation in sodicity definitions. Exchangeable sodium percentage (ESP) values that are reported to pose a sodicity problem vary around the world due to the different mineralogy of the soils investigated, but variations in threshold ESP values have also been caused by a lack of consideration of the solution electrolyte concentration when determining ESP. In practice, the effects of sodicity may be evident in soils that are well under reported threshold values. When the effects of sodicity are identified, the landholder at least has the opportunity to implement remediation practices. However, more often than not, the effects of sodium from irrigation water are latent, leading to considerable problems following the cessation of effluent irrigation and changed land use.

Sharma and Pal (2001) conducted a greenhouse experiment on a sandy loam soil continuously for two years with water of high SAR (12.5, 25.0, 37.5) and concluded that pH of soil increased significantly (8.54, 9.00 and 9.28, respectively) with increasing SAR of irrigation water.

Bagoria (2002) observed an increase in pH value with an increase in SAR of irrigation water.

Ram (2003) reported that pH of soils and pH of irrigation water had significant positive correlation with SAR of irrigation water and soil and increased in RSC content of irrigation water. The pH of soil held negative correlation with EC ($r = -0.166$) of irrigation. The pH values of irrigation waters and soil solution are mostly governed by the amount and proportion of carbonates and bicarbonates ions.

Sharma (2005) reported that the pH of soil increased with the increase in SAR and Adj. SAR of irrigation water.

Abedi-Koupai *et al.* (2006) this study was carried out to investigate the effect of treated wastewater on soil chemical and physical properties. Field experiment was conducted in Borkhar region in Isfahan province in central Iran with two water treatments of wastewater and groundwater under sprinkler and surface irrigation systems for three crops of sugar beet, corn and sunflower. Soil samples were collected to 120 cm depth to

determine concentration of lead (Pb), manganese (Mn), iron (Fe), cadmium (Cd), nickel (Ni), cobalt (Co), copper (Cu) and zinc (Zn). Irrigation systems had no significant effect on extractable heavy metals in soil. The accumulation of Pb, Mn, Ni and Co in the soil increased significantly in the wastewater treatment as compared to the groundwater treatment. The accumulation of Pb, Mn, Ni, Co, Cu and Zn decreases with the soil depth. Treated wastewater showed no effect on the increase of Fe, Cd, Ni, Cu and Zn during growing season. The irrigation system had a significant effect on infiltration rate, bulk density and total porosity. Under sprinkler irrigation system the infiltration rate increased significantly.

Avnish (2010) to investigate the nutrient value of bottom soil pH, conductivity, potassium, exchangeable potassium, total phosphorus, available phosphorus, organic carbon, total nitrogen, available nitrogen, calcium and magnesium were analyzed from monthly samples collected from six sampling stations during two years of study, that is, April 2002-March 2004 of study. Soil from station A was found unpolluted due to low level of pollution load and less human activities. While at other stations sewage and municipal wastes increased the amount of calcium, magnesium and other nutrient.

Khurana and Singh (2012) paucity of quality fresh water for agriculture has made waste water (WW) application a popular option. Available data on chemical composition of different waste water, their effect on soil fertility, soil heavy-metal content, crop yield and quality parameters and maximum permissible limits (MPL) of different international environment protection agencies and governments of different countries has been summarized. Chemical composition of WW varied remarkably with respect to their heavy-metal content, pH, electrical conductivity (EC), biological oxidation demand (BOD), chemical oxidation demand (COD), alkalinity and hardness. Field application of all types of waste water significantly increases soil OC percentage, soil EC, cation exchange capacity (CEC), total and DTPA-extractable heavy-metal/ micro-nutrient

content, available macro-nutrient (N, P and K) content with significant decreases in calcium carbonate content of surface soil. However, high content of nitrogen, phosphorus and potassium strengthens its high fertigation/ manural value for field crops. Significantly higher heavy-metal accumulation in soils irrigated with WW than ground water has been observed in surface layer than the lower depths of soil profile. Since crop genotypes and even crop cultivars within genotypes respond differently to waste water irrigation, their selection becomes more important under such situations. More importantly, carbon sequestration through WW irrigation could sustain long-term soil fertility. Periodic monitoring of chemical composition of waste water, soil and crop produce is however, suggested for safe and long-term use of waste water.

Singh and Agrawal (2012) the present study deals with the assessment of changes in physical and biochemical characteristics of soil and metal partitioning in *Beta vulgaris* L. grown in farmer's fields irrigated with waste water in Dinapur and Lohta areas of Varanasi, India, during December to February, 2007–2008 and 2008–2009. Nutrient concentrations, organic carbon, microbial biomass, C, N, and P, enzymatic activities and heavy metal concentrations in soil and plant parts were estimated at waste water (DW₁, DW₂ and LW) and clean water-irrigated sites (DC and LC). Sites receiving waste water irrigation showed an increase in organic C by 36 and 64 % and in available phosphorus by 15 and, 21 % at DW₁ and DW₂ sites compared to DC and 88 and 29 % at LW compared to LC during the first year. Dehydrogenase and urease activities increased two to threefold at waste water-irrigated sites compared to the respective clean water-irrigated ones during both the years of study. Microbial biomass (C, N, and P) and concentrations of exchangeable cations (Na⁺, K⁺ and Ca²⁺) also showed increments varying from two to threefold at waste water-irrigated sites. During both the years, total heavy metal concentration in soil was the highest for Mn followed by Zn, Pb, Ni, Cu, Cr, and Cd at Dinapur, whereas at Lohta the trend was Mn, Zn, Cr, Pb, Cu, and Cd. The accumulation of heavy metals in the plants was several-fold higher in roots and shoots at waste water-irrigated sites, and Cd, Pb, and Ni were above the safe limits in edible tissues. Lower metal concentrations were recorded at DW₁ site

compared to DW₂ and LW sites. The study suggests that waste water irrigation led to beneficial changes in physico-chemical and biological properties of the soil, but increased the soil contamination of heavy metals. However, the intermittent use of clean water in such areas may not only reduce the metal contamination in the plants but will also maintain soil fertility.

Alghobar *et al.* (2014) use of sewage water for irrigation improved chemical properties and fertility status in soil. Sewage water contains elements essential for plant growth and also contains heavy metals which may be toxic for animals if their concentration exceeds than permissible limit. To monitor this situation, a survey was conducted to ascertain the addition of heavy metals into agricultural fields through sewage water irrigation for grass crop in the farmlands of selected areas of Vidyaranyapuram in Mysore city. The results indicated that in sewage water the permissible amounts of total N, total P and potassium which are considered essential nutrients for productivity levels (grass growth) and soil fertility. The concentrations of heavy metals in the sewage water were in the proposed Food and Agriculture Organization range. The analysis showed that in soil concentration the irrigation with sewage water (SW) and treated sewage water (TSW) induces significant ($P < 0.05$) decrease of soil pH when compared to MW and control treatment GW. The SW and TSW affect significantly the EC. Indeed, in comparison with groundwater (GW), EC is greater with SW and TSW treatment. For Major elements contents and fertilizer as observed in the irrigation with SW led to a significant increase of Ca, Na, N, P, K and SO₄ in comparison with the control ground water (GW). For Cl, in irrigation with SW has no effect on the Cl of soil. For heavy metals in comparison to the standard, the SW has no a significant ($P < 0.05$) effect in all elements except significant increase was noticed for Fe. In the grass, our investigation showed that irrigation with SW reuse led to a significant increase ($P < 0.05$) of N, P, K, Ca, Mg and Na contents. Heavy metals shown in grass irrigated with sewage water (SW) caused a significant increase ($p < 0.05$) of Fe, Mn, Cu, Zn and Pb as compared to irrigated ground water (GW). Where was no significant effect in growth of the grass as shown for heavy metals concentrations as Cd, Ni,

Co and Cr.

To effectively utilize water and soil resources and address water and soil concerns, a comprehensive assessment of water and soil quality is required. Rajasthan's semi-arid and dry regions demand the use of additional water to maximise crop output. The majority of tube well waters are high in salts, and their continued use for irrigation has a negative impact on agricultural output and soil deterioration. It is necessary to increase the better crop production in that area. It necessitates continuous monitoring of ground water for assessing the possible damage on salinity and alkalinity induced soil health. Salinity and sodicity are known to influence physiological, biochemical and morphological changes in plants, which reflect on overall performance of the plant. Generally, these changes due to salinity stress may adversely affect the plant growth and metabolism. However, under such conditions some plant species may thrive and yield better than other species by effectively adjusting or modifying their metabolism.

Since, the characterization of soil health parameters is lacking in the study area under the influence of underground irrigation water which is essential for better utilization of soil and irrigation water to obtain satisfactory yield by modifying the cultural practices in accordance with the nature of soil and quality of water. The present investigation, therefore, implies impact of quality of ground water irrigation on soil health in Jaipur district.

2.3 Physical properties of soil

Bhuyan *et al.* (2014) studied on soils of Lakhimpur district of Assam and their relationship with different physicochemical properties of soils and found that the soils varied from sandy to clay. Sand, silt and clay content varied from 4 to 88, 4 to 68 and 4 to 68 per cent, respectively.

Nath (2015) studied the roadside tea cultivated soils in Dibrugarh district of Assam, India. and reported the sand, silt and clay content of soil samples varied from 72.80 ± 6.71 to 73.27 ± 6.56 , 5.02 ± 0.37 to 5.18 ± 0.48 and 21.56 ± 6.08 to 22.18 ± 6.34 %, respectively.

Singh *et al.* (2017) reported that the relative high pH of the soils might be due to the presence of high degree of base saturation. The pH, electrical conductivity, organic carbon, B.D., P.D. and Water holding capacity of the soils varied from 7.23-8.03, 0.32 to 0.82 dSm⁻¹, 0.24 to 0.49%, 1.21-1.41 Mg M⁻³, 2.09-2.57 Mg M⁻³ and 4.42-76.55 % with a mean value of 7.68, 0.62 dSm⁻¹, 0.33%, 1.32 Mg M⁻³, 2.27 Mg M⁻³ and 44.43 % respectively. Available N content varied from 241.75-335.26 kg ha⁻¹; available phosphorus content varied from 20.83 to 31.65 kg ha⁻¹, available Fe content of these soils was ranged from 3.34 to 4.99 mg kg⁻¹ and 40% deficient iron content in soils of Chambal region.

Khadka *et al.* (2018) assessed particle size distribution of the soils and showed that sand content ranged from 15.6 to 41.1% with a mean of 24.41 %. Clay content ranged from 14.8 to 26.2% with a mean of 21.03 %, while silt content ranged from 40.8 to 63.2 % with a mean of 54.57 %

2.4 Fertility status

2.4.1 Physico-chemical properties of irrigated soil

Srinivasarao *et al.* (2009) studied the relationships of 1/3 and 15 bar and available water content with soil physiological properties. 147 soil samples collected from 21 profiles from rainfed regions of country. Results indicated that number of profiles showed an increasing trend in water retention with increase in soil depth. Reduction in water retention from 1/3 bar to 15 bar was greater in Entisols/Inceptisols, Oxisols/ Alfisols and Aridisols than in Vertisols. Amount of clay and CEC showed significant positive correlation.

Sharma (2010) conducted an experiment on water retention characteristics of salt affected soils of Bhilwara, Rajasthan. He analyzed 26 pedons at different depths and collected soil samples. Results showed that water retention characteristics are associated with texture of soil. Soils with lowest sand and highest clay showed highest water retention at 0.033 MPa.

Pulakeshi *et al.* (2012) reported the pH of soils of Mantagani village in north Karnataka was slightly acidic to alkaline in nature. Plant Available

nitrogen (low; 93% area), available phosphorus (low; 24% area, medium; 76% area) was generally low to medium and available potassium and sulphur were low to high.

Pramod *et al.* (2013) reported that the surface and subsurface soil samples of Muzaffarnagar district were collected to characterize their chemical properties. The pH value of study area varied from 6.02 to 8.39 and 6.35 to 8.50, electrical conductivity from 0.069 to 0.390 and 0.73 to 1.10 dSm^{-1} , organic matter content 7.241 to 15.221 and 3.695 to 10.179 g kg^{-1} for surface and subsurface soils, respectively.

Sharma *et al.* (2015) reported that, pH of Vertisols of Nignoti village varied from 7.0 to 8.0, EC ranged from 0.11 to 1.09 dSm^{-1} and SOC varied from 0.23% to 0.80%. In general, the SOC status was low to medium.

Behera *et al.* (2016) reported that the soils of south Goa and north Goa were acidic to neutral in reaction. Other soil properties (EC and OC) varied widely in both the soil layers in soil properties.

Patidar *et al.*, (2017) conducted an experiment during the *kharif* seasons of 2014-15 under All India Coordinated Research Project for Dry land Agriculture at College of Agriculture, Indore Madhya Pradesh to study the major nutrient and others. Soil pH varied from 7 to 8 with a mean value of 7.5. EC of soil water suspension ranged from 0.17 to 0.86 dS m^{-1} with a mean value of 0.37 dS m^{-1} . The variation in organic carbon content in this soil was from 0.23% to 0.80% with a mean value of 0.53%. In general, the organic carbon status of Ralyawan village soils of was low to medium.

Bala *et al.* (2018) reported that the pH value of soils of Golpura village of 7.25 EC of soil of 0.36 dS m^{-1} and available organic carbon content value of 0.55%. The available micro nutrient content of Zn, Fe, Mn and Cu content of 0.58 mg kg^{-1} , 6.0 mg kg^{-1} , 2.87 mg kg^{-1} and 0.38 mg kg^{-1} , respectively.

Lohiya *et al.*, (2018) reported that the concluded from the above results on soils Golpura village in Dhar district of Madhya Pradesh were characterized under neutral to alkaline in soil reaction (pH) and less than one dSm^{-1} soluble salt (EC) comes under safe limit for soils. The organic carbon

level exhibited low to medium status and positively significant correlation is exhibited amongst OC. The study of concluded that, soils of Golpura village in Malwa Plateau Agro climatic western zone of Madhya Pradesh are low in soil available organic matter content, Soil organic carbon, are important soil nutrients constraints indicating their immediate attention for sustained crop production.

2.4.2 Salinity and alkalinity indices of soil

Accumulation of soluble salts in soils takes place due to irrigation with saline water, evaporation and impeded internal drainage. Accumulation of salts in soil is dependent on soil type, temperature and salt composition of irrigation water. Muhr *et al.* (1965) and Seth (1967) classified the salt affected soils based on salinity and alkalinity indices. The limits and ratings for salinity and alkalinity are given in table 2.2 and table 2.3.

Table: 2.2 Limits for salinity and alkalinity classes (Muhr *et al.*, 1965)

Classes	Electrical conductivity (dSm ⁻¹)	Classification	pH range	Classification
A	<1.0	Normal	<8.0	Normal
B	1.0-2.0	Tending to become saline (Critical for germination)	8.0-8.5	Alkaline
C	2.0-3.0	Saline (Critical for growth of salt sensitive crops)	8.5-9.0	Very alkaline (Soil tending to become alkali)

D	>3.0	Highly saline (Injurious for most of the crops)	>9.0	Highly alkaline (Alkali soils)
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Table: 2.3 Rating chart of salinity and alkalinity indices (Seth, 1967)

Index	Rating for salinity	Rating for alkalinity
<1.5	No salinity problem	No alkalinity problem
1.5-2.5	Mild salinity problem	Slight alkalinity problem
2.5-3.0	Moderate salinity problem	Moderate alkalinity problem
>3.0	Severe salinity problem	Severe alkalinity problem

Sehgal *et al.* (1987) classified salt affected soils on the basis of salinity and alkalinity hazards. The limits for salinity and alkalinity groups are given table 2.4.

Table: 2.4 Limits for salinity and alkalinity groups (Sehgal *et al.*, 1987)

Groups	Salinity classes		Alkalinity classes		
	EC (dSm ⁻¹)	Classification	Groups	pH	Classification
Vs	0-2	Very slight	S	7.3-8.3	Slight to Negligible
S	2-4	Slight	M	8.3-9.0	Moderate
M	4-8	Moderate	St	>9.0	Strong
St	8-15	Strong	-	-	-

Fertility status

Fertility status and nutrient index of soils have been given by different workers *viz*, available nitrogen, (Subbiah and Asija, 1956), organic carbon,

available phosphorus and available potassium (Muhr *et al.*, 1965) into low, medium and high classes as given below in Table 2.4.

2.4.3 Organic carbon, Available N, P, K

Bali *et al.* (2010) indicated that the available K and P ranged from 33.6 to 1192 kg ha⁻¹ (mean = 280.57 kg ha⁻¹) and 1.12 to 23.8 kg ha⁻¹ (mean = 42.77 kg ha⁻¹), respectively.

Chaudhari *et al.* (2012) studies that almost all samples were found to be deficient in N, while P and K varied from low to high in soils of Haridwar (Uttarakhand).

Ganorkar and Chinchmalatpure (2013) reported that the pH, OC, available N, P and K in the soil samples collected from Amravati district ranged from 7.80-8.46, 1.25-1.69%, 219-298 kg ha⁻¹, 18.5-25 kg ha⁻¹ and 445-648 kg ha⁻¹, respectively.

Begum and Khan (2014) reported that the EC value of soil significantly ($p < 0.05$) increased with application of saline water and the available nitrogen content 16.18 per cent and phosphorous content 19.23 per cent increase in soil at maturity stage with increased level of salinity, but available sulphur content 18.33 per cent decrease with the increase level of salinity as compared with control.

Singh *et al.* (2015) reported 15.6 to 410 mg kg⁻¹ of total P and 0.29 to 30.6 mg kg⁻¹ of available P in soils of south-central Missouri, USA. Tundup *et al.* (2015) reported that the pH, EC and OC of the soils of Kishtwar district varied from 6.65-7.47, 0.15-0.23 dSm⁻¹ and 5.8-8.1 g kg⁻¹ with mean values of 7.26, 0.19 dSm⁻¹ and 6.8 g kg⁻¹, respectively. They also reported the available N and P was varied from 280 to 385 and 12 to 20 kg ha⁻¹ with mean values of 331 and 15.3 kg ha⁻¹, respectively.

Chauhan *et al.* (2015) reported that majority of soil samples (77%) were poor in total nitrogen, 51% were deficient in available phosphorus, while exchangeable potassium was adequate in soils of Taluka Ghora Bari district Thatta.

Mustafa *et al.* (2016) reported that six pedons of the Kheragarah tehsil of Agra district were studied soils were low in available N (72.0 to 220.0 kg ha⁻¹), low to high in available P (3.7–15.0 kg ha⁻¹) and medium to high in available K (153.0 - 361.6 kg ha⁻¹). However, the soils were adequate in available Fe and Mn but low in available Zn and Cu content.

Singh and Benbi (2016) that studied on soil health and results revealed average soil pH to be 8.2, EC 0.27 dSm⁻¹, organic carbon 0.49 per cent, available phosphorus content 17 mg kg⁻¹ soil, and available potassium content 171 mg kg⁻¹ soil.

Pathak *et al.* (2017) reported that the available nitrogen in the Inceptisol and Vertisol of Gwalior district is 219.3 and 222.6 kg ha⁻¹, respectively and available –P value of 11.3 and 12.1 kg ha⁻¹, respectively. About 90 % soil samples were found to be under low rating (< 250 N kg ha⁻¹) and remaining in the category of medium (250-500 N kg ha⁻¹). Considering 2.0 mg kg⁻¹ as critical limit for Mn deficiency, all the soil samples were found under sufficient category.

