

A Close Study on the Nitrate Fertilizer Use and Environmental Pollution for Human Health in Iran

Saeed Rezaeian, M. Rezaee Boroon

I. INTRODUCTION

Abstract—Nitrogen accumulates in soils during the process of fertilizer addition to promote the plant growth. When the organic matter decomposes, the form of available nitrogen produced is in the form of nitrate, which is highly mobile. The most significant health effect of nitrate ingestion is methemoglobinemia in infants under six months of age (blue baby syndrome). The mobile nutrients, like nitrate nitrogen, are not stored in the soil as the available forms for the long periods and in large amounts. It depends on the needs for the crops such as vegetables. On the other hand, the vegetables will compete actively for nitrate nitrogen as a mobile nutrient and water. The mobile nutrients must be shared. The fewer the plants, the larger this share is for each plant. Also, this nitrate nitrogen is poisonous for the people who use these vegetables. Nitrate is converted to nitrite by the existing bacteria in the stomach and the Gastro-Intestinal (GI) tract. When nitrite is entered into the blood cells, it converts the hemoglobin to methemoglobin, which causes the anoxemia and cyanosis. The increasing use of pesticides and chemical fertilizers, especially the fertilizers with nitrates compounds, which have been common for the increased production of agricultural crops, has caused the nitrate pollution in the (soil, water, and environment). They have caused a lot of damage to humans and animals. In this research, the nitrate accumulation in different kind of vegetables such as; green pepper, tomatoes, egg plants, watermelon, cucumber, and red pepper were observed in the suburbs of Mashhad, Neisabour, and Sabzevar cities. In some of these cities, the information forms of agronomical practices collected were such as; different vegetable crops fertilizer recommendations, varieties, pesticides, irrigation schedules, etc., which were filled out by some of our colleagues in the research areas mentioned above. Analysis of the samples was sent to the soil and water laboratory in our department in Mashhad. The final results from the chemical analysis of samples showed that the mean levels of nitrates from the samples of the fruit crops in the mentioned cities above were all lower than the critical levels. These fruit crop samples were in the order of: 35.91, 8.47, 24.81, 6.03, 46.43, 2.06 mg/kg dry matter, for the following crops such as; tomato, cucumber, eggplant, watermelon, green pepper, and red pepper. Even though, this study was conducted with limited samples and by considering the mean levels, the use of these crops from the nutritional point of view will not cause the poisoning of humans.

Keywords—Environmental pollution, human health, nitrate accumulations, nitrate fertilizers.

Saeed Rezaeian is Scientific Research Staff of Soil and Water Department, Agricultural Research, Education and Natural Resources Center of Khorasan Razavi Province, Agricultural Research, Education and Extension Organization, Mashhad, Iran (e-mail: saeed_Rezaeian@yahoo.com).

Maryam Rezaee Boroon is General Practitioner (e-mail: rezaeemaryam16@gmail.com).

NITROGEN in plant tissues is used for acids and for the synthesis of proteins and other organic compounds. Generally, unscientific and excessive use of nitrate pollution is caused by nitrogen. Many environmental factors influence the concentration of nitrate through an effect on enzyme activity reducing nitrate and nitrate uptake. In addition, nitrate accumulation in plants depends on the species, varieties and different parts of the plant and its age as shown in Table I. In general, different varieties of a plant nitrogen uptake are different. The amount of manure, fertilizers, release rate and method of fertilizer application on nitrate accumulation would affect the amount of nitrate in the soil before harvest and during the harvest as a critical factor in determining the amount of nitrate in the plant [6]. Since the processes of building amines (conversion of nitrate to amines for protein synthesis) would occur in the plant, whether it is energy needed (such as ATP), any factor such as environmental stresses, which would weaken the plants, will help to accumulate nitrate in the plant. In a plant, the amount of nitrate among different textures, which weakens the plant, is different. Nitrate is usually seen in leaves, roots, and stem with a maximum amount, and hardly the nitrate accumulation problem is seen in the fruit and flower or fruity vegetables. However, the nitrate accumulation in some conditions is seen in fruity vegetables [7]. Reference [2] suggested that foliar application of molybdenum can reduce the accumulation of nitrates in fruits. In the case the eggplant crop, also similar results have been observed with the use of molybdenum. In addition, it is reported that foliar application of manganese in pineapple plants may facilitate the absorption of the leaves, and its entry into circulation of sap in plants cultivated.

