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RESEARCH PAPER

Assessment of nitrate levels in soil and water quality for sustainable agriculture in district Muzaffargarh, Pakistan

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Key Message: This research study highlights the importance of monitoring and maintaining safe nitrate levels for sustainable agriculture. The current nitrate levels in district Muzaffargarh Pakistan do not pose immediate contamination risks. It stresses the need for continuing monitoring and responsible agricultural practices to safeguard both soil and groundwater quality.

Abstract

This research study focuses on assessing the levels of nitrate (NO_3-) in soil and groundwater in various regions of district Muzaffargarh, Pakistan. Nitrate, a compound comprising one nitrogen atom and three oxygen atoms, can accumulate in soil due to nitrogen fertilizer application and potentially leach into groundwater, leading to contamination problems. The study collected soil samples at different depths from tehsil Muzaffargarh, Kot Adu, Ali Pur, and Jatoi to analyze nitrate concentrations. The results indicated that nitrate levels varied across depths, with the highest concentrations observed at 60-90 cm. Nitrate tended to decrease at greater depths (90-120 cm) due to capillary action, which transported nitrates upward with water movement. Water samples from canals and underground sources were also analyzed for pH, electrical conductivity (EC), and ion concentrations. The canal water was found suitable for irrigation, while the underground water was marginally fit. Hence, this study provides valuable insights into the distribution of nitrate in soil profiles and water sources in district Muzaffargarh. It suggests that current nitrate levels do not pose immediate contamination risks, but ongoing monitoring and responsible agricultural practices are essential to maintain safe nitrate levels in both soil and groundwater.

Keywords: Muzaffargarh, Groundwater contamination, Nitrate levels, Nitrogen fertilizer, Soil assessment, Sustainable agriculture, Water quality

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Introduction

Nitrate comprises one nitrogen atom and three oxygen atoms. Nitrite (NO_2) can be generated through the reduction of nitrate (Yu & Zhang, 2017). The nitrogen fertilizer undergoes nitrification, transforming into NO_3, a negatively charged substance (Purwanto et al., 2017). This compound gradually leaches downward, potentially reaching groundwater and causing contamination. Various factors such as tillage method, crop rotation, irrigation technique, and the rate of nitrogen fertilizer application influence the leaching of NO_3 (Kanwar, 1998). Nitrate stands as the most prevalent chemical contaminant in global groundwater supplies (Spalding & Exner, 1993). Fertilizer nitrogen applied to the soil surface can leach into groundwater through the soil profile (Randall et al., 1995). Particularly concerning situations arise in regions with coarse and medium-textured soils, where the nitrification process is rapid, leading to rapid nitrate leaching. The extent of NO_3 leaching from the soil is directly correlated with drainage volume (Ritter & Manager, 1985; Borin et al., 1998), and employing controlled irrigation practices can significantly reduce NO_3 losses through leaching (Burt & Trudgill, 1993).

In Pakistan, limited information is available regarding the impact of irrigation and nitrogen (N) fertilizer application on groundwater pollution resulting from NO_3 leaching. A research study conducted by Ibrahim & Nisar (1998) suggests that the risk of groundwater pollution from NO_3 leaching is low due to minimal N fertilizer usage and the application of a modest quantity of irrigation water (7.5 cm) under specific climatic conditions. Despite these findings, it is crucial to recognize the potential danger of nitrates as they can adversely affect the ecological balance of rivers and lakes posing a threat to human health. Nitrate (NO_3) is an inorganic compound present in the environment under various conditions, both naturally and synthetically. While nitrate itself typically does not pose health problems, it can become harmful if reduced to nitrite. Therefore, understanding and monitoring the factors influencing NO_3 leaching are essential for safeguarding water quality and human well-being.