Singh *et al.* (2017) reported that the relative high pH of the soils might be due to the presence of high degree of base saturation. The pH, electrical conductivity, organic carbon, B.D., P.D. and Water holding capacity of the soils varied from 7.23-8.03, 0.32 to 0.82 dSm⁻¹, 0.24 to 0.49%, 1.21-1.41 Mg M⁻³, 2.09-2.57 Mg M⁻³ and 4.42-76.55 % with a mean value of 7.68, 0.62 dSm⁻¹, 0.33%, 1.32 Mg M⁻³, 2.27 Mg M⁻³ and 44.43 % respectively. Available N content varied from 241.75-335.26 kg ha⁻¹; available phosphorus content varied from 20.83 to 31.65 kg ha⁻¹, available Fe content of these soils was ranged from 3.34 to 4.99 mg kg⁻¹ and 40% deficient iron content in soils of Chambal region.

Kumar *et al.* (2020) reported that the soil samples were collected from three villages (Parasai, Chhatpur and Bachhauni) of watershed site-I of Jhansi district (U.P.), three villages (Shivrampur, Kundar and Dabar) of Tikamgarh district (M.P.) of watershed site-II and two villages (Ganeshgarh and Nayakhera) of Jhansi district (U.P.) as control site. The soils were slightly (pH: 7.3-7.8) to moderately alkaline (pH: 7.8-8.4). The organic carbon status

ranged from low to medium and available nitrogen (N) was found mostly in low category. The soil available phosphorus (P) was low to medium; available potassium (K) in medium range; and available sulphur (S) in low category.

Sashikala *et al.* (2021) studies that the GIS and GPS based two hundred fifty geo-referenced surface soil samples (0-15 cm) from Tatrakallu village located Scarce Rainfall Zone of Andhra Pradesh were collected at 250 m grid interval and analyzed for their fertility parameters. Analytical data was interpreted and statistical parameters like range, mean, standard deviation and coefficient of variation were calculated. Soil fertility maps were prepared for each parameter under GIS environment using Arc GIS v 10.3. Soils were neutral to strongly alkaline (6.49-8.90) in reaction, non-saline (0.01-0.84 dS m⁻¹) and low to medium (0.3-7.0 g kg⁻¹) in organic carbon. The soils were low to medium in available nitrogen (13-266 kg ha⁻¹) and low to high in available phosphorus (2.0-91.0 kg P₂O₅ ha⁻¹) and available potassium (0.4-628 kg K₂O ha⁻¹) and deficient to sufficient in available Sulphur (0.1-50.1 mg kg⁻¹).

Chapter - III

MATERIAL AND METHODS

The present investigation entitled “**Evaluation of ground water quality and its effects on Soil properties in Morar block of Gwalior**” was carried out during 2021-22. The general description of area including materials used and methods followed during the course of investigation are presented in this chapter under the following headings:

3.1 Description of the study area

3.1.1 Location

For the present investigation, Morar block of Gwalior district were selected for study area, which are situated at 26°14'15" N to 78°13'50" E in the North part of the Gwalior district. With 663 ft. Elevation in the NE (lowest) to 1360 ft. in the SW (highest). Height increases from east to west. The district has an area of 456.4 ('000 ha). The Gwalior District is bounded by the districts of Bhind to the northeast, Datia to the east, Shivpuri to the southwest, Sheopur and Morena to the northwest. The location of the sites from where water and soil samples collected were marked is shown in fig:3.1

3.1.2 Climate

The climate of the study area is semi-arid. In summer average maximum temperature is 45⁰C, where in winter minimum temperature lies to 2⁰C. The area studied Gwalior district is located at the center of the Gird region of Madhya Pradesh. The mean annual rainfall of the locality is 751 mm. Main source of irrigation is canal/tube well. The winds are generally low and variable during winter and start building up from March on wards and become strongest during the month of May-June.

Table:3.1 List of villages of Morar block of Gwalior along with their GPS location and code used from where water and soil samples were collected

S.No.	Village name	Soil Sample Code	GPS location	Water Sample Code	GPS location	Source of water (Tube-well/sewage)
1	Mohanpur	F1	N 26° 12' 37" E 78° 14' 11"	F1	N 26° 12' 35" E 78° 14' 09"	Tube well
		F2	N 26° 12' 39" E 78° 14' 09"	F2	N 26° 12' 33" E 78° 14' 06"	Tube well
		F3	N 26° 12' 40" E 78° 14' 12"	F3	N 26° 12' 30" E 78° 14' 09"	Tube well
2	Sonsa	F1	N 26° 10' 12" E 78° 16' 50"	F1	N 26° 10' 10" E 78° 16' 40"	Tube well
		F2	N 26° 10' 14" E 78° 16' 47"	F2	N 26° 10' 08" E 78° 16' 36"	Tube well
		F3	N 26° 10' 10" E 78° 16' 48"	F3	N 26° 10' 06" E 78° 16' 40"	Tube well
3	Tankoli	F1	N 26° 10' 12" E 78° 16' 50"	F1	N 26° 10' 08" E 78° 16' 45"	Tube well
		F2	N 26° 10' 14" E 78° 16' 46"	F2	N 26° 10' 09" E 78° 16' 41"	Tube well
		F3	N 26° 10' 9" E 78° 16' 52"	F3	N 26° 10' 09" E 78° 16' 40"	Tube well
4	Baderafutker	F1	N 26° 08' 50" E 78° 23' 40"	F1	N 26° 08' 50" E 78° 23' 40"	Tube well
		F2	N 26° 08' 49" E 78° 23' 39"	F2	N 26° 08' 49" E 78° 23' 40"	Tube well
		F3	N 26° 08' 45" E 78° 23' 39"	F3	N 26° 08' 49" E 78° 23' 39"	Tube well
5	Laxmangarh	F1	N 26° 09' 44" E 78° 23' 37"	F1	N 26° 09' 44" E 78° 23' 37"	Tube well
		F2	N 26° 09' 46" E 78° 23' 35"	F2	N 26° 09' 40" E 78° 23' 36"	Tube well
		F3	N 26° 09' 48" E 78° 23' 33"	F3	N 26° 09' 46" E 78° 23' 38"	Tube well
6	Maharajpura	F1	N 26° 17' 10" E 78° 12' 59"	F1	N 26° 17' 01" E 78° 12' 50"	Tube well
		F2	N 26° 17' 08" E 78° 12' 64"	F2	N 26° 17' 09" E 78° 12' 54"	Tube well
		F3	N 26° 17' 12" E 78° 12' 62"	F3	N 26° 17' 09" E 78° 12' 55"	Tube well
7	Rora	F1	N 26° 07' 30" E 78° 15' 45"	F1	N 26° 07' 20" E 78° 15' 35"	Tube well
		F2	N 26° 07' 32" E 78° 15' 47"	F2	N 26° 07' 25" E 78° 15' 40"	Tube well

		F3	N 26° 07' 28" E 78° 15' 42"	F3	N 26° 07' 22" E 78° 15' 34"	Tube well
8	Sunarpura mafi	F1	N 26° 16' 38" E 78° 22' 54"	F1	N 26° 16' 28" E 78° 22' 45"	Tube well
		F2	N 26° 16' 40" E 78° 22' 56"	F2	N 26° 16' 32" E 78° 22' 49"	Tube well
		F3	N 26° 16' 36" E 78° 22' 52"	F3	N 26° 16' 30" E 78° 22' 48"	Tube well
9	Jalalpur	F1	N 26° 15' 44" E 78° 14' 51"	F1	N 26° 15' 34" E 78° 14' 42"	Sewage
		F2	N 26° 15' 45" E 78° 14' 53"	F2	N 26° 15' 38" E 78° 14' 45"	Sewage
		F3	N 26° 15' 43" E 78° 14' 54"	F3	N 26° 15' 36" E 78° 14' 46"	Sewage
10	Jamahar	F1	N 26° 16' 25" E 78° 10' 23"	F1	N 26° 16' 15" E 78° 10' 13"	Sewage
		F2	N 26° 16' 23" E 78° 10' 19"	F2	N 26° 16' 18" E 78° 10' 15"	Sewage
		F3	N 26° 16' 27" E 78° 10' 25"	F3	N 26° 16' 19" E 78° 10' 18"	Sewage

3.1.3 Land use pattern

The main crops grown in the study area are wheat (*Triticum stivum*), mustard (*Brassica juncea* L.), taramira (*Eruca sativa*), gram (*Cicer arietinum*), in rabi season. Whereas, in kharif season pearl millet (*Pennisetum typhoides*), cluster bean (*Cyamopsis tetragonoloba*), sorghum (*Sorghum bicolor*), and sesame (*Sesamum indicum*) are cultivated. In zaid crops grown are chilli (*Capsicum annum*) and tomato (*Lycopersicon esculentum*). Fruit vegetation are scanty and common trees are ber (*Zyzyphus mauritiana*), lime (*Citrus aurantifolia*) and papaya (*Carica papaya*), Guava (*Psidium guajava*) and potato (*Solanum tuberosum*) grown in both Rabi and Kharif crop season.

3.1.4 Natural vegetation

Natural vegetation affects soil development by furnishing organic matter, adsorbing and recycling plant nutrients and by supplying a cover to the surface. The nature of organic matter with respect to its composition as affected by plant species and environment was an important factor for soil variations. Litter fall brings about important changes in physical, chemical and biological characteristics of soil and balance the nutrients reserve of soils.

It was therefore, desirable to add information on natural vegetation of the study area. The natural vegetation found in the area can be categorized as follow:

Trees: Trees commonly found in the areas were Ashoka (*Saraca asoca*), babool (*Acacia arabica*), vilayati babool (*Prosopis juliflora*), neem (*Azadirachta indica*), ber (*Zizyphus mauritiana*), eucalyptus (*Eucalyptus globulus*), shisam (*Dalbergia sissoo*), Bel (*Aegle marmelos*), Bar (*Ficus bengalensis*), mango (*Mangifera indica*).

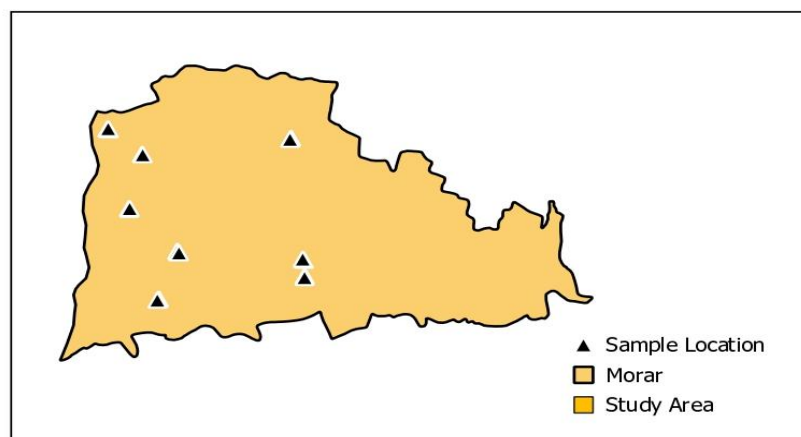
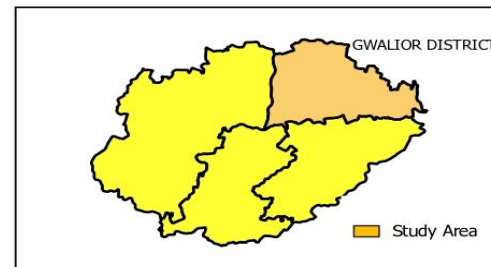
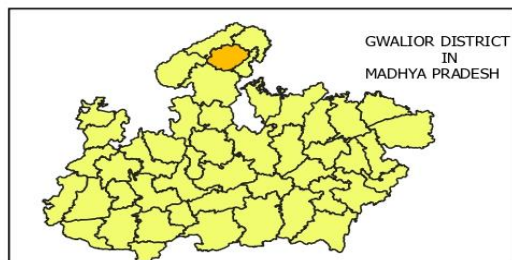
Shrubs and Bushes: The most common plant under this category were aak (*Calotropis spp.*), Adusa (*Adhatoda vasica*), Karonda (*Carissa spinarum*), Kath Jamun (*Eugenia heyneana*).

Grasses: The important grasses were dub (*Cynodon dactylon*), kans (*Saccharum spontaneum*), karan (*Dicanthium annulatum*) and motha (*Cyprus rotundus*), Phuli (*Apluda varia*), Sama (*Echinochloa colona*).

3.2 Site selection and sampling

A preliminary survey of study area was carried out during the October and December 2021 to select the area for the soil and water sampling to fulfill the objectives of the present investigation. Ten villages of Morar block of Gwalior district were selected for sampling.

LOCATION MAP OF STUDY AREA



Map No.3.1: Map of Morar Block of Gwalior District of Madhya Pradesh Showing sample Collection Sites

3.2.1 Collection of water samples

Thirty georeferenced water samples were collected from ten villages Morar block of Gwalior district during October and December 2021 from the tube well/sewage water which were used for irrigating the fields. In order to get representative samples, pump was kept in operation at least half to one hour before collecting the sample. Collected water samples were stored in clean, rinsed and properly labeled plastic bottles. Before the bottles were corked, few drops of toluene were also added to check the microbial growth.

3.2.2 Collection of soil samples

Ninety composite surface soil samples (0-15,15-30,30-45 cm) depth were collected from irrigated field. The approximately one kg soil were drawn from each sampling pits and kept in clean and properly labeled cloth bag. Soil Samples were air dried, grind and passed through 2 mm sieve for analysis work in the laboratory.

3.3 Analysis of samples

3.3.1 Analysis of water samples

All the water samples collected were subjected to chemical analysis in the laboratory for pH, EC, soluble cations (Ca^{++} , Mg^{++} , Na^+ and K^+), soluble anions (CO_3^{--} , HCO_3^- , Cl^- and SO_4^{--}), RSC and SAR.

3.3.2 Analysis of soil samples

The soil samples collected were subjected to analysis in the laboratory for pH, EC, OC, available nitrogen, phosphorus, potassium, and, Bulk density, Particle density and Porosity.

Table 3.1: Methods of water and soil analysis

S. No.	Properties	Procedure	Reference
A.	Soil Analysis		
a.	Chemical analysis		
1.	pH	Using glass electrode pH meter	Richards (1954)
2.	EC	Using the standard precision conductivity bridge	Richards (1954)

3..	Organic carbon	Rapid titration method	Walkely and Black (1934)
4.	Available N	Alkaline permanganate method	Subbiah and Asija 1956
5.	Available P	0.5 M sodium bicarbonate	Olsen <i>et al.</i> 1954
6.	Available K	Flame photometer method	Jackson 1973
b.	Mechanical analysis		
1.	Bulk density	Core method	Richards et.al 1954
2.	Particle size analysis	Bouyoucous Hydrometer method	Bouyoucous 1962
3.	Porosity	Method No. 40 of USDA hand book No 60	Richards 1954
B. Water Analysis			
1.	pH	Using glass electrode pH meter	Richards (1954)
2.	EC	Using the standard precision conductivity bridge	Richards (1954)
3.	Cation- Ca ²⁺ , Mg ²⁺	Using Versenate titration method	Richards (1954)
4.	Na ⁺ , K ⁺	Using Flame photometry method	Richards (1954)
5.	Anion-CO ₃ ²⁻ , HCO ₃ ⁻	Titration with standard H ₂ SO ₄ (Method No.12)	Richards (1954)
6.	Cl ⁻	Titration was carried with standard AgNO ₃ (Method No. 13)	Richards (1954)
7.	SO ₄ ⁻²	Using method by precipitation as barium sulphate (Method No.14)	Richards (1954)
8.	Residual Sodium Carbonate (RSC)	Calculated by formula RSC=(CO ₃ ²⁻ +HCO ₃ ⁻)– (Ca ²⁺ + Mg ²⁺)	Richards (1954)
9.	Sodium Adsorption Ratio	Calculated by formula SAR= $\frac{\text{Na}^+}{\sqrt{\frac{\text{Ca}^{2+} + \text{Mg}^{2+}}{2}}}$	Richards (1954)

3.4 Soil analysis:

3.4.1 Bulk density

The soil samples were collected with manually operated core sampler up to 15 cm depth and oven dried at 105 °C for 24 hours (Richards et al., 1954). The bulk density was calculated by using the following relation: -

$$BD = \frac{\text{Weight of oven dry soil (Mg)}}{\text{Volume of soil (m}^3\text{)}}$$

Where BD = Bulk density, Mg m⁻³ = Mega gram per cubic meter

3.4.2 Particle- density

Particle density of soil was determined by pycnometer. To exclude air, pycnometer containing the soil with enough water to cover should be subjected to several pressure reductions in a vacuum desiccator and then allowed to stand for a number of hours under reduced pressure before completely filling with water for weighing (Richard, 1968).

3.4.3 Porosity

The porosity of soil is the fraction of the soil space not occupied by soil particles. The porosity may be calculated from the formula described by Richard, (1968).

$$\text{Porosity (\%)} = 1 - \frac{\text{Bulk density}}{\text{Particle density}} \times 100$$

3.4.4 Sodium (Na⁺)

Sodium of soil was determined with the help of flame photometer as per method (10a) USDA, Hand book No. 60 (Richards, 1954). The reagents are used ammonium acetate (1 N), sodium chloride (0.04 N) and lithium chloride. Calibrate the flame photometer for operation over the concentration range 0 to 1 meL⁻¹ of sodium. Determine the sodium concentration by use of the flame photometer and the appropriate calibration curve.

3.4.5 Calcium and Magnesium (Ca²⁺ + Mg²⁺)

Calcium and Magnesium by titration with ethylene diamine tetra acetate (Versenate) solution as per method No. 7 USDA, Hand book No. 60 (Richards, 1954). Ammonium acetate and dispersed organic matter, when present in appreciable amounts, must be almost entirely removed from soil extracts prior to titration with versenate.

3.4.6 Chloride (Cl⁻)

Chloride of soil was determined by titration with silver nitrate (AgNO₃) as per method No. 13, USDA Hand book No. 60 (Richards, 1954).

3.4.7 Carbonate and Bicarbonate (CO₃²⁻ and HCO₃⁻)

Carbonate and bicarbonate of soil was determined by titration with sulfuric acid (H₂SO₄) as per method No. 12, USDA Hand book No. 60 (Richards, 1954). The reagents were used phenolphthalein, methyl orange and sulfuric acid (0.010 N) standardized as per method No. 12, USDA Hand Book No. 60 (Richards, 1954).

3.4.8 Physico-chemical properties:

The soil pH was measured in a soil: water ratio of 1: 2.5 using the pH meter and supernatant of same was used for electrical conductivity determination with the help of conductivity-meter (Jackson, 1973). Organic carbon (OC) in soil was determined using method as described by Walkley and Black (1934). The calcium carbonate in soil was carried out using rapid back titration method as described by Jackson (1973).

3.4.9 Macronutrients:

Available nitrogen (N) was determined as per method given by Subbiah and Asija (1956). Available phosphorus (P) was determined by 0.5 M sodium bicarbonate by Olsen *et al.* (1954) and then read on Spectrophotometer. Available potassium (K) was extracted with 1 N NH₄OAc and then measured by Flame Photometer (Jackson, 1973).

Table 3.2 Critical limits of soil characteristics for soils categorization
(Singh *et al.*, 2007)

Parameters	Low	Medium	High
OC (gkg^{-1})	<2.5	2.5-7.5	>7.5
N (kg ha^{-1})	<250	250-400	>400
P (kg ha^{-1})	<10	10-20	>20
K (kg ha^{-1})	<250	250-400	>400

3.5 Statistical analysis

Statistical analysis was carried out with standard methods as given by Snedecor and Cochran (1967).

3.6 Recommendation for better utilization of irrigation water and soils.



Plate 3.1 Different lab analysis during water and soil analysis

Chapter- IV

RESULTS

This Chapter deals with the consequence of the findings data on title entitled **“Evaluation of ground water quality and its effects on Soil properties in Morar block of Gwalior”**. The experimental results are presented here under different headings.