Nitrate ion (NO_3^-) is very dynamic, absorbed by the roots, and leads directly to the leaves and from the leaves (source) with the carbohydrate move to the fruits (sink). Since a large amount of carbohydrates in the fruit is used for breathing, results in decreased nitrate accumulation ability, result nitrate accumulation in the fruits will happen. On the other hand, pesticide spraying or spraying with substances including nitrates is a key factor in the accumulation of nitrates in fruits, because nitrate adsorption by fruits is easily done [7]. Researchers have found that the concentration of nitrate in vegetables is different at different times of the day. Other environmental factors can be mentioned, such that if the temperature and light intensity are low, it leads to the accumulation of nitrate. Moisture stress also affects the

accumulation of nitrate, and nitrate accumulation in many cases such as their toxicity for livestock with fodder results in a water stress. Perhaps, a result of water stress is the accumulation of nitrate to reduce nitrate-reducing enzyme activity and metabolism before the light build up. Before the reduction of the soil nitrate uptake, reduced nitrate assimilation has happened, and nitrate concentration has increased. Nitrate accumulation mostly increases in the older parts of the plant, since the nitrate-reducing enzyme activity is low. For example, nitrate accumulated in older and matured leaves and its amount in the younger parts are lower. The amount of manure, fertilizers, release rate and method of fertilizer application will affect the nitrate accumulation [5].

Since the decomposition of nitrate in the plant following the light intensity is carried out in winter, larger amount of nitrate in plants is stored, whether due to lack of light, or no nitrate is converted into proteins. In Germany, Austria, Switzerland and the Netherlands to limit the losses to human health due to the presence of nitrate in water and vegetables, there have been restrictions (Table II).

TABLE I
LEVELS OF NITRATE IN DIFFERENT VEGETABLES (MG-NITRATE/KG FRESH VEGETABLES) [4]

Nitrate Amount-Fresh Wt (mg/Kg)	Different Vegetables	Nitrate Amount-Fresh Wt (mg/Kg)	Different Vegetables
261-1186	Radish	10-200	Tomato
200-1700	Turnip cabbage	10-120	Peas
150-5690	Sugar beet	20-300	Cucumber
400-3400	Cabbage	80-832	Snap bean
382-3620	Cabbage lettuce	30-800	Carrots
345-3890	Spinach		

TABLE II
NITRATE CLEARANCE LIMIT IN DIFFERENT COUNTRIES

mg/Kg nitrate in fresh lettuce		Country
Winter	Summer	
4000	3000	Germany
4500	3500	Austria
4500	3500	Netherlands
3000	2000	Swiss

Over all, the factors that would affect the nitrate accumulation includes: environment, crop management, genetics, and changing after harvest. Some people believe that the following numbers in the table below for spinach could be used for other vegetables also [6] as shown in Table III.

TABLE III
THE DECREASING METHOD OF NITRATE CONCENTRATION IN SPINACH [8]

Espesial nitrate balancing	Original nitrate amount	Final nitrate amount
	mg/kg	
Using clear smooth leaf instead of curled leaves	1673	444
Using ammonium instead of nitrate fertilizers	20300	1300
Using one to one ratio of nitrate nitrogen and ammonium nitrogen	13000	9000

In the United States, the groundwater is used for drinking water by the majority of the population. Also, many rural residents are not regulated by the Environmental Protection Agency (EPA). On the other hand, public water utilities are obligated to maintain the amount of nitrate levels below a Level of 10 mg/L nitrate-nitrogen (N) which was supposed to protect against methemoglobin (blue baby syndrome). When nitrates are high in the drinking water, a range of other health effects such as various cancers, adverse reproductive outcome, diabetes, and thyroid conditions will occur [13].

When the amount of nitrate levels in waters are below 10 mg/L, then the risk of reaching those health effects will decrease. The average daily intake of nitrate has been estimated to be in the range 30-130 mg nitrate/day [9]. Although, drinking water can contribute the majority of nitrate intake when levels are near 10 mg/L [3].

II. MATERIALS AND METHODS

In this study, after selecting the fields for the measurement of nitrate, major products of each city were selected and their forms for data collection of the field (crop type varieties, fertilizer, pesticides, irrigation, etc.) were completed, and then early in the morning we collected the desired product in the second stage, and these samples were sent to our laboratory for analysis. During the summer, a large number of samples of soil, leaves and fruit of different areas of cultivated vegetables in the cities of Mashhad, Neyshabur, and Sabzevar were randomly selected and composite samples were collected at the time. Coinciding with the harvest time in those areas, operation measurement of nitrates was conducted, and the total nitrogen, phosphorus, and potassium and some micronutrients were measured. Data from the analysis of samples were consistent with the standard limits.