Nitrate contents in both soil and plant tissues serve as a recognized indicator of the nitrogen nutrition status in crops (Non Renseigné et al., 2007). Consequently, the measurement of nitrate levels in soil and plants becomes crucial for recommending nitrogenous fertilizers to address deficiencies in standing crops (Bondada & Oosterhuis, 2001). For this purpose, a simple, rapid, and reliable nitrate assessment method is essential. Traditional steam distillation procedures, while effective demand specialized equipment and are time-consuming due to the need to evaporate the extract to dryness. Nitrate is not only derived from nitrogenous fertilizers but also results from the breakdown of soil organic matter, as well as the decomposition of manure or plant residues (Li et al., 2017). The nitrate ion (NO_3-) exhibits high solubility in water making it prone to leaching from the soil. This leaching process occurs as water drains through the soil leading to nitrate loss through surface water runoff, land drains, and deep percolation into groundwater (Schoumans et al., 2014). Understanding and managing nitrate dynamics are critical for sustainable agricultural practices and environmental conservation.

Over the past three decades, there has been a significant rise in nitrate concentrations in natural water sources such as rivers, lakes, and underground aquifers. Agricultural activities have been identified as a major contributor to the increase in nitrate levels in drinking water (Archer & Thompson, 1993). Globally, there is growing political and legislative pressure to mitigate nitrate leaching from agricultural land to adhere to established maximum permissible nitrate concentrations in drinking water. The assessment of nitrate levels in drinking water can be conducted by measuring the amount of nitrogen present or by considering both nitrogen and oxygen. The standards set for nitrate in drinking water are 10 mg per liter nitrate-N or 45 mg/L NO_3-N. Short-term exposure to drinking water containing nitrate levels at or slightly above the health standard of 10 mg/L NO_3-N poses a potential health risk particularly for infants. Infants, due to their relatively high-water consumption in proportion to their body weight are more susceptible, especially when water is used to prepare powdered or concentrated formulas and juices. Additionally, the immature digestive systems of infants are more prone than adult digestive tracts to facilitate the conversion of nitrate to nitrite. This becomes a significant concern as the presence of nitrite in the digestive tract of newborns can lead to a condition known as methemoglobinemia.

Recognizing the significance of high nitrate concentrations in soil and water, this study was undertaken to evaluate the levels of NO_3 in soil and underground water. The potential issues related to nitrate toxicity can be effectively mitigated through the proper management of forage and livestock. To minimize nitrate accumulation, it is crucial to conduct soil analyses and implement a well-balanced fertility program that aligns with plant requirements and moisture conditions. However, it is important to note that the likelihood of issues may be reduced but not eliminated. Nitrogen fertilizers have the potential to accumulate in the soil or leach into groundwater as nitrate, particularly in regions cultivating maize and potatoes where high nitrogen doses are common, leading to pollution problems. Hence, this study is designed to systematically survey and monitor nitrate levels in both soil and underground water in these specific areas.

Materials and Methods

Soil sampling and processing

Eight sub-samples were taken per hectare (ha) in a diagonal pattern for obtaining one composite sample. A uniform slice was taken from the surface (0-15 cm) to the depth of insertion of the tool. These soil samples were kept in plastic bags (tags and markers were required) and then transported to the laboratory in cardboard boxes or sacks. All information about samples was recorded; and each sample was given a laboratory number. These samples were put in a freezer to minimize microbial activity. Samples were air-dried and cleaned off any stones and plant residues. After drying these samples were ground in a stainless-steel soil grinder and passed through a 2-mm sieve.

Soil analysis

For soil saturated paste, 200 g of air-dry soil was taken in a beaker; distilled water was added and left the sample overnight. After leaving the sample overnight, it became homogeneous and was easy to mix. Next day, soil samples were mixed with a spatula until an ideal soil paste was prepared. To determine the soil pH, the following materials and methods were employed. The apparatus utilized included a plastic beaker, spatula, and a pH meter. The reagents employed were buffer solutions with pH values of 4.0 and 9.0. The procedure started with the connection of the pH meter to an electricity source, followed by a warm-up period as per the manufacturer's instructions. A known standard buffer solution with a pH of 7.00 was then placed in a beaker, and the glass electrode of the pH meter was immersed in it. The pH meter reading was adjusted to match the pH value of the buffer solution, after which the electrode was removed and cleaned using deionized water. This procedure was repeated once more for accuracy. Subsequently, the electrode was washed again with deionized water before being inserted into a saturated soil paste and the pH reading was noted. Finally, the electrode was washed to ensure accurate results.