Thirty geo-referenced tube well and sewage water samples from ten villages sample from each three field of Morar block of Gwalior district of Madhya Pradesh from the tube wells / sewage which were used for irrigating the fields and ninety soil samples from three different depth (0-15, 15-30 and 30-45 cm depth) of soil samples were also collected from fields from same sites from which water samples have collected. The collected water samples were analyses for their chemical characteristics and similarly soil samples were analyses for physical and chemical parameters. The results obtained have been presented and in this chapter under the following headings:

- 4.1 To evaluate the irrigation water quality of Morar block of Gwalior district.
- 4.2 To evaluate the effect of irrigation water quality on soil properties.
- 4.3 To find out the inter-connection between quality characteristics of ground water and some selected soil properties.

4.1 To evaluate the irrigation water quality of morar block of Gwalior district

4.1.1 Characteristics of tube well water

The main objectives of water quality assessment are to see if the water fits previously specified criteria for designated applications, to describe water quality at regional, national and international scales and to look at trends over time, among other things, etc. The criteria of tube well that are used to determine its appropriateness for irrigation and residential purposes are listed below. The analysis of tube well samples collected from tube wells and open wells is used to monitor the quality of the tube well. The water samples were

collected during December, 2021 from ten villages of three fields of Morar block of Gwalior district of Madhya Pradesh with an objective to evaluate tube well quality and inference management option.

The water samples of the studied area were analyzed for ionic composition *i.e.*, cations (Ca^{++} , Mg^{++} , Na^+ and K^+) and anions (CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-}), pH, EC, the values of SAR, RSC were calculated. The data related to the chemical analysis of tube well are presented in Table 4.1 and discussed below.

4.1.1.1 Ionic composition of tube well water

It observed from data (Table 4.1) that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) values were ranged between 0.17 to 4.36, 0.05 to 1.24, 1.18 to 5.98 and 0.02 to 0.09 (me L^{-1}) with an average value of 2.51, 0.40, 3.02 and 0.06 (me L^{-1}), SD of 1.15, 0.30, 1.52 and 0.02 value and CV (%) of 45.87, 74.00, 50.23 and 30.69 in Morar block of Gwalior.

The maximum soluble cation Ca^{++} (me L^{-1}) in water samples was observed in village Rora (4.36 me L^{-1}) at field-1 and minimum value was recorded in village Baderafutker (0.17 me L^{-1}) at field-2, respectively. The maximum soluble cation Mg^{++} (me L^{-1}) in water samples was observed in village tankoli (1.24 me L^{-1}) at field-1 and minimum value was recorded in village Baderafutker (0.05 me L^{-1}) at field-2, respectively.

The maximum soluble cation Na^+ (me L^{-1}) in water samples was observed in village Laxmangarh (5.98 me L^{-1}) at field-2 and minimum value was recorded in village sonsa (1.18 me L^{-1}) at field-1, respectively. The maximum soluble cation K^+ (me L^{-1}) in water samples was observed in village Rora (0.09 me L^{-1}) at field-2 and minimum value was recorded in village Sonsa (0.02 me L^{-1}) at field-3, respectively.

It observed from data (Table 4.1) that the soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) values were ranged

between 0.08 to 0.66 , 1.11 to 4.91, 0.28 to 3.11, and 0.10 to 0.90 (me L⁻¹) with an average value of 0.36, 3.34, 1.82 and 0.36 (me L⁻¹), SD of 0.14, 1.04, 0.73 and 0.23 value and CV (%) of 37.35, 31.04, 40.38 and 62.38 in Morar block of Gwalior district of Madhya Pradesh.

The maximum soluble anions CO₃²⁻ (me L⁻¹) in water samples was observed in village Maharajpura (0.66 me L⁻¹) at field-2 and minimum value was recorded in village Tankoli (0.08 me L⁻¹) at field-2, respectively. The maximum soluble anions HCO₃⁻ (me L⁻¹) in water samples was observed in village Baderafutker (4.91 me L⁻¹) at field-1 and minimum value was recorded in village Sonsa (1.11 me L⁻¹) at field-2, respectively.

The maximum soluble anions Cl⁻ (me L⁻¹) in water samples was observed in village Tankoli (3.11 me L⁻¹) at field-1 and minimum value was recorded in village Baderafutker (0.28 me L⁻¹) at field-3, respectively. The maximum soluble anion SO₄²⁻ (me L⁻¹) in water samples was observed in village Rora(0.90 me L⁻¹) at field-1 and minimum value was recorded in village Sonsa (0.10 me L⁻¹) at field-3, respectively.

Table 4.1: Ionic composition of tube well water in Morar block of Gwalior

Morar Block	Ionic composition (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

4.1.2 Characteristics of sewage water

The main objectives of water quality assessment are to see if the water fits previously specified criteria for designated applications, to describe water quality at regional, national and international scales and to look at trends over time, among other things, etc. The criteria of sewage water that are used to determine its appropriateness for irrigation and residential purposes are listed

below. The analysis of sewage water samples collected from tube wells and open wells is used to monitor the quality of the sewage water. The water samples were collected during December, 2021 from ten villages of three fields of Morar block of Gwalior district of Madhya Pradesh with an objective to evaluate the sewage water quality and inference management option.

The water samples of the studied area were analyzed for ionic composition *i.e.*, cations (Ca^{++} , Mg^{++} , Na^+ and K^+) and anions (CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{--}), pH, EC, the values of SAR, RSC were calculated. The data related to the chemical analysis of sewage water are presented in Table 4.2 and discussed below.

4.1.2.1 Ionic composition of sewage water

It observed from data (Table 4.2) that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) values were ranged between 2.73 to 5.39, 0.19 to 1.79, 1.34 to 4.34 and 0.10 to 0.20 (me L^{-1}) with an average value of 3.95, 0.88, 2.70 and 0.15 (me L^{-1}), SD of 1.03, 0.64, 1.44 and 0.04 value and CV (%) of 26.06, 73.22, 53.49 and 28.18 in Morar block of Gwalior district of Madhya Pradesh.

The maximum soluble cation Ca^{++} (me L^{-1}) in water samples was observed in village Jamahar ((5.39 me L^{-1}) at field-1 and minimum value was recorded in village Jalalpur (2.73 me L^{-1}) at field-2, respectively. The maximum soluble cation Mg^{++} (me L^{-1}) in water samples was observed in village Jamahar (1.79 me L^{-1}) at field-3 and minimum value was recorded in village Jalalpur (0.19 me L^{-1}) at field-1, respectively.

The maximum soluble cation Na^+ (me L^{-1}) in water samples was observed in village Jamahar (4.34 me L^{-1}) at field-2 and minimum value was recorded in village Jalalpur (1.34 me L^{-1}) at field-3, respectively. The maximum soluble cation K^+ (me L^{-1}) in water samples was observed in village Jalalpur (0.20 me L^{-1}) at field-3 and minimum value was recorded in village Jalalpur (0.10 me L^{-1}) at field-1, respectively.

It observed from data (Table 4.2) that the soluble anions CO_3^{2-} , HCO_3^- , Cl^-

and SO_4^{2-} (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) values were ranged between 0.37 to 0.44, 2.27 to 4.78, 1.58 to 2.78, and 0.90 to 1.30 (me L^{-1}) with an average value of 0.40, 3.79, 2.26 and 1.12 (me L^{-1}), SD of 0.03, 1.08, 0.49 and 0.13 value and CV (%) of 06.70, 28.62, 21.92 and 11.90 in Morar block of Gwalior district of Madhya Pradesh.

The maximum soluble anions CO_3^{2-} (me L^{-1}) in water samples was observed in village Jalalpur (0.44 me L^{-1}) at field-3 and minimum value was recorded in village Jamahar (0.37 me L^{-1}) at field-2, respectively. The maximum soluble anions HCO_3^- (me L^{-1}) in water samples was observed in village Jamahar (4.78 me L^{-1}) at field-3 and minimum value was recorded in village Jalalpur (2.27 me L^{-1}) at field-3, respectively.

The maximum soluble anions Cl^- (me L^{-1}) in water samples was observed in village Jamahar (2.78 me L^{-1}) at field-2 and minimum value was recorded in village Jamahar (1.58 me L^{-1}) at field-1, respectively. The maximum soluble anion SO_4^{2-} (me L^{-1}) in water samples was observed in village Jamahar (1.30 me L^{-1}) at field-1 and minimum value was recorded in village Jalalpur (0.90 me L^{-1}) at field-3, respectively.

Table 4.2: Ionic composition of sewage irrigation water in Morar block of Gwalior

Morar Block	Ionic composition (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	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

4.1.3 Characteristics of tube well irrigation water in Morar block of Gwalior

4.1.3.1 pH

The pH of a solution is the negative logarithm of the active hydrogen ion activity, $\text{pH} = -\log (\text{H}^+)$. In dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration. The pH of water is a measure of the acid–base equilibrium and in most natural water is controlled by the carbon dioxide–bicarbonate– carbonate equilibrium system.

It observed from data (Table 4.3) that the pH of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the pH values were ranged between 7.30 to 8.30 with an average value of 7.80, SD of 0.31 value and CV (%) of 3.91 in Morar block of Gwalior district of Madhya Pradesh. The lowest pH in water samples was observed in village Sunarpura (pH 7.30) at field-2 and highest value was recorded in village Baderafutker (pH 8.30) at field-1, respectively.

4.1.3.2 EC

Electrical conductivity is used for determination of total concentration of soluble salts in water. The importance of electrical conductivity (EC) is its measure of salinity which greatly affects the productivity of crops.

It observed from data (Table 4.3) that the EC of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the EC values were ranged between 0.32 dSm^{-1} to 0.79 dSm^{-1} with an average value of 0.60 dSm^{-1} , SD of 0.12 value and CV (%) of 20.53 in Morar block. The lowest EC in water samples was observed in village Sonsa ($\text{EC } 0.32 \text{ dSm}^{-1}$) at field-1 and highest EC value was recorded in village Laxmangarh ($\text{EC } 0.79 \text{ dSm}^{-1}$) at field-2, respectively.

4.1.3.3 Residual sodium carbonate

The RSC indicates the excess of carbonate and bicarbonate over calcium and magnesium in tube well.

It observed from data (Table 4.3) that the RSC of each water samples range, means, standard deviation and CV (%) of different tube well quality parameter of Morar block that the RSC values were ranged between Nil me L^{-1} to 4.57 me L^{-1} with an average value of 1.23 me L^{-1} , SD of 1.56 value and CV (%) of 127.25 in Morar block. The highest RSC value was recorded in village Baderafutker ($\text{RSC } 4.57 \text{ me L}^{-1}$) at field-2.

4.1.3.4 Sodium adsorption ratio

Electrical conductivity (EC) is an assessment of all the soluble salts in water sample while sodium hazard is defined separately because of its specific detrimental effect on soil physical properties. The sodium hazard is typically expressed as sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) in a sample.

It observed from data (Table 4.3) that the SAR of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the SAR values were ranged between 2.04 to 8.21 with an average value of 3.99, SD of 1.75 value and CV (%) of 43.90 in Morar block. The highest SAR value was recorded in village Baderafutker (SAR 8.21) at field-2 and lowest SAR in water samples was observed in village Tankoli (SAR 2.04) at field-1, respectively. Increase in SAR values of tube well with the increase of pH and EC tube well might be due to dominance of soluble Na^+ over Ca^{++} , Mg^{++} .

Table 4.3: Characteristics of tube well irrigation water of Morar block of Gwalior

Morar Block	pH	EC (dSm^{-1})	RSC (me L^{-1})	SAR
Range	7.30-8.30	0.32-0.79	Nil-4.57	2.04-8.21
Mean	7.80	0.60	1.23	3.99
SD	0.31	0.12	1.56	1.75
CV (%)	3.91	20.53	127.25	43.90

Nil-Negative RSC values

4.1.4 Characteristics of sewage irrigation water of Morar block of Gwalior

4.1.4.1 pH

The pH of a solution is the negative logarithm of the active hydrogen ion activity, $\text{pH} = -\log (\text{H}^+)$. In dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration. The pH of water is a measure of the acid–base equilibrium and in most natural water is controlled by the carbon dioxide–bicarbonate– carbonate equilibrium system.

It observed from data (Table 4.4) that the pH of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the pH values were ranged between 7.40 to 7.90 with an average value of 7.71, SD of 0.19 value and CV (%) of 2.49 in Morar block of Gwalior district of Madhya Pradesh. The lowest pH in water samples was observed in village Jamahar (pH 7.40) at field-3 and highest value was recorded in village Jamahar (pH 7.90) at field-1, respectively.

4.1.4.2 EC

Electrical conductivity is used for determination of total concentration of soluble salts in water. The importance of electrical conductivity (EC) is its measure of salinity which greatly affects the productivity of crops.

It observed from data (Table 4.4) that the EC of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the EC values were ranged between 0.63 dSm^{-1} to 0.90 dSm^{-1} with an average value of 0.77 dSm^{-1} , SD of 0.12 value and CV (%) of 15.40 in Morar block. The lowest EC in water samples was observed in village Jalalpur (EC 0.63 dSm^{-1}) at field-3 and highest EC value was recorded in village Jamahar (EC 0.90 dSm^{-1}) at field-2, respectively.

4.1.4.3 Residual sodium carbonate

The RSC indicates the excess of carbonate and bicarbonate over calcium and magnesium in sewage water.

It observed from data (Table 4.4) that the RSC of each water samples range, means, standard deviation and CV (%) of different sewage water quality parameter of Morar block that the RSC values were ranged between Nil L^{-1} to 1.28 meL^{-1} with an average value of 0.30 meL^{-1} , SD of 0.52 value and CV (%) of 173.06 meL^{-1} in Morar block. The highest RSC value was recorded in village Jamahar (RSC 1.28 meL^{-1}) at field-1.

4.1.4.4 Sodium adsorption ratio

Electrical conductivity (EC) is an assessment of all the soluble salts in water sample while sodium hazard is defined separately because of its specific

detrimental effect on soil physical properties. The sodium hazard is typically expressed as sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^+) to calcium (Ca^{++}) and magnesium (Mg^{++}) in a sample.

It observed from data (Table 4.4) that the SAR of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the SAR values were ranged between 2.62 to 3.15 with an average value of 2.87, SD of 0.20 value and CV (%) of 6.96 in Morar block. The highest SAR value was recorded in village Jamahar (SAR 3.15) at field-2 and lowest SAR in water samples was observed in village Jalapur (SAR 2.62) at field-1, respectively.

Increase in SAR values of sewage water with the increase of pH and EC of sewage water might be due to dominance of soluble Na^+ over Ca^{++} , Mg^{++} .

Table 4.4: Characteristics of sewage irrigation water of Morar block of Gwalior

Morar Block	pH	EC (dSm^{-1})	RSC (me L^{-1})	SAR
Range	7.40-7.90	0.63-0.90	Nil-1.28	2.62-3.15
Mean	7.71	0.77	0.30	2.87
SD	0.19	0.12	0.52	0.20
CV (%)	2.49	15.40	173.06	6.96

Nil-Negative RSC values

4.1.5 Classification of irrigation water of Morar block of Gwalior

The data (Table 4.5) showed that the irrigation water of Morar block of Gwalior district were classified into four salinity and sodium classes according to the standards set by the.

1. Medium salinity and low sodium water (C_2S_1)
2. High salinity and low sodium water (C_3S_1)

Table 4.5: Classification of irrigation water of Morar block of Gwalior district according to the USSL standards

S. No.	Water Classes	Symbol	Number of water samples	Percent of water samples
1	Medium salinity and low sodium water (C ₂ S ₁)	A	27	90.00
2	High salinity and low sodium water (C ₃ S ₁)	B	3	10.00

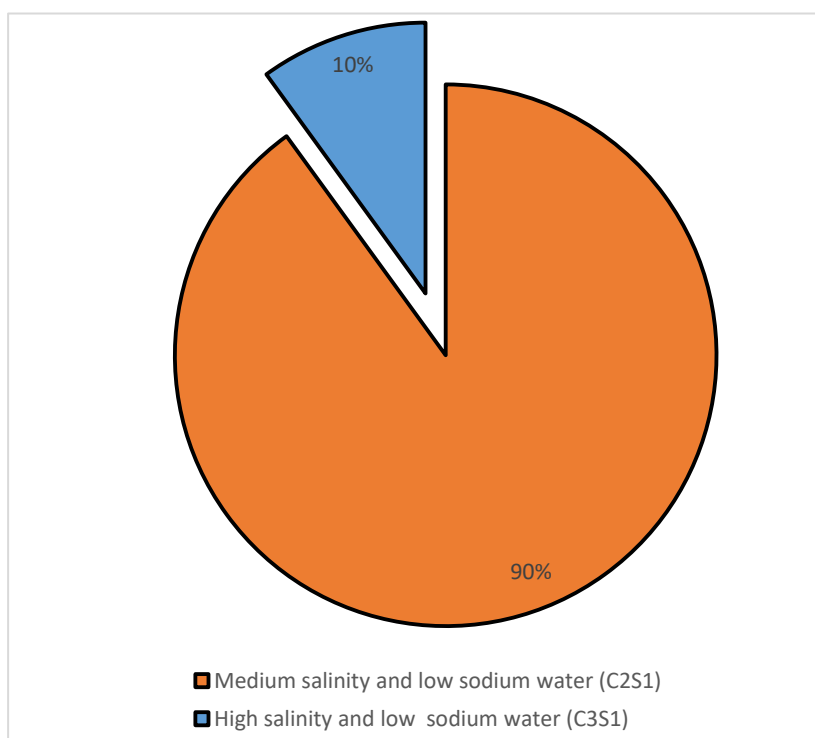


Fig. 4.1: Classification of irrigation of Morar block of Gwalior according to the USSL standards

Furthermore, according to USSL standards about 90.00, 10.00

per cent water samples fell into the C₂S₁ and C₃S₁ categories, respectively.

The irrigation water of Morar block of Gwalior district were classified into five salinities (C₁, C₂, C₃, C₄ and C₅), four sodicity (S₀, S₁, S₂ and S₃) and five alkalinity (A₁, A₂, A₃, A₄ and A₅) classes. It is evident from the data (Table 4.6) that 100.00 per cent of water samples fell into the C₁ (Normal water) category. Similarly, in terms of sodicity, approximately 80.00 per cent of water samples fell into the S₀ (Non sodic water) category, 20.00 per cent into the S₁ (Normal water) category. Moreover, according to alkalinity hazards, 63.33 per cent of water samples fell into the A₁ (Normal water) category, 26.67 per cent into the A₂ (Low alkalinity water) category and 10.00 per cent into the A₃ (Medium alkalinity water) category. As a result, roughly 35 per cent water samples may predict certain issues in the successful management of irrigated agriculture in the study area (Table 4.6).

The irrigation water of the study area was also classified according to guidelines proposed by data (Table 4.7) indicated that 90.00, 3.33 and 6.67 per cent water samples fell under good, marginally alkali and alkali categories, respectively. The list of villages of study area according to water quality classes as suggested by was also showed in Table 4.8.

Table 4.6: Classification of irrigation water of Morar block of Gwalior on the basis of salinity (EC), sodicity (SAR) and alkalinity (RSC).