III. RESULTS

A. Tomato

The average nitrate concentration resulting in a total of 13 samples of fresh tomatoes produced chemical analysis of land under cultivation of this product in the city of Mashhad, Sabzevar and Neyshabur was 35.91 mg per kg of dry matter. The highest and lowest amounts of nitrates accumulate in the tomato fruit in Neyshabur of Hossein Mokhtari farm in the first stage and later in Sabzevar were 0.84 and 125 mg per kg dry matter, respectively. The limit for nitrate in fresh tomatoes is between 10-100 [4], and the critical level of nitrate toxicity in tomato fruits was recorded in Hungary as 200 mg per kg. Since this number is much lower than the limit and critical number, there was no problem about tomato consumption.

TABLE IV
NITRATE CHEMICAL ANALYSIS OF FRUITS AND VEGETABLE CROP LEVELS OF KHORASAN RAZAVI PROVINCE FARMS

escription of fruits and leaves	Dry Wt	(F.W) NO3	(F.W) NH4
Chemical Analysis	%	mg/kg	mg/kg
Ali Safary-Tomato Fruit-2 nd Stage	93.12	17.51	104.80
Safary-Green Pepper Fruit-2 nd Stage	91.65	27.96	41.25
Hosein Safary-Tomato Fruit-2 nd Stage	93.50	23.10	52.47
Hosein Safary-Egg Plant Fruit-2 nd Stage	92.15	5.26	36.90
Ali Safary-Cucumber Fruit - Khojeh Rabieh	96.58	2.12	8.92
Ali Safary-Green Pepper Fruit - Khojeh Rabieh	91.93	64.90	21.04
Ali Safary-Tomato Fruit - Khojeh Rabieh	93.37	13.18	14.55
Hosein Safary-Egg Plant Fruit - Khojeh Rabieh	92.27	21.29	21.29
Hosein Safary-Tomato Fruit - Khojeh Rabieh	93.34	6.39	3.66
Ali Safary-Cucumber Leaf - Khojeh Rabieh	82.66	95.45	52.08
Ali Safary- Green Pepper Leaf - Khojeh Rabieh	81.07	488.28	114.60
Ali Safary- Tomato Leaf - Khojeh Rabieh	80.59	144.96	169.23
Hosein Safary-Egg Plant Leaf - Khojeh Rabieh	80.02	93.64	225.57
Hosein Safary- Tomato Leaf - Khojeh Rabieh	82.98	71.41	257.00
Ali Safary- Tomato Leaf - Khojeh Rabieh-2 nd Stage	82.16	78.26	79.34
Ali Safary- Green Pepper Leaf - Khojeh Rabieh-2 nd Stage	80.16	248.44	25.90
Hosein Safary- Tomato Leaf - Khojeh Rabieh-2 nd Stage	81.95	116.03	68.08
Hosein Safary- Egg Plant Leaf - Khojeh Rabieh-2 nd Stage	79.50	119.17	72.97
Dehnavi- Cucumber Fruit- Neishabour-2 nd Stage	94.12	7.26	20.19
Shamsaky- Cucumber Fruit- New Village-Khalesh-2 nd Stage	95.06	8.60	46.52
Ashna-Tomato Fruit- Hamid Abad-2 nd Stage	94.09	8.83	41.43
Hosein Mokhtari-Tomato Fruit- Hamid Abad-2 nd Stage	92.23	8.65	23.56
Ashna-Egg Plant- Fruit- Hamid Abad-2 nd Stage	91.62	8.43	33.20
Hosein Mokhtari-Tomato Fruit- Hamid Abad-Neishabour	28.21	124.88	108.52
Hosein Ashna-Tomato Fruit- Hamid Abad-Neishabour	37.33	112.02	305.24
Hosein Ashna-Egg Plant Fruit- Hamid Abad-Neishabour	86.48	47.98	87.93
Gholam Aram-Egg Plant Fruit- Hamid Abad-Neishabour	85.67	70.25	138.51
Kooshki-Cucumber Fruit- Kooshk Abad-Neishabour	94.67	9.27	12.00
Dehnavi- Cucumber Leaf- Kalaghan -2 nd Stage	84.26	1.57	44.85
Shamsaky- Cucumber Leaf- New Village-Khalesh-2 nd Stage	83.77	2.27	143.50
Hosein Ashna-Tomato Leaf- Hamid Abad-Neishabour	83.58	2.87	235.77
Hosein Mokhtari-Tomato Leaf- Hamid Abad-Neishabour	82.84	0.88	83.03
Ashna-Egg Plant Leaf - Hamid Abad-2 nd Stage	79.83	2.20	142.43
Aram-Egg Plant Leaf - Hamid Abad-2 nd Stage	79.06	4.93	171.47
A-Razandi- Cucumber Leaf- Hallage Village	83.21	169.12	29.03
G-Dehnavi- Cucumber Leaf- Kalaghan Village	82.45	223.82	19.76
A-Shamsaky- Cucumber Leaf- KhaleshVillage	83.26	137.81	3.52
A-Razandi- Cucumber Fruit- Hallage Village	95.31	32.96	1.19
G-Dehnavi- Cucumber Fruit- Kalaghan Village	94.89	6.65	0.92
A-Shamsaky- Cucumber Fruit- KhaleshVillage	96.10	0.68	0.47
Hosein Mokhtari-Tomato Leaf- Hamid Abad-Neishabour	82.85	36.42	126.74
Hosein Ashna-Tomato Leaf- Hamid Abad-Neishabour	79.72	18.25	244.02
Hosein Ashna-Egg Plant Leaf- Hamid Abad-Neishabour	75.63	140.33	298.79
Bozan-Tomato Leaf- Neishabour	80.00	153.32	213.78
Kooshki-Cucumber Leaf- Kooshk Abad-Neishabour	82.45	63.79	0.88
Razi Services-Tomato Leaf- Neishabour	78.99	229.81	163.97
Esteghlal-Tomato Leaf- Sabzevar	78.70	156.46	169.81
Mohamad Abadi-Argentine Watermelon Leaf- Sabzevar	69.45	319.58	172.62
Etka Firm-Charlston Watermelon Leaf- Davarzan	69.25	39.47	137.60
Etka Firm- Red Pepper Leaf- Davarzan	69.44	6.42	25.66
Tomato Fruit- Sabzevar-1	95.90	0.94	1.03
Tomato Fruit- Sabzevar-2	95.95	2.54	5.76
Tomato Fruit- Sabzevar-3	96.33	0.84	2.33
Esteghlal-Tomato Fruit- Jovein	92.89	85.65	32.45
Razi Services-Tomato Fruit- Neishabour	92.06	55.37	20.73
Akbari- Watermelon Fruit- Jovein	89.94	16.15	2.52
M-Mohamad Abadi- Watermelon Fruit- Sabzevar	91.02	0.62	0.90
Etka Firm-Charlston Watermelon Fruit- Davarzan	91.26	1.31	0.70
Etka Firm-Red Pepper Fruit- Davarzan	82.86	2.06	47.91