Determination of soil electrical conductivity

The electrical conductivity of the soil (ECe) was determined using the following method and apparatus. Two suction pumps were employed along with a plastic beaker and a conductivity meter. To prepare the soil extract, a saturated soil paste was obtained using the suction pump. Subsequently, a drop of

sodium hexametaphosphate was added to every 25 ml of the extract to prevent salt precipitation during storage. The EC meter was calibrated using a 0.01 N KCl solution to determine the cell constant. Once calibrated, the electrode was immersed in the soil extract, and the conductivity value was measured. Between each sample measurement, the electrode was thoroughly washed.
The cell constant was calculated by the formula:

$$K = \frac{1.4118\ (dSm^{-1})}{EC\ of\ 0.01N\ KCl}$$

Nitrate-Nitrogen

Nitrate-Nitrogen (NO_3-N) content was determined using a spectrophotometric method employing chromotropic acid. This method was initially developed for water analysis and later adapted for soil samples with speed and accuracy (Sims & Jackson, 1971; Hadjidemetriou, 1982). The apparatus used included a spectrophotometer, a mechanical shaker, and standard laboratory glassware such as beakers, volumetric flasks, pipettes, and funnels. Several reagents were employed in the process, including (A) 0.02 N Copper sulfate solution ($CuSO_4.5H_2O$), (B) 0.1% Chromotropic acid solution ($C_{10}\ H_6\ Na_2\ O_8\ S_2.\ 2H_2O$), (C) Concentrated sulfuric acid (H_2SO_4), and (D) Standard stock solution.

To prepare the standard stock solution, 3.6092 g of potassium nitrate (previously dried at 100°C for 2 hours) were dissolved in 500 mL of 0.02 N copper sulfate solution. This stock solution was then diluted by adding 0.02 N copper sulfate solution, yielding a diluted stock solution containing 50 ppm NO_3-N. A series of standard solutions were subsequently prepared by diluting specific volumes (4, 8, 16, 24, and 32 mL) of the diluted stock solution to 100 mL final volume with 0.02 N copper sulfate solution, resulting in standard solutions with NO_3-N concentrations of 2, 4, 8, 12, and 16 ppm, respectively.

The procedure began with the addition of 10 g of air-dried soil (2 mm) to an Erlenmeyer flask, followed by the addition of 50 mL of 0.02 N copper sulfate solution. After shaking for 15 minutes, the mixture was filtered through double Whatman No. 42 filter paper. Next, 3 mL of the filtrate were pipetted into a 50 mL conical flask, cooled in cold water for a few minutes, and then treated with 1 mL of 0.1% chromotropic acid solution added drop by drop. Following thorough mixing, 6 mL of concentrated sulfuric acid was added to the flask's wall without stirring. The samples were left to cool at room temperature, during which time a yellow color developed after 45 minutes.

Calculation of Nitrate-N in soil

To determine the concentration of Nitrate-N (NO3- N) in soil, the following formula was used:

NO_3-N (ppm) = ppm NO_3 - N (obtained from the calibration curve) × A/wt × 10/V
Where

A = Total volume of the extract (mL)
V = Volume of the extract used for measurement (3 mL)
Wt = Weight of air-dried soil (g)

This calculation method was used to quantify the concentration of Nitrate-N in soil samples, enabling accurate analysis and assessment of nitrogen content in the soil.

Water analysis

Total soluble salts (TSS)

The determination of total soluble salts (TSS) in the water sample was accomplished by multiplying the electrical conductivity of the extract (ECe) measured in deciSiemens per meter (dS/m) by a conversion factor of 10, expressed as:

$$TSS = EC_e\ (dSm^{-1}) \times 10$$

Determination of Ca^{2+} and Mg^{2+} ($meqL^{-1}$)

A 5 mL aliquot of the water sample was placed into a porcelain dish, to which 2-3 drops of Eriochrome black tea (EBT) were added as an indicator. The sample was then titrated against a 0.01 N ethylenediaminetetraacetic acid (EDTA) solution until the color transitioned from vine red to bluish green. The concentration of Ca^{2+} and Mg^{2+} in the water sample, expressed in milliequivalents per liter ($meqL^{-1}$) was calculated using the following formula:

$$Ca^{+2}+Mg^{+2}\ (meqL^{-1}) = \frac{Vol.\ of\ EDTA\ used \times N\ of\ EDTA \times 1000}{Vol.\ of\ sample\ taken}$$

This method allowed for the determination of the combined concentrations of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions in the water sample.