S. No.	Water classes	Number of watersamples	Percentage of water samples
Salinity (EC)			
1	Normal saline water (C ₁)	30	100.00
Sodicity (SAR)			
1	Non sodic water (S ₀)	24	80.00
2	Normal water (S ₁)	06	20.00
Alkalinity (RSC)			
1	Normal water (A ₁)	19	63.33
2	Low alkalinity water (A ₂)	08	26.67

3	Medium alkalinity water (A ₃)	03	10.00
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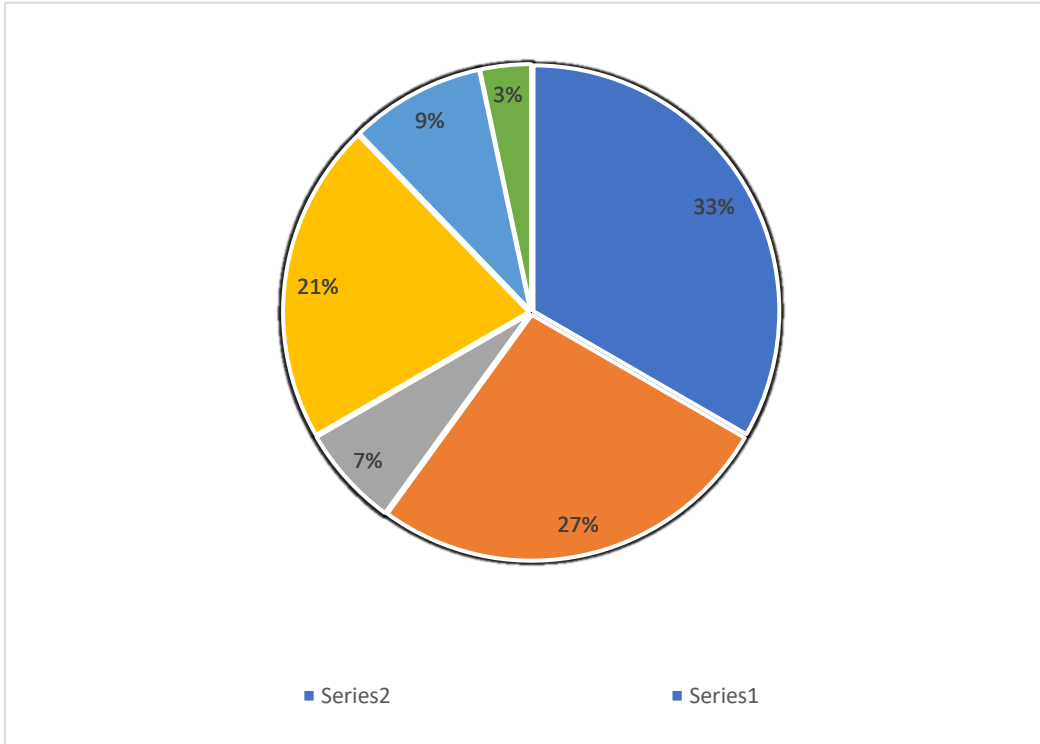


Fig.4.2: Classification of irrigation water of Morar block of Gwalior on the basis of salinity (EC), sodicity (SAR) and alkalinity (RSC)

Table 4.7: Classification of ground water Morar block of Gwalior on the basis of EC, SAR and RSC

S.NO.	Water quality classes	Number of water samples	Per cent of water samples
1	Good	27	90.00
2	Marginally alkali	1	3.33
3	Alkali	2	6.67

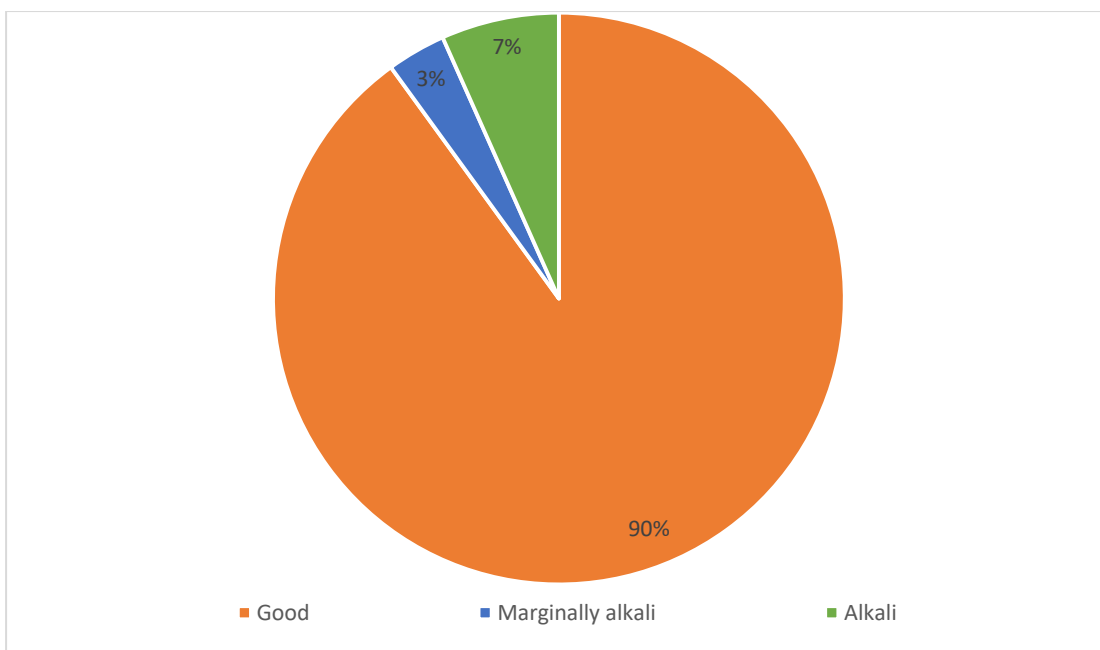


Fig.4.3: Classification of irrigation water Morar block of Gwalior on the basis of EC, SAR and RSC

Table 4.8: Villages of Morar block of Gwalior under different water quality classes.

S. No.	Water quality	Name of villages
1	Good	Mohanpur Field 1, Mohanpur Field 2, Mohanpur Field 3, Sonsa Field 1, Sonsa Field 2, Sonsa Field 3, Tankoli Field 1, Tankoli Field 2, Tankoli Field 3, Jalalpur Field 1, Jalalpur Field 2, Jalalpur Field 3, Rora Field 1, Rora Field 2, Rora Field 3, Sunarpura Field 1, Sunarpura Field 2, Sunarpura Field 3, Laxmangarh Field 1, Laxmangarh Field 2, Laxmangarh Field 3, Maharajpura Field 1, Maharajpura Field 2, Maharajpura Field 3.
2	Marginally alkali	Baderafutker Field 1
3	Alkali	Baderafutker Field 2, Baderafutker Field 3

4.2 To evaluate the effect of irrigation water quality on soil properties

4.2. a Soil characterization

4.2.1 Physical parameters of tube well water irrigated soil

4.2.1.1 Bulk density

Data related to bulk density (Mg m^{-3}) were presented in tables 4.9. Data indicated that bulk density (Mg m^{-3}) content of soils at 0-15, 15-30 and 30-45 cm depth Morar block of Gwalior district were varied range from 1.24 to 01.42, 1.22 to 1.41 and 1.21 to 1.40 Mg m^{-3} with the mean value of 1.33, 1.32 and 1.31 Mg m^{-3} , SD value 0.06, 0.06, 0.06 of and CV (%) of 4.40, 4.60 and 4.60 % respectively.

4.2.1.2 Particle density

Data related to particle density (Mg m^{-3}) were presented in tables 4.9. Data indicated that particle density (Mg m^{-3}) content of soils at 0-15, 15-30 and 30-45 cm depth Morar block of Gwalior district were varied range from 2.56 to 2.72, 2.43 to 2.87 and 2.37 to 2.77 Mg m^{-3} with the mean value of 2.65, 2.62 and 2.54 Mg m^{-3} , SD value 0.04, 0.15, 0.14 of and CV (%) of 1.52, 5.63 and 5.37 % respectively.

4.2.1.3 Porosity (%)

Data related to porosity (%) were presented in tables 4.9. Data indicated that particle density (%) content of soils at 0-15, 15-30 and 30-45 cm depth of Morar block of Gwalior district were varied range from 44.53 to 54.41, 40.51 to 55.64 and 42.39 to 57.49 % with the mean value of 49.69, 47.73 and 49.65 %, SD value 2.95, 5.12, 5.06 of and CV (%) of 5.93, 10.73 and 10.19 %, respectively.

Table 4.9: Physical parameters of tube well water irrigated soil of Morar block of Gwalior

1. Tube well water									
Particulars	Bulk density			Particle density			Porosity (%)		
Depth	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
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

4.2.2 Physical parameters of sewage water irrigated soil

4.2.2.1 Bulk density

Data related to bulk density (Mg m^{-3}) were presented in tables 4.10. Data indicated that bulk density (Mg m^{-3}) content of soils at 0-15, 15-30 and 30-45 cm depth Table 4.10 of Morar block of Gwalior district were varied range from 1.25 to 01.33, 1.22 to 1.33 and 1.26 to 1.30 Mg m^{-3} with the mean value of 1.28, 1.29 and 1.28 Mg m^{-3} , SD value 0.03, 0.04, 0.01 of and CV (%) of 2.29, 2.89 and 1.06 % respectively.

4.2.2.2 Particle density

Data related to particle density (Mg m^{-3}) were presented in tables 4.10. Data indicated that particle density (Mg m^{-3}) content of soils at 0-15, 15-30 and 30-45 cm depth Table 4.10 of Morar block of Gwalior district were varied range from 2.56 to 2.66, 2.61 to 2.69 and 2.52 to 2.61 Mg m^{-3} with the mean value of 2.60, 2.66 and 2.58 Mg m^{-3} , SD value 0.03, 0.03, 0.03 of and CV (%) of 1.30, 1.05 and 1.26 % respectively.

4.2.2.3 Porosity (%)

Data related to porosity (%) were presented in tables 4.10. Data indicated that particle density (%) content of soils at 0-15, 15-30 and 30-45

cm depth and of Morar block of Gwalior district were varied range from 49.61 to 51.92, 48.65 to 51.59 and 50.19 to 53.16 % with the mean value of 50.61, 50.20 and 51.81 %, SD value 0.88, 1.03, 0.98 of and CV (%) of 1.75, 2.06 and 1.89 %, respectively.

Table 4.10: Physical parameters of sewage water irrigated soil of Morar block of Gwalior

2. Sewage water									
Particulars	Bulk density			Particle density			Porosity (%)		
Depth	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
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

4.2.3 Chemical parameters of tube well water irrigated soil

4.2.3.1 pH

Based on the activity of H⁺ or OH⁻ ions in soil solution, soil reactions are classified as acidic, neutral or alkaline. Soil reaction is one of the most essential parameters that have a significant impact on the availability of nutrients to plants, microbial activity and the physical characteristics of soils. Data pertaining to pH of the soils of Morar block of Gwalior district were presented in table 4.11.

Data revealed that pH of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior district ranged from 7.25 to 8.07, 7.32 to 8.15 and 7.38 to 8.30 with mean values of 7.71, 7.69 and 7.77, SD value 0.26, 0.27, 0.27 of and CV (%) of 3.39, 3.45 and 3.54 %, respectively.

4.2.3.2 Electrical conductivity

The electrical conductivity of soil is a measure of the total concentration of soluble salts. A perusal of data in table 4.11 indicated that the electrical conductivity of soils of Morar block of Gwalior district varied from 0.17 to 0.67, 0.25 to 0.68 and 0.25 to 0.68 with a mean value of 0.42, 0.46 and 0.46 dS m⁻¹, SD value 0.19, 0.15, 0.15 of and CV (%) of 44.01,

31.77 and 31.81%, respectively.

Table 4.11: Chemical parameters of Tube well water in Morar block of Gwalior

1. Tube well water						
Particulars	pH			EC (dSm ⁻¹)		
Depth	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
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
MEAN	7.71	7.69	7.77	0.42	0.46	0.46
SD	0.26	0.27	0.27	0.19	0.15	0.15
CV %	3.39	3.45	3.54	44.01	31.77	31.81

4.2.4 Chemical parameters of sewage water irrigated soil

4.2.4.1 pH

Based on the activity of H⁺ or OH⁻ ions in soil solution, soil reactions are classified as acidic, neutral or alkaline. Soil reaction is one of the most essential parameters that have a significant impact on the availability of nutrients to plants, microbial activity and the physical characteristics of soils. Data pertaining to pH of the soils of Morar block of Gwalior district were presented in table 4.12.

Data revealed that pH of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior district ranged from 7.62 to 7.72, 7.56 to 7.73 and 7.67 to 7.77 with mean values of 7.67, 7.65 and 7.72, SD value 0.05, 0.08, 0.04 of and CV (%) of 0.63, 1.08 and 0.58 %, respectively.

4.2.4.2 Electrical conductivity

The electrical conductivity of soil is a measure of the total concentration of soluble salts. A perusal of data in table 4.12 indicated that the electrical conductivity of soils of Morar block of Gwalior district varied from 0.33 to 0.35, 0.36 to 0.42 and 0.36 to 0.42 with a mean value of 0.34, 0.40 and 0.39 dSm⁻¹, SD value 0.01, 0.02, 0.02 of and CV (%) of 2.88, 6.11

and 6.07 %, respectively.

Table 4.12: Chemical parameters of sewage water in Morar block of Gwalior

2.Sewage water						
Particulars	pH			EC (dSm ⁻¹)		
Depth	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
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
MEAN	7.67	7.65	7.72	0.34	0.40	0.39
SD	0.05	0.08	0.04	0.01	0.02	0.02
CV %	0.63	1.08	0.58	2.88	6.11	6.07

4.2.5 Fertility parameters of tube well water irrigated soil

4.2.5.1 Organic carbon

The organic carbon content of soils not only plays a significant role in improving cation exchange capacity, aggregation, water holding capacity, and fertility status of soils but also influences many physico- chemical aspects of soils, both directly and indirectly.

Organic carbon content in the soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior district varied from 0.19 to 0.39, 0.20-0.41 and 0.15 to 0.36 per cent with the mean values of 0.30, 0.29 and 0.27 per cent, standard deviation of 0.05,0.05 and 0.06, CV (%) of 18.01, 18.68 and 21.02 percent, respectively (Table 4.13).

4.2.5.2 Available nitrogen

A perusal of data Table 4.13 indicated that the available nitrogen content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior district varied from 180.53 to 294.21, 175.49 to 278.01 and 157.50 to 275.65 kg N ha⁻¹ with te mean values of 229.14, 221.09 and 209.58 kg N ha⁻¹, standard deviation of 39.41, 33.31 and 33.26, CV (%) of 17.20, 15.07 and 15.87 percent, respectively.

4.2.5.3 Available phosphorus

A perusal of data Table 4.13 indicated that the available phosphorus content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior district varied from 07.78 to 16.15, 07.69 to 16.16 and 07.62 to 16.09 kg P ha⁻¹ with the mean values of 11.68, 11.39 and 11.26 kg P ha⁻¹, standard deviation of 2.81, 2.83 and 2.58, CV (%) of 24.04, 24.90 and 22.89 percent, respectively.

4.2.5.4 Available potassium

On visualization of data presented in table 4.13 showed that the available potassium status of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior district ranged between 184.98 to 360.00, 178.02 to 353.93 and 168.01 to 342.74 with the mean values of 262.71, 249.69 and 242.06 kg K₂O ha⁻¹, standard deviation of 57.9253.74 and 53.85, CV (%) of 22.05, 21.52 and 22.25 percent, respectively.

Table 4.13: Fertility parameters of tube well water irrigated soil in Morar block of Gwalior

Tube well water												
Morar Block	Organic Carbon (%)			Available nitrogen (kg ha ⁻¹)			Available phosphorus(kg ha ⁻¹)			Available potassium (kg ha ⁻¹)		
Depth	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Range	0.19-0.39	0.20-0.41	0.15-0.36	180.53-294.21	175.49-278.01	157.50-275.65	7.78-16.15	7.69-16.16	7.62-16.09	184.98-360.00	178.02-353.93	168.01-342.74
Mean	0.30	0.29	0.27	229.14	221.09	209.58	11.68	11.39	11.26	262.71	249.69	242.06
SD	0.05	0.05	0.06	39.41	33.31	33.26	2.81	2.83	2.58	57.92	53.74	53.85
CV (%)	18.01	18.68	21.02	17.20	15.07	15.87	24.04	24.90	22.89	22.05	21.52	22.25

4.2.5 Fertility parameters of sewage water irrigated soil

4.2.5.1 Organic carbon

The organic carbon content of soils not only plays a significant role in improving cation exchange capacity, aggregation, water holding capacity, and fertility status of soils but also influences many physico-chemical aspects of soils, both directly and indirectly.

Organic carbon content in the soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior district varied from 0.38 to 0.48, 0.24-0.42 and 0.22 to 0.36 per cent with the mean values of 0.40, 0.37 and 0.31 per cent, standard deviation of 0.05, 0.07 and 0.07, CV (%) of 11.52, 17.81 and 21.55 percent, respectively (Table 4.14).

4.2.5.2 Available nitrogen

A perusal of data Table 4.14 indicated that the available nitrogen content of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior district varied from 295.57 to 354.19, 228.50 to 278.01 and 157.50 to 252.08 kg N ha⁻¹ with the mean values of 332.75, 251.92 and 201.52 kg N ha⁻¹, standard deviation of 20.20, 21.33 and 34.81, CV (%) of 6.07, 8.47 and 17.27 percent, respectively.

4.2.5.3 Available phosphorus

A perusal of data Table 4.1 indicated that the available phosphorus content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior district varied from 19.15 to 22.10, 19.15 to 20.35 and 18.15 to 20.42 kg P ha⁻¹ with the mean values of 20.53, 19.62 and 19.09 kg P ha⁻¹, standard deviation of 1.16, 0.66 and 0.84, CV (%) of 5.64, 3.37 and 4.40 percent, respectively.

4.2.5.4 Available potassium

On visualization of data presented in table 4.14 showed that the available potassium status of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior district ranged between 288.80 to 328.20, 248.38 to 307.78 and 233.81 to 283.23 with the mean values of 305.83, 282.08 and 254.19 kg

K₂O ha⁻¹, standard deviation of 15.49, 21.04 and 20.16, CV (%) of 5.06, 7.46 and 7.93 percent, respectively.

Table 4.14: Fertility parameters of sewage water water irrigated soil in Morar block of Gwalior

Sewage water												
Morar Block	Organic Carbon (%)			Available nitrogen (kg ha⁻¹)			Available phosphorus(kg ha⁻¹)			Available potassium (kg ha⁻¹)		
Depth	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Range	0.36-0.48	0.24-0.42	0.22-0.36	295.57-354.19	228.50-278.01	157.50-252.08	19.15-22.10	19.01-20.35	18.15-20.42	268.80-328.20	248.38-307.78	233.81-283.23
Mean	0.40	0.37	0.31	332.75	251.92	201.52	20.53	19.62	19.09	305.83	282.08	254.19
SD	0.05	0.07	0.07	20.20	21.33	34.81	1.16	0.66	0.84	15.49	21.04	20.16
CV (%)	11.52	17.81	21.55	6.07	8.47	17.27	5.64	3.37	4.40	5.06	7.46	7.93

4.2.b Classification of soils on the basis of fertility index in Morar block of Gwalior

The fertility index for organic carbon, available nitrogen, phosphorus and potassium were calculated for soils of studied area as per method suggested by Muhr *et al.* (1965).

4.2.1 Fertility index of soil organic carbon irrigated by tube well water

The fertility index for organic carbon was 1.88, 1.79 and 1.63 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium at each depth in organic carbon status through irrigated with tube well water (Table 4.15).

4.2.2 Fertility index of soil organic carbon irrigated by Sewage water

The fertility index for organic carbon was 2.00, 1.83 and 1.67 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium at each depth in organic carbon status through irrigated with Sewage water (Table 4.16).

4.2.3 Fertility index of soil available nitrogen irrigated by tube well water

The fertility index for available nitrogen was 1.38, 1.25 and 1.17 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be low at each depth in available nitrogen status through irrigated with tube well water (Table 4.17).

4.2.4 Fertility index of soil available nitrogen irrigated by Sewage water

The fertility index for available nitrogen was 1.83, 1.33 and 1.17 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium, low and low depth in available nitrogen status through irrigated with Sewage water (Table 4.18).

4.2.5 Fertility index of soil available phosphorous irrigated by tube well water

The fertility index for available phosphorous was 1.75, 1.63 and 1.58 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium at each depth in available phosphorous status

through irrigated with tube well water (Table 4.19).

4.2.6 Fertility index of soil available phosphorous irrigated by Sewage water

The fertility index for available phosphorous was 2.67, 2.50 and 2.17 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be high at each depth in available phosphorous status through irrigated with Sewage water (Table 4.20).

4.2.7 Fertility index of soil available potassium irrigated by tube well water The fertility index for available potassium was 1.63, 1.58 and 1.46 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium, medium and low at each depth in available potassium status through irrigated with tube well water (Table 4.21).

4.2.8 Fertility index of soil available potassium irrigated by Sewage water The fertility index for available potassium was 2.00, 1.83 and 1.50 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium, medium and low at each depth in available potassium status through irrigated with sewage water (Table 4.22).

Table 4.15: Fertility index of soil organic carbon (OC) with tube well water in different depth of Morar block of Gwalior

Organic carbon (OC)												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	03	21	0	24	05	19	0	24	09	15	0	24
Percentage of samples in each category	12.50	87.50	0.00	100	20.83	79.17	0.00	100	37.50	62.50	0.00	100
Index	1.88 (Medium)				1.79 (Medium)				1.63 (Medium)			

Table 4.16: Fertility index of soil organic carbon (OC) with sewage water in different depth of Morar block of Gwalior

Organic carbon (OC)												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	0	06	0	06	01	05	0	06	02	04	0	06
Percentage of samples in each category	0.00	100.00	0.00	100	16.67	83.33	0.00	100	33.33	66.67	0.00	100
Index	2.00 (Medium)				1.83 (Medium)				1.67 (Medium)			

Table 4.17: Fertility index of available nitrogen with tube well water in different depth of Morar block of Gwalior

Available Nitrogen												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	15	09	0	24	18	06	0	24	20	04	0	24
Percentage of samples in each category	62.50	37.50	0.00	100	75.00	25.00	0.00	100	83.33	16.67	0.00	100
Index	1.38 (Low)				1.25 (Low)				1.17 (Low)			

Table 4.18: Fertility index of soil available nitrogen with sewage water in different depth of Morar block of Gwalior

Available Nitrogen												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	01	05	0	06	04	02	0	06	05	01	0	06
Percentage of samples in each category	16.67	83.33	0.00	100	66.67	33.33	0.00	100	83.33	16.67	0.00	100
Index	1.83 (Medium)				1.33 (Low)				1.17 (Low)			

Table 4.19: Fertility index of available phosphorus with tube well water in different depth of Morar block of Gwalior

Available Phosphorus												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	06	18	0	24	09	15	0	24	10	14	0	24
Percentage of samples in each category	25.00	75.00	0.00	100	37.50	62.50	0.00	100	41.67	58.33	0.00	100
Index	1.75 (Medium)				1.63 (Medium)				1.58 (Medium)			

Table 4.20: Fertility index of soil available phosphorus with sewage water in different depth of Morar block of Gwalior

Available Phosphorus												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	0	02	04	06	0	03	03	06	0	05	01	06
Percentage of samples in each category	0.00	33.33	66.67	100	0.00	50.00	50.00	100	0.00	83.33	16.67	100
Index	2.67 (High)				2.50 (High)				2.17 (High)			

Table 4.21: Fertility index of available potassium with tube well water in different depth of Morar block of Gwalior

Available potassium												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	09	15	0	24	10	14	0	24	13	11	0	24
Percentage of samples in each category	37.50	62.50	0.00	100	41.67	58.33	0.00	100	54.17	45.83	0.00	100
Index	1.63 (Medium)				1.58 (Medium)				1.46 (Low)			

Table 4.22: Fertility index of soil available potassium with sewage water in different depth of Morar block of Gwalior

Available potassium												
Particulars	0-15 cm				15-30 cm				30-45 cm			
	Low	Medium	High	Total	Low	Medium	High	Total	Low	Medium	High	Total
Number of samples	0	06	0	06	01	05	0	06	03	03	0	06
Percentage of samples in each category	0.00	100.00	0.00	100	16.67	83.33	0.00	100	50.00	50.00	0.00	100
Index	2.00 (Medium)				1.83 (Medium)				1.50 (Low)			

4.3 To find out the inter- connection between quality characteristics of ground water and some selected soil properties

4.3.1 The inter- connection between quality characteristics of tube well water and some selected soil properties

0-15 cm soil depth

A significant positive correlation was found (Table.4.23) between soil bulk density with EC ($r=0.832^{**}$), Ca^{++} ($r=0.843^{**}$), Mg^{++} ($r=0.866^{**}$) and porosity with pH ($r=0.674^{**}$), Na^+ ($r=0.834^{**}$), K^+ ($r=0.873^{**}$) and pH with ground water pH ($r=0.531^{**}$) and soil EC with water EC ($r=0.945^{**}$), Ca^{++} ($r=0.886^{**}$), Mg^{++} ($r=0.769^{**}$) and OC with pH ($r=0.754^{**}$) and N with Mg^{++} ($r=0.645^{**}$), HCO_3^- ($r=0.520^{**}$) and P with EC ($r=0.798^{**}$), Ca^{++} ($r=0.683^{**}$), Mg^{++} ($r=0.539^{**}$) and K with pH ($r=0.606^{**}$), Na^+ ($r=0.718^{**}$), K^+ ($r=0.720^{**}$) of the study area.

A significant partially positive correlation was found (Table.4.23) between soil particle density with RSC ($r=0.417^*$) and soil pH with K^+ ($r=0.442^*$) and soil EC with Cl^- ($r=0.425^*$) and soil OC with Ca^{++} ($r=-0.502^*$), Mg^{++} ($r=0.434^*$) and N with EC ($r=0.434^*$), Ca^{++} ($r=0.510^*$) and P with V ($r=0.507^*$) and K with RSC ($r=0.476^*$) of the study area.

A significant negative correlation was found (Table.4.23) between soil bulk density with Na^+ ($r=-0.812^{**}$) and K^+ ($r=-0.862^{**}$) and porosity with EC ($r=-0.838^{**}$), Ca^{++} ($r=-0.911^{**}$), Mg^{++} ($r=-0.869^{**}$) and soil EC with Na^+ ($r=-0.700^{**}$), K^+ ($r=-0.765^{**}$) and N with Na^+ ($r=-0.602^{**}$), K^+ ($r=-0.635^{**}$) and P with K^+ ($r=-0.535^{**}$) and K with EC ($r=-0.564^{**}$), Ca^{++} ($r=-0.673^{**}$), Mg^{++} ($r=-0.707^{**}$) of the study area.

A significant partially negative correlation was found (Table.4.24) between soil bulk density with pH ($r=-0.498^*$) and soil pH with Mg^{++} ($r=-0.451^*$) and soil EC with pH ($r=-0.436^*$) and N with SO_4^{2-} ($r=-0.449^*$) and P with Na^+ ($r=-0.479^*$) of the study area.

15-30 cm soil depth

A significant positive correlation was found (Table.4.24) between soil bulk density with EC ($r=0.832^{**}$), Ca^{++} ($r=0.843^{**}$), CO_3^{2-} ($r=0.647^{**}$), HCO_3^- ($r=0.746^{**}$) and porosity with pH ($r=0.674^{**}$), SO_4^{2-} ($r=0.853^{**}$), RSC ($r=0.635^{**}$),

SAR ($r=0.765^{**}$) and soil EC with water EC ($r=0.945^{**}$), Ca^{++} ($r=0.886^{**}$), CO_3^{2-} ($r=0.553^{**}$), HCO_3^- ($r=0.687^{**}$) and OC with pH ($r=0.754^{**}$) and P with EC ($r=0.798^{**}$), Ca^{++} ($r=0.683^{**}$) and K with pH ($r=0.606^{**}$), Na^+ ($r=0.601^{**}$), K^+ ($r=0.634^{**}$), SO_4^{2-} ($r=0.689^{**}$), RSC ($r=0.562^{**}$), SAR ($r=0.571^{**}$) of the study area.

A significant partially positive correlation was found (Table.4.24) between soil particle density with Na^+ ($r=0.455^*$), K^+ ($r=0.441^*$) and soil porosity with Na^+ ($r=0.451^*$), K^+ ($r=0.507^*$) and soil pH with SAR ($r=0.414^*$) and soil EC with Cl^- ($r=0.483^*$), SO_4^{2-} ($r=0.440^*$) and N with EC ($r=0.434^*$), Ca^{++} ($r=0.510^*$), and P with HCO_3^- ($r=0.491^*$) of the study area.

A significant negative correlation was found (Table.4.24) between soil bulk density with SO_4^{2-} ($r=-0.738^{**}$), SAR ($r=-0.766^{**}$) and porosity with EC ($r=-0.838^{**}$), Ca^{++} ($r=-0.911^{**}$), Mg^{++} ($r=-0.515^{**}$), CO_3^{2-} ($r=-0.740^{**}$), HCO_3^- ($r=-0.783^{**}$) and soil pH with Mg^{++} ($r=-0.528^{**}$), CO_3^{2-} ($r=-0.598^{**}$) soil EC with SO_4^{2-} ($r=-0.630^{**}$), SAR ($r=-0.760^{**}$) and P with SAR ($r=-0.583^{**}$) and K with EC ($r=-0.564^{**}$), Ca^{++} ($r=-0.673^{**}$), Mg^{++} ($r=-0.636^{**}$), CO_3^{2-} ($r=-0.716^{**}$), HCO_3^- ($r=-0.636^{**}$) of the study area.

A significant partially negative correlation was found (Table.4.24) between soil bulk density with pH ($r=-0.498^*$), RSC ($r=-0.465^*$) and soil particle density with Mg^{++} ($r=-0.445^*$) and soil pH with HCO_3^- ($r=-0.510^*$) and soil EC with pH ($r=-0.436^*$) and soil OC with Ca^{++} ($r=-0.502^*$), CO_3^{2-} ($r=-0.441^*$), HCO_3^- ($r=-0.445^*$) and P with SO_4^{2-} ($r=-0.438^*$) of the study area.

30-45cm soil depth

A significant positive correlation was found (Table.4.25) between soil bulk density with EC ($r=0.832^{**}$), Ca^{++} ($r=0.843^{**}$), Mg^{++} ($r=0.858^{**}$) and porosity with pH ($r=0.674^{**}$), Na^+ ($r=0.838^{**}$), K^+ ($r=0.846^{**}$), SO_4^{2-} ($r=0.603^{**}$) and soil pH with water pH ($r=0.531^{**}$) and soil EC with EC ($r=0.945^{**}$), Ca^{++} ($r=0.886^{**}$), Mg^{++} ($r=0.767^{**}$) and OC with pH ($r=0.754^{**}$) and N with Mg^{++} ($r=0.656^{**}$) and P with EC ($r=0.798^{**}$), Ca^{++} ($r=0.683^{**}$), Mg^{++} ($r=0.543^{**}$) and K with pH ($r=0.606^{**}$), Na^+ ($r=0.700^{**}$), K^+ ($r=0.686^{**}$), SO_4^{2-} ($r=0.565^{**}$), RSC ($r=0.521^{**}$) of the study area.

A significant partially positive correlation was found (Table.4.25) between soil porosity with RSC ($r=0.432^*$) and soil pH with Na^+ ($r=0.465^*$), K^+ ($r=0.442^*$), SO_4^{2-} ($r=0.434^*$) and soil EC with Cl^- ($r=0.466^*$) and soil OC with Na^+

($r=0.454^*$), K^+ ($r=0.447^*$) and N with EC ($r=0.434^*$), Ca^{++} ($r=0.510^*$), CO_3^{2-} ($r=0.413^*$), HCO_3^- ($r=0.478^*$) and P with Cl^- ($r=0.505^*$) of the study area.

A significant negative correlation was found (Table.4.25) between soil bulk density with Na^+ ($r=-0.842^{**}$), K^+ ($r=-0.861^{**}$), SO_4^{2-} ($r=-0.739^{**}$) and porosity with EC ($r=-0.838^{**}$), Ca^{++} ($r=-0.911^{**}$), Mg^{++} ($r=-0.826^{**}$) and soil EC with Na^+ ($r=-0.713^{**}$), K^+ ($r=-0.763^{**}$) and N with Na^+ ($r=-0.698^{**}$), K^+ ($r=-0.673^{**}$), SO_4^{2-} ($r=-0.642^{**}$) and P with K^+ ($r=-0.539^{**}$) and K with EC ($r=-0.564^{**}$), Ca^{++} ($r=-0.673^{**}$), Mg^{++} ($r=-0.650^{**}$) of the study area.

A significant partially negative correlation was found (Table.4.25) between soil bulk density with pH ($r=-0.498^*$) and soil pH with Mg^{++} ($r=-0.409^*$) and soil EC with pH ($r=0.436^*$) and soil OC with Ca^{++} ($r=-0.502^*$), Mg^{++} ($r=-0.409^*$) and P with Na^+ ($r=-0.482^*$), SO_4^{2-} ($r=-0.437^*$) and K with CO_3^{2-} ($r=0.489^*$) of the study area.

Table 4.23: The correlation between quality characteristics of tube well water and some selected soil properties at 0-15 cm depth Morar Block of Gwalior

Parameters	pH	EC dSm ⁻¹	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ⁻⁻ ₄	RSC	SAR
BD	-0.498*	0.832**	0.843**	0.866**	-0.812**	-0.862**	0.136 ^{NS}	0.240 ^{NS}	0.089 ^{NS}	-0.153 ^{NS}	-0.176 ^{NS}	-0.137 ^{NS}
PD	0.232 ^{NS}	0.321 ^{NS}	0.146 ^{NS}	0.019 ^{NS}	0.018 ^{NS}	-0.013 ^{NS}	-0.246 ^{NS}	-0.133 ^{NS}	0.363 ^{NS}	0.207 ^{NS}	0.417*	0.153 ^{NS}
Porosity	0.674**	-0.838**	-0.911**	-0.869**	0.834**	0.873**	-0.158 ^{NS}	-0.178 ^{NS}	-0.229 ^{NS}	0.138 ^{NS}	0.330 ^{NS}	0.126 ^{NS}
pH	0.531**	-0.221 ^{NS}	-0.356 ^{NS}	-0.451*	0.400 ^{NS}	0.442*	-0.253 ^{NS}	-0.254 ^{NS}	0.233 ^{NS}	0.249 ^{NS}	0.288 ^{NS}	0.243 ^{NS}
EC	-0.436*	0.945**	0.886**	0.769**	-0.700**	-0.765**	-0.033 ^{NS}	0.074 ^{NS}	0.425*	0.017 ^{NS}	0.027 ^{NS}	-0.016 ^{NS}
OC	0.754**	-0.375 ^{NS}	-0.502*	-0.434*	0.294 ^{NS}	0.404 ^{NS}	0.046 ^{NS}	0.051 ^{NS}	-0.056 ^{NS}	-0.045 ^{NS}	0.039 ^{NS}	-0.023 ^{NS}
N	-0.192 ^{NS}	0.434*	0.510*	0.645**	-0.602**	-0.635**	0.403 ^{NS}	0.520**	-0.307 ^{NS}	-0.449*	-0.217 ^{NS}	-0.381 ^{NS}
P	-0.324 ^{NS}	0.798**	0.683**	0.539**	-0.479*	-0.535**	-0.093 ^{NS}	0.008 ^{NS}	0.507*	0.070 ^{NS}	0.124 ^{NS}	0.003 ^{NS}
K	0.606**	-0.564**	-0.673**	-0.707**	0.718**	0.720**	-0.385 ^{NS}	-0.379 ^{NS}	-0.014 ^{NS}	0.368 ^{NS}	0.476*	0.357 ^{NS}

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 4.24 The correlation between quality characteristics of tube well water and some selected soil properties at 15-30

Parameters	pH	EC dSm ⁻¹	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻⁻	RSC	SAR
BD	-0.498 [*]	0.832^{**}	0.843^{**}	0.315 ^{NS}	-0.272 ^{NS}	-0.308 ^{NS}	0.647^{**}	0.746^{**}	-0.333 ^{NS}	-0.738 ^{**}	-0.465 [*]	-0.766 ^{**}
PD	0.232 ^{NS}	0.321 ^{NS}	0.146 ^{NS}	-0.445 [*]	0.455[*]	0.441[*]	-0.160 ^{NS}	-0.015 ^{NS}	0.272 ^{NS}	0.079 ^{NS}	0.323 ^{NS}	-0.115 ^{NS}
Porosity	0.674^{**}	-0.838 ^{**}	-0.911 ^{**}	-0.515 ^{**}	0.451[*]	0.507[*]	-0.740 ^{**}	-0.783 ^{**}	0.317 ^{NS}	0.753^{**}	0.635^{**}	0.765^{**}
pH	0.531^{**}	-0.221 ^{NS}	-0.356 ^{NS}	-0.528 ^{**}	0.545^{**}	0.528^{**}	-0.598 ^{**}	-0.510 [*]	0.372 ^{NS}	0.601^{**}	0.351 ^{NS}	0.414[*]
EC	-0.436 [*]	0.945^{**}	0.886^{**}	0.136 ^{NS}	-0.082 ^{NS}	-0.132 ^{NS}	0.553^{**}	0.687^{**}	-0.100 ^{NS}	-0.630 ^{**}	-0.298 ^{NS}	-0.760 ^{**}
OC	0.754^{**}	-0.375 ^{NS}	-0.502 [*]	-0.256 ^{NS}	0.268 ^{NS}	0.265 ^{NS}	-0.441 [*]	-0.445 [*]	0.483[*]	0.440[*]	0.286 ^{NS}	0.383 ^{NS}
N	-0.192 ^{NS}	0.434[*]	0.510[*]	0.002 ^{NS}	-0.043 ^{NS}	-0.030 ^{NS}	0.230 ^{NS}	0.285 ^{NS}	-0.285 ^{NS}	-0.363 ^{NS}	-0.220 ^{NS}	-0.281 ^{NS}
P	-0.324 ^{NS}	0.798^{**}	0.683^{**}	-0.002 ^{NS}	0.052 ^{NS}	0.004 ^{NS}	0.388 ^{NS}	0.491[*]	0.064^{NS}	-0.438 [*]	-0.115 ^{NS}	-0.583 ^{**}
K	0.606^{**}	-0.564 ^{**}	-0.673 ^{**}	-0.636 ^{**}	0.601^{**}	0.634^{**}	-0.716 ^{**}	-0.637 ^{**}	0.237 ^{NS}	0.689^{**}	0.562^{**}	0.571^{**}

cm depth Morar Block of Gwalior

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 4.25: The correlation between quality characteristics of tube well water and some selected soil properties at 30-45 cm depth Morar Block of Gwalior

Parameters	pH	EC dSm ⁻¹	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ₄ ⁻	RSC	SAR
BD	-0.498 [*]	0.832 ^{**}	0.843 ^{**}	0.858 ^{**}	-0.842 ^{**}	-0.861 ^{**}	0.322 ^{NS}	0.224 ^{NS}	0.159 ^{NS}	-0.739 ^{**}	-0.313 ^{NS}	-0.025 ^{NS}
PD	0.232 ^{NS}	0.321 ^{NS}	0.146 ^{NS}	0.067 ^{NS}	0.025 ^{NS}	-0.036 ^{NS}	-0.122 ^{NS}	-0.126 ^{NS}	0.319 ^{NS}	-0.091 ^{NS}	0.321 ^{NS}	0.111 ^{NS}
Porosity	0.674 ^{**}	-0.838 ^{**}	-0.911 ^{**}	-0.826 ^{**}	0.838 ^{**}	0.846 ^{**}	-0.361 ^{NS}	-0.195 ^{NS}	-0.308 ^{NS}	0.603 ^{**}	0.432 [*]	0.036 ^{NS}
pH	0.531 ^{**}	-0.221 ^{NS}	-0.356 ^{NS}	-0.409 [*]	0.465 [*]	0.442 [*]	-0.260 ^{NS}	-0.211 ^{NS}	0.156 ^{NS}	0.434 [*]	0.278 ^{NS}	0.064 ^{NS}
EC	-0.436 [*]	0.945 ^{**}	0.886 ^{**}	0.767 ^{**}	-0.713 ^{**}	-0.763 ^{**}	0.224 ^{NS}	0.083 ^{NS}	0.466 [*]	-0.616 ^{**}	-0.128 ^{NS}	0.056 ^{NS}
OC	0.754 ^{**}	-0.375 ^{NS}	-0.502 [*]	-0.409 [*]	0.454 [*]	0.447 [*]	-0.051 ^{NS}	0.045 ^{NS}	-0.128 ^{NS}	0.214 ^{NS}	0.125 ^{NS}	-0.143 ^{NS}
N	-0.192 ^{NS}	0.434 [*]	0.510 [*]	0.656 ^{**}	-0.698 ^{**}	-0.673 ^{**}	0.413 [*]	0.478 [*]	-0.295 ^{NS}	-0.642 ^{**}	-0.371 ^{NS}	-0.296 ^{NS}
P	-0.324 ^{NS}	0.798 ^{**}	0.683 ^{**}	0.543 ^{**}	-0.482 [*]	-0.539 ^{**}	0.143 ^{NS}	0.006 ^{NS}	0.505 [*]	-0.437 [*]	-0.022 ^{NS}	0.069 ^{NS}
K	0.606 ^{**}	-0.564 ^{**}	-0.673 ^{**}	-0.650 ^{**}	0.700 ^{**}	0.686 ^{**}	-0.489 [*]	-0.367 ^{NS}	-0.046 ^{NS}	0.565 ^{**}	0.521 ^{**}	0.224 ^{NS}

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

4.3.2 The inter- connection between quality characteristics of sewage water and some selected soil properties

0-15 cm soil depth

A significant positive correlation was found (Table.4.26) between soil pH with Ca^{++} ($r=0.917^{**}$), HCO_3^- ($r=0.956^{**}$) and soil EC with RSC ($r=0.969^{**}$) of the study area.

A significant partially positive correlation was found (Table.4.26) between soil particle density Ca^{++} ($r=0.901^*$), HCO_3^- ($r=0.857^*$), RSC ($r=0.867^*$) and porosity with Na^+ ($r=0.813^*$), SO_4^{2-} ($r=0.909^*$) and soil pH with RSC ($r=0.860^*$) and soil EC with Ca^{++} ($r=0.896^*$) and P with RSC ($r=0.846^*$) of the study area.

A significant negative correlation was found (Table.4.26) between soil EC with SO_4^{2-} ($r=-0.977^{**}$) of the study area.

A significant partially negative correlation was found (Table.4.26) between soil particle density with SO_4^{2-} ($r=-0.862^*$) and porosity with RSC ($r=-0.904^*$) soil pH with SO_4^{2-} ($r=-0.841^*$) and soil OC with SO_4^{2-} ($r=-0.853^*$) and P with SO_4^{2-} ($r=-0.852^*$) of the study area.

15-30 cm soil depth

A significant positive correlation was found (Table.4.27) between soil bulk density with SAR ($r=0.941^{**}$) soil pH with Ca^{++} ($r=0.917^{**}$), Mg^{++} ($r=0.956^{**}$), HCO_3^- ($r=0.964^*$) and soil EC with RSC ($r=0.968^{**}$) and N with Cl^- ($r=0.967^{**}$) of the study area.

A significant partially positive correlation was found (Table.4.27) between particle density with Ca^{++} ($r=0.901^*$), Mg^{++} ($r=0.857^*$), HCO_3^- ($r=0.846^*$) RSC ($r=0.851^*$) soil porosity with SO_4^{2-} ($r=0.910^*$) and soil pH with CO_3^{2-} ($r=0.904^*$), RSC ($r=0.851^*$) and soil EC with Ca^{++} ($r=0.896^*$) and P with RSC ($r=0.825^*$) of the study area.

A significant negative correlation was found (Table.4.27) between pH with Na^+ ($r=-0.940^{**}$), K^+ ($r=-0.780^{**}$) and soil EC with SO_4^{2-} ($r=-0.978^{**}$) of the study area.

A significant partially negative correlation was found (Table.4.27)

between particle density with Na^+ ($r=-0.859^*$), K^+ ($r=-0.894^*$), Cl^- ($r=-0.883^*$), SO_4^{2-} ($r=-0.861^*$) and porosity with RSC ($r=-0.917^*$), soil pH with Cl^- ($r=-0.850^*$), SO_4^{2-} ($r=-0.408419^*$) P with SO_4^{2-} ($r=-0.852^*$) of the study area.

30-45cm soil depth

A significant positive correlation was found (Table.4.28) soil pH with Ca^{++} ($r=0.917^{**}$), HCO_3^- ($r=0.940^{**}$) and soil EC with CO_3^{2-} ($r=0.933^{**}$), SAR ($r=0.960^{**}$) of the study area.

A significant partially positive correlation was found (Table.4.28) between particle density with Ca^{++} ($r=0.901^*$), CO_3^{2-} ($r=0.884^*$), HCO_3^- ($r=0.874^*$), SAR ($r=0.900^*$) and soil pH with CO_3^{2-} ($r=0.908^*$), SAR ($r=0.815^*$) and soil EC with Ca^{++} ($r=0.896^*$), HCO_3^- ($r=0.857^*$), SO_4^{2-} ($r=0.900^*$) and P with CO_3^{2-} ($r=0.835^*$), SAR ($r=0.886^*$) of the study area.

A significant partially negative correlation was found (Table.4.28) between porosity with CO_3^{2-} ($r=-0.871^*$), SO_4^{2-} ($r=-0.842^*$), SAR ($r=-0.818^*$) and soil pH with SO_4^{2-} ($r=-0.877^*$), K^+ ($r=-0.865^*$) and K with RSC ($r=0.846^*$) of the study area.

Table 4.26: The correlation between quality characteristics of sewage water and some selected soil properties at 0-15 cm depth Morar Block of Gwalior

Parameters	pH	EC dSm ⁻¹	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ⁻⁻ 4	RSC	SAR
BD	0.138 ^{NS}	0.662 ^{NS}	0.123 ^{NS}	-0.282 ^{NS}	-0.275 ^{NS}	0.176 ^{NS}	-0.154 ^{NS}	-0.429 ^{NS}	-0.428 ^{NS}	-0.090 ^{NS}	0.065 ^{NS}	0.338 ^{NS}
PD	0.219 ^{NS}	0.285 ^{NS}	0.901 *	0.661 ^{NS}	-0.467 ^{NS}	-0.659 ^{NS}	0.657 ^{NS}	0.857 *	-0.634 ^{NS}	-0.862*	0.867 *	-0.061 ^{NS}
Porosity	-0.370 ^{NS}	-0.767 ^{NS}	-0.802 ^{NS}	-0.367 ^{NS}	0.813 *	0.488 ^{NS}	-0.619 ^{NS}	-0.466 ^{NS}	0.654 ^{NS}	0.909 *	-0.904*	-0.449 ^{NS}
pH	0.003 ^{NS}	0.137 ^{NS}	0.917 **	0.724 ^{NS}	-0.618 ^{NS}	-0.745 ^{NS}	0.791 ^{NS}	0.956 **	-0.480 ^{NS}	-0.841*	0.860 *	-0.171 ^{NS}
EC	0.461 ^{NS}	0.730 ^{NS}	0.896 *	0.456 ^{NS}	-0.673 ^{NS}	-0.532 ^{NS}	0.605 ^{NS}	0.590 ^{NS}	-0.791 ^{NS}	-0.977**	0.969 **	0.349 ^{NS}
OC	-0.608 ^{NS}	-0.034 ^{NS}	0.459 ^{NS}	0.622 ^{NS}	-0.853*	-0.712 ^{NS}	0.806 ^{NS}	0.569 ^{NS}	0.262 ^{NS}	-0.318 ^{NS}	0.355 ^{NS}	-0.067 ^{NS}
N	-0.377 ^{NS}	0.038 ^{NS}	-0.530 ^{NS}	-0.102 ^{NS}	-0.049 ^{NS}	0.075 ^{NS}	-0.121 ^{NS}	-0.534 ^{NS}	0.664 ^{NS}	0.550 ^{NS}	-0.549 ^{NS}	0.328 ^{NS}
P	0.426 ^{NS}	0.445 ^{NS}	0.810 ^{NS}	0.621 ^{NS}	-0.361 ^{NS}	-0.602 ^{NS}	0.565 ^{NS}	0.729 ^{NS}	-0.646 ^{NS}	-0.852*	0.846 *	0.166 ^{NS}
K	-0.738 ^{NS}	-0.447 ^{NS}	0.496 ^{NS}	0.389 ^{NS}	-0.486 ^{NS}	-0.434 ^{NS}	0.502 ^{NS}	0.611 ^{NS}	-0.013 ^{NS}	-0.173 ^{NS}	0.212 ^{NS}	-0.736 ^{NS}

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 4.27: The correlation between quality characteristics of sewage water and some selected soil properties at 15-30 cm depth Morar Block of Gwalior

Parameters	pH	EC dSm ⁻¹	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO -- 4	RSC	SAR
BD	0.138 ^{NS}	0.662 ^{NS}	0.123 ^{NS}	-0.429 ^{NS}	0.423 ^{NS}	0.394 ^{NS}	0.000 ^{NS}	-0.238 ^{NS}	0.413 ^{NS}	-0.091 ^{NS}	0.078 ^{NS}	0.941 ^{**}
PD	0.219 ^{NS}	0.285 ^{NS}	0.901 [*]	0.857 [*]	-0.859 [*]	-0.894 [*]	0.771 ^{NS}	0.846 [*]	-0.883 [*]	-0.861 [*]	0.851 [*]	-0.151 ^{NS}
Porosity	-0.370 ^{NS}	-0.767 ^{NS}	-0.802 ^{NS}	-0.466 ^{NS}	0.622 ^{NS}	0.589 ^{NS}	-0.762 ^{NS}	-0.624 ^{NS}	0.379 ^{NS}	0.910 [*]	-0.917 [*]	-0.311 ^{NS}
pH	0.003 ^{NS}	0.137 ^{NS}	0.917 ^{**}	0.956 ^{**}	-0.940 ^{**}	-0.978 ^{**}	0.904 [*]	0.964 ^{**}	-0.850 [*]	-0.841 [*]	0.851 [*]	-0.330 ^{NS}
EC	0.461 ^{NS}	0.730 ^{NS}	0.896 [*]	0.590 ^{NS}	-0.716 ^{NS}	-0.702 ^{NS}	0.760 ^{NS}	0.692 ^{NS}	-0.616 ^{NS}	-0.978 ^{**}	0.968 ^{**}	0.266 ^{NS}
OC	-0.608 ^{NS}	-0.034 ^{NS}	0.459 ^{NS}	0.569 ^{NS}	-0.438 ^{NS}	-0.507 ^{NS}	0.711 ^{NS}	0.657 ^{NS}	0.042 ^{NS}	-0.317 ^{NS}	0.368 ^{NS}	-0.298 ^{NS}
N	-0.377 ^{NS}	0.038 ^{NS}	-0.530 ^{NS}	-0.534 ^{NS}	0.668 ^{NS}	0.625 ^{NS}	-0.421 ^{NS}	-0.498 ^{NS}	0.967 ^{**}	0.550 ^{NS}	-0.539 ^{NS}	0.276 ^{NS}
P	0.426 ^{NS}	0.445 ^{NS}	0.810 ^{NS}	0.729 ^{NS}	-0.766 ^{NS}	-0.783 ^{NS}	0.607 ^{NS}	0.696 ^{NS}	-0.799 ^{NS}	-0.852 [*]	0.825 [*]	-0.025 ^{NS}
K	-0.738 ^{NS}	-0.447 ^{NS}	0.496 ^{NS}	0.611 ^{NS}	-0.417 ^{NS}	-0.522 ^{NS}	0.688 ^{NS}	0.669 ^{NS}	-0.355 ^{NS}	-0.171 ^{NS}	0.216 ^{NS}	-0.390 ^{NS}

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Table 4.28: The correlation between quality characteristics of sewage water and some selected soil properties at 30-45 cm depth Morar Block of Gwalior

Parameters	pH	EC dSm ⁻¹	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SO ⁻⁻ 4	RSC	SAR
BD	0.138 ^{NS}	0.662 ^{NS}	0.123 ^{NS}	-0.241 ^{NS}	0.618 ^{NS}	0.434 ^{NS}	0.002 ^{NS}	-0.083 ^{NS}	-0.132 ^{NS}	0.210 ^{NS}	0.483 ^{NS}	0.238 ^{NS}
PD	0.219 ^{NS}	0.285 ^{NS}	0.901*	0.636 ^{NS}	-0.759 ^{NS}	-0.713 ^{NS}	0.884*	0.874*	0.270 ^{NS}	0.714 ^{NS}	-0.563 ^{NS}	0.900*
Porosity	-0.370 ^{NS}	-0.767 ^{NS}	-0.802 ^{NS}	-0.397 ^{NS}	0.420 ^{NS}	0.434 ^{NS}	-0.871*	-0.802 ^{NS}	0.215 ^{NS}	-0.842*	-0.025 ^{NS}	-0.818*
pH	0.003 ^{NS}	0.137 ^{NS}	0.917**	0.777 ^{NS}	-0.877*	-0.865*	0.908*	0.940**	0.340 ^{NS}	0.631 ^{NS}	-0.684 ^{NS}	0.815*
EC	0.461 ^{NS}	0.730 ^{NS}	0.896*	0.434 ^{NS}	-0.512 ^{NS}	-0.484 ^{NS}	0.933**	0.857*	-0.100 ^{NS}	0.900*	-0.130 ^{NS}	0.960**
OC	-0.608 ^{NS}	-0.034 ^{NS}	0.459 ^{NS}	0.788 ^{NS}	-0.495 ^{NS}	-0.730 ^{NS}	0.460 ^{NS}	0.579 ^{NS}	0.409 ^{NS}	0.250 ^{NS}	-0.303 ^{NS}	0.160 ^{NS}
N	-0.377 ^{NS}	0.038 ^{NS}	-0.530 ^{NS}	-0.128 ^{NS}	0.568 ^{NS}	0.323 ^{NS}	-0.522 ^{NS}	-0.477 ^{NS}	0.030 ^{NS}	-0.249 ^{NS}	0.624 ^{NS}	-0.606 ^{NS}
P	0.426 ^{NS}	0.445 ^{NS}	0.810 ^{NS}	0.503 ^{NS}	-0.655 ^{NS}	-0.578 ^{NS}	0.835*	0.791 ^{NS}	0.124 ^{NS}	0.807 ^{NS}	-0.332 ^{NS}	0.886*
K	-0.738 ^{NS}	-0.447 ^{NS}	0.496 ^{NS}	0.663 ^{NS}	-0.453 ^{NS}	-0.625 ^{NS}	0.319 ^{NS}	0.450 ^{NS}	0.686 ^{NS}	-0.123 ^{NS}	-0.846*	0.222 ^{NS}

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

Chapter- V

Discussion

5.1 To evaluate the irrigation water quality of morar block of Gwalior district

5.1.1 Characteristics of tube well water

5.1.1.1 Ionic composition of tube well water

It observed from data that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) values were ranged between 0.17 to 4.36, 0.05 to 1.24, 1.18 to 5.98 and 0.02 to 0.09 (me L^{-1}) with an average value of 2.51, 0.40, 3.02 and 0.06 (me L^{-1}), SD of 1.15, 0.30, 1.52 and 0.02 value and CV (%) of 45.87, 74.00, 50.23 and 30.69 in Morar block of Gwalior.

It observed from data that the soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) values were ranged between 0.08 to 0.66, 1.11 to 4.91, 0.28 to 3.11, and 0.10 to 0.90 (me L^{-1}) with an average value of 0.36, 3.34, 1.82 and 0.36 (me L^{-1}), SD of 0.14, 1.04, 0.73 and 0.23 value and CV (%) of 37.35, 31.04, 40.38 and 62.38 in Morar block of Gwalior. Similar results were reported by Lal *et al.* (1998) and Singh *et al.* (2006).

5.1.2 Characteristics of sewage water

5.1.2.1 Ionic composition of sewage water

It observed from data that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) values were ranged between 2.73 to 5.39, 0.19 to 1.79, 1.34 to 4.34 and 0.10 to 0.20 (me L^{-1}) with an average value of 3.95, 0.88, 2.70 and 0.15 (me L^{-1}), SD of 1.03, 0.64, 1.44 and 0.04 value and CV (%) of 26.06, 73.22, 53.49 and 28.18 in Morar block of Gwalior district of Madhya Pradesh.

It observed from data that the soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) values were ranged between 0.37 to 0.44, 2.27 to 4.78, 1.58 to 2.78, and 0.90 to 1.30 (me L^{-1}) with an average value of 0.40, 3.79, 2.26 and 1.12 (me L^{-1}), SD of 0.03, 1.08, 0.49 and 0.13 value and CV (%) of 06.70, 28.62, 21.92 and 11.90 in Morar block of Gwalior. Similar results were reported by Singh *et al.* (2006).

5.1.3 Characteristics of tube well irrigation water in Morar block of Gwalior

5.1.3.1 pH

It observed from data that the pH of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the pH values were ranged between 7.30 to 8.30 with an average value of 7.80, SD of 0.31 value and CV (%) of 3.91 in Morar block of Gwalior. . Similar results were reported by Sharma (2005), Selvakumar *et al.* (2017)

5.1.3.2 EC

It observed from data that the EC of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the EC values were ranged between 0.32 dSm^{-1} to 0.79 dSm^{-1} with an average value of 0.60 dSm^{-1} , SD of 0.12 value and CV (%) of 20.53 in Morar block. The similar results of investigation get from the findings of Kumar *et al.* (2017). Deo and Lal (1982).

5.1.3.3 Residual sodium carbonate

It observed from data that the RSC of each water samples range, means, standard deviation and CV (%) of different tube well quality parameter of Morar block that the RSC values were ranged between Nil me L^{-1} to 4.57 meL^{-1} with an average value of 1.23 me L^{-1} , SD of 1.56 value and CV (%) of 127.25 in Morar block. The RSC indicates the excess of carbonate and bicarbonate over calcium and magnesium in tube well. Similar results were reported by Verma *et al.* (2003), Ram (2003).

5.1.3.4 Sodium adsorption ratio

It observed from data that the SAR of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the SAR values were ranged between 2.04 to 8.21 with an average value of 3.99, SD of 1.75 value and CV (%) of 43.90 in Morar block. . Similar results were reported by Verma *et al.* (2003), Ram (2003).

5.1.4 Characteristics of sewage irrigation water of Morar block of Gwalior

5.1.4.1 pH

It observed from data that the pH of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the pH values were ranged between 7.40 to 7.90 with an average value of 7.71, SD of 0.19 value and CV (%) of 2.49 in Morar block of Gwalior. Such a view was supported (Schipper *et al.* 1996).

5.1.4.2 EC

It observed from data that the EC of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar block that the EC values were ranged between 0.63 dSm⁻¹ to 0.90 dSm⁻¹ with an average value of 0.77 dSm⁻¹, SD of 0.12 value and CV (%) of 15.40 in Morar block. supported (Hayes *et al.* 1990).

5.1.4.3 Residual sodium carbonate

It observed from data that the RSC of each water samples range, means, standard deviation and CV (%) of different sewage water quality parameter of Morar block that the RSC values were ranged between Nil L⁻¹ to 1.28 meL⁻¹ with an average value of 0.30 me L⁻¹, SD of 0.52 value and CV (%) of 173.06 meL⁻¹ in Morar block. The RSC indicates the excess of carbonate and bicarbonate over calcium and magnesium in sewage water. Such a view was supported Sharma *et al.* (2015).

5.1.4.4 Sodium adsorption ratio

It observed from data that the SAR of each water samples range, means, standard deviation and CV (%) of different water quality parameter of Morar

block that the SAR values were ranged between 2.62 to 3.15 with an average value of 2.87, SD of 0.20 value and CV (%) of 6.96 in Morar block. Increase in SAR values of sewage water with the increase of pH and EC of sewage water might be due to dominance of soluble Na^+ over Ca^{++} , Mg^{++} . Such a view was supported Sharma *et al.* (2015).

5.1.5 Classification of irrigation water of Morar block of Gwalior

The 100.00 per cent of water samples fell into the C_1 (Normal water) category. Similarly, in terms of sodicity, approximately 80.00 per cent of water samples fell into the S_0 (Non sodic water) category, 20.00 per cent into the S_1 (Normal water) category. Moreover, according to alkalinity hazards, 63.33 per cent of water samples fell into the A_1 (Normal water) category, 26.67 per cent into the A_2 (Low alkalinity water) category and 10.00 per cent into the A_3 (Medium alkalinity water) category. As a result, roughly 35 per cent water samples may predict certain issues in the successful management of irrigated agriculture in the study area.

The irrigation water of the 90.00, 3.33 and 6.67 per cent water samples fell under good, marginally alkali and alkali categories, respectively. The list of villages of study area according to water quality classes as suggested by Gupta *et al.* (1994).

5.2 To evaluate the effect of irrigation water quality on soil properties

5.2. a. Soil characterization

5.2.1 Physical parameters of tube well water irrigated soil

5.2.1.1 Bulk density

The bulk density (bulk density (Mg m^{-3}) content of soils at 0-15, 15-30 and 30-45 cm depth Morar block of Gwalior were varied range from 1.24 to 01.42, 1.22 to 1.41 and 1.21 to 1.40 Mg m^{-3} with the mean value of 1.33, 1.32 and 1.31 Mg m^{-3} , SD value 0.06, 0.06, 0.06 of and CV (%) of 4.40, 4.60 and 4.60 % respectively. Similar trend was also noticed by Yadav *et al.* (2018) and Mathan and Mahendra (1994).

5.2.1.2 Particle density

The particle density (Mg m^{-3}) content of soils at 0-15, 15-30

and 30-45 cm depth Morar block of Gwalior were varied range from 2.56 to 2.72, 2.43 to 2.87 and 2.37 to 2.77 Mg m^{-3} with the mean value of 2.65, 2.62 and 2.54 Mg m^{-3} , SD value 0.04, 0.15, 0.14 of and CV (%) of 1.52, 5.63 and 5.37 % respectively. Similar results were reported by Naga (1984). Yadav *et al.* (2018).

5.2.1.3 Porosity (%)

The Porosity (%) content of soils at 0-15, 15-30 and 30-45 cm depth of Morar block of Gwalior were varied range from 44.53 to 54.41, 40.51 to 55.64 and 42.39 to 57.49 % with the mean value of 49.69, 47.73 and 49.65 %, SD value 2.95, 5.12, 5.06 of and CV (%) of 5.93, 10.73 and 10.19 %, respectively. Similar observations were also reported by Srinivasarao *et al.* (2009) and Bhuyan *et al.* (2014).

5.2.2 Physical parameters of sewage water irrigated soil

5.2.2.1 Bulk density

The bulk density (Mg m^{-3}) was indicated that bulk density (Mg m^{-3}) content of soils at 0-15, 15-30 and 30-45 cm depth of Morar block of Gwalior were varied range from 1.25 to 1.33, 1.22 to 1.33 and 1.26 to 1.30 Mg m^{-3} with the mean value of 1.28, 1.29 and 1.28 Mg m^{-3} , SD value 0.03, 0.04, 0.01 of and CV (%) of 2.29, 2.89 and 1.06 % respectively. Similar results were reported by Halliwell (2001), Singh (2012)

5.2.2.2 Particle density

The particle density (Mg m^{-3}) was indicated that particle density (Mg m^{-3}) content of soils at 0-15, 15-30 and 30-45 cm depth of Morar block of Gwalior were varied range from 2.56 to 2.66, 2.61 to 2.69 and 2.52 to 2.61 Mg m^{-3} with the mean value of 2.60, 2.66 and 2.58 Mg m^{-3} , SD value 0.03, 0.03, 0.03 of and CV (%) of 1.30, 1.05 and 1.26 % respectively. Similar results were reported by Halliwell (2001), Singh (2012)

5.2.2.3 Porosity (%)

The porosity (%) were indicated that porosity (%) content of soils at 0-15, 15-30 and 30-45 cm depth and of Morar block of Gwalior were varied range from 49.61 to 51.92, 48.65 to 51.59 and 50.19 to 53.16 % with the mean value of 50.61, 50.20 and 51.81 %, SD value 0.88, 1.03, 0.98

of and CV (%) of 1.75, 2.06 and 1.89 %, respectively. Such a view was supported Halliwell (2001), Singh (2012).

5.2.3 Chemical parameters of tube well water irrigated soil

5.2.3.1 pH

pH of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior ranged from 7.25 to 8.07, 7.32 to 8.15 and 7.38 to 8.30 with mean values of 7.71, 7.69 and 7.77, SD value 0.26, 0.27, 0.27 of and CV (%) of 3.39, 3.45 and 3.54 %, respectively. Such a view was supported Sharma *et al.* (2015).

5.2.3.2 Electrical conductivity

The electrical conductivity of soil is a measure of the total concentration of soluble salts. A perusal of data in indicated that the electrical conductivity of soils of Morar block of Gwalior varied from 0.17 to 0.67, 0.25 to 0.68 and 0.25 to 0.68 with a mean value of 0.42, 0.46 and 0.46 dS m⁻¹, SD value 0.19, 0.15, 0.15 of and CV (%) of 44.01, 31.77 and 31.81%, respectively. Similar results were reported by by Yadav *et al.* (2018).

5.2.4 Chemical parameters of sewage water irrigated soil

5.2.4.1 pH

pH of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior ranged from 7.62 to 7.72, 7.56 to 7.73 and 7.67 to 7.77 with mean values of 7.67, 7.65 and 7.72, SD value 0.05, 0.08, 0.04 of and CV (%) of 0.63, 1.08 and 0.58 %, Significant increase of 0.5 units in surface soil irrigated with mixed domestic and industrial effluents from EIKhashab (Egypt) has also been reported (El-Hady *et al.* 2007). Such effect may be attributed to the high content of basic cations *viz.* Na⁺, Ca²⁺ and Mg²⁺ in the WW, which after accumulation in surface soil layer for a long period of time. Such a view was supported (Schipper *et al.* 1996).

5.2.4.2 Electrical conductivity

The electrical conductivity of soil is a measure of the total concentration of soluble salts. A perusal of data in indicated that the electrical conductivity of soils of Morar block of Gwalior varied from 0.33 to 0.35, 0.36

to 0.42 and 0.36 to 0.42 with a mean value of 0.34, 0.40 and 0.39 dSm^{-1} , SD value 0.01, 0.02, 0.02 of and CV (%) of 2.88, 6.11 and 6.07 %, However, soil $\text{Ca}^{2+}+\text{Mg}^{2+}$ concentrations were greater in soils irrigated with industrial effluent by 0.5 mmol L^{-1} but were lesser when compared with potable irrigation. Leachate collected at 61 cm depth indicated that effluent irrigated soil leachate was higher than potable water irrigated leachate primarily in EC by 0.2 d S m^{-1} and Na^+ content by 0.8 mmol L^{-1} . Such a view was supported (Hayes *et al.* 1990).

5.2.5 Fertility parameters of tube well water irrigated soil

5.2.5.1 Organic carbon

Organic carbon content in the soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior varied from 0.19 to 0.39, 0.20-0.41 and 0.15 to 0.36 per cent with the mean values of 0.30, 0.29 and 0.27 per cent, standard deviation of 0.05, 0.05 and 0.06, CV (%) of 18.01, 18.68 and 21.02 percent, respectively. Similar trend was also noticed by Prakash (2001), Yadav and Meena (2009)

5.2.5.2 Available nitrogen

The available nitrogen content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior varied from 180.53 to 294.21, 175.49 to 278.01 and 157.50 to 275.65 kg N ha^{-1} with the mean values of 229.14, 221.09 and 209.58 kg N ha^{-1} , standard deviation of 39.41, 33.31 and 33.26, CV (%) of 17.20, 15.07 and 15.87 percent, respectively. Similar trend was also noticed by

Sharma *et al.* (2008).

5.2.5.3 Available phosphorus

The available phosphorus content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior varied from 07.78 to 16.15, 07.69 to 16.16 and 07.62 to 16.09 kg P ha^{-1} with the mean values of 11.68, 11.39 and 11.26 kg P ha^{-1} , standard deviation of 2.81, 2.83 and 2.58, CV (%) of 24.04, 24.90 and 22.89 percent, respectively. Similar results were reported by Singh

et al. (2017), Meena *et al.* (2006), Yadav *et al.* (2018).

5.2.5.4 Available potassium

The available potassium status of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior ranged between 184.98 to 360.00, 178.02 to 353.93 and 168.01 to 342.74 with the mean values of 262.71, 249.69 and 242.06 kg K₂O ha⁻¹, standard deviation of 57.92, 53.74 and 53.85, CV (%) of 22.05, 21.52 and 22.25 percent, respectively. Similar results were reported by

Meena *et al.* (2006), Ravikumar and Soma Shekar (2014), Yadav *et al.* (2018).

5.2.5 Fertility parameters of sewage water irrigated soil

5.2.5.1 Organic carbon

Organic carbon content in the soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior varied from 0.38 to 0.48, 0.24-0.42 and 0.22 to 0.36 per cent with the mean values of 0.40, 0.37 and 0.31 per cent, standard deviation of 0.05, 0.07 and 0.07, CV (%) of 11.52, 17.81 and 21.55 percent, Sewage irrigation for 50-60 years in soils of Calcutta (India) has exhibited an increase in soil OC from 0.19 to 0.37% [49] and from 1.24 to 1.73% after 25 years in soils of Kurukshetra (Haryana, India). Similar results were reported by Yadav *et al.* (2002).

5.2.5.2 Available nitrogen

The available nitrogen content of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior varied from 295.57 to 354.19, 228.50 to 278.01 and 157.50 to 252.08 kg N ha⁻¹ with the mean values of 332.75, 251.92 and 201.52 kg N ha⁻¹, standard deviation of 20.20, 21.33 and 34.81, CV (%) of 6.07, 8.47 and 17.27 percent, In 36-years long-term experiment on the use of domestic sewage WW, the build-up of 2908 kg TN ha⁻¹ in surface soil has also been reported by Rusan *et al.* (2007).

5.2.5.3 Available phosphorus

The available phosphorus content of soils at different depth 0-15, 15-30 and

30-45cm of Morar block of Gwalior varied from 19.15 to 22.10, 19.15 to 20.35 and 18.15 to 20.42 kg P ha⁻¹ with the mean values of 20.53, 19.62 and 19.09 kg P ha⁻¹, standard deviation of 1.16, 0.66 and 0.84, CV (%) of 5.64, 3.37 and 4.40 percent, In 36-years long-term experiment on the use of domestic sewage WW, the build-up of 58 kg Av-P ha⁻¹, 2115 kg TP ha⁻¹ in surface soil has also been reported by Rusan *et al.* (2007).

5.2.5.4 Available potassium

The available potassium status of soils at different depth 0-15, 15-30 and 30-45cm of Morar block of Gwalior ranged between 288.80 to 328.20, 248.38 to 307.78 and 233.81 to 283.23 with the mean values of 305.83, 282.08 and 254.19 kg K₂O ha⁻¹, standard deviation of 15.49, 21.04 and 20.16, CV (%) of 5.06, 7.46 and 7.93 percent, In 36-years long-term experiment on the use of domestic sewage WW, the build-up of 305 kg Av-K ha⁻¹ and 4712 kg TK ha⁻¹ in surface soil has also been reported by Rusan *et al.* (2007).

5.2.b Classification of soils on the basis of fertility index in Morar block of Gwalior

The fertility index for organic carbon, available nitrogen, phosphorus and potassium were calculated for soils of studied area as per method suggested by Muhr *et al.* (1965).

5.2.1 Fertility index of soil organic carbon irrigated by tube well water

The fertility index for organic carbon was 1.88, 1.79 and 1.63 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium at each depth in organic carbon status through irrigated with tube well water. Such a view was supported Pathak (2010), Bagherzadeh *et al.* (2018).

5.2.2 Fertility index of soil organic carbon irrigated by Sewage water

The fertility index for organic carbon was 2.00, 1.83 and 1.67 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium at each depth in organic carbon status through irrigated with Sewage water. Salehi *et al.* (2013).

5.2.3 Fertility index of soil available nitrogen irrigated by tube well water

The fertility index for available nitrogen was 1.38, 1.25 and 1.17 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be low at each depth in available nitrogen status through irrigated with tube well water available nitrogen. Such a view was supported Pathak (2010)

5.2.4 Fertility index of soil available nitrogen irrigated by Sewage water

The fertility index for available nitrogen was 1.83, 1.33 and 1.17 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium, low and low depth in available nitrogen status through irrigated with Sewage water. Similar results were reported by **Salehi et al. (2013)**.

5.2.5 Fertility index of soil available phosphorous irrigated by tube well water

The fertility index for available phosphorous was 1.75, 1.63 and 1.58 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium at each depth in available phosphorous status through irrigated with tube well water. Such a view was supported Banerjee *et al.* (2012)

5.2.6 Fertility index of soil available phosphorous irrigated by Sewage water

The fertility index for available phosphorous was 2.67, 2.50 and 2.17 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be high at each depth in available phosphorous status through irrigated with Sewage water. Similar results were reported Banerjee *et al.* (2012)

5.2.7 Fertility index of soil available potassium irrigated by tube well water

The fertility index for available potassium was 1.63, 1.58 and 1.46 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium, medium and low at each depth in available potassium status through irrigated with tube well water. Such a view was supported Pathak (2010)

5.2.8 Fertility index of soil available potassium irrigated by Sewage

water

The fertility index for available potassium was 2.00, 1.83 and 1.50 for soils at 0-15 cm, 15-30cm and 30-45 depth, Thus, soils of the studied area was found to be medium, medium and low at each depth in available potassium status through irrigated with sewage water. Similar results were reported by

Salehi *et al.* (2013).

5.3 To find out the inter- connection between quality characteristics of ground water and some selected soil properties

5.3.1 The inter- connection between quality characteristics of tube well water and some selected soil properties

0-15 cm soil depth

A significant positive correlation was found between soil bulk density with EC ($r=0.832^{**}$), Ca^{++} ($r=0.843^{**}$), Mg^{++} ($r=0.866^{**}$) and porosity with pH ($r=0.674^{**}$), Na^+ ($r=0.834^{**}$), K^+ ($r=0.873^{**}$) and pH with ground water pH ($r=0.531^{**}$) and soil EC with water EC ($r=0.945^{**}$), Ca^{++} ($r=0.886^{**}$), Mg^{++} ($r=0.769^{**}$) and OC with pH ($r=0.754^{**}$) and N with Mg^{++} ($r=0.645^{**}$), HCO_3^- ($r=0.520^{**}$) and P with EC ($r=0.798^{**}$), Ca^{++} ($r=0.683^{**}$), Mg^{++} ($r=0.539^{**}$) and K with pH ($r=0.606^{**}$), Na^+ ($r=0.718^{**}$), K^+ ($r=0.720^{**}$) of the study area.

A significant partially positive correlation was found between soil particle density with RSC ($r=0.417^*$) and soil pH with K^+ ($r=0.442^*$) and soil EC with Cl^- ($r=0.425^*$) and soil OC with Ca^{++} ($r=-0.502^*$), Mg^{++} ($r=0.434^*$) and N with EC ($r=0.434^*$), Ca^{++} ($r=0.510^*$) and P with V ($r=0.507^*$) and K with RSC ($r=0.476^*$) of the study area.

A significant negative correlation was found between soil bulk density with Na^+ ($r=-0.812^{**}$) and K^+ ($r=-0.862^{**}$) and porosity with EC ($r=-0.838^{**}$), Ca^{++} ($r=-0.911^{**}$), Mg^{++} ($r=-0.869^{**}$) and soil EC with Na^+ ($r=-0.700^{**}$), K^+ ($r=-0.765^{**}$) and N with Na^+ ($r=-0.602^{**}$), K^+ ($r=-0.635^{**}$) and P with K^+ ($r=-0.535^{**}$) and K with EC ($r=-0.564^{**}$), Ca^{++} ($r=-0.673^{**}$), Mg^{++} ($r=-0.707^{**}$) of the study area.

A significant partially negative correlation was found between soil bulk density with pH ($r=-0.498^*$) and soil pH with Mg^{++} ($r=-0.451^*$) and soil EC with

pH ($r=-0.436^*$) and N with SO_4^{2-} ($r=-0.449^*$) and P with Na^+ ($r=-0.479^*$) of the study area.

15-30 cm soil depth

A significant positive correlation was found between soil bulk density with EC ($r=0.832^{**}$), Ca^{++} ($r=0.843^{**}$), CO_3^{2-} ($r=0.647^{**}$), HCO_3^- ($r=0.746^{**}$) and porosity with pH ($r=0.674^{**}$), SO_4^{2-} ($r=0.853^{**}$), RSC ($r=0.635^{**}$), SAR ($r=0.765^{**}$) and soil EC with water EC ($r=0.945^{**}$), Ca^{++} ($r=0.886^{**}$), CO_3^{2-} ($r=0.553^{**}$), HCO_3^- ($r=0.687^{**}$) and OC with pH ($r=0.754^{**}$) and P with EC ($r=0.798^{**}$), Ca^{++} ($r=0.683^{**}$) and K with pH ($r=0.606^{**}$), Na^+ ($r=0.601^{**}$), K^+ ($r=0.634^{**}$), SO_4^{2-} ($r=0.689^{**}$), RSC ($r=0.562^{**}$), SAR ($r=0.571^{**}$) of the study area.

A significant partially positive correlation was found between soil particle density with Na^+ ($r=0.455^*$), K^+ ($r=0.441^*$) and soil porosity with Na^+ ($r=0.451^*$), K^+ ($r=0.507^*$) and soil pH with SAR ($r=0.414^*$) and soil EC with Cl^- ($r=0.483^*$), SO_4^{2-} ($r=0.440^*$) and N with EC ($r=0.434^*$), Ca^{++} ($r=0.510^*$), and P with HCO_3^- ($r=0.491^*$) of the study area.

A significant negative correlation was found between soil bulk density with SO_4^{2-} ($r=-0.738^{**}$), SAR ($r=-0.766^{**}$) and porosity with EC ($r=-0.838^{**}$), Ca^{++} ($r=-0.911^{**}$), Mg^{++} ($r=-0.515^{**}$), CO_3^{2-} ($r=-0.740^{**}$), HCO_3^- ($r=-0.783^{**}$) and soil pH with Mg^{++} ($r=-0.528^{**}$), CO_3^{2-} ($r=-0.598^{**}$) soil EC with SO_4^{2-} ($r=-0.630^{**}$), SAR ($r=-0.760^{**}$) and P with SAR ($r=-0.583^{**}$) and K with EC ($r=-0.564^{**}$), Ca^{++} ($r=-0.673^{**}$), Mg^{++} ($r=-0.636^{**}$), CO_3^{2-} ($r=-0.716^{**}$), HCO_3^- ($r=-0.636^{**}$) of the study area.

A significant partially negative correlation was found between soil bulk density with pH ($r=-0.498^*$), RSC ($r=-0.465^*$) and soil particle density with Mg^{++} ($r=-0.445^*$) and soil pH with HCO_3^- ($r=-0.510^*$) and soil EC with pH ($r=-0.436^*$) and soil OC with Ca^{++} ($r=-0.502^*$), CO_3^{2-} ($r=-0.441^*$), HCO_3^- ($r=-0.445^*$) and P with SO_4^{2-} ($r=-0.438^*$) of the study area.

30-45cm soil depth

A significant positive correlation was found between soil bulk density with EC ($r=0.832^{**}$), Ca^{++} ($r=0.843^{**}$), Mg^{++} ($r=0.858^{**}$) and porosity with pH ($r=0.674^{**}$), Na^+ ($r=0.838^{**}$), K^+ ($r=0.846^{**}$), SO_4^{2-} ($r=0.603^{**}$) and soil pH with

water pH ($r=0.531^{**}$) and soil EC with EC ($r=0.945^{**}$), Ca^{++} ($r=0.886^{**}$), Mg^{++} ($r=0.767^{**}$) and OC with pH ($r=0.754^{**}$) and N with Mg^{++} ($r=0.656^{**}$) and P with EC ($r=0.798^{**}$), Ca^{++} ($r=0.683^{**}$), Mg^{++} ($r=0.543^{**}$) and K with pH ($r=0.606^{**}$), Na^+ ($r=0.700^{**}$), K^+ ($r=0.686^{**}$), SO_4^{2-} ($r=0.565^{**}$), RSC ($r=0.521^{**}$) of the study area.

A significant partially positive correlation was found between soil porosity with RSC ($r=0.432^*$) and soil pH with Na^+ ($r=0.465^*$), K^+ ($r=0.442^*$), SO_4^{2-} ($r=0.434^*$) and soil EC with Cl^- ($r=0.466^*$) and soil OC with Na^+ ($r=0.454^*$), K^+ ($r=0.447^*$) and N with EC ($r=0.434^*$), Ca^{++} ($r=0.510^*$), CO_3^{2-} ($r=0.413^*$), HCO_3^- ($r=0.478^*$) and P with Cl^- ($r=0.505^*$) of the study area.

A significant negative correlation was found between soil bulk density with Na^+ ($r=-0.842^{**}$), K^+ ($r=-0.861^{**}$), SO_4^{2-} ($r=-0.739^{**}$) and porosity with EC ($r=-0.838^{**}$), Ca^{++} ($r=-0.911^{**}$), Mg^{++} ($r=-0.826^{**}$) and soil EC with Na^+ ($r=-0.713^{**}$), K^+ ($r=-0.763^{**}$) and N with Na^+ ($r=-0.698^{**}$), K^+ ($r=-0.673^{**}$), SO_4^{2-} ($r=-0.642^{**}$) and P with K^+ ($r=-0.539^{**}$) and K with EC ($r=-0.564^{**}$), Ca^{++} ($r=-0.673^{**}$), Mg^{++} ($r=-0.650^{**}$) of the study area.

A significant partially negative correlation was found between soil bulk density with pH ($r=-0.498^*$) and soil pH with Mg^{++} ($r=-0.409^*$) and soil EC with pH ($r=0.436^*$) and soil OC with Ca^{++} ($r=-0.502^*$), Mg^{++} ($r=-0.409^*$) and P with Na^+ ($r=-0.482^*$), SO_4^{2-} ($r=-0.437^*$) and K with CO_3^{2-} ($r=0.489^*$) of the study area. Similar results were obtained by Mehta (1970) and Khandelwal and Lal (1991), Singh and Singh (1997).

5.3.2 The inter- connection between quality characteristics of sewage water and some selected soil properties

0-15 cm soil depth

A significant positive correlation was found between soil pH with Ca^{++} ($r=0.917^{**}$), HCO_3^- ($r=0.956^{**}$) and soil EC with RSC ($r=0.969^{**}$) of the study area.

A significant partially positive correlation was found between soil particle density Ca^{++} ($r=0.901^*$), HCO_3^- ($r=0.857^*$), RSC ($r=0.867^*$) and porosity with Na^+ ($r=0.813^*$), SO_4^{2-} ($r=0.909^*$) and soil pH with RSC ($r=0.860^*$) and soil EC with Ca^{++} ($r=0.896^*$) and P with RSC ($r=0.846^*$) of the study area.

A significant negative correlation was found between soil EC with SO_4^{2-} ($r=-0.977^{**}$) of the study area.

A significant partially negative correlation was found between soil particle density with SO_4^{2-} ($r=-0.862^*$) and porosity with RSC ($r=-0.904^*$) soil pH with SO_4^{2-} ($r=-0.841^*$) and soil OC with SO_4^{2-} ($r=-0.853^*$) and P with SO_4^{2-} ($r=-0.852^*$) of the study area.

15-30 cm soil depth

A significant positive correlation was found between soil bulk density with SAR ($r=0.941^{**}$) soil pH with Ca^{++} ($r=0.917^{**}$), Mg^{++} ($r=0.956^{**}$), HCO_3^- ($r=0.964^*$) and soil EC with RSC ($r=0.968^{**}$) and N with Cl^- ($r=0.967^{**}$) of the study area.

A significant partially positive correlation was found between particle density with Ca^{++} ($r=0.901^*$), Mg^{++} ($r=0.857^*$), HCO_3^- ($r=0.846^*$) RSC ($r=0.851^*$) soil porosity with SO_4^{2-} ($r=0.910^*$) and soil pH with CO_3^{2-} ($r=0.904^*$), RSC ($r=0.851^*$) and soil EC with Ca^{++} ($r=0.896^*$) and P with RSC ($r=0.825^*$) of the study area.

A significant negative correlation was found between pH with Na^+ ($r=-0.940^{**}$), K^+ ($r=-0.780.9^{**}$) and soil EC with SO_4^{2-} ($r=-0.978^{**}$) of the study area.

A significant partially negative correlation was found between particle density with Na^+ ($r=-0.859^*$), K^+ ($r=-0.894^*$), Cl^- ($r=-0.883^*$), SO_4^{2-} ($r=-0.861^*$) and porosity with RSC ($r=-0.917^*$), soil pH with Cl^- ($r=-0.850^*$), SO_4^{2-} ($r=-0.408419^*$) P with SO_4^{2-} ($r=-0.852^*$) of the study area.

30-45cm soil depth

A significant positive correlation was found soil pH with Ca^{++} ($r=0.917^{**}$), HCO_3^- ($r=0.940^{**}$) and soil EC with CO_3^{2-} ($r=0.933^{**}$), SAR ($r=0.960^{**}$) of the study area.

A significant partially positive correlation was found between particle density with Ca^{++} ($r=0.901^*$), CO_3^{2-} ($r=0.884^*$), HCO_3^- ($r=0.874^*$), SAR ($r=0.900^*$) and soil pH with CO_3^{2-} ($r=0.908^*$), SAR ($r=0.815^*$) and soil EC with Ca^{++} ($r=0.896^*$), HCO_3^- ($r=0.857^*$), SO_4^{2-} ($r=0.900^*$) and P with CO_3^{2-} ($r=0.835^*$), SAR ($r=0.886^*$) of the study area.

A significant partially negative correlation was found between porosity with CO_3^{2-} ($r=-0.871^*$), SO_4^{2-} ($r=-0.842^*$), SAR ($r=-0.818^*$) and soil pH with SO_4^{2-} ($r=-0.877^*$), K^+ ($r=-0.865^*$) and K with RSC ($r=0.846^*$) of the study area. Similar results were obtained by Hayes *et al.* (1990), Rusan *et al.* (2007).

Chapter-VI

Summary, Conclusion and Suggestions for further work

6.1 Summary

Field research entitled “**Evaluation of ground water quality and its effects on Soil properties in Morar block of Gwalior**” was conducted during October and December, at the 2021. During the investigation, ninety soils (0-15,15-30,30-45 cm depth) and water samples (tube well and sewage) (30 samples) were collected from different of location Morar block of Gwalior. Results highlights of the present research are summarized and concluded in this chapter.

6.1.1 To evaluate the irrigation water quality of morar block of Gwalior district

6.1.1.1 Characteristics of tube well water

6.1.1.2 Ionic composition of tube well water

The soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) values were ranged between 0.17 to 4.36, 0.05 to 1.24, 1.18 to 5.98 and 0.02 to 0.09 (me L^{-1})

The soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) values were ranged between 0.08 to 0.66, 1.11 to 4.91, 0.28 to 3.11, and 0.10 to 0.90 (me L^{-1}).

6.1.1.3 Characteristics of sewage water

6.1.1.4 Ionic composition of sewage water

The soluble cation Ca^{++} , Mg^{++} , Na^+ and K^+ (me L^{-1}) values were ranged between 2.73 to 5.39, 0.19 to 1.79, 1.34 to 4.34 and 0.10 to 0.20 (me L^{-1})

The soluble anions CO_3^{2-} , HCO_3^- , Cl^- and SO_4^{2-} (me L^{-1}) values were ranged between 0.37 to 0.44, 2.27 to 4.78, 1.58 to 2.78, and 0.90 to 1.30 (me L^{-1})

6.1.1.5 Characteristics of tube well irrigation water in Morar block of Gwalior

The pH values were ranged between 7.30 to 8.30, EC values were ranged between 0.32 dSm^{-1} to 0.79 dSm^{-1} and RSC values were ranged between Nil me L^{-1} to 4.57 meL^{-1} , SAR values were ranged between 2.04 to 8.21.

6.1.1.6 Characteristics of sewage irrigation water of Morar block of Gwalior

pH values were ranged between 7.40 to 7.90, EC values were ranged between 0.63 dSm^{-1} and RSC values were ranged between Nil L^{-1} to 1.28 meL^{-1} , SAR values were ranged between 2.62 to 3.15.

6.1.1.7 Classification of irrigation water of Morar block of Gwalior

The 100.00 per cent of water samples fell into the C_1 (Normal water) category. Similarly, in terms of sodicity, approximately 80.00 per cent of water samples fell into the S_0 (Non sodic water). Moreover, according to alkalinity hazards, 63.33 per cent of water samples fell into the A_1 (Normal water) category, as a result, roughly 35 per cent water samples may predict certain issues in the successful management of irrigated agriculture in the study area. The irrigation water of the 90.00, 3.33 and 6.67 per cent water samples fell under good, marginally alkali and alkali categories, respectively.

6.1.2 To evaluate the effect of irrigation water quality on soil properties

6.1.2.1 Physical parameters of tube well water irrigated soil

The bulk density (Mg m^{-3}), particle density (Mg m^{-3}), porosity (%) content of soils at 0-15, 15-30 and 30-45 cm depth of Morar block were varied range from 1.24 to 01.42, 1.22 to 1.41 and 1.21 to 1.40 Mg m^{-3} , 2.56 to 2.72, 2.43 to 2.87 and 2.37 to 2.77 Mg m^{-3} and 44.53 to 54.41, 40.51 to 55.64 and 42.39 to 57.49 % respectively.

6.1.2.2 Physical parameters of sewage water irrigated soil

The bulk density (Mg m^{-3}), particle density (Mg m^{-3}), porosity (%) content of soils at 0-15, 15-30 and 30-45 cm depth of Morar block were varied range from 1.25 to 01.33, 1.22 to 1.33 and 1.26 to 1.30 Mg m^{-3} ,

2.56 to 2.66, 2.61 to 2.69 and 2.52 to 2.61 Mg m⁻³ and 49.61 to 51.92, 48.65 to 51.59 and 50.19 to 53.16 % respectively

6.1.2.3 Chemical parameters of tube well water irrigated soil

The pH of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior district ranged from 7.25 to 8.07, 7.32 to 8.15 and 7.38 to 8.30.

The electrical conductivity of soils of Morar block of Gwalior district varied from 0.17 to 0.67, 0.25 to 0.68 and 0.25 to 0.68.

6.1.2.4 Chemical parameters of sewage water irrigated soil

The pH of soils at different depth 0-15, 15-30 and 30-45 cm of Morar block of Gwalior district ranged from 7.62 to 7.72, 7.56 to 7.73 and 7.67 to 7.77

The electrical conductivity of soils of Morar block of Gwalior district varied from 0.33 to 0.35, 0.36 to 0.42 and 0.36 to 0.42.

6.1.2.5 Fertility parameters of tube well water irrigated soil

Organic carbon content in the soils at different depth 0-15, 15-30 and 30-45cm of Morar block varied from 0.19 to 0.39, 0.20-0.41 and 0.15 to 0.36 percent, respectively.

The available nitrogen content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block varied from 180.53 to 294.21, 175.49 to 278.01 and 157.50 to 275.65 kg N ha⁻¹, respectively.

The available phosphorus content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block varied from 07.78 to 16.15, 07.69 to 16.16 and 07.62 to 16.09 kg P ha⁻¹, respectively.

The available potassium status of soils at different depth 0-15, 15-30 and 30-45cm of Morar block ranged between 184.98 to 360.00, 178.02 to 353.93 and 168.01 to 342.74 K ha⁻¹, respectively.

6.1.2.6 Fertility parameters of sewage water irrigated soil

Organic carbon content in the soils at different depth 0-15, 15-30 and 30-45cm of Morar block varied from 0.38 to 0.48, 0.24-0.42 and 0.22 to 0.36 percent, respectively.

The available nitrogen content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block varied from 295.57 to 354.19, 228.50 to 278.01 and 157.50 to 252.08 kg N ha⁻¹, respectively.

The available phosphorus content of soils at different depth 0-15, 15-30 and 30-45cm of Morar block varied from 19.15 to 22.10, 19.15 to 20.35 and 18.15 to 20.42 kg P ha⁻¹, respectively.

The available potassium status of soils at different depth 0-15, 15-30 and 30-45cm of Morar block ranged 288.80 to 328.20, 248.38 to 307.78 and 233.81 to 283.23 kha⁻¹, respectively.

6.1.3 Classification of soils on the basis of fertility index in Morar block of Gwalior

6.1.3.1 Fertility index of soil irrigated by tube well water

The fertility index for organic carbon was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be medium at each depth.

The fertility index for available nitrogen was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be low at each depth.

The fertility index for available phosphorous was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be medium at each depth.

The fertility index for available potassium was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be medium, medium and low at depth.

6.1.3.2 Fertility index of soil irrigated by sewage water

The fertility index for organic carbon was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be medium at each depth.

The fertility index for available nitrogen was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be medium, low and low depth depth.

The fertility index for available phosphorous was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be high at each depth.

The fertility index for available potassium was 0-15 cm, 15-30cm and 30-45 depth Thus, soils of the studied area was found to be medium, medium and low at each depth.

6.1.4 To find out the inter- connection between quality characteristics of ground water and some selected soil properties

6.1.4.1 The inter- connection between quality characteristics of ground water and some selected soil properties irrigated by tube well water

0-15 cm soil depth

A significant positive correlation was found) between soil bulk density with EC ($r=0.832^{**}$), $Ca^{++}(r=0.843^{**})$, $Mg^{++}(r=0.866^{**})$ and porosity with pH ($r=0.674^{**}$), $Na^{+}(r=0.834^{**})$, $K^{+}(r=0.873^{**})$ and pH with ground water pH ($r=0.531^{**}$) and soil EC with water EC ($r=0.945^{**}$), $Ca^{++}(r=0.886^{**})$, $Mg^{++}(r=0.769^{**})$ and OC with pH($r=0.754^{**}$) and N with $Mg^{++}(r=0.645^{**})$, $HCO_3^{-}(r=0.520^{**})$ and P with EC ($r=0.798^{**}$), $Ca^{++}(r=0.683^{**})$, $Mg^{++}(r=0.539^{**})$ and K with pH ($r=0.606^{**}$), $Na^{+}(r=0.718^{**})$, $K^{+}(r=0.720^{**})$ of the study area.

15-30 cm soil depth

A significant positive correlation was found between soil bulk density with EC ($r=0.832^{**}$), $Ca^{++}(r=0.843^{**})$, $CO_3^{2-}(r=0.647^{**})$, $HCO_3^{-}(r=0.746^{**})$ and porosity with pH ($r=0.674^{**}$), $SO_4^{2-}(r=0.853^{**})$, RSC ($r=0.635^{**}$), SAR ($r=0.765^{**}$) and soil EC with water EC ($r=0.945^{**}$), $Ca^{++}(r=0.886^{**})$, $CO_3^{2-}(r=0.553^{**})$, $HCO_3^{-}(r=0.687^{**})$ and OC with pH($r=0.754^{**}$) and P with EC ($r=0.798^{**}$), $Ca^{++}(r=0.683^{**})$ and K with pH ($r=0.606^{**}$), $Na^{+}(r=0.601^{**})$, $K^{+}(r=0.634^{**})$, $SO_4^{2-}(r=0.689^{**})$, RSC($r=0.562^{**}$), SAR ($r=0.571^{**}$) of the study area.

30-45cm soil depth

A significant positive correlation was found (Table.4.23) between soil bulk density with EC ($r=0.832^{**}$), $Ca^{++}(r=0.843^{**})$, $Mg^{++}(r=0.858^{**})$ and porosity

with pH ($r=0.674^{**}$), Na^+ ($r=0.838^{**}$), K^+ ($r=0.846^{**}$), SO_4^{2-} ($r=0.603^{**}$) and soil pH with water pH ($r=0.531^{**}$) and soil EC with EC ($r=0.945^{**}$), Ca^{++} ($r=0.886^{**}$), Mg^{++} ($r=0.767^{**}$) and OC with pH ($r=0.754^{**}$) and N with Mg^{++} ($r=0.656^{**}$) and P with EC ($r=0.798^{**}$), Ca^{++} ($r=0.683^{**}$), Mg^{++} ($r=0.543^{**}$) and K with pH ($r=0.606^{**}$), Na^+ ($r=0.700^{**}$), K^+ ($r=0.686^{**}$), SO_4^{2-} ($r=0.565^{**}$), RSC ($r=0.521^{**}$) of the study area.

6.1.4.1 The inter-connection between quality characteristics of ground water and some selected soil properties irrigated by sewage water

0-15 cm soil depth

A significant positive correlation was found between soil pH with Ca^{++} ($r=0.917^{**}$), HCO_3^- ($r=0.956^{**}$) and soil EC with RSC ($r=0.969^{**}$) of the study area.

15-30 cm soil depth

A significant positive correlation was found (Table.4.25) between soil bulk density with SAR ($r=0.941^{**}$) soil pH with Ca^{++} ($r=0.917^{**}$), Mg^{++} ($r=0.956^{**}$), HCO_3^- ($r=0.964^{**}$) and soil EC with RSC ($r=0.968^{**}$) and N with Cl ($r=0.967^{**}$) of the study area.

30-45cm soil depth

A significant positive correlation was found (Table.4.26) soil pH with Ca^{++} ($r=0.917^{**}$), HCO_3^- ($r=0.940^{**}$) and soil EC with CO_3^{2-} ($r=0.933^{**}$), SAR ($r=0.960^{**}$) of the study area.

6.2 Conclusion

From the results interpreted, discussed summarized in the present investigation following conclusions are arranged out –

1. The dominant texture was found to be sandy loam to clay loam soils in across to block.
2. The natures of soils are neutral to alkaline except small area was represented by saline to alkaline patches.

3. Soils Morar block remain low in Organic Carbon, and available N, while available P was low to medium, available K found to be medium to high.

4. The quality of Irrigation water is of good to alkaline in nature. The alkaline in nature water are require some management practices and may affect the physical, chemical and biological properties of soil when used in excess and without amendments. Hence, irrigation water may be used with suitable management practices.

5. Most irrigation water fall are of good quality and the effect of various characteristics of irrigation water on physical, chemical and biological properties of soil remain unaffected, if used and with some suitable

6.3. Suggestions for further work

- Periodic assessment of irrigation water quality to evaluate the harnessing effect of water on soil physical, chemical and biological properties.
- Characterization of irrigation water quality at field level will help farmers directly in crop management practices and reclaiming soil health.
- Intervallic assessment in soil properties need to be done for assessing the depletion pattern of nutrients potential of soil to contribute towards plant needs from sub surface horizons.
- Characterization of soil at village level will assist farmers directly in balanced nutrient application and preparation of soil health cards of individual armers.

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