Paper No. 185

ESTIMATION OF INVISIBLE GROUNDWATER QUALITY AND ENVIRONMENTAL POLLUTION CAUSED BY NITROGENOUS FERTILIZERS IN CANAL AND TUBE WELL IRRIGATED AREAS OF PUNJAB-A REVIEW

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By:

Abid Niaz[1], M. Akhtar[2], A. Kalsoom[3], Q.M. Akram[4], G. Rasul[5], H.T. Ahmad[5], M.S.A. Khan[5] and N.U. Ain[5]

Abstract:

Groundwater is invisible but it is considered as a substantial reserve that provides almost half of all drinking water worldwide, about 40% of water for irrigated agriculture and about one third of water needed for industry. Likewise, this invisible water is an influential segment of climate change adaptation process and is sometimes a solution for people without access to safe water. Human (anthropological) activities (including population- and economic growth) and climate variability are speedily aggregating the pressure on groundwater resources: serious depletion and pollution problems are reported for many parts of the world. Consumption of N fertilizer in Pakistan especially in Punjab has been increased substantially owing to high yielding varieties. This increase in N application rates may eventually raise the potential groundwater N-pollution. Nitrogen (N) in the form of Nitrites (NO_2), Nitrates (NO_3) and NH_4 is an essential source of nutrition for plants. Although many studies have shown that most of the applied fertilizer N (approximately 40-50% is up-taken by plants) and according to a study in USA, only 1-2% of the N is leached beyond the root zone. Nitrate leaching is mainly affected by soil texture (more leaching in sandy texture soils); N rates; N sources (slow-releasing N fertilizers can reduce leaching); application timing; age of site (younger sites usually have less organic matter and need to be fertilized more therefore increasing the chance of leaching); irrigation practices (more irrigation, more NO_3 leaching) (Nolan et al., 2002). Therefore, high NO_3-N levels in drinking water (>50 ppm) are linked with health problems, like methemoglobinemia (Craun et al., 1981). Keeping in view the significance of this important health related issues this study was conducted to give the overview about the nitrate concentration in invisible groundwater samples from the areas where high doses of nitrogenous fertilizers are being applied to crops. Some recent studies about Pakistan revealed that the potable-water quality parameters of most of the reported results exceeded the guidelines suggested by the NEQS and WHO according

1 Chief Scientist, Provincial Reference Fertilizer Testing Lab., Raiwind, Lahore, Author Correspondence Email: draniazch@gmail.com

2 Chief Scientist, Ayub Agricultural Research Institute, Faisalabad

3 Soil Chemistry Section, ISCES, AARI, Faisalabad

4 Chief Scientist, Rapid Soil Fertility Research Institute Pujab, Lahore

5 Provincial Reference Fertilizer Testing Lab., Raiwind, Lahore

to their findings, natural sources of groundwater contamination have been activated due to anthropogenic activities like mining, and open dumping of domestic or industrial wastes which resulted-in weak underground water quality (Maimoona et al., 2017). The earlier published data about nitrate pollution in the groundwater due to nitrogenous fertilizers is far from reality and their findings showed that the existing irrigation practices and nitrogen application levels are too low to create pollution in the irrigated areas of Pakistan (Niaz *et el., 2003;* Niaz et al., 2004; Latif et al., 1999). 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 of 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 NO_3 concentrations more than the WHO standard limit of 50 mgL^{-1}. The results of groundwater samples collected from FSD, LHR, Okara, Hafizabad, Sialkot, Chiniot, Vehari, Multan, Sahiwal and Jhang districts showed that NO_3 were found in all the water samples in traces. In the surveyed areas, nitrate concentration was measured in groundwater samples and the data showed that NO_3 levels were lower than 50 mg L^{-1} of maximum admissible limit of WHO in almost 100 % of the surveyed samples. This study clearly revealed that present doses of N fertilizer for maize, potatoes, wheat and cotton crops are safe in regular use and did not pose any environmental pollution threats in these areas.

Keywords: Invisible, groundwater, pollution, quality, nitrogenous, Punjab.

Introduction:

Nitrogen (N) is an essential mineral element for all living things as it is a basic component of protein. It exists as a major constituent of the earth's atmosphere and occurs in many different gaseous forms such as elemental nitrogen, nitrate and ammonia. Nitrate leaching is one of the greatest pathways of N-loss which leads to groundwater contamination or surface water eutrophication. 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 (Burt and Trudgill, 1993). 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).

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). Microbial biomass, nutrient availability and nutrient uptake by wheat in two soils with organic amendments. *J. Soil Sci Plant Nutr.* 13, 955–966 (2013). 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; 2005). 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, present in the soil for nitrifying bacteria. Some investigations revealed that 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, 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). 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).

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.

In UK (House of Lords, 1989) and 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 pollution which ultimately destroy the quality of environment (Ramos, 1996). 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; Randall and Mulla, 2001; 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). Keeping in view the significance of this important health related issue, this study was conducted to give the overview about the nitrate concentration in invisible groundwater samples from the areas where high doses of nitrogenous fertilizers are being applied to crops.

Materials and Method:

Collection of canal water samples:

This study was conducted at Soil Chemistry Section, Ayub Agricultural Research Institute (AARI), Faisalabad during 2011-2015 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 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 surveyed area was comprised of Central Punjab Districts including FSD, LHR, Okara, Hafizabad,

Sialkot, Chiniot, Vehari, Multan, Sahiwal and Jhang. The groundwater sampling was done by collecting the water samples from tube wells installed at the field areas in villages of these districts (Figure-1). 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).

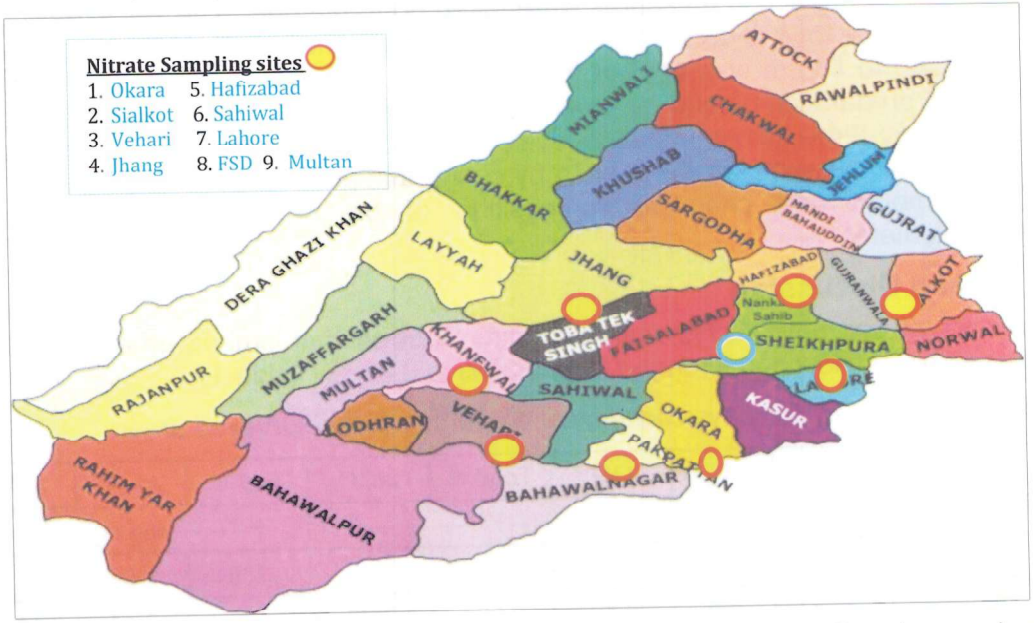


Figure-1: Map of the sampling sites for nitrates concentration in soil and groundwater samples in areas where high doses of N-fertilizer are being applied in central and southern Punjab districts.

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. The grinding and sieving operations should ensure a homogeneous mixture for 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, phosphorous, potassium and organic matter is designed to handle the analyses in series of groups of ten. All the samples were analyzed by following the Standard Methods (Standard Method for Examination of Water and Waste Water, 1992) all the samples were collected in ½ liter polystyrene bottles. Necessary information regarding sampling was recorded in the sampling Proforma whereas all the samples were analyzed for Nitrate-Nitrogen (NO_3-N) in the laboratory by Ion Selective Electrode Method on Ion Meter (Model-3345, Jenway England). Before sowing of crops and before

fertilizer applications, all the soil samples were taken from each field to analyze the physico-chemical properties of soil. A composite soil sample was analyzed for ECe (Rhoades, 1982), pHs (McLean, 1982), Organic matter (Nelson and Sommers, 1982). Total soil N (Tecator, 1991) and particle size analysis (Gee and Bauder, 1986). All plots were irrigated with canal and or tube well water. 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 after harvest for the determination of NO_3 movement in soil profiles. The uniform irrigation of 40 to 48 cm was applied to all plots locally known as rauni (application of water for the preparation of land for sowing of crops like wheat, maize, potato and cotton crops) and then three inches irrigation levels were applied to wheat, maize, potato and cotton crops. 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

The results of soil physic chemical properties showed that organic matter of all soil samples were very low and it ranged from 0.39% to 0.80 % (Table-1).

Table-1: Soil physicochemical properties of the surveyed areas.

District	EC_e dS m^{-1}	pH_s	OM	Total N	$CaCO_3$	Ext. K	Av. P	NO_3-N
			←----------%----------→			←---------mg kg^{-1}--------→		
FSD	2.18	8.0	0.39	0.021	1.42	189	7.32	8.56
LHR	3.01	8.0	0.46	0.024	3.79	123	8.11	11.39
Okara	2.20	7.95	0.51	0.022	2.98	136	6.35	14.65
Hafizabad	1.48	8.10	0.59	0.023	5.78	149	7.42	15.12
Sialkot	2.88	7.90	0.62	0.029	6.42	221	7.69	5.78
Chiniot	3.06	8.20	0.69	0.035	7.10	187	9.14	6.34
Vehari	2.81	8.00	0.72	0.034	3.44	166	12.36	5.96
Sahiwal	1.72	8.10	0.73	0.040	3.91	201	10.45	8.33
Jhang	3.36	7.95	0.80	0.041	5.42	205	8.42	9.48

The results depicted in Table-1 showed that all the soil samples were free from salinity or sodicity hazards. The pH of soil samples is more than 7.00 and alkaline in reaction. The fertility status is very low in all districts. Groundwater contamination either caused by the addition or presence of excessive quantities of nitrites and nitrates that were washed-out from inorganic chemical fertilizers (urea, CAN, NP, DAP, NH_4SO_4 etc.) or by mineral decomposition of organic materials (e.g. Farmyard manure, compost, press-mud). These added organic materials changes the level of nitrates in soil. Nitrites (NO_2) and Nitrate (NO_3) are naturally occurring forms of N 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 soil samples collected from all district showed that NO_3 content were ranged from 5.78-15.12 mg kg^{-1} (Table-1).

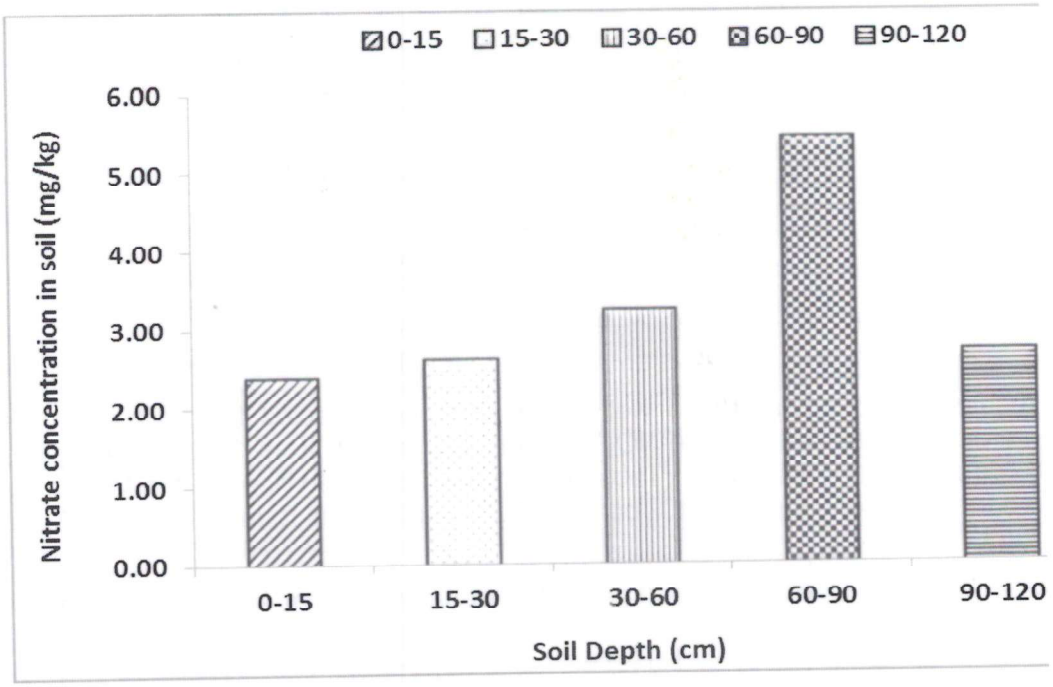


Figure-2: Soil Profile Analysis and NO_3-N Concentration in soil profiles

The results 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 (5.50 mg kg^{-1}) was found at 60-90 cm soil depth and the lowest was obtained at surface soil (0-15 cm) (Figure-2). It is generally thought that the high doses of N for hybrid maize and potato may cause nitrate pollution in soil and underground-water. The results of 75 soil and water 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. The results are also in accordance with the findings of other researchers (Knight, et al., 2000). 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. The results showed that ground water samples collected from hand pump contained more nitrates than tube well water samples (Figure-3).

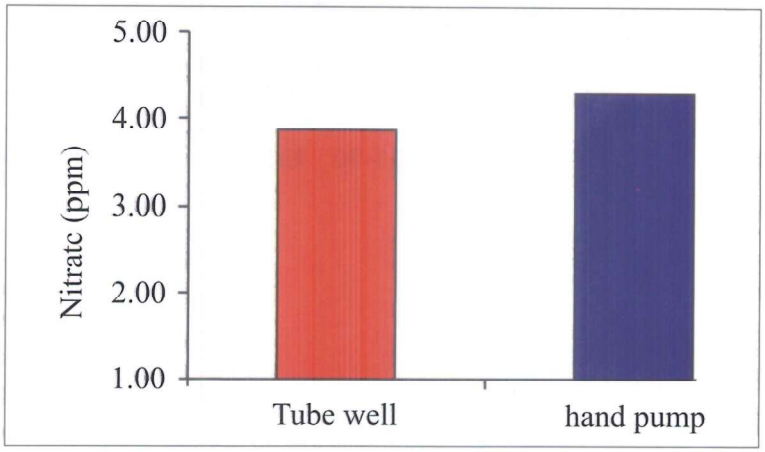


Figure-3: Nitrate status of water samples of district Vehari

The results of groundwater/tube well water samples collected from 15 villages from Sahiwal district exhibited that the NO_3 content were ranged from 1.80-10.00 mg L^{-1} with an average value of 4.94 mg L^{-1} (Table-1). The results of 12 villages from Multan district showed that the highest mean NO_3 content (3.75 mg L^{-1}) was found with range from 1.9-8.60 mg L^{-1} (Table-2).

Table-2: Nitrate Concentration in groundwater samples from 15 villages of Sahiwal District.

Range	Mean	SD
1.80-10.0	4.94	1.76

Table-3: Nitrate Concentration in groundwater samples from 12 villages of Multan District.

Range	Mean	SD
1.9-8.60	3.75	1.80

Table-4: Nitrate Concentrations in groundwater samples from Chiniote and Hafizabad Districts

Depth of Boring (Feet)	Range	Mean	SD
40	4.40- 17.95	9.28	4.19
60	2.40- 11.20	6.55	2.79

70	3.55- 36.88	16.56	6.39
100	3.65- 20.10	10.16	4.35
120	4.43- 21.10	7.00	3.45
150	1.40- 19.91	6.53	4.78
200	1.80- 4.67	6.04	3.21
250	2.80- 13.05	8.16	4.32
300	2.12- 10.63	4.23	2.00
400	1.45- 17.00	5.39	2.11

The results depicted in Table-3 showed that NO_3 was not much higher to create the NO_3 leaching problem in both districts. The results of 85 groundwater samples collected from both districts showed that the highest mean NO_3 content (16.56 mg L^{-1}) was found at 70 feet deep samples followed by 100 feet (10.16 mg L^{-1} and then 40 feet deep (9.28 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-5: NO_3 concentration (mg kg^{-1}) in 52 soil samples from Sahiwal district.

Soil Depth (cm)	Range	Mean	SD
10	6.3-16.34	17.5	2.00
20	7.63-19.65	16.7	1.50
60	12.2-28.7	19.8	2.00
100	8.22-19.98	7.4	1.60
130	3.24-9.66	5.63	1.00

Table-6: NO_3 concentration (mg/kg) in 92 soil samples from Multan district

Depth (cm)	Range	Mean	SD
10	2.3-20.4	12.5	1.60
20	2.11-12.2	14.63	2.50
50	2.65-19.8	16.52	2.10
100	2.33-18.6	8.45	2.00
130	1.00-10.7	6.42	1.50

These results clearly showed that nitrates moved downward with irrigation water, but this leaching process did not go beyond the 60 cm depth in 52 soil samples from Sahiwal District (Table-4). The results of 52 soil samples collected from Sahiwal district (Table-4) showed that mean NO_3 content at 10, 20, 50, 100 and 130 cm depths were 17.50±2.00, 16.70±1.50, 19.80±2.00, 7.40±1.60 and 5.63±1.00 mg kg^{-1}, respectively. Similarly the results of 92 soil samples collected from Multan district (Table-5) showed that mean NO_3 content at 10, 20, 50, 100 and 130 cm depths were 12.50± 1.60, 14.63± 2.50, 16.52±2.10, 8.45±2.00 and 6.42±1.50 mg kg^{-1}, respectively. Whereas nitrate content at same depths were ranged from 2.30-20.40, 2.11-12.20, 2.65-19.80, 2.33-18.60 and 1.00-10.70 mg kg^{-1}, respectively (Table-5).

Discussion

In underground water samples, the forms of N having maximum concerns 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.

The results obtained are in contradiction of the results from USA and other countries. Few researchers from China (Nie et.al., 2012.) discovered that NO3 build-up under inter-cropping systems declined considerably at the profile depths of 140-200 cm. They concluded that inter-cropping is meticulous way to diminish N-leaching from over-dosed N-fertilized fields. In calcareous soils, ionic forms of nitrates (NO3-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 public might be exposed to high NO3 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 (WHO, 2004). 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 25-30°C. Nitrification causes waters to decrease in pH. 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., 1986; Addiscott, 2005). 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). The results showed that low nitrate content at lower depths was due to low leaching losses and upward nitrate movements during dry seasons. Further in these areas maize is a major crop which is well known because of its high nutrient uptake capacity (exhaustive crop) and it remove the nitrates from lower zones with its tap root system. Likewise, the potato is another high value crop in Okara, Sahiwal and Chiniote districts and its early sowing and wheat crops improved autumn growth and N uptake and reduced N leaching during the winter compared with the normal seeding time. Maize, sugarcane, wheat and potato 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).

CONCLUSIONS

This study concludes The results of groundwater samples collected from FSD, LHR, Okara, Hafizabad, Sialkot, Chiniot, Vehari, Multan, Sahiwal and Jhang districts showed that NO_3 were found in all the water samples in traces. In the surveyed areas, nitrate concentration was measured in groundwater samples and the data showed that NO_3 levels were lower than 50 mg L^{-1} of maximum admissible limit of WHO in almost 100 % of the surveyed samples. This study clearly revealed that present doses of N fertilizer for maize, potatoes, wheat and cotton crops are safe in regular use and did not pose any environmental pollution threats in these areas. Further 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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