Determination of carbonate (CO_3^{-2})

A 5 mL aliquot of the water sample was carefully transferred into a conical flask. To this sample, 2-3 drops of phenolphthalein were added as an indicator. The development of a pink color indicated the presence of carbonates. The sample was subsequently titrated against a 0.1 N H_2SO_4 solution until a colorless endpoint was achieved. The concentration of carbonates (CO_3^2- meq/L) was calculated using the following formula:

$$CO_3^-\ (meqL^{-1}) = \frac{2\ (Vol.\ of\ acid\ used) \times Normality\ of\ acid \times 1000}{Vol.\ of\ sample\ taken}$$

Determination of bicarbonate (HCO_3^-)

In the same china dish used for the carbonate determination, 2-3 drops of methyl orange were added to the remaining sample. Titration was carried out with 0.1 N H_2SO_4 until a pinkish-yellow endpoint was observed. The concentration of bicarbonates (HCO_3^- meq/L) was calculated using the formula:

$$HCO_3^{-1}\ (\text{meqL}^{-1}) = \frac{(\text{Vol. of acid used}) \times N \times 1000)}{\text{Vol. of sample taken}}$$

Determination of chloride (Cl^-)

In the chloride determination method, the sample that had been previously preserved from the carbonate-bicarbonate determination was utilized. To initiate the procedure, precisely four drops of potassium chromate were added to the sample. With continuous and gentle stirring, the titration process was carried out under well-illuminated conditions using silver nitrate (AgNO3) from a burette until the first permanent reddish-brown coloration appeared.
The chloride concentration (Cl- meq/L) was calculated using the following formula:

$$Cl^{1-}\ (\text{meqL}^{-1}) = \frac{\text{Vol. of } AgNO_3 \text{ x N of } AgNO_3 \text{ x } 1000}{\text{Vol. of sample taken}}$$

Determination of sulphate

Sulphates were determined by the following difference method:

$$SO_4^{2-} = TSS - (CO_3^{-2} + HCO_3^{-1} + Cl^{-1})$$

(All expressed in meL^{-1})

Determination of sodium

Na^+ was determined by the following difference method:

$$Na^{+1} = TSS - (Ca^{+2}+Mg^{+2})$$

(All expressed in meL^{-1})

Determination of sodium adsorption ratio (SAR)

The criteria for fitness of water samples are given in Table 1. SAR was calculated by using the following formula:
$SAR = Na^+ / [(Ca^{++} + Mg^{++})/2]^{1/2}$

Determination of residual sodium carbonate (RSC)

RSC was calculated by using the formula:

$$RSC\ (\text{meL}^{-1}) = (CO_3^{-2}+HCO_3^{-1}) - (Ca^{+2}+\ Mg^{+2})$$

Table 1 Criteria for fitness of water samples

Parameters	Fit	Marginally fit	Unfit
EC (µs/cm)	0 - 1150	1150 -1450	> 1450
SAR	0 - 6	6 -10	> 10
RSC (meL^{-1})	0 - 1.25	1.25 -2.5	> 2.5

Results

Standards curve

Fig. 1 demonstrates the linear relationship between the NO_3-N concentration in the standards and the corresponding readings obtained from the spectrophotometer. As the NO_3-N concentration increases, the readings also increase, indicating a proportional relationship between the two variables. This standard curve can be used to determine the concentration of NO_3-N in unknown samples by measuring their spectrophotometer readings and then interpolating the concentration using the linear relationship established by this curve.

