Available online at www.ap.iauardabil.ac.ir Islamic Azad University, Ardabil Branch
Anthropogenic Pollution Journal, Vol 4 (1), 2020: 24-35 DOI: 10.22034/ap.2020.1882082.1055
ISSN: 2588-4646

Evaluating the Effects of Agricultural Activities on Nitrate Contamination at the Kamfirooz District, Shiraz, Iran

Jalal Valiallahi[1]* Smael Moradi Koochi[2]

1Department of Environmental Science, Shahid Rajaee Teacher Training University, Lavizan , Tehran, Iran

[1] Director of Scientific Association of Environmental Education and Sustainable Development (EESD) www.srttu.edu.environment

[2] Graduated Student of Environmental Science, Shahid Rajaee Teacher Training University, Lavizan, Tehran , Iran

*Corresponding author: jvaliallahi@yahoo.com

Received: 29 October 2019/ **Accepted:** 29 February 2020/ **Published:** 07 March 2020

Abstract: To investigate the pollutants of the Kor River, water samples were collected during the rice-growing season in 2014. The first fertilizer was diammonium phosphate ($(NH_4)2HPO_4$). After first irrigation, supplemented with fertilizer usage, in the upper layers of soil causes an increase of NO^{3-} concentrations to reach from 7.3 to 25.7 mgl^{-1} at the agricultural lands beside the Sarbast village. At this point, the NO^{3-} concentration was 5.3 mgl^{-1}. After the application of the third fertilizer (by using of urea fertilizer) flood irrigation, lead to decreasing of NO^{3-} concentration at surface soil samples to 3.5 mgl^{-}. At the same time, before first fertilizer application at the soils located beside of Doroodzan Lake the NO^{3-} concentration was 17.9 mgl^{-1} but after the first fertilizing it increased up to 31.4 mgl^{-1}. Therefore, the NO^{3-} concentrations (31.4 mgl^{-1}) exceeded from the acceptable limits for drinking water at this site. During the second and the third periods of urea fertilizer application, at this point the NO^{3-} concentration decreased from 4.43 mgl^{-1} to 2.2 mgl^{-1}. In spite of using high amounts of fertilizer because of flood irrigation, the NO^{3-} concentrations leaches to surface groundwater. The maximum nitrate pollution occurs in June, when the rice plants are in the early stage of growth. As rice canopy coverage is increased, the nitrate concentration reduces. The result focuses on the vital roles of plant coverage in nitrate absorption. However if the fertilizer is rationally applied, phosphate loading into the river will be minimized. The rationality behind these procedures is explained.

Keywords: Nitrate leaching; Irrigation; Agriculture; land use; Kor River; Kamfirooz; Fars; Iran.

1. Introduction

Background:

"There is a potential increase in the pollution of nitrate compounds (NO_3) in the area that the poetical capacity of nitrate pollution is high at the subsurface and sub-surface waters. This contamination creates a set of environmental problems in plains, beaches, and other aquatic environments" (ESA, 2000). Water security problems are becoming more and more challenging in Iran for several reasons such as population growth, urbanization, land-use change, unsustainable water use and climate change. All the mentioned reasons result in an increase in the human exploitation of water resources and consequently increasing anthropogenic impacts on rivers, flood plains, and fresh groundwater(Mostafavi and Teimori 2018).

“High nitrate concentrations in drinking water can cause methemoglobinemia in infants, stomach cancer in adults and nitrate poisoning in animals as well” (Ehteshami and Biglarijoo 2014).

“The Potential Nitrate Contamination is believed to derive from three sources: agricultural, urban, and pier urban. The first one is related to the use of fertilizers.” (Daniela 2018).

"Nutrient leakage be influenced by fertilization level, type, time and method of fertilizer using; soils characters (i.e., pH, texture and organic substance), categories of crops and their fertilizer needs; method of farming and agriculture practices; and the amount of animal production" (Bechmann 2014; Kyllmar et al. 2014 a,b). "Climate situations and basin land use also have a vital influence on the concentration and amount of nitrogen leaching" (Jiang R. et al. 2014; Yoon 2005; Woli et al. 2008).

"A crucial issue defining plant nutrient uptake is the accessibility of microelement and macro element in the farmland" (Cakmak 2005; Fageria 2001; Güsewell et al. 2003; Szczepaniak et al. 2013, 2014). "As the study of Lawniczak et al. (2009) and Lawniczak (2011) indicates an inadequate amount of potassium will reduces nitrogen uptake by plants and in that way may upsurge nitrogen leakage from soil Lawniczak et al. (2009) However, relationships between these elements are not well understood in terms of nutrient leaching in agricultural areas.

High concentrations of nitrate in groundwater are usually due to anthropogenic effects. Gholami Deljomanesh et al. (2017) showed that leaching of nitrogen increased due to enhance of nitrogen fertilizer utility per unit area.

"The urban source contemplates leakages from the sewage network and, therefore, it depends on the anthropogenic pressure, stated by the population density, predominantly concentrated in the urbanized areas".(Daniela 2018) "Besides degrading drinking water resources, NO_3^- leaching to groundwater may also affect aquatic ecosystems when the pollutant-bearing groundwater discharges to surface water" (Hamilton and Helsel 1995). "Also in the lack of main human's activities, water–rock interaction is the foremost process that distresses the groundwater chemistry in a farmland"(Corteel. et al. 2005). These geochemical processes are accountable for the spatial–temporal changes in groundwater chemistry.

"Due to the application of chemical fertilizer as well as irrigation area extension, food production has increased in recent decades" (Kaneko et al 2005). "In fact, the fertilizer was over-applied to most fields in recreation of high yields" (Zhang et al, 1996). "For example, reported that over half of 69 groundwater samples collected in north China exceed the NO_3^-standard for drinking water, and the highest NO_3^- concentration was 300 mgL^{-1} in some intensive vegetable-producing areas, indicating a serious situation of NO_3^- pollution in groundwater"(Yanjun et al, 2011). The N or NO_3^- aspects of groundwater contamination caused by agricultural activities in the North China Plain (NCP) has been reported by Chen et al. (2002), "Even in the region where the groundwater table is deep, NO-3 pollution of groundwater has been detected" (Tang et al, 2004). Nitrate concentrations in groundwater, which exceed the drinking water limit are already a serious problem, Under existing climate conditions are predicted to continue to rise (Stuart et al. 2011).

"Cover crops have been shown to be highly effective in reducing nitrate loss" (Davies et al., 1996; Shepherd, 1999). A review of research by Harrison et al. (1998) indicated that "depending on species, weather, soil type, and establishment date, cover crops can typically take up 10-60 kg N/ha, with higher values under certain conditions. This nitrogen would otherwise have been lost from the soil in drainage waters". In an experimental work they found that" 25-33% of this cover crop N was released within three months of destruction, making it available to the crop"(Harrison et al. 1998). Shepherd & Lord (1996) considered that "cover crops are probably the single most effective control of nitrate leaching in arable rotations - even though they can only be employed one year in four in a rotation prior to a spring sown crop". (ADAS, 2007).

The Kor River basin characters:

The regions irrigated by the Kor River play the central role in rice production in the Fars Province in Iran. The Kor River spans a length of 270 km and is 30–40 m wide; it is the longest and the most important river in the Fars Province. Kamfirooz is a well-known rice-production site, spanning 11,000 ha in the Kor River basin in the Fars Province.

The Doroodzan Dam has been constructed on the Kor River and regulates 760 million m^3 of water per year and supplies the required water for 42,000 ha of the Ramjerd farmlands and 34,000 ha of the Korbal and the Marvdasht farmlands. This reservoir dam also supplies the significant portion of drinking water to the cities of Shiraz and Marvdasht. In the Kamfirooz District, the water table is shallow: it is ten meters deep. Nitrate pollution in the water from the Kor River and the Doroodzan reservoir cause health problems, particularly for the inhabitants of Shiraz and Marvdasht. The present research will exhibit the effects of irrigation and agricultural action on Kor River water, which is a result of irrigation of rice paddy in the Kamfirooz District. The goals of this investigation are to evaluate regional water quality and to assess the effects of irrigating a paddy rice field on surface and ground water quality. The goal is to manage the system in order to reduce nitrogen leakage to the environment, while maintaining efficiency of the fertilizer on agricultural activity, especially on rice production in the Kamfirooz District.

2. Materials and methods

STUDY AREA

The study area extended to the whole region of the Kamfirooz Irrigation District (KID) located in the north Shiraz in the Fars Province with the coordinates 52.7–52.2° N and 30.2–30.1° E (Fig. 1). The height of this area is from 1,620–1,800 m above the sea level. KID is one of the most major rice production sites in the Fars Province, with an agricultural area of 11,000 ha. Around 50 villages, with a total population of 36,000 are involved in agricultural practices in the study area.

This investigation has been conducted at Kamfirooz district, located at both sides of a river in the upstream of Doroodzan dam reservoir. Also, GIS information of this district was prepared. GIS is a powerful tool which is used for storing, analyzing and displaying spatial data used for investigating groundwater and surface water quality information.

This area has a semi-arid to semi-humid climate. The yearly average air temperature is 17.6° C and the average annual precipitation range is 474 mm, of which 70 percent occurs during autumn and winter (Fars Metrological Bureau, 2020). Fig. 1 and 2 show the location of the study area in the Fars Province of Iran.

FIELD SURVEY

For studying the impacts of irrigation practices on the Kor River’s water quality, surface and groundwater sampling was performed before initiating irrigation. For rice production, periodic irrigation is annually performed twice during the year: during the rice-growing season and up to 15 days after the end of the fertilizing period in the paddy fields. Before the beginning of the rice cultivation, (May) the Kor River water table was under normal conditions. The location of the water sample was selected by a GPS system and the Google Earth software.

Scientific Society of Environmental Education and Sustainable Development EESD
Available online at www.ap.iauardabil.ac.ir
Islamic Azad University, Ardabil Branch
Anthropogenic Pollution Journal, Vol 4 (1), 2020: 24-35
DOI: 10.22034/ap.2020.1882082.1055
ISSN:1908-1043
I.A.U Islamic Azad University Ardabil Branch

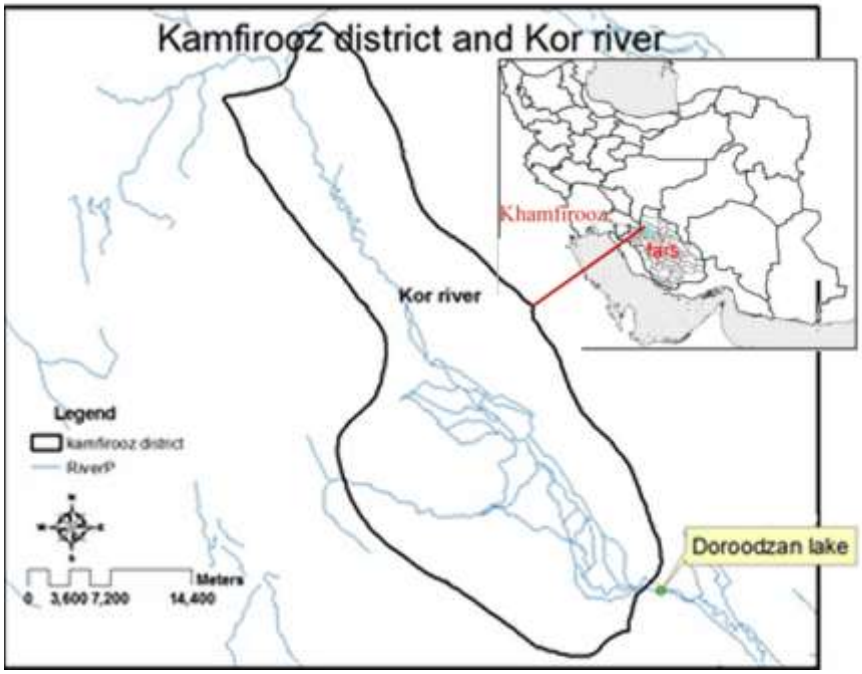

Figure 1. Location of The Kamfirooz irrigation district in Iran and Fars province

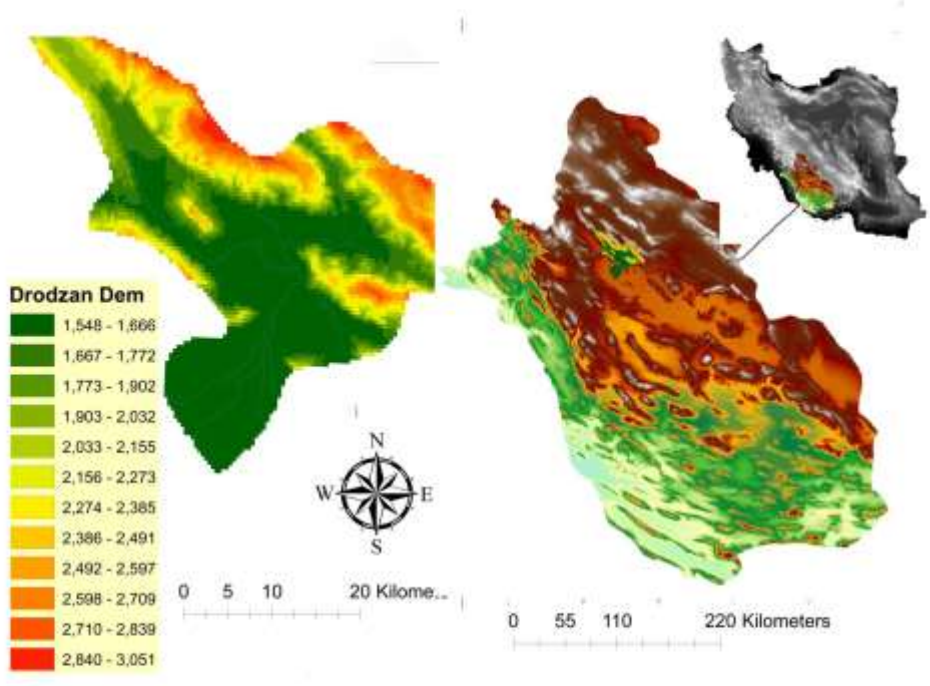

Figure 2. Dem (Digital Elevation Map) of The Kamfirooz irrigation district in Iran and Fars province

Table 1- Survey content design and number of collected samples in 2014

Survey item	**Contents**	**Investigated/sampled sites**	**Survey time**
Land use and agricultural practice	Cropping system crop yield fertilizer application(type, amount, application time) irrigation(times, periods, amount)	30	May- Sept
Surface water	Kor river discharge usage purpose (drinking, washing) quality (sampling)	3	May- Sept

Table 2 Agricultural practices and associated information with respect to different land uses

Land use	Growing period	Yield (10^3Kg ha^{-1})	Irrigation events	N-fertilizer type/time	Amount (N Kg ha^{-1} year^{-1})
wheat	Dec- Jun	5-7	4	Urea/ DAP*	150/150
maize	Jun - Oct	5-7	frequent	Urea/DAP	250/150
rice	May - Sep	2.5-3	frequent	Urea/ DAP	350/350

*DAP = diammonum phosphate

Table 3: NO_3^- concentration before and after fertilizer application at study area in 2013 to 2014

Time of sampling	8 May	22 Jun	18 Jul	6 Aug	21Aug
Nitrate concentration(mgL^{-1}) at site 1(32 sample)	7.3	25.7	5.3	3.5	3.9
Nitrate concentration(mgL^{-1}) at site 2 (32 sample)	17.9	31.4	4.43	2.2	1.8

Two main sampling district were selected along the Kor River as a set of sampling stations and seven water-quality parameters, including dissolve oxygen (O_2), nitrite, nitrate, pH value, EC, TDS, and turbidity were analyzed during May–September 2014. These parameters were chosen with respect to pollution sources in the watershed. Site one is located 35 km away from the second. The sampling was carried out according to APHA, (2005), Standard methods. At 4 time intervals (August 6th, August 22th, June 15th, and May 15th, 2014). 64 water samples were collected along the Kor River.

Alongside of site one, 8 samples, at 4-time intervals, and alongside of site Two, and 8 samples at 4-time intervals. The site one, is located on upstream from the agricultural lands beside the village of Sarbast, and site two, is by the

Doroodzan reservoir (Fig. 1). Clean polyethylene bottles were used for sampling. Certain parameters, such as pH value, TDS, and EC, were determined in situ using portables devices. The samples were delivered to the laboratory in up to two hours. The average of the selected parameters of the water sample characters are summarized in Table 2. Although the authors measured seven parameter of water quality but the aim of this paper is to justifying the relation of these parameters with nitrate concentration and visualizing the effects of agricultural activities and natural vegetation on Nitrate Contamination

3. Results

Nitrate Leaching to Kor River Water *:* This study was directed before the first irrigation for the rice farms.

The first fertilizer that was used in Kamfirooz paddy fields was diammonium phosphate ($(NH_4)2HPO_4$). This fertilizer combines with soil before agriculture and irrigation.

After first irrigation, supplemented with fertilizer usage, in the upper layers of soil causes an increase of NO^{3-} concentrations to reach from 7.3 to 25.7 mgl^{-1} at the agricultural lands beside the Sarbast village. At this point, the NO^{3-} concentration was 5.3 mgl^{-1}. After the application of the third fertilizer (by using of urea fertilizer) flood irrigation, lead to decreasing of NO^{3-} concentration at surface soil samples to 3.5 mgl^{-}. At the same time, before first fertilizer application at the soils located beside of Doroodzan Lake the NO^{3-} concentration was 17.9 mgl^{-1} but after the first fertilizing it increased up to 31.4 mgl^{-1}. Therefore, the NO^{3-} concentrations (31.4 mgl^{-1}) exceeded from the acceptable limits for drinking water at this site. During the second and the third periods of urea fertilizer application, at this point the NO^{3-} concentration decreased from 4.43 mgl^{-1} to 2.2 mgl^{-1}.

In spite of using high amounts of fertilizer because of flood irrigation in paddy field, the NO^{3-} concentrations leaches from soils to surface groundwater. This study showed that 3 out of 10 water samples had NO^{3-} concentrations that surpassed the acceptable limits for drinking water and the highest NO^{3-} concentration was 31.4 mgl^{-1}. Under this condition, surface groundwater will gain high contamination of NO^{3-}, probably because of nitrogen-leaching in the area.

Table 1 shows the seasonal change of NO^{-3} concentration in the Kor River water at two specified site including a set of sampling points or stations (Fig. 1 and 2), where an experimental system was designed based on the interactions of the surface water with the soil and the plant system. In this system, the NO^{3-} concentration changes meaningfully according to the agricultural events between the two growing seasons of rice production. The changes in NO^{3-} concentration occurs at two sites in the Kor River water—before and after irrigation. Fertilizer-use causes a large increase in the NO^{3-} loading into the Kor River water and the highest amount of nitrate (NO^{3-}) concentration occurred in June. This indicates that much of the N-fertilizer is not used by the crops, and leaches into the surface and groundwater through irrigation, thereby causing Kor River and groundwater contamination.

Fig. 3 and 4 show how NO^{3-} leaching related to irrigation effects on groundwater and Kor River water quality.

Table 3 shows all the results of NO^{3-} concentration measured in this research. Significantly, NO^{3-}-leaching shows that this irrigation procedure, i.e. flood irrigation, will lead to low N-use efficiency and will increase the risks of nitrite-leaching into the aquatic environment.

This results in the leaching of fertilizer into the Kor River. Therefore, it has been suggested that the direct arrival of agricultural waste into Kor River should be prevented by creating a soil barrier and plant covering the sides of the river. Fig. 3 and 4 indicate N-concentrations at different time periods.

Both charts show that maximum nitrate pollution occurs in June. At this time, there are plants covering the paddy fields and agricultural lands are exposed to erosion because of plowing and water over the fields.

For all the types of croplands located in this District, a great quantity of N fertilizer is being used (Table 3), chiefly, for the cultivation of vegetables and other crops. The ratio of the yield-to-income per unit area of land is listed in Table 3. These amounts are meaningfully high in comparison to other regions. The annual N-fertilizer inputs range from 500 to 1,400 kg ha^{-1} N, dependent on the cultivation crop type. In the rural areas of Iran, there is less official environmental awareness or restrictions about the various impacts of the unnecessary application of N fertilizer.

4. Discussion

Water, Land Use, and Agricultural Practices: The land-use outline through the irrigation area depends on land features, such as topography and land-use (Fig. 1, 2,). The growing season of the crops is shown in Table 3. However, rice and wheat are the principal crops that are cultivated on a rotational basis in the area. In the Kamfirooz District, farmers only cultivate rice, over 90 percent of the agricultural land is allocated to rice cultivation. The part of the district that includes dense agriculture; is located on elevated land, with a height ranging from 2,800 to 3,000 m above sea level (Fig. 2). The major crop of the area is rice. The borders of this district constitute mixed forests and low forests, and the central parts include mid-range and agricultural lands; the field survey was directed at the upper and the central parts of the agricultural land, and the upper parts include the irrigation area of the Kamfirooz district.

The field survey of nitrate concentration and the analysis of the geostatic layers of the Kamfirooz Irrigation District indicated that the maximum nitrate pollution occurs in June, when the rice plants are in the early stage of growth. With increase in the rice canopy, coverage is increased and nitrate concentration reduces in nearly all samples in this stage of rice production. Nitrate concentration was above the permissible level only in a few samples. The result of this investigation shows the vital role of plant coverage in nitrate absorption. This investigation revealed that in spite of high fertilizer loading, if the fertilizer is rationally applied, phosphate-loading into the river will be minimized.

These rationality procedures constitute essential practices such as decreasing fertilization rates, creating soil barriers, planting strips at the edge of a river, programming fertilizer use, and improving irrigation. These activities have latent and practical effects on reducing NO^{3-} loading into the Kor River water.

This study shows that the thick sandy-loam soil of the Kor River sediments, with a high saturated hydraulic conductivity, causes fertilizer leaching from the mentioned zone, which contaminates the Kor River water and consequently the downstream paddy fields.

The seasonal change of NO^{3-} concentration in Kor River water indicates that there is a risk of seasonal change in NO^{3-} contamination in river water in the Kamfirooz District area, particularly during spring and the beginning of summer.

The agricultural practices in the Kamfirooz District mainly depend on the Kor River water. Although this district experiences over 470 mm of annual rainfall, the rice farms do not use any green water as the alternative for irrigation as during the rice-growing season, no rainfall occurs. Fig. 1 shows that rice farmlands on both sides of the Kor River within the study area are irrigated by diverting water from both sides of the river, except a number of farms that are located on high elevation and water cannot be delivered by gravity. As an alternative, groundwater from shallow aquifers is pumped for irrigation or from piezometric wells in places that are far away from the Kor River.

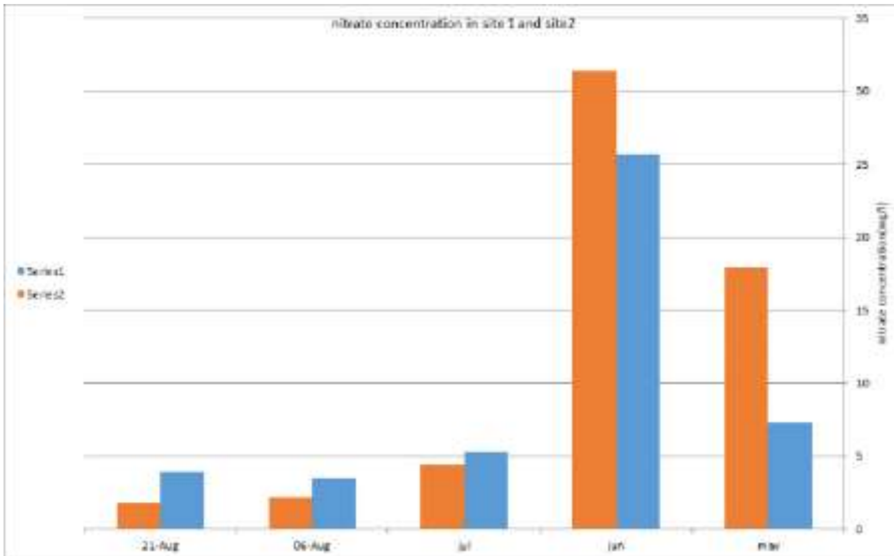

Figure 3. Nitrate concentration (mgL^{-1})in Kor River water at two sites(1 and 2). maximum nitrate pollution occurs in June

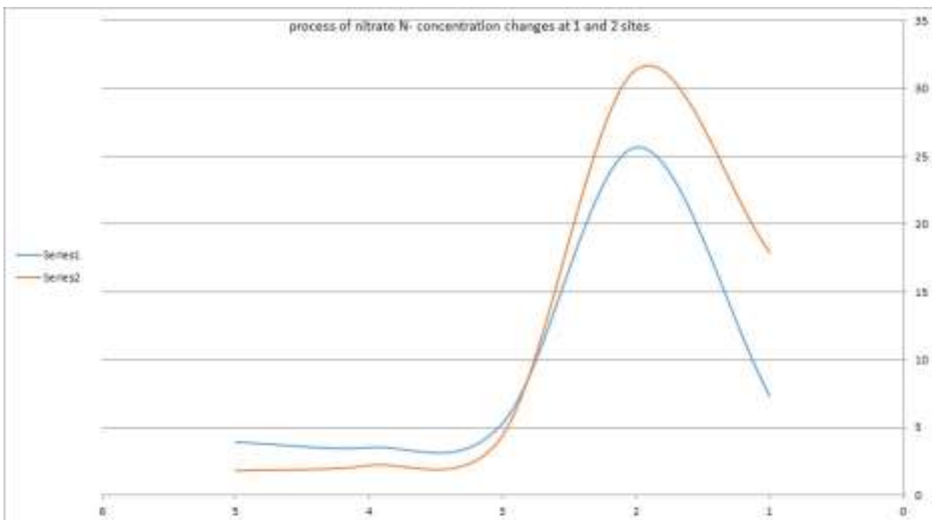

Figure 4. Process of nitrate concentration changes at sites 1 and 2 nitrate pollution occurs in June

In this area, after anthropogenic effects, water–rock interaction is the leading process that affects groundwater quality. These processes are the main factors that affect the spatial and the temporal variations in groundwater quality. With regard to the residential activities in the South of this District, however, urban and industrial activities have less impact on the levels of nitrate analyzed in this study. The main anthropogenic effect on nitrate concentration is derived from agricultural activities.

5. Conclusions

This investigation showed that during and at the end of the growing season of the rice plant, nitrate concentrations will decrease. This means that plant cover has a major role to play in nitrate absorption and decreases nitrate pollution in the Kor River water. Planting trees between paddy fields and the river will work as a buffer and a biological conservation system, in which by absorbing phosphate and nitrate, and by denitrifying, loading these elements into the river could be minimized.

Collecting and treating wastewater from the villages is another effective action for decreasing fertilizer loading into the Kor River. In addition, cultivation in spring may reduce the nitrate lost after plowing, even though increased leaching may be observe during winter. The best course of action may be to carrying out grass reseeding in spring or in early autumn, plowing out of the grassland when a crop has been established.

Controlling the NO^{3-}-loading into the ground and surface water is a difficult procedure. As denitrification is a multipart process and is difficult to practice on a domiciliary scale, using better N-fertilizer is better choice for protecting drinking water in these areas.

The farmers, in the Kamfirooz paddy fields, annually apply 3,850 tons of nitrate, 3,850 tons of diammonium phosphate fertilizers, and different types of herbicides. In order to decline fertilize-se, farmers can practice crop rotation. Crop rotation is an effective method to enhance the soil. Certain farmers grow clover to increase soil nitrogen and use less nitrate fertilizers in the Kamfirooz District. Authors recommendation for N-controlling and -leaching involves more precise irrigation and fertilization technologies to improve water- and N-use efficiency in the Kamfirooz District. Authors recommendation for N-controlling and -leaching may involve be more precise irrigation and fertilization technologies to improve water- and N-use efficiency in the Kamfirooz District. Application of this approach for N fertilization and irrigation will not only reduce ground and surface water contamination from NO^{3-}-leaching but also water-use for moderating water crises in the large area of the Fars Province.

5. Acknowledgment

The authors would like to have many thanks to Dr. Alimorad Hassanli, associate professor of Shiraz University, for his precious advice, encouragements and helps. The authors would like thank Members of the Board of Directors of Scientific Association of Environmental Education and Sustainable development EESD

https://www.srttu.edu/environment/ for ethical approval of performing the project and monitoring its implementation process. This project approved in Shahid Rajaee Teacher Training University, so it is the authors duty thanks all of the staff of these institution.

7. Additional information and declarations

Funding

There was no funder for this study.

Grant Disclosures

There was no grant funder for this study.

Competing Interests

The authors declare there is no competing interests, regarding the publication of this manuscript

Author Contributions

Valiallahi Jalal: prposed the plan, conceived the experiments, analyzed the data, prepared figures, and tables, authored or revised drafts of the paper, approved the final draft.

Smael Moradi Koochi: conceived and designed the experiments, analyzed the data, contributed reagents /materials/analysis tools, prepared figures, and tables.

Data Availability

All the data are shown in the tables of this article.

Ethics Statement

The study was conducted by national and international guidelines (Directive 2007/526/EC of the European Commission) for the protection of animal welfare. Also approved by Scientific Association of Environmental Education and Sustainable Development(EESD)

http://www.ac.ir/environment

Supplemental Information

There is no supplementary information on this paper. Any questions and request for more information should be addressed on correspondence author.

References

ADAS, 2007, Nitrates in water – the current status in England, Diffuse nitrate pollution from agriculture strategies for reducing nitrate leaching, report to Defra – supporting paper D3 for the consultation on the implementation of the Nitrates Directive in England, p. 22.

APHA, 2005, Standard methods for the examination of water and wastewater, 20th edition, APHA, AWWA, WEF

Publication, Washington D.C.

Bechmann M.2014, Nitrogen losses from agriculture in the Baltic Sea region. Agriculture, Ecosystems and Environment. 198(15):13–24. doi: 10.1016/j.agee. 2014.05.010.

Billen G, Garnier J, Lassaletta L.2013, The nitrogen cascade from agricultural soils to the sea: modeling nitrogen transfers at regional watershed and global scales. Philosophical Transactions of the Royal Society B. 368:1–13. doi: 10.1098/rstb.2013.0123.

Cakmak I. 2005, The role of potassium in alleviating determinal effects of abiotic stresses in plants. Journal of Plant Nutrition and Soil Science. 168:521–530. doi: 10.1002/jpln.200420485.

Corteel C, Dini A, Deyhle A. 2005, Element and isotope mobility during water–rock interaction processes. Phys Chem Earth 30:993–996.

Chen, J. Y., Tang, C. Y., Sakura, Y., Kondoh, A. &Shen, Y. J. 2002 Groundwater flow and geochemistry in the lower reaches of the Yellow River: a case study in Shandong Province, China. Hydrogeol. J. 10, 587–599.

Daniela Ducci, 2018, An Easy-to-Use Method for Assessing Nitrate Contamination Susceptibility in Groundwater, Geofluids Volume, Article ID 1371825, https://doi.org/10.1155/2018/1371825.

Ecological Society of America(ESA), 2000, Nutrient Pollution of Coastal , Rivers, Bays, and Seas,Issues in Ecology, Number 7, http://esa.sdsc.edu/

Ehteshami Majid , Biglarijoo Nader, 2014, Determination of Nitrate Concentration in Groundwater in Agricultural Area in Babol County, Iran, Iranian Journal of Health Sciences 2014; 2(4).

Fageria VD. 2001, Nutrient interactions in crop plants. Journal of Plant Nutrition. 2001; 2498:1269–1290. doi: 10.1081/PLN-100106981. [Cross Ref]

Fars Metrological Bureau, 2020. http://www.farsmet.ir/ReportAmar.aspx

Garnier M, Recanatesi F, Ripa MN, Leone A. 2010, Agricultural nitrate monitoring in a lake basin in central Italy: a further step ahead towards an integrated nutrient management aimed at controlling water pollution. Environmental Monitoring and Assessment. 170:273–286. doi: 10.1007/s10661-009-1231-z. [PubMed] [Cross Ref]

Gholami Deljomanesh E, Fataei1 E, Ghodrati A, Mostafavi Rad M. 2017, Accumulation of dry matter and nitrogen in the shoots of maize (Zea mays L.) and nitrogen leaching as affected by organic and chemical nitrogen fertilizers in Guilan province, Journal of Research in Ecology, 5(2): 1052-1059.

Güsewell S. 2004, N:P ratios in terrestrial plants: variation and functional significance. New Phytologist. 164:243–266. doi: 10.1111/j.1469-8137.2004.01192.x. [Cross Ref]

Güsewell S, Koerselman W, Verhoeven JTA. 2003, N:P ratios as indicators of nutrient limitation for plant populations in wetlands. Ecological Applications. 13(2):372–384. doi: 10.1890/1051-0761(2003)013[0372:BNRAIO]2.0.CO;2. [Cross Ref]

Hamilton, P. A. &Helsel, D. A. 1995, Effects of agriculture on ground-water quality in five regions of the United States. Ground Water 33, (9 pages).

Harrison, R. and Silgram, M. 1998. Final report to MAFF on project NT1508 (cover crops). Includes Appendix: the mineralisation of nitrogen in cover crops – a review.

Jiang R, Hatano R, Zhao Y, Woli KP, Kuramochi K, Shimizu M, Hayakawa A. 2014, Factors controlling nitrogen and dissolved organic carbon exports across timescales in two watersheds with different land uses. Hydrological Processes. 28:5105–5121. doi: 10.1002/hyp.9996.

Kyllmar K, Bechmann M, Deelstra J, Iital A, Blicher-Mathiesen G, Jansons V. 2014, Long-term monitoring of nutrient losses from agricultural catchments in the Nordic-Baltic region: a discussion of methods, uncertainties and future needs. Agriculture, Ecosystems & Environment. 198:4–12. doi: 10.1016/j.agee.07.005.[Cross Ref]

Kyllmar K, Stjernman Forsberg L, Andersson S, Mårtensson K. 2014, Small agricultural monitoring catchments in Sweden representing environmental impact. Agriculture, Ecosystems & Environment. 198:25–35. doi: 10.1016/j. agee.2014.05.016.[Cross Ref]

Kaneko, S., Kondoh, A., Shen, Y. & Tang, C. 2005, The inter-relationship of the water cycle, crop production, and human activities in North China Plain. J. Japan Soc. Hydrology and Water Resources 18(5), 575–583.

Lawniczak AE. 2011, Response of two wetland graminoids to N:K supply ratios in a two-year growth experiment. Journal of Elementology. 16(3):421–437.

Lawniczak AE, Choiński A, Kurzyca I. 2011, Dynamics of lake morphometry and bathymetry in various hydrological conditions. Polish Journal of Environmental Studies. 20(4):931–940.

Lawniczak AE, Güsewell S, Verhoeven JTA. 2009, Effect of N:K supply ratios on the performance of three grass species from herbaceous wetlands. Basic and Applied Ecology. 10(8):715–725. doi: 10.1016/j.baae.2009.05.004. [Cross Ref]

Mostafavi, H, Teimori A. 2018, Investigating multiple human pressure types in the southern Caspian Sea Basin Rivers at different spatial scales toward Integrating Water Resource Management (IWRM) in Iran. Anthropogenic Pollution Journal, 2(1): 38-47 .DOI: 10.22034/ap.2018.538376.

Stuart, D.C. Gooddy, J.P. Bloomfield, A.T. Williams, 2011, A review of the impact of climate change on future nitrate concentrations in groundwater of the UK M.E. Science of the Total Environment 409, 2859–2873.

Szczepaniak W, Barłóg P, Łukowiak R, Przygocka-Cyna K. 2013, Effect of balanced nitrogen fertilization in four-year rotation on plant productivity. Journal of Central European Agriculture. 14(1):64–77. doi: 10.5513/JCEA01/14.1.1157. [Cross Ref]

Szczepaniak W., Grzebisz W. , Jarosław P. 2014, An assessment of the effect of potassium fertilizing systems on maize nutritional status in critical stages of growth by plant analysis ,J. Elem. s. 533–548 DOI: 10.5601/jelem.2014.19.1.576 1.

Tang, C., Chen, J., &Shen, Y. 2003, Long-term effect of wastewater irrigation on nitrate in groundwater in the North ChinaPlain. In: Wastewater Re-use and Groundwater Quality (ed. by J. Steenvorden& T. Endreny), 34–40. IAHS Publ. 285. IAHS Press, Wallingford, UK.

Tang, C., Chen, J., Shindo, S., Sakura, Y., Zhang, W. &Shen, Y. 2004 Assessment of groundwater contamination by nitrates associated with wastewater irrigation: a case study in Shijiazhuang region, China. Hydrol. Processes 18, 2303–2312.

Yanjun Sh. 2011, Effects of agricultural activities on nitrate contamination of groundwater in a Yellow River irrigated region, Water Quality: Current Trends and Expected Climate Change Impacts (Proceedings of symposium H04 held during IUGG in Melbourne, Australia, (IAHS Publ. 348).

Yoon GH. 2005, Leaching of nitrogen and phosphorus from agricultural soils with different cropping practices and with respect to preferential transport. Göttingen: Kiel, University, Diss. Cuvillier Verlag.

Woli KP, Hayakawa A, Kuramochi K, Hatano R. 2008, Assessment of river water quality during snowmelt and base flow periods in two catchment areas with different land use. Environmental Monitoring and Assessment. 137(1-3):251–60. doi: 10.1007/s10661-007-9757-4. [PubMed] [Cross Ref]

Zhang, W. L., Tian, Z. X., Zhang, N. & Li, X. Q. 1996, Nitrate pollution of groundwater in northern China. Agric. Ecosystems& Environ. 59, 223–231.