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Nitrate pollution of ground water and impacts of nitrogenous fertilizers and irrigation on dynamics of NO3-N movement in soils of Punjab, Pakistan

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Abstract
Increase in N application rates may eventually raise the potential groundwater N-pollution. This survey study was conducted by Soil Chemistry Section, ISCES to assess the NO_3 contents of soil from 0 to 120 cm depth with different intervals. For this purpose, the soil and water samples were collected from Okara, Vehari Sialkot, Chiniot, Hafizabad, Sahiwal and Multan districts. The results showed that nitrate leaching occurred but it is only up to 2 feet soil depth. The NO_3-N contents were maximum at two upper depths (i.e. 0-30 cm and 30-60 cm) and then decreased gradually downward. The highest average NO_3-N content was found at 0-30 cm soil depth and the lowest were found at 90-120 cm. The data also revealed that mean NO_3-N content at 0-30, 30-60, 60-90 and 90-120 cm depths were 16.85±4.05, 15.21±4.77, 9.94±3.36 and 6.54±2.62 mg kg^{-1}, respectively, whereas NO_3-N content at same depths were ranged from 11.50-26.20, 6.53-21.15, 5.24-16.12, 1.45-9.36 mg kg^{-1}, respectively. The results regarding underground water samples (tube well) from the same sites from all the three districts showed that NO_3 were found in all the water samples but it was only in traces and their concentration were not much higher to create the health hazardous problem owing to NO_3 leaching. The data showed that the highest NO_3 contents did not exceed than 8.61 and 10.6 ppm in Multan and Sahiwal districts respectively, which were much lower than permissible limit i.e. 50 ppm (FAO). Similarly, the nitrate content in underground water are well below the maximum admissible limit of WHO i.e. 50 mg L^{-1}.

Keywords
Nitrate, Impacts, Fertilizer, Dynamics, Southern, Punjab.

Introduction

The nitrate (NO_3^-) and nitrite (NO_2^{--}) frequently used as food-additives to restrain or inhibit the growth of some microorganisms in preserved, cured or processed products like meats. In the same way, vegetables also contain substantial amounts of nitrate and nitrite (Kalaycioglu and Erim, 2019). In fact, the larger proportion of consumed NO_2^{--} and NO_3^- originated from natural sources like water, fruits and vegetables instead of food additives. For years, the cancer risks of these two ions have been discussed,

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since they potentially convert into the carcinogenic nitrosamines. The dietary nitrate originated from green, leafy vegetables, partly engrossed into blood via duodenal mucosa where recycled nitrate is re-absorbed and amassed by specific glands and then transformed into salivary appearance. This ultimately leads to nitrite (NO_2) by oral commensal bacteria under the tongue or in the stomach, following which nitrite is converted to nitric oxide (NO) through non-enzymatic synthesis. However, in current scenarios, these two ions have been considered essential nutrients too which stimulate nitric oxide formation and subsequently helps in cardiovascular health (Ma *et al.,* 2018). Some researchers publicized that livestock and cattle poisoning from NO_2^{--} and NO_3^- exposure could be a foremost reason of mortalities as well as morbidities under poor Agri-husbandry systems (Carrigan and Gardner, 1982). The PCRWR conducted a comprehensive study in Pakistan and revealed the substantial contamination owing to NO_3 (23 %) is found in water samples collected from both the Balochistan and Punjab provinces from irrigated or non-irrigated regions of Lahore (79), Kasur (46), Faisalabad (30), Khushab (50), Chakwal (51), Mianwali (30), Jhelum (53), Bahawalpur (60), Karachi (60), Mirpur Khas (55), Peshawar (38), Risalpur (35), Quetta (81), Ziarat (21), Loralai (21) and Mastung districts(37) (Tahir and Rasheed, 2008). Soomro et al., (2017) conducted an extensive study in Sindh Province and revealed that 88.5% (n = 215) of the underground water samples contain NO3 concentrations more than the WHO standard limit of 50 mg/L. In recent research performed by some scientists revealed that higher NO_3^- concentrations in groundwater can be mitigated naturally via fraternization or de-nitrification (Sarah et al., 2019).

In a recent study about Pakistan, the potable-water quality parameters of most of the reported results exceeded the guidelines suggested by the NEQS and WHO according to their findings, natural sources of groundwater contamination have been activated owing to anthropogenic activities like mining, and open dumping of domestic or industrial wastes which resulted-in weak underground water quality (Maimoona et al., 2017). Nitrate leaching is one of the utmost pathways of N-loss which leads to groundwater contamination. Nitrogen is an essential mineral element for all living things as it occurs in many different gaseous forms such as elemental nitrogen, nitrate and ammonia. Natural reactions of atmospheric forms of nitrogen with rainwater result in the formation of nitrate and ammonium ions. While nitrate is a common nitrogenous compound due to natural processes of the nitrogen cycle (Galloway et al., 2008), anthropogenic sources have greatly increased the nitrate concentration, particularly in groundwater cycle. Since the 1990s, nitrogen fertilizer consumption in Pakistan has markedly been increased. Sometimes NO_3-N in groundwater may result from non-point sources as fertilized cropland or naturally occurring N-sources and from point sources like sewage disposal systems as well as livestock facilities. It was reported that the major anthropogenic sources of nitrate pollution are septic tanks, application of nitrogen-rich fertilizers to pastures grass, and other field agricultural processes. In a recent study, agricultural scientists have identified NO_3 removal hotspots from agricultural lands (ASA, 2017). The reported data from China revealed that overuse of chemical N fertilizers, high net mineralization and nitrification, together with predominance of rainfall in the summer season with light soil texture are the main controlling factors responsible for the high nitrate leaching loss in this soil-crop-climatic system (Tao et al., 2017). The main sources of nitrogen, used in agriculture are organic and inorganic-N in which inorganic-N composed of urea, ammonium and nitrate. Most of the N applied to soil is initially in forms other than nitrate. Manures available in Pakistan generally contain total N in the forms of organic-N, NH_4-N and NO_3-N (Malik, et al., 2013). Microbial biomass, nutrient availability and nutrient uptake by wheat in two soils with organic amendments. Fortunately or unfortunately, no matter what forms of nitrogen are added to the soil, all of them ultimately transformed into NO_2-N or NO_3-N (DeHaan et al., 2017). The process in which biological oxidation of NH_3 to NO_2 and NO_3 occurred is known as nitrification (Li et al., 2015). This process consists of various steps and is initiated by in aerobic conditions by obligatory autotrophic bacteria but under waterlogged conditions, the oxidation process of NH_4^+ is thus restricted. Urea is synthesized by urease enzyme or chemically hydrolyzed into NH_3 and CO_2 (Addiscott, 1990). Nevertheless, this NH_3 is ultimately converted into ionic form (NH_4^+) by ammonium-oxidizing bacteria by an ammonification process. Finally, this NH_4^+ ion is converted into nitrate (nitrification process) by nitrifying bacteria. The nitrogen conversion rate depends on the conditions,

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present in the soil for nitrifying bacteria.

In USA (Pennsylvania), the water quality monitoring exhibited that NO_3 concentrations reach or exceed the MAC of 50 ppm (Shuval and Gruener, 1977). Some researchers revealed that N requirement is more for agriculture and application of mineral fertilizer along with manure can cause the N buildup in soil (Pretty,1998; Preussman and Stewart, 1984). The normal level of nitrates in soil not fertilized or used for commercial crops ranges from 5-10 mg/kg. Some researchers revealed that optimum nitrate level for soil used for maize production is ≥ 25 mg/kg (Ju et al., 2004; Macdonald *et al.,* 1989). On the other hand use of excess N-fertilizer to agricultural soils leads to agricultural pollution which ultimately destroy the quality of environment (Ramos, 1996). In most studies, the fate of applied N have shown that most of it is up taken by plants, though some of it remained in soil and a fraction is also lost from the system. Many studies have shown that most of the N (~ 40-50% is taken up by the plant. In one study in USA showed that only 1-2% of the N is leached beyond the root zone (Burkat and Koplin, 1993; Kanwar *et al.,* 1998; Bocher, 1995). Researchers described that Six main factors affect NO_3 leaching from agricultural fields i.e. (1)season or time of application (in winter, plants take up less nitrogen then summer and there is a greater chance for leaching to occur); (2) soil texture (more leaching in sandy soils); (3) N-rates; (4) irrigation practices (more the irrigation, more will be the chances for NO_3 leaching); (5) N-source (slow-release fertilizers can reduce the chance of leaching); (5) and the age of site (younger sites usually have less organic matter and need to be fertilized more therefore increasing the chance of leaching) (Baker and Johnson, 1981; Randall and Irgavarapu, 1995; Weeds and Kanwar, 1996; Bocher, 1995).

Human activities such as fertilizer use, manure application, and sewage treatment can contaminate sources of drinking water with nitrate, which can easily leach through soil into groundwater and surface water. Numerous studies indicate significant contamination of groundwater by nitrate across the U.S., particularly in shallow or unconfined groundwater wells underlying agricultural areas with high levels of fertilizer use and well-drained soils. While nitrate does occur naturally in groundwater, concentrations greater than 3 mg/L generally indicate contamination (Madison and Brunett, 1985), and a more recent nationwide study found that concentrations over 1 mg/L nitrate indicate human activity (Dubrovsky et al., 2010).

Some factors severely affect the rate of NO_3-N transformation like time, temperature, soil type, N source, rate, and application method so it has been considered very problematic to assessment of the extent of NO_3-N transformation owing to these factors (Scherer et al., 2014). Previous work about nitrate pollution was conducted to ascertain the ground water contamination due to nitrates in the irrigated areas of Pakistan (Niaz et el., 2003; Niaz et al., 2004; Latif et al., 1999) as the provinces of Punjab and Sindh, in the east and south, is well irrigated by the Indus and its tributaries. Similar type of studies was carried out in the rural areas of Rawalpindi and Islamabad (Tahir et al., 1998; Sajjad et al., 1998). Considering the wide application of bio or commercial fertilizers and the lack of detailed data in context to nitrate contamination from the whole country, it becomes essential to know the details regarding the nitrate content of the water sources and thus the present study has the aim of evaluating nitrate levels in the wide range of irrigated and non-irrigated regions of the Punjab. Keeping in view the significance of this important health related issue, this survey study was conducted to assess the nitrate concentration in soils and ground water samples from the areas where high doses of nitrogenous fertilizers are being applied to crops in Punjab, Pakistan.

Materials and Methods

This study was conducted at Soil Chemistry Section, Ayub Agricultural Research Institute (AARI), Faisalabad and all the soil and water samples were collected from the farmer's fields. All the soil samples were collected from surveyed areas of central and southern Punjab districts including Okara (30.8138°N, 73.4534°E), Vehari (30.0442°N, 72.3441°E), Sialkot (32.4945°N, 74.5229°E), Chiniot (31.7292°N, 72.9822°E), Hafizabad (32.0712° N, 73.6895°E), Sahiwal (30.6682°N, 73.1114°E), Multan (30.1575°N, 71.5249 °E) from 0 to 120 cm depth with different intervals (0-15, 15-30, 30-60, 60-90, and 90-120 cm). Likewise, tube well water samples were collected from the similar areas along with their installed depths. The texture of surveyed area of Punjab districts including Okara, Vehari Sialkot, Chiniot, Hafizabad, Sahiwal and Multan was loam and sandy loam, sandy loam, silt loam, sandy

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loam, clay loam, silt loam and silt loam, respectively. The groundwater sampling was done by collecting the water samples from tube wells installed at the field areas in villages of these districts (Fig. 1).

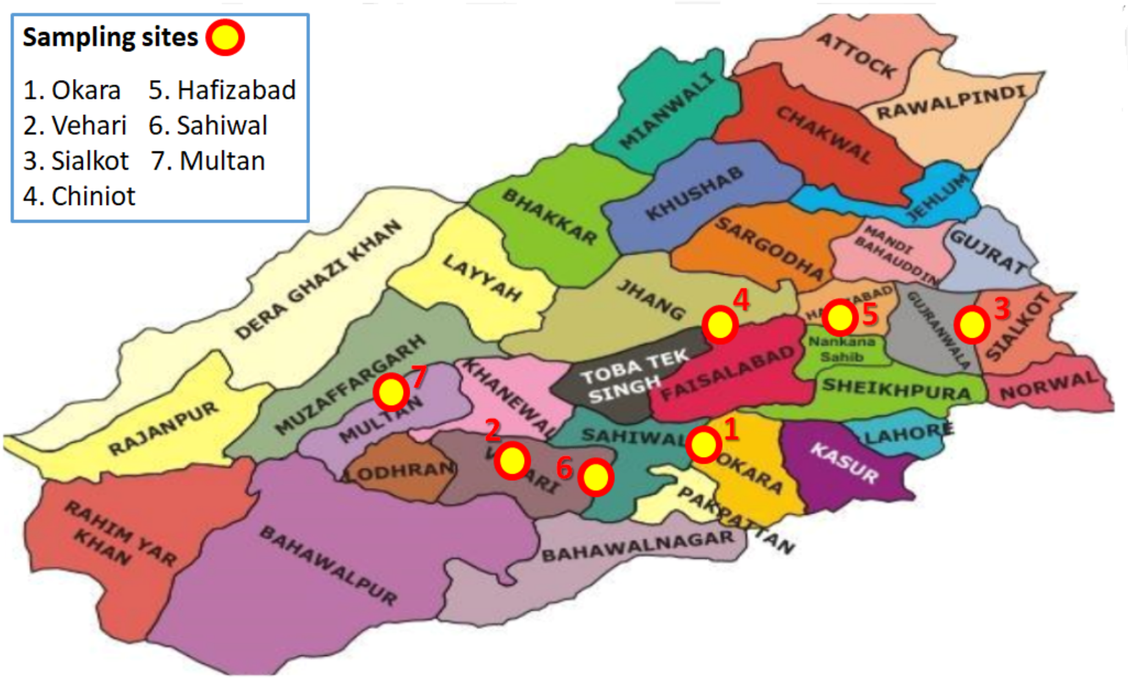

Figure 1 *Map of the sampling sites for nitrates concentration in soil and groundwater samples in areas where high doses of N-fertilizer are being applied in central and southern Punjab districts.*

All the soil and water samples were analyzed for pH, electrical conductivity (EC), total soluble salts (TSS) and nitrate concentration by following the methods given by (Addiscott, 1990; Keeney. and Nelson, 1982; Badiadka and Kenchaiah, 2009).

NH_4^+-N and NO_3-N forms of nitrogen were determined by using 2 M KCl solution as extractant by following the methods given by Keeney and Nelson, (1982). Time of extraction varies from 5 to 30 minutes for various states (APHA, 1992; Kenny et al., 2009). Kelly and Brown (20) found that shaking the sample for 5 minutes gave similar results to shaking for 8 hours. Oien and Selmer-Olsen (26) found a 2-minute shaking time sufficient to extract nitrates.

Soil samples are dried, ground and sieved prior to analysis. Soil samples are dried at 50°C in cardboard boxes. The dried soil is ground in a mechanical mortar and pestle and passed through a 12-mesh (approximately 2 mm) screen. Routine testing for pH, lime requirement, Olsen phosphorous, extractable potassium and organic matter is designed to handle the analyses in series of groups of ten. The soil samples, at the time they are received, are recorded and placed in trays holding five rows of ten boxes each (boxes are 2.5" x 3" x 3" deep), making a total of 50 samples. Each tray is lettered or numbered and sample identification follows each set of numbered racks through the entire analysis.

A composite soil sample was analyzed for ECe (Rhoades, 1982), pHs (McLean, 1982), Organic matter (Nelson and Sommers, 1982). Total soil N (Tecator, 1981) and Olsen phosphorus (Olsen, 1954) and extractable potassium (Richards, 1954). Meteorological data was also recorded at the observatory of Plant Physiology Section, Ayub Agricultural Research Institute, Faisalabad. Plant protection measures were taken up-to maturity. The soil sampling was done before each irrigation and after harvest for the determination of NO_3 movement in soil profiles The evapotranspiration by different crops denoted as ET was estimated by formula given by Jensen and Stetter, 1965 as

$$ET = Kc\O \times ETp \qquad [1]$$

whereas the potential evapotranspiration (ET p) was measured by following the formula of Hargreaves and Samani (1985):

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$$ETp = 0.0023 \times RA \times TD^{0.5} (Tc + 17.8) \quad [2]$$

in which ETp = Average potential evapotranspiration (mm/day); RA = Extra terrestrial radiation (mm/day); TD = Av. Maximum temperature - Av Minimum temperature (°C); Tc = {(Tmax + Tmini) / 2}; 17.8 = empirical temperature Hargreaves constant (TH).

All the samples were taken by coring and putting containers beneath plots and the amount and chemical composition of the water was determined by spectrophotometer.

Results and Discussion

In table 1 soil analysis of the surveyed areas showed that maximum electrical conductivity (3.72 dS m^{-1}) and minimum pH (7.81) was observed in Sahiwal while highest organic matter (0.80%) and N content (0.041%) was observed in Multan. However, maximum $CaCO_3$ content (7.10%) was noticed in Chiniot. Highest K (221 mg kg^{-1}) and P content (12.36 mg kg^{-1}) was observed in Sialkot and Vehari, respectively. Highest NO_3-N content (15.12 mg kg^{-1}) was observed in Hafizabad.

Table 1. *Soil physicochemical properties of the surveyed areas*

Location/ Area/ District	n	ECe dS m^{-1}	pHs	OM	N	$CaCO_3$	K	P	NO_3-N
				%			mg kg^{-1}		
1. Okara	34	2.20	7.95	0.51	0.022	2.98	136	6.35	14.65
2. Vehari	25	2.81	7.92	0.72	0.034	3.44	166	12.36	5.96
3. Sialkot	63	2.88	7.90	0.62	0.029	6.42	221	7.69	5.78
4. Chiniot	33	3.06	8.20	0.69	0.035	7.10	187	9.14	6.34
5. Hafizabad	42	1.48	8.10	0.59	0.023	5.78	149	7.42	15.12
6. Sahiwal	30	3.72	7.81	0.73	0.040	3.91	201	10.45	8.33
7. Multan	47	3.36	7.96	0.80	0.041	5.42	205	8.42	9.48

Note: n= number of samples, EC= Electrical Conductivity, OM= Organic Matter

Nitrate contamination of soil and water

Groundwater contamination either caused by the addition/presence of excessive quantities of nitrites and nitrates washed-out from inorganic chemical fertilizers (urea, CAN, NP, DAP, NH_4SO_4 etc.) or by mineral decomposition of organic materials. Added organic matter changes the level of nitrates in soil. Nitrites (NO_2) and Nitrate (NO_3) is a naturally occurring form of nitrogen in soil. These forms of N are formed in soil after nitrification processes, the conversion of ammonium into nitrate, occurs. Nitrate is used as food by plants for growth and production. It is generally considered that the high doses of N being used for cotton in cotton growing areas may pose nitrate pollution in soil and under ground-water. The results of 140 soil (Fig. 2) and 33 water (Fig. 3) samples collected from Vehari districts showed that nitrate status of soil and underground water is within safe limit. The water analysis revealed that present dose of N fertilizer for BT Cotton (400-175-125 kg/ha) is safe and nitrate content in underground water are below maximum admissible limit of 50 mg/L.

Okara and Sialkot

The results (Table 2a) of soil analysis revealed that NO_3 content increased with increasing depth up to 90 cm depth and then it again decreased at lowest depth of 90-120 cm. The highest average nitrate content (7.52 mg kg^{-1}) was found at 60-90 cm soil depth and the lowest was obtained at surface soil (0-15 cm). The results of 616 soil samples collected from Okara district (Table 2) showed that mean NO_3 content at 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths were 3.81± 3.11, 4.47± 3.66, 5.22± 3.33, 7.52± 1.18 and 4.49± 2.82 mg kg^{-1}, respectively. Whereas nitrate content at depths of 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths were ranged from 1.50-10.18, 1.92-12.10, 2.27-11.10, 1.68-16.40 and 1.64-10.70 mg kg^{-1}, respectively. These results clearly showed that nitrates moved downward with irrigation water, but this leaching process did not go beyond the 90 cm depth. The results of 195 soil samples collected from Sialkot district (Table 2b) showed that mean NO_3 content at 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths were 2.89± 1.85, 2.49± 1.80, 4.85±

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1.50, 5.23±1.98 and 2.47± 0.88 mg kg^{-1}, respectively. Whereas nitrate content at depths of 0-15, 15-30, 30-60, 60-90 and 90-120 cm depths were ranged from 1.50-6.06, 2.34-4.96, 2.50-7.80, 1.43-8.90 and 1.37-3.93 mg kg^{-1}, respectively.

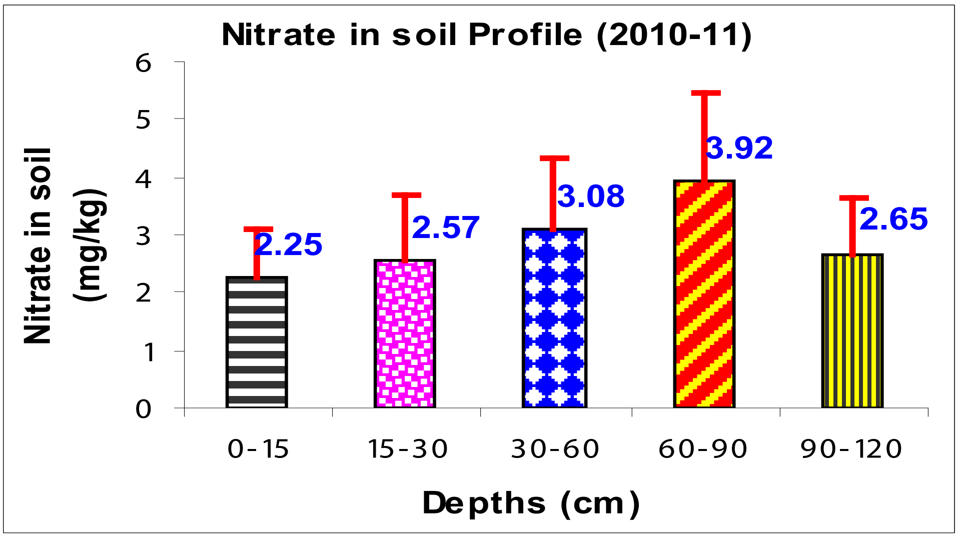

Figure 2 *Nitrate status of soil samples of district Vehari*

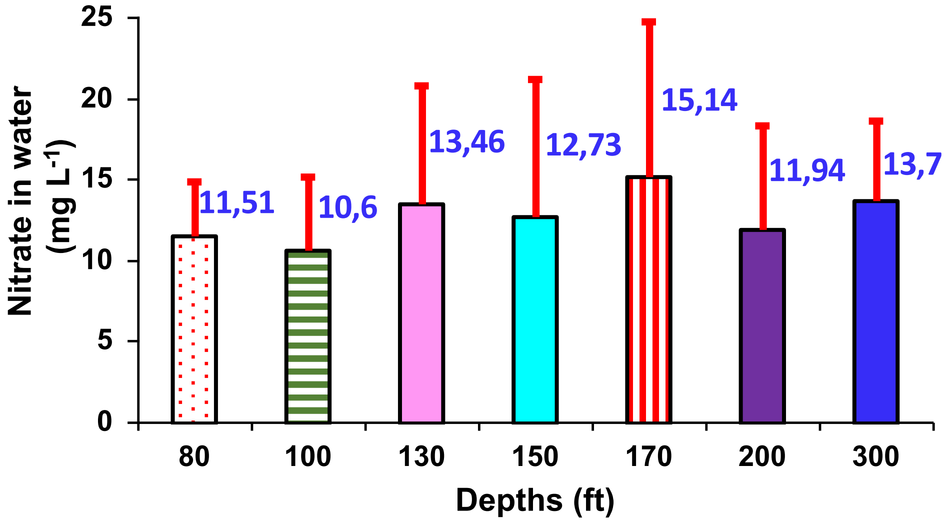

Figure 3. *Nitrate status of water samples of district Vehari*

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Table 2
NO_3 concentration in soil samples

Districts	Depth cm	Range	Mean	SD
			mg kg^{-1}	
a) Okara	0-15	1.50-10.18	3.81	3.11
	15-30	1.92-12.10	4.67	3.66
	30-60	2.27-11.10	5.22	3.33
	60-90	1.68-16.40	7.52	1.18
	90-120	1.64-10.70	4.49	2.82
b) Sialkot	0-15	1.50-6.06	2.89	1.85
	15-30	2.34-4.96	2.49	1.80
	30-60	2.50-7.80	4.85	1.50
	60-90	1.43-8.90	5.23	1.98
	90-120	1.37-3.93	2.47	0.88
c) Chiniot and Hafizabad	0-15	1.10-4.59	2.39	0.91
	15-30	1.12-4.94	2.62	0.93
	30-60	1.80-5.90	3.24	1.22
	60-90	3.39-11.51	5.44	1.34
	90-120	1.30-3.52	2.70	1.01
d) Sahiwal	0-15	3.4-15.0	7.3	1.8
	15-30	4.1-10.0	9.2	3.7
	30-60	4.3-17.4	13.2	3.8
	60-90	8.2-22.5	18.8	3.84
	90-120	11.0-20.5	17.4	2.6
e) Multan	0-15	0.5-17.9	7.7	5.0
	15-30	5.1-20.8	10.4	6.5
	30-60	3.3-28.3	12.0	6.5
	60-90	4.1-28.9	15.2	7.5
	90-120	1.5-30.9	15.2	6.8

The results of both districts showed that NO_3 was not much high to create the NO_3 leaching problem. The results (Table 3) of 281 water samples collected from both districts showed that the highest mean NO_3 content (17.6 mg L^{-1}) was found at 60 feet deep well samples followed by 130 feet (13.94 mg L^{-1} and then 100 feet deep (12.64 mg L^{-1}) water samples. In ground water samples, nitrates are present at all depths but their concentrations are well below the MAC of 50 mg L^{-1}.

Table 3
NO_3 concentrations (mg L^{-1}) in water samples from district Sialkot and Okara

Hand pump/tube- well			
depth (feet)	**Range**	**Mean**	**SD**
30	6.47-13.15	9.80	2.93
60	11.3-28.90	17.60	5.23
100	7.79-20.10	12.64	4.60
130	8.20-15.57	13.94	3.81
140	2.36-10.90	3.97	3.15
150	2.97-9.92	5.63	2.90
160	1.80-4.67	3.85	1.50
200	3.30-10.73	6.50	2.67
250	3.19-14.60	8.04	4.87

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Chiniot and Hafizabad

It is generally thought that the high doses of N for hybrid maize and potato may cause nitrate pollution in soil and under ground-water. The results of soil (Table 2c) and (Fig. 4) samples collected from Chiniot and Hafizabad districts showed that nitrate status of soil and under-ground water is within the safe limit. The water analysis revealed that present dose of N fertilizer is safe and nitrate content in under-ground water are below maximum admissible limit of 50 mg/L.

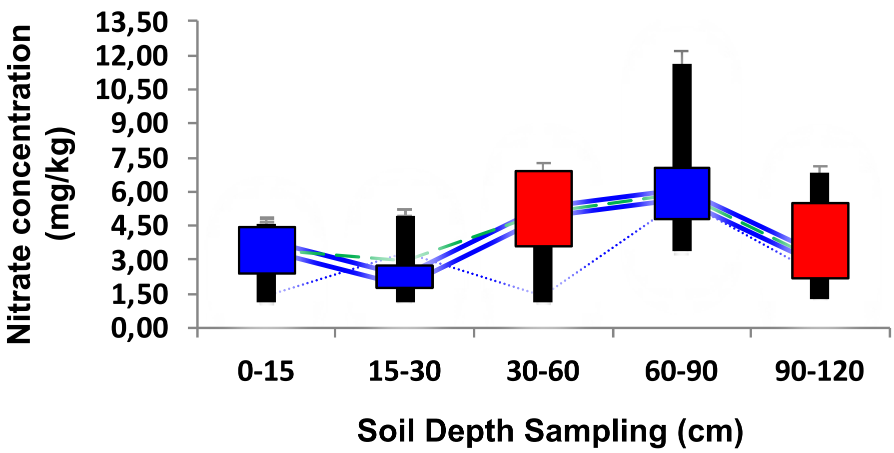

Figure 4 *Nitrate status of soil samples of district Chiniot and Hafizabad*

It was also noted that those underground water samples which were collected from village pond/pool surroundings had very high NO_3 concentrations and these were above permissible limits. This might be due to the sewage wastes, animal and human urine and dung depositing in the pond and seepage to underground water.

Sahiwal and Multan

These results (Table 2d and 2e) clearly showed that nitrates moved downward with irrigation water, but this leaching process did not go beyond the 90 cm depth. The results of soil samples collected from Sahiwal and Multan district (Table 3) showed that mean NO_3 content are within safe limit.

The data (Table 4a & 4b) showed that the highest NO_3 contents did not exceed than 10.0 and 8.6 ppm in Sahiwal and Multan districts respectively, which were much lower than permissible limit i.e. 50 ppm (FAO).

Table 4 *NO_3 concentration (mg/L) in water samples*

Districts	Tube well		
	Range	Mean	SD
a) Sahiwal	1.8- 10.0	4.94	1.76
b) Multan	1.9- 8.6	3.75	1.83

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Nitrate concentration in soil of Punjab

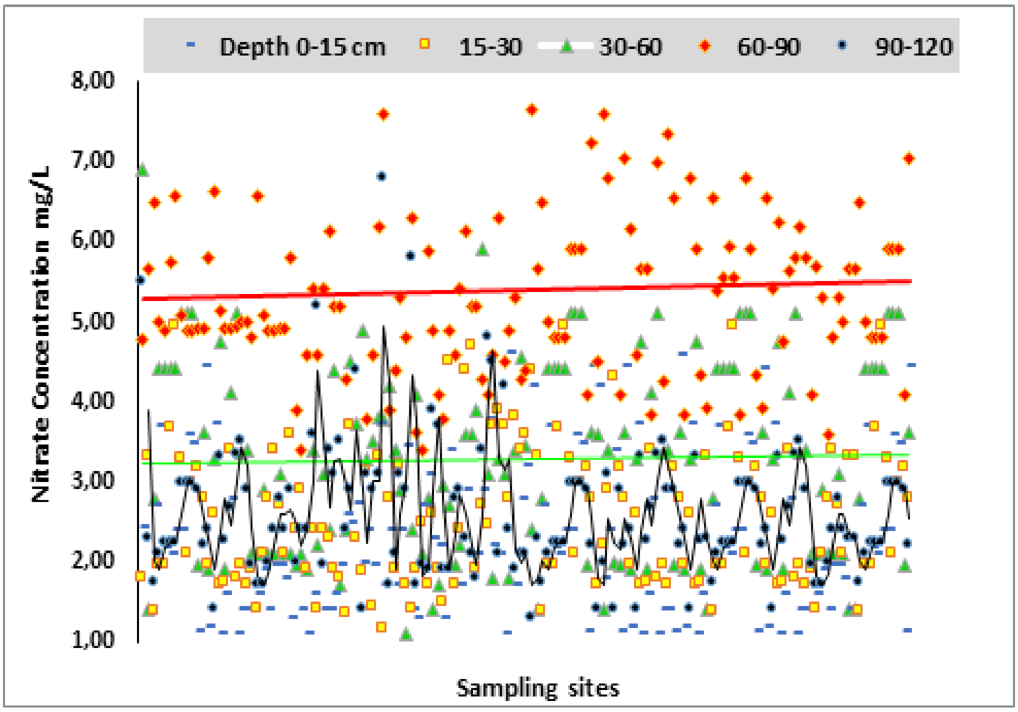

Figure 5 *Nitrate status in soil of Punjab*

The figure 5 showed that nitrate concentration varied with variation in soil depths. Maximum nitrate concentration in soil was observed at 60-90cm depth while minimum nitrate content was observed at 0-15 cm depth at different sampling sites.

Discussion

In underground water samples, the forms of nitrogen of utmost concern are NO_3-N, NO_2-N, NH_3 and or to some extent organic N-forms. These N-forms are substitutable, being constituents of the nitrogen cycle. Nitrate (NO_3-N) in tube well water is a major environmental and public health concern. Nitrates are converted to nitrites in the animal or human intestines and once absorbed into bloodstream, nitrites prevent hemoglobin from transporting oxygen (older children have an enzyme that restores hemoglobin). Therefore, high NO_3-N levels in drinking water (>10 ppm) are linked with health problems (methemoglobinemia) (Craun et al., 1981). Thus, while using water with high NO_3-N should be very careful to avoid health problems of masses.

In calcareous soils, ionic forms of nitrates (NO_3-N) are natural proportion of the N-cycle and generally these levels in ground water are in the range of few mg L^{-1}. But in many developed countries, an increase of nitrate levels has been observed due to high cropping intensity and the intensification of farming practice. This concentration may even reach up to several hundred mg L^{-1}. In some countries, up to 10 % of the population may be exposed to nitrate levels in drinking water of above 50 mg/l. In general, for humans vegetables will be the main source of nitrate intake when levels in drinking water are below 10 mg/l. When nitrate levels in drinking water exceed 50 mg/l, drinking water will be the major source of total nitrate intake. Extensive epidemiological data support the current guideline value proposed by the World Health Organization (WHO) for nitrate-nitrogen of 10 mg/l. However, this value should not be expressed on the basis of nitrate nitrogen but on the basis of nitrate itself, which is the chemical entity of concern to health, and the guideline value for nitrate is therefore 50 mg/l. Click here for further information about this. Nitrification is the oxidation of an ammonia compound into nitrite, especially by the action of the nitrifying bacteria called *Nitrosomas.* The nitrites will then be oxidized to nitrates by the bacteria *Nitrobacter*. Nitrate is less toxic than nitrite and is used as a food source by live plants. The process of converting ammonia to nitrate is diagramed in the nitrogen cycle. Nitrification is most rapid at pH of 7-8 and at temperatures of 25-

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30°C. Nitrification causes waters to decrease in pH. Nitrate is one of the most frequent groundwater pollutants in rural areas. It needs to be regulated in drinking water basically because excess levels can cause methaemoglobinaemia, or "blue baby" disease (Avery, 1999; Benjamin, 2000; Fewtrell, 2004.). Although nitrate levels that affect babies are not dangerous for older children and adults, they do indicate the possible presence of other more serious residential or agricultural pollutants, such as bacteria or pesticides. The origin of nitrate in groundwater is primarily from fertilizers, septic systems, and manure storage or spreading operations. Fertilizer nitrogen not taken up by plants, volatilized, or carried away by surface runoff ends up in the groundwater in the form of nitrate (Powlson et al., 1986b; Addiscott, 1990). This makes the nitrogen unavailable to the plants, and can also raise the concentration in groundwater above the admissible levels for drinking water quality. Similar kind of studies have also been reported by other researchers in which they revealed that N from manure can be similarly lost from fields, barnyards, or storage locations (Probert et al., 2005). Septic systems remove only half of the nitrogen in wastewater, leaving the other half to leach to groundwater, this way raising groundwater nitrate concentrations. Nitrate in drinking water is measured either in terms of the amount of nitrogen present or in terms of both nitrogen and oxygen. The federal standard for nitrate in drinking water is 10 mg/l nitrate-N, or 50 mg/l nitrate-NO3, when the oxygen is measured as well as the nitrogen. Unless otherwise specified, nitrate levels usually refer only to the amount of nitrogen present, and the usual standard, therefore, is 10 mg/l. Short-term exposure to drinking water with a nitrate level above the health standard is a potential health problem especially for babies. Babies drink large quantities of water considering their body weight, especially if water is used to mix powdered or concentrated recipes or juices. Also, their digestive systems are in mature, and thus more likely to allow the reduction of nitrate to nitrite. The nitrite in the digestive tract of babies can cause methaenoglobinaemia. Nitrate occurs naturally in many vegetables, such as lettuce and spinach, and is produced by microbes in the human gut, with the result that only a small part of the nitrate in the body comes from drinking water. The intake of nitrate from vegetables is unlikely to cause health problems because very little of this nitrate is converted to nitrite. Meat products account for less than 10 percent of nitrate in the diet, but 60 to 90 percent of the nitrite consumed. This is basically because sodium nitrite is added to foods such as hot dogs, bacon, or ham. Fruits, grains, and dairy products contribute almost no nitrate or nitrite to people's diets.

The results showed that low nitrate content at lower depths was due to low leaching losses and upward nitrate movements during dry seasons. Further maize is known due to its high nutrient uptake capacity (exhaustive crop) and it remove the nitrates from lower zones with its tap root system. Similarly, the early sowing of potato and wheat crops improved autumn growth and N uptake and reduced N leaching during the winter compared with the normal seeding time. The early seeded potato, maize, sugarcane and wheat crops in winter season were as efficient as sorghum and maize fodders in summer in reducing N leaching. These results are in accordance with the findings of other researchers (Munkholm et al., 2017). This study also revealed that early seeding of potato, wheat, maize, sugarcane and canola improved the root growth throughout the growing seasons compared with normal seeding time as well as significant effects on growth and yields.

Conclusions

The rate of downward movement of nitrate is affected by the water content of the soil during leaching This study concludes that under controlled conditions of Iysimeters, the leaching of nitrates occurred at higher irrigation application frequencies and nitrates leached from four feet (4') soil column which clearly indicated that due to nitrate leaching, there is a possibility of ground water contamination but the concentration of nitrates are well below the world health organization (WHO) recommended maximum admissible concentration (MAC) for drinking water of 11.3 mg L, (equivalent to 50 mg NO_3 L^{-1}).

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