B. Green Pepper and Red Pepper

The average nitrate accumulated in the chemical analysis of two samples of fresh fruit green pepper in Mashhad in was 46.43 mg per kg of dry matter, and the highest amount of

nitrate in fruits of green peppers was 46.9 mg per kg dry matter, respectively. Nitrate accumulated in a sample of fresh fruit pepper in the city of Sabzevar in the field relied on the amount of 2.06 mg per kg. However, due to low levels of

nitrate in green and red pepper that were studied, it can be said that the amount of nitrate in green pepper and chili will be much lower than the permitted range. Reference [11] stated that the critical levels for the green pepper have been between 200-500 mg per kg. For human consumption, there would be no dietary restrictions in Khorasan. Although, in this study, all three areas were wetted with water and the soil samples were air dried and considering the type of farm management in terms of time and the amount of nitrogen fertilizers, animal and municipal wastewater, time of harvest and other factors can alter the amount of nitrates in the crops. But, the amounts of nitrate in the fruit of tomato, cucumber, eggplant, onion, green pepper and red pepper were much lower than the limit and critical number, in terms of nutritional poisoning.

IV. CONCLUSION

According to the joint report of Food, Agriculture Organization (FAO) and the World Health Organization (WHO) and the combination of these two organizations as experts on the Joint Expert Committee on Food Additives (JECFA), acceptable limit for adults is 0.139 mg nitrite, which equals about 9.73 mg per kg per day in terms of nitrate, which is based on the weight of an adult of 70 kg. Critical acceptable formula for children's milk and food for people with diabetes versus standard is 250 mg per kg of nitrate [11]. The research showed that the majority of nitrate in our body moved into human organs by drinking water and using vegetables [10]. Another study reported that 7% of the nitrate is mainly through crops especially vegetables, and 20% of drinking water and 10% from the meat [12].

The main reason of methemoglobinemia is for the bad quality of drinking water. The JECFA acceptable daily value for nitrate is between the minimum 0-3.7 mg per kilogram of body weight, the minimum amount of nitrite is between 0-0.6 recorded mg per kg of body weight, only on the basis of the toxicity studies. The committee (JECFA) has accepted the situation tolerable, and amounts of nitrate from vegetables are acceptable. These limits are not recommended for children under three months. In addition, spinach is high in nitrates and should not be given to babies under three months. The JECFA organization from the conservative point of view for such a comparison considers that, for example supposing that a person's weight is 60 kg, the maximum allowable level of nitrate in the body per day is 219 mg, which can be taken per day for the body (ADI). This means that if in a day, 100 g of fresh vegetables with a nitrate concentration of 2500 mg/ kg of fresh weight, such as spinach and lettuce was taken, the consumption has already exceeded the daily limit nitrate (ADI) up to 13% ahead or more. More than the amount calculated for nitrite (5% conversion of nitrate), means that the counter is 12.5 mg nitrite or more than the daily limit of nitrite to 250%. Therefore, in general, the full amount of nitrate from all other sources should be considered. The daily consumption of vegetable products should be calculated on average.

According to the WHO [14], nitrate in drinking water should not exceed 50 mg per liter of nitrate NO₃⁻. The activities of human metabolism also generate 30 to 60 mg

nitrate which increases the amount of intestinal infections. The total daily activity and metabolism of nitrate for humans is about 130 mg or more. Originally nitrate ion is not toxic. The recommended 50 mg of nitrate per liter in order to avoid "bruising baby syndrome", methemoglobinemia, in infants fed formula with water containing nitrate. Complications were limited to the use of contaminated water and unsanitary wells. Another concern is that nitrite in the stomach with food combines and creates carcinogenic compounds. The combination of nitrite (NO₂⁻) with substances such as vitamin C or ascorbic acid leads to loss combination of reactions which are dominant in the stomach [1]. Because most soils in Iran are calcareous (with a pH of about 8) and negatively charged, nitrate anions could not be retained by the soils. Nitrate nitrogen leaching losses are usually more from coarse textured soils compared to fine textured soils, because of the faster drainage of the former. Usually, the nitrate that leaches beyond the crop root zone, should pass through the unsaturated soil zone before entering the ground water. The objective of this experiment was, therefore, to review the results of nitrate fertilizer use in northern Khorasan Razavi province in Iran.

REFERENCES

- [1] Baybordi, M., H. Siadat. Agriculture, Fertilizers and Environment (translated). Nezhat Publishing Institute. Yara International Company. 2005. pp.305.
- [2] Chongpraditnum, P., P. Luksanawimol, P. Limsutchaiporn, and S. Vasunnun, Effect of fertilizers on the content of nitrate in pineapple fruit. *Acta Horticulturae*, 2000, 529:17-22.
- [3] Chilvers C, Inskip H, Caygill C, Bartholomew B, Fraser P, Hill M. A survey of dietary nitrate in well-water users. *Int J Epidemiol*. 1984;13(3):324-331. (PubMed).
- [4] Lorenz, O. A. Potential nitrate level in edible plants part. In: D. R. Nielsen et al. (eds.). Nitrogen in the environment, Vol. 2, Soil-Plant-Nitrogen Relationship, Academic Press, New York. 1976. pp. 201-220.
- [5] Malekouti, M. J., The effect of nitrogen fertilizers on nitrate accumulation of vegetables in the Iran farms. Agricultural Research and Natural Resources and Educational Organization, Tehran. Iran. Final report. Unpublished. 2002.
- [6] Malekouti, M. J., A. Baybordi. And S. J. Tabatabaei. Optimized use of manure which is an effective tool in yield increase and optimum quality and pollution decrease in the vegetable crops and upgrade of society health level. Agricultural Science Publishing. Tehran. Iran. 2004.
- [7] Malekouti, M. J., A. Nouri, S. Samavat. And M. Basirat. The nitrate accumulation reasons in fruity vegetables such as; (cucumber, tomