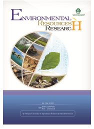

Environmental Resources Research
Vol. 7, No. 1, 2019

GUASNR

Evaluation of water pollution from rice cultivation using Nitrogen fertilizer in North of Iran

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Received: August 2018 ; Accepted: September 2018

Abstract

The increase of nitrite and nitrate concentrations in surface and groundwater is a great concern in our lives nowadays. Nitrate and nitrite in drinking water normally originate from agricultural operation and chemical fertilizers. Therefore, the present study aims to investigate the effect of nitrogen fertilizers used in rice cultivation and levels of nitrate and nitrite in farm wastewater and water quality parameters. The study was conducted in 2015 using a randomized complete block design with three replications in the research farm of Gonbad Kavous University. The treatments included four levels of nitrogen (control, 37, 70 and 150 kg ha with 46%urea). Urea fertilizer was applied to rice in two vegetative and early reproductive stages. Results showed that the effect of fertilizer on water pollution (concentration of nitrite and nitrate) is significant at the one percent level of confidence. Mean comparison of nitrogen indicated that the highest nitrate concentration (0.480 ppm) and the high nitrite (0.044 ppm) were related to treatment with high fertilizer application (150 kilograms per hectare) and the lowest nitrate concentration (0.083 ppm) and nitrite (0.014 ppm) were attributed to control treatment. Mean comparison of different stages of sampling revealed that rice in the vegetative stage and early reproductive stage absorbed more nitrogen while at the end of the growing period plant nitrogen uptake declined.

Keywords: Nitrates, Nitrites, Water pollution, Agriculture

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Introduction

Although almost three-quarter of Earth's surface is covered by water, yet fresh water resources are very limited and of which 70 percent is used in agricultural sectors. Of this share, around 30-25 percent is applied in the production of irrigated rice (Sedaghat and *et al.,* 2011). About 4 percent of Iran is under rice cultivation (Salahshour *et al.,* 2009). Rice consumes the highest amount of water among crops (Baumann *et al.,* 2007). In the past two decades, fertilizers and chemical pesticides have been used to increase rice production. The amount of fertilizer used in the agricultural sector is about 5.4 million tons annually, 87% of which are in the form of urea - phosphate (Kavoosikelashemiand Haider Shalmani, 2014). In rice growing areas, Nitrogen accelerates growth and vitality and also increases plant protein. This is the reason why farmers apply it to a large extent (ZareAbyaneh *et al.,* 2011). The amount of nitrogen fertilizer used for rice cultivation is about 200 kilograms per hectare (Momeni *et al.,* 2013). In other words, 20 kg of nitrogen is used to produce one ton of rice (Rasouli and Maftoon, 2007). The high productivity of nitrogen fertilizer is at best 40 percent (Rezvani and Etemadifard, 2012). Nitrogen fertilizer use efficiency in rice is low, so that less than 15 percent of nitrogen fertilizer is used by plants and the rest is removed and becomes unavailable to the plants (Divsalar *et al.,* 2011). The Nitrogen fertilizers which are not used by rice plants get out of reach by surface water and join groundwater and surface water network. Nitrate contamination of groundwater and surface water is a known problem to human society. Due to its solubility in water, its poor absorption, and stability of its composition in water, nitrite is examined as an indicator to show chemical pollution of surface and groundwater (Mozafarizadeh and Sajjadi, 2013). Presence of nitrate in water supplies leads to chemical pollution and decreasing water quality and limitations imposed on water use (Hoseinzadeh and Hajjilari 2009). More pollution caused by nitrates in groundwater is associated with agricultural waste and the use of nitrogen fertilizers (Turban *et al.,* 2003, Lerner and Paptolius, 2014). High amount of Nitrogen in water, such as in soil may have a negative impact on plant growth and seeds production and its quality (Rasuli and Maftoon, 2010). Nitrogen had a positive effect on grain yield in the vegetative stage and the early reproductive stage. Fertilizing at this stage reduced the loss of nitrate and nitrite in the surface and groundwater (Ahmadi *et al.,* 2007; Mobser *et al.,* 2005 Faraji *et al.,* 2011). Improper use of high nitrogen fertilizers increased planting costs and pollution of surface and ground waters. Therefore, the methods that enhance the plant performance and at the same time prevent environmental pollution must be applied (Sharpe *et al.,* 1988; Ellis *et al.,* 2001). Ehteshami and Beiglari (2014) found that in 82% of cases the nitrate concentration in groundwater of agricultural areas in Babol exceeded global standard. Jose Miguel et al (2002), in a study on the impact of nitrate leaching to groundwater and pollution of agricultural land in the Basque Country of Spain found that nitrate concentration was increased from 50 mg to 200 mg per liter due to the increase in indiscriminate use of chemical fertilizers and incorrect farm management. Zion et al (2006), reported that nitrate concentrations in groundwater downstream of paddy fields in the province of Xiang Xie, China, measured in most instances as 11.3 mg l, which exceeded the limit set by World Health Organization (10 mg L). Malakooti (1995) sampled water, including groundwater, rivers, wells, domestic and semi-deep wells and concluded that 13% of the samples in the wet season and 3% in the dry season had nitrogen concentrations up to 10 mg per liter. In a research by Aghafathi (1998) to determine the concentration of nitrate in water wells around the paddies in Babol, positive correlation was found between nitrogen fertilizer consumption and nitrate pollution of groundwater More specifically, the amount of nitrite concentration in 25% of drinking water wells sampled in Babol exceeded the permitted amount suggested by the World Health Organization (10 mg per liter). Afroos and Liaghat (2004) while evaluating nitrate concentration surrounding wells in Qazvin province showed that the concentration of nitrates in groundwater was between 11.2 and 15.2 mg/l which was more than the authorized threshold level. Accordingly, the nitrite pollution of well water was alarming since the drinking water of the residents adjacent to the area of the study was dependent on the groundwater. Jalali (2005) studied nitrate leaching in farmland in the plains of Hamadan, Iran. His results showed that the average concentration of nitrate in groundwater is 49 mg and that 37% of the total number of 311 wells tested had nitrate concentration of more than 45 mg.

The studies reviewed above indicate that in most wells around which agricultural activities are carried out, water pollution and nitrates and nitrites parameters have increased. Due to shrinking of freshwater resources and the increase in their pollution, this research attempts to study the role of rice cultivation in contaminating water resources (surface and underground) by nitrate and nitrite.

Materials and Methods

Geographical location and climatic characteristics of the study area

A field experiment was conducted in 2015 in a Research Station of Gonbad Kavous University. The coordinates are 55 21 E longitude and 37 26 N latitude and the area is 45 meters above sea level. According to the synoptic stations of Gonbad Kavous, the average annual precipitation is 450 mm and average annual relative humidity and annual average air temperature are 65% and 18.6℃, respectively.

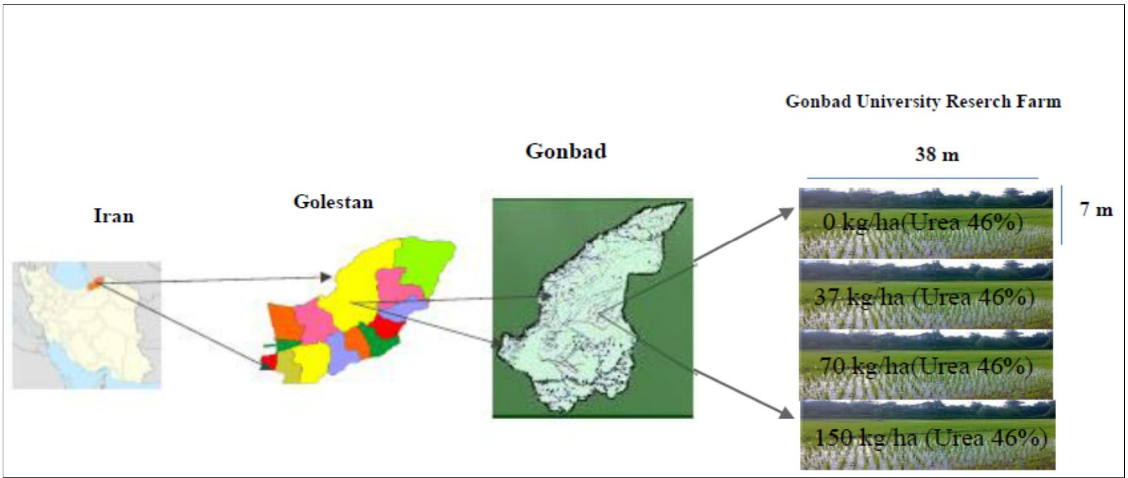

Figure 1. Location of the study area

To study the effects of nitrogen fertilizer used in rice farm on water pollution, an experimental randomized complete block design with three replications was conducted. The study area covered an area of 1064 square meters, the 4 plots measuring 38 meters long and 7 meters wide, 266 square meters in size equally converted and prepared for rice plantation. At first, the Domsiah rice cultivar seeds were planted in pots. After 30 days in mid-July while land was under preparation, seedlings were transferred to the field. One of the plots was considered as control and three plots next to the manure nitrogen (urea 46%) were applied 37, 70 and 150 kg of nitrogen per hectare in both vegetative and reproductive growth stages of the rice plant. Irrigation was performed following the flooding method in appropriate times using 1.5 inch pipe. Each plot in the rice cultivation period was 810 cubic meters. To assess nitrate and nitrite in irrigation and plot outflow water in rice cultivation, 4 treatments (plot) with dimensions (7 x 38 meters) were selected and replicated at intervals of 10 days with 3 water samples taken from each treatment. Water samples taken from the plots were immediately transferred to a laboratory and using spectrophotometry nitrate and nitrite were read using 410 NM and 543 NM wavelengths, respectively. The of standards for measuring concentration of nitrate and nitrite the assessments were conducted based on Standard and Research Institute of Iran, (2009) in mg per liter.

Table 1. Specifications of meteorology station in Gonbad Kavous

Climatic characteristics of the study area				
	July	August	Sep	Oct
Average air temperature (° C)	30.7	31.0	29.8	21.4
(%) Average relative humidity	55.2	51.1	54.7	61.6
Total rainfall (mm)	1.1	1.6	13.4	24.3
Total number of raining days	1	3	3	6
Average sunny hours	8.9	9.9	9.1	6.6
Average evaporation rate	7.4	7.4	6.5	3.6
The mean maximum wind speed (meters per second)	6.5	5.4	5.8	6.5

Soil and water properties

Soil samples were taken from the top 30 cm of the ground and nitrogen and phosphorus were measured using the Kjeldahl method and a spectrophotometer, respectively. The results are shown in Table 2. Characteristics of well water are showed in Table 3.

Table 2. Specifications of soil before planting rice in the research farm

Soil texture class	N (%)	Phosphorus (ppm)	pH
Loam clay silt	0.17	12	7.80

Table 3. Specifications of well water

N (ppm)	Phosphorus (ppm)	Nitrate (ppm)	pH
0	0	0.22	7.58

Data analysis

The experimental data were analyzed per unit of time using split plot design. The statistical software for data was analysis was SAS ver. 9.2 and for comparison the least significant difference (LSD) test was applied at 1% and 5%, respectively.

Results and Discussion

Descriptive statistics

Water was collected from the plots at intervals of 10 days from 7 August 2015 t0 5 October 2015. Sampling was carried out in each plot with three replications. Of the total 84 samples, 24 samples belonged to the vegetative stage and 60 samples to the reproductive stage. Table 4 represents descriptive statistics for the data. The Kolmogorov - Smirnov test showed that the nitrates and nitrite data were normal during the growth period but not so within the reproduction period.

Table 4. Data description for plots

The average concentration of nitrate and nitrite									
Stage		Plot1		Plot2		Plot3		Plot4	
	Date	Nitrate concentration	Nitrite concentration	Nitrate concentration	Nitrite concentration	Nitrate concentration	Nitrite concentration	Nitrate concentration	Nitrite concentration
Vegetative Stage	2015/08/08	0.18	0.07	0.40	0.074	0.62	0.096	0.97	0.182
	2015/08/18	0.14	0.011	0.37	0.011	0.51	0.048	0.60	0.075
Reproductive Stage	2015/08/28	0.12	0.006	0.30	0.007	0.40	0.011	0.86	0.028
	2015/09/7	0.09	0.006	0.17	0.006	0.29	0.010	0.56	0.012
	2015/09/17	0.02	0.002	0.06	0.002	0.10	0.003	0.27	0.005
	2015/09/27	0.02	0.002	0.04	0.003	0.05	0.003	0.13	0.005
	2015/10/07	0.01	0.003	0.04	0.003	0.05	0.003	0.10	0.005
	SD	0.066	0.034	0.158	0.026	0.233	0.035	0.343	0.065

Analysis of the data and hypothesis test

Analysis of variance was used to measure the concentration of nitrate and nitrite. The aim was to show possible significance of mutual fertilizer consumption level in the sample plots within periods of rice cultivation in vegetative and reproduction stages.

Analysis of variance for nitrate and nitrite concentration data

Statistical results (Table 5) showed that differences in the measurements between different levels of fertilizer were significant at the 1 % level. The difference between the different iterations of the data on the concentrations of nitrite and nitrate was not significant.

Table 5. Analysis of variance for concentration of nitrite and nitrate

S.O.V	df	Mean Square	
		nitrite(ppm)	nitrate(ppm)
Rep	2	0.0004^{ns}	0.01^{ns}
Fertilizer level	3	0.003^{**}	0.650^{**}
Error 1	6	0.0001	0.015
Stage growth	6	0.016^{**}	0.462^{**}
Fertilizer level × Stage growth	18	0.001^{**}	0.047^{**}
Error 2	48	0.0001	0.007

Mean comparison of applied nitrogen fertilizer for experimental plots in the combined analysis of the entire rice growing period

Mean comparison in Table 6 showed that the highest nitrite and nitrate concentrations in farm water were 0.480 and 0.044 ppm in the fourth plot upon application of 150 kg per hectare of fertilizer respectively. The lowest concentrations in farm water were 0.83 and 0.014 ppm in the first control plot.

Table 6 shows that concentrations of nitrite and nitrate in the field under rice cultivation in the plots has increased with increase in fertilizer consumption. Based on the coefficient of determination (R^2) which is depicted in Figures 2 and 3, it can be said that this relationship is strong. Therefore, it can be concluded that the application of nitrogen fertilizer affected surface water pollution in watershed.

Table 6. Mean comparison for nitrogen fertilizer applied to experimental plots in the combined analysis for the entire rice growing period

Fertilizer levels	Fertilizer application rate	Nitrate concentration ppm	Nitrate concentration (ppm)
No application	0 kg/ha	0.014c	0.083d
Low application	37 kg/ha	0.016c	0.244c
Optimum application	70 kg/ha	0.028b	0.287b
High application	150 kg/ha	0.044a	0.480a

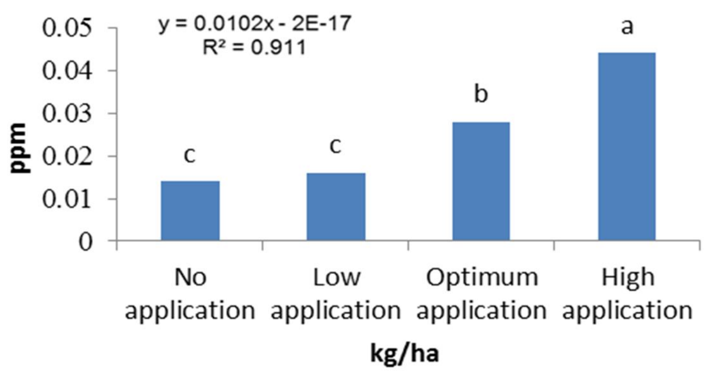

Figure 2. The trend of nitrate concentration in vegetative and reproductive stages for different levels of fertilizer

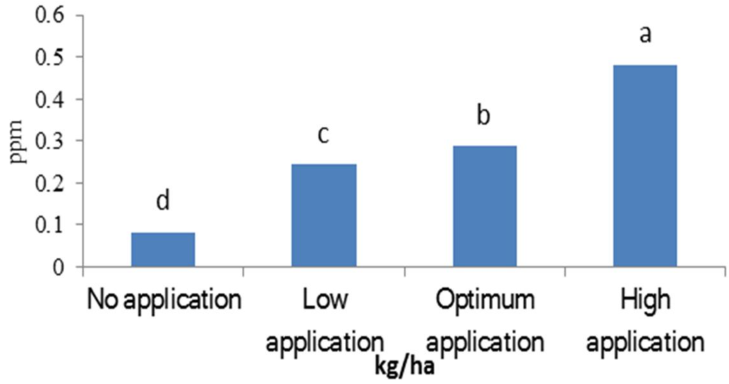

Figure 3. The trend of nitrite concentration in vegetative and reproductive stages for different levels of fertilizer

Mean comparison of applied nitrogen fertilizers for experimental plots in the combined analysis in vegetative stage

Results of applying 46% urea-based nitrogen fertilizer at each stage is shown in Table 7. In the vegetative stage, 24 samples were collected from rice farm water and its nitrite and nitrate levels were determined. Average data show that the highest concentration of nitrite and nitrate in the water are found in the fourth plots with total fertilizer consumption in vegetative stage as 3.035 kg. Water volume in the growth stages was 300 cubic meters. The average nitrite and nitrate entering the farm and leaving it to each plot in the growing period is shown in Table 7. Given the amount of input and output achieved, the average concentration of nitrate and nitrite in the growth period, the percentage difference between the output of the plots of nitrite and nitrate concentrations in surface water and especially nitrate and nitrite were calculated.

Table 7. Mean comparison for nitrogen fertilizer application to the experimental plots in vegetative stage

Nitrogen application	Application rate in vegetative level	Input nitrogen concentration	Drainage nitrite concentration	Drainage nitrate concentration	Percent of plot output	Specific concentration
No	0 kg/ha	0.22	0.040	0.160	90.90	0.00007
Low	1.005 kg	1.714	0.045	0.385	25.08	0.0048
Optimum	1.875 kg	3.09	0.083	0.565	20.97	0.009
High	3.035 kg	4.90	0.128	0.785	18.63	0.014

Mean comparison of applied nitrogen fertilizers for experimental plots in the combined analysis in reproductive stage

The results of applying 46% urea-based nitrogen fertilizer at reproductive stage to each plot is shown in Table 5. In the reproductive stage, 60 water samples of rice fields were taken and their nitrite and nitrate levels were determined. Comparison of the means showed that the highest concentrations of water nitrate and nitrate was in the fourth plots with total fertilizer consumption in the reproductive stage as 1 kg. Water consumed during the reproductive period was 210 cubic meters per plot. The average nitrite and nitrate entering the farm and leaving it in the reproductive period is shown in Table 8, respectively. Given the amount of input and output, the average concentration of nitrate and nitrite in the growth period, the percentage difference between the output of the plots for nitrite and nitrate in surface waters were calculated for each treatment. The combined analysis of nitrite and nitrate concentration obtained from the experimental farm drainage water under rice cultivation for different levels of fertilizer showed that nitrogen fertilizer pollution of water in different levels of the output of rice cultivation in reproductive stage plots is not different. As the rice cultivation area is 60,000 hectares in Golestan Province of which 10,000 hectares is located in Gonbad (Statistics Agency of Agriculture, 2014 and 2015) and according to a special concentration calculated in this study, a considerable amount of nitrate and nitrite enters into surface waters each year. Therefore, it can be concluded that the application of nitrogen affects the pollution of surface waters in the study area.

Table 8. Mean comparison of applied nitrogen fertilizers for experimental plots in the combined analysis in reproductive stage

N2 levels	Application rate in vegetative level	Input nitrogen concentration	Drainage nitrite concentration	Drainage nitrate concentration	Percent of plot output	Specific concentration
No application	0 kg	0.22	0.003	0.053	25.45	0.0006
Low application	0 kg	0.22	0.004	0.122	57.27	0.003
Optimum application	0 kg	0.22	0.005	0.176	82.27	0.0001
High application	1 kg	2.41	0.011	0.364	15.56	0.007

Mean comparison of nitrite and nitrate concentrations in vegetative and reproductive stages

Mean comparison of nitrite and nitrate concentrations in the vegetative and reproductive stage is given in Table 9. The values show that nitrite and nitrate concentration in vegetative state of the plots becomes less as these are absorbed by rice. The nitrate concentration in the early reproductive stage showed a reducing trend and reached a nearly constant value in the late reproductive stage. Also, the amount of nitrate and nitrite in plot water was lower than that of the fully grown stage. The nitrogen uptake by plants was also reduced in the late reproductive stage. The process of reduction of nitrite and nitrate concentrations in the water during rice growing has been demonstrated (4).

Table 9. Mean comparison of nitrite and nitrate concentration in vegetative and reproductive stages

Sampling date	nitrite (ppm)	nitrate (ppm)
2015/08/08	0.111a	0.542a
2015/08/18	0.037b	0.405b
2015/08/28	0.013c	0.418b
2015/09/7	0.007cd	0.276c
2015/09/17	0.003d	0.114d
2015/09/27	0.003 d	0.058d
2015/10/07	0.003d	0.050d

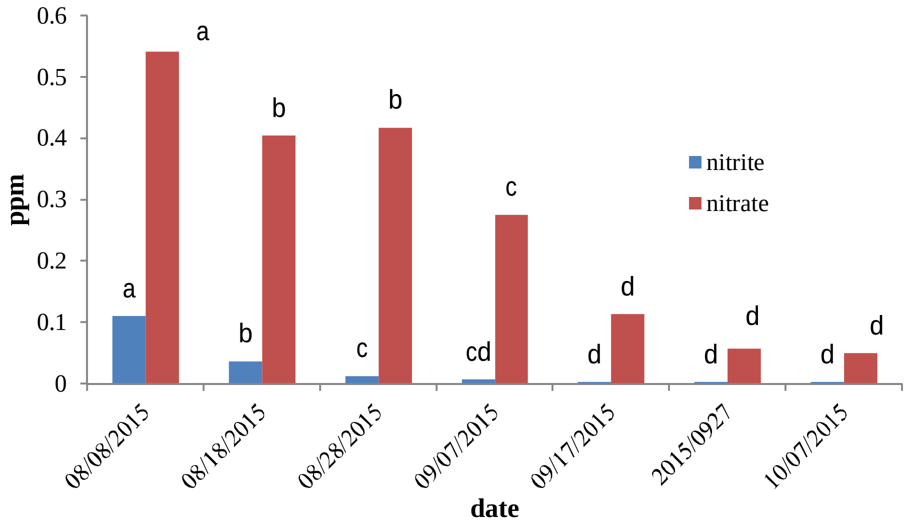

Figure 4. The trend of nitrite and nitrate concentrations in vegetative and reproductive stages

Conclusion

In this study, nitrite and nitrate concentration in farm waters under rice cultivation were investigated in four different treatments. The study was conducted in 2015 in a randomized complete block design with three replications in the research farm of University of Gonbad Kavous. The treatments included four levels of nitrogen (control, 37, 70 and 150 kg ha with 46% urea). Urea fertilizer in two vegetative and early reproductive stages was applied to the rice. The results showed that the effect of fertilizer on water pollution (concentration of nitrite and nitrate) was significant at the one percent level. Comparison of mean nitrogen showed that the highest nitrate concentration (0.480 ppm) and nitrite (0.044 ppm) were related to treatment with the high fertilizer application (150 kilograms per hectare) and the lowest nitrate concentration (0.083 ppm) and nitrite (0.014 ppm) was attributed to control treatment. Mean comparisons revealed that rice in vegetative and early reproductive stage absorbed more nitrogen and at the end of the growing period its nitrogen uptake was declined. This is in line with results of Mobser et al (2005), Ahmadi et al. (2007), and Faraji et al. (2011). The amount of nitrogen uptake by rice in the vegetative and early reproductive stages increased and nitrite absorption decreased in the late reproductive stage. This may result in contamination of surface and groundwater with nitrate and nitrite. Hence, it is suggested that rice plants be given the minimum possible amount of fertilizer needed at the late reproductive stage to minimize water pollution.

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