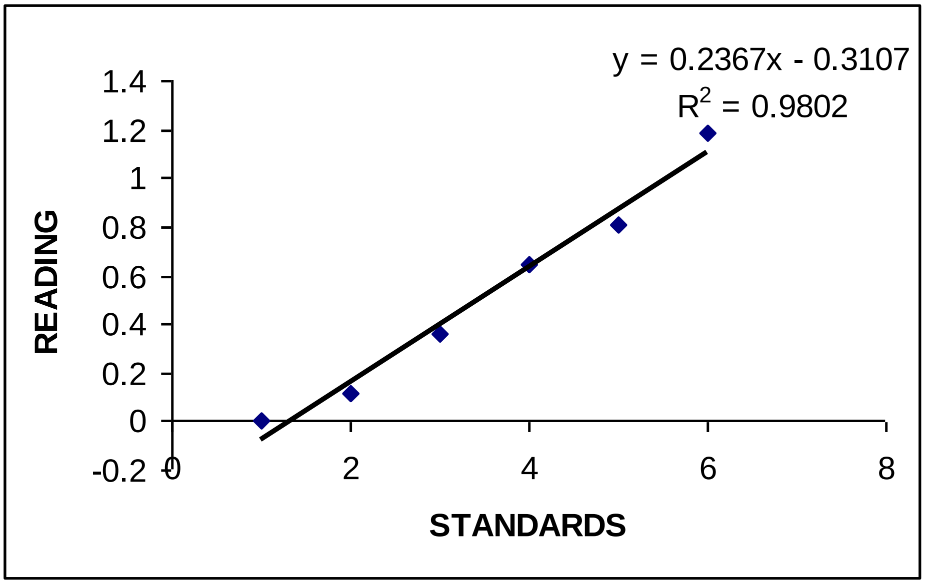

Fig. 1 This graph shows the linear relationship between standars and readings of NO_3 -Concentration

Nitrate-N concentration analysis in soil from tehsil Muzaffargarh

The samples were collected from tehsil Muzaffargarh from a farmer field at various depths ranging from 0-15 cm to 90-120 cm. The results indicate that the nitrate content in the soil varies across these depths, ranging from 1.7 ppm to 4.86 ppm (Table 2). The highest concentration of nitrates was found at a depth of 60-90 cm, where the soil contains 4.86 ppm of NO_3-N (Table 2). In contrast, at greater depths (90-120 cm), the nitrate concentration decreases to 3.66 ppm. The lowest nitrate concentration in the soil was observed at a depth of 15-30 cm, which is likely due to nitrate leaching down into deeper soil layers after irrigation. These results provide insights into the distribution of nitrates in the soil at different depths in tehsil Muzaffargarh, which can have implications for agricultural practices and nutrient management.

Table 2 NO_3-N concentrations in soil at different depth from tehsil Kot Adu

S. No.	Depth (cm)	NO_3-N (ppm)
1	0-15	2.8
2	15-30	1.7
3	30-60	2.2
4	60-90	4.86
5	90-120	3.66

Nitrate-N concentration analysis in soil from tehsil Kot Adu

Table 3 presents the NO3-N (nitrate nitrogen) concentration in soil samples collected from a farmer field from various depths in Tehsil Kot Adu. The results demonstrate a clear variability in nitrate levels at different depths. At the shallowest depth of 0-15 cm, the NO3-N concentration is measured at 3.24 ppm. Slightly deeper, within the range of 15-30 cm, the nitrate concentration increases to 4.97 ppm. Continuing down to 30-60 cm, the NO3-N concentration remains relatively high at 4.87 ppm. However, at a depth of 60-90 cm, the soil exhibits the highest NO3-N concentration at 5.80 ppm. Finally, at the greatest depth sampled, 90-120 cm, the nitrate concentration decreases to 3.28 ppm. These findings highlight a clear variation in nitrate levels with soil depth. Specifically, the soil's nitrate content is highest at a depth of 60-90 cm, while it gradually declines at greater depths. This information is valuable for understanding the distribution of nitrate within the soil profile in tehsil Kot Adu.

Table 3 NO_3-N concentration in soil at different depths from tehsil Kot Adu

S. No.	Depth (cm)	NO_{3-} N (ppm)
6	0-15	3.24
7	15-30	4.97
8	30-60	4.87
9	60-90	5.8
10	90-120	3.28

Nitrate-N concentration analysis in soil from tehsil Ali Pur

The samples in Table 4 were collected from a farmer's field in Tehsil Ali Pur at different depths: 0-15 cm, 15-30 cm, 30-60 cm, 60-90 cm, and 90-120 cm. This Table illustrates the nitrate concentration in the soil, which ranges from 1.25 ppm to 3.73 ppm. It is evident from the table that there is a higher concentration of nitrates at the depth of 60-90 cm, while at greater depths (90-120 cm), nitrate concentrations are relatively lower. Conversely, fewer nitrates are present at the shallow depth of 0-15 cm, likely due to leaching of nitrates deeper into the soil after irrigation. This variation in nitrate levels across different soil depths may have implications for agricultural practices and nutrient management in tehsil Ali Pur.

Table 4 NO_3-N concentration in soil at different depths from tehsil Ali Pur

S. No.	Depth (cm)	NO_3–N (ppm)
11	0-15	1.25
12	15-30	2.91
13	30-60	1.86
14	60-90	3.73
15	90-120	1.38

Nitrate-N concentration analysis in soil from tehsil Jatoi

The samples in Table 5 were collected from a farmer's field in tehsil Jatoi at various depths, ranging from 0-15 cm to 90-120 cm. The results indicate that the nitrate levels in the soil vary across the different depth ranges. The lowest nitrate concentration was observed in the 30-60 cm depth range, with a value of 1.71 ppm. In contrast, the highest nitrate concentration was found at the depth of 60-90 cm, where it reached 11.2 ppm. At the depth of 90-120 cm, the nitrate concentration was 3.75 ppm. There was a substantial increase in nitrate levels at the depth of 60-90 cm compared to the shallower depths. This suggests that nitrate may be accumulating or being transported to this deeper soil layer, possibly due to factors such as leaching from higher layers or nutrient management practices. In contrast, the 0-15 cm depth shows relatively lower nitrate levels (2.07 ppm), which could be attributed to nitrate leaching from this upper layer, possibly as a result of irrigation or other environmental factors.

Table 5 NO_3-N concentration in soil at different depths from tehsil Jatoi

S. No.	Depth (cm)	NO_3–N (ppm)
16	0-15	2.07
17	15-30	2.22
18	30-60	1.71
19	60-90	11.2
20	90-120	3.75

Canal water analysis

The analysis of canal water presented in Table 6 reveals several key parameters that are essential for determining its suitability for irrigation purposes. The pH level of the water was recorded at 6.90, which falls within the generally acceptable range for irrigation. The electrical conductivity (EC) was measured at 0.60 dSm^{-1}, indicating that the water has a relatively low salt content, making it suitable for irrigation without causing salt-related issues. Additionally, the absence of carbonate ions (CO_3) suggests that there is no excessive alkalinity present in the water. The combined concentration of calcium (Ca) and magnesium (mg) is reported at 4 $meqL^{-1}$, which is within acceptable limits. The sodium adsorption ratio (SAR) was found to be 1.41, further confirming the water's suitability for irrigation. The presence of bicarbonate ions (HCO_3) at 4 $meqL^{-1}$ also contributes positively to its usability for irrigation. In conclusion, based on these results, it can be confidently stated that the canal water meets the necessary criteria and is indeed fit for irrigation purposes.

Table 6 Results of analysis of canal water

Parameters	Readings	Parameters	Readings
pH	6.90	Cl	2 $meqL^{-1}$
EC	0.60 dSm^{-1}	(Ca+Mg)	4 $meqL^{-1}$
CO_3	Absent	SAR	1.41
HCO_3	4 $meqL^{-1}$		

Underground water analysis

The analysis of underground water, as presented in Table 7, reveals several key parameters. The pH level was measured at 7.42, indicating a near-neutral condition. The electrical conductivity (EC) was 1.57 dS/m, suggesting moderate salinity. Carbonate (CO^-_3) concentration was relatively low at 0.11 meq/L, while bicarbonate (HCO^-_3) content is higher at 7.92 meq/L. The presence of sodium (Na+) was found to be 5.56 meq/L, and sulfate ($SO\text{-}_4$) was 1.64 meq/L. The combined calcium (Ca) and magnesium (Mg) content were 10.18 meq/L. The sodium absorption ratio (SAR) was measured as 2.80, indicating a moderate risk of sodium-related soil degradation. However, the residual sodium carbonate (RSC) was negligible. Overall, these results suggest that the underground water source is marginally suitable for irrigation purposes. While the pH is suitable and the salinity is within manageable limits, attention may be required to address the moderate SAR to ensure it doesn't negatively impact soil quality over time.

Table 7 Results of analysis of underground water

Parameters	Readings	Parameters	Readings
pH	7.42	SO^-_4	1.64 meq/L
EC	1.57 dS/m	Ca+Mg	10.18 meq/L
CO^-_3	0.11 meq/L	Na^+	5.56 meq/L
HCO^-_3	7.92 meq/L	SAR	2.80
Cl^-	6.07 meq/L	RSC	Nil

The results shows that the underground water is marginally fit for irrigation purpose

Discussion

Usually uptake of NH_4 – N decreases with the pH whereas uptake of NO_3 increases the pH in the growth medium. This phenomenon is due to the imbalance uptake of cations and anions. Whether NH_4-N or NO_3-N is a superior nitrogen source for plant growth has been extensively studied (Hachiya & Sakakibara, 2017). However contradictory results were frequently found in the literature mainly due to plant species examined and experimental condition such as pH control and level of nitrogen supply in the growing media.

The findings of this research study provide a comprehensive overview of the NO_3-N concentration variations within different soil depths in district Muzaffargarh. The data indicates that at the depth of 0-15 cm, the NO_3-N concentration ranges between 1.70 ppm and 4.86 ppm, while at 15-30 cm, it ranges from 3.24 ppm to 5.80 ppm. Moving deeper into the soil profile, at 30-60 cm, the concentration ranges from 1.25 ppm to 3.73 ppm, and at 60-90 cm, it reaches the highest levels, peaking at 11.2 ppm. This pattern is attributed to irrigation practices, as NO_3-N tends to leach down into the soil with irrigation, concentrating in the 60-90 cm layer. Simultaneously, capillary action within the soil causes NO_3-N to rise with water, resulting in lower concentrations at 0-15 cm and 90-120 cm depths. In summary, these findings offer valuable insights into the distribution of NO_3-N concentrations in district Muzaffargarh's soil, with implications for understanding nutrient dynamics in the region.

In a study conducted by Griffin and Wengel (1974), an experiment was carried out to investigate the quantity and movement of soil water nitrates in both fragipan and non-fragipan soils on cornfields with and without added nitrogen fertilization. The focus of the study was particularly on assessing nitrate movement along the fragipan surface, situated at a depth of two feet in this specific soil. Over the three years of the study, no lateral movement of nitrate was observed, but there was evidence of movement into the fragipan. Soil water nitrates resulting from previous field fertilization, before the initiation of the study, were detected at depths of two and four feet in the fragipan soil, influencing the results in the first year. Swoboda (1977) discovered that when nitrogen was applied in the fall, up to three times more nitrate leached below 60 cm in the soil by June compared to applications made in March. Additionally, slow-release sulfur-coated urea and the treatment of nitrogen fertilizers with n-serve were identified as effective methods for minimizing leaching losses of nitrate, particularly when fertilizers were applied in the fall or winter. In runoff water, losses of 0.5% to 3.6% of applied nitrogen as fertilizer occurred when normal rates of nitrogen were applied to a grassland watershed. Lysimeter studies indicated that leaching of fertilizer nitrogen below 120 cm in a silt loam soil ranged from 0.04% to 6%, depending on the nitrogen source. Stone (1982) evaluated the movement of water and nitrate-nitrogen in a deep, silt loam soil. Nitrate-nitrogen concentration in the soil profile was not significantly affected by the amount of irrigation. Water use efficiency was notably greater with irrigation amounts of 114 and 152 mm compared to the 76 mm amount. Excessive amounts of nitrogen fertilizers and irrigation water could undoubtedly lead to nitrate-nitrogen leaching from these soils.

Crum (1990) found that the nitrogen content at a depth of approximately one meter in the soil exhibited variations among different crops. Corn showed the highest nitrogen content, averaging around 26 ppm N for the year, followed by alfalfa with an average of about 16 ppm N for the year. In contrast, the hardwood forest had nitrogen levels just above the detection limit, approximately 0.2 ppm N for the year. The reduced availability of nitrogen in the second year following alfalfa cultivation had a detrimental impact on corn yield and quality. These effects were more pronounced in no-tillage and ridge-tillage systems compared to conventional tillage methods. However, the total inorganic nitrogen contents in the 0-60 cm soil profile showed no significant variation between different tillage or nitrogen treatments. This information emphasizes the complex relationship between nitrogen application rates and the subsequent changes in soil and plant nitrogen levels. Steffens et al. (1991) indicated that ammonia losses as well as nitrate leaching are kept low if a maximum of nitrogen can be used for crop growth by slurry application with regard to application date, amount, splitting of the dressing, and incorporation.

In a previous research study conducted by Bahadoran et al. (2016), it was observed that the nitrate content within a given volume of soil was influenced by its movement in and out of the soil, primarily driven by the mass flow of water. Additionally, the net production of nitrate within the soil volume was attributed to the mineralization of organic compounds. Subsequent research by Gentry et al. (2000) revealed variations in the ionic composition of drainage water in tile drains and ditches, contingent upon the type of fertilizer used. The water samples collected from tile drains and ditches showed a prevalence of ions such as calcium, magnesium, sodium, chloride, nitrate, and sulfate. Tile drains exhibited lower pH levels, minimal or absent bicarbonate presence, and higher concentrations of nitrate and chloride, indicating the influence of nitrogen and the nitrification of ammonium. Further insights from Showers et al. (2006) demonstrated the spatial heterogeneity of ground water nitrate concentrations beneath biosolid waste application fields (WAFs). Particularly, significant variations in nitrate concentrations were identified within a single field, emphasizing the intricate dynamics at play in the distribution of nitrate across different spatial points.

According to Conrad and Bill (2008), the nitrogen and oxygen isotopic compositions of nitrate in the environment are predominantly influenced by the nitrate source. At the Hanford site, nitrate and other nitrogenous compounds played a crucial role in various chemical processes implemented on the premises. The majority of the oxygen present in nitrate-based chemicals such as nitric acid originates from atmospheric oxygen. Consequently, this imparts a significantly higher oxygen isotopic value to these chemicals compared to naturally occurring nitrate, which predominantly acquires its oxygen from the groundwater at Hanford. This distinctive isotopic fingerprint allows for the differentiation of nitrate resulting from Hanford site activities from background nitrate at the location.

A similar type of study was conducted by Moore and Brauer (2009) during the year August 2004 to July 2005 on a typical dairy farm in northwest Arkansas for determination of nitrate contamination in groundwater. Stainless steel lysimeters were strategically installed to a depth of 1 meter and sampled weekly. Throughout the year, soil cores were extracted periodically from seven depths (0-5, 5-10, 10-20, 20-40, 40-60, 60-80, and 80-100 cm), totaling 20 sampling events. Notably, nitrate levels in lysimeter samples exhibited peaks exceeding 100 mg NO_3-N/L. Despite the application of approximately 280 kg N/ha (250 lbs N/acre) through effluent, it was deemed insufficient to account for the observed high nitrate levels. Furthermore, lysimeter phosphorus (P) concentrations were notably elevated. Observations indicated that, starting in November, the farmer repurposed the 4.05 ha fields as a loafing area or high use area for his cows. Considering the effluent application in conjunction with this land use change, the total nitrogen loading to these fields amounted to approximately 1100 kg N/ha (1000 lbs N/acre) within a single year. Given that nitrate toxicity poses a threat to cow health and production, dairy farmers would find it prudent to monitor this parameter. Detecting high nitrate levels in forage could serve as an indicator of excessive nitrogen input to specific fields, enabling farmers to adjust their applications accordingly and optimize nutrient management practices.

Conclusion

During this study, lower NO_3 –N concentration was found at the depth of 0-15 cm and it increases with increasing depth upto 60-90cm. But beyond that depth (90-120 cm) this concentration decreases. The reason of this trend in our soil is that when we give the irrigation, NO_3-N leach down with water up to the depth of 60-90 but with the passage of time, water removal by crop use and these nitrates moved up with capillary rise and remained at upper depth. There are less NO_3-N present at the depth of 90-120cm, the reason is that due to the capillary action NO_3-N starts to move upward with the water. Results of water analyses showed that pH, EC and nitrate are in normal range. The results of soil analysis showed that NO_3-N is also in the safe limit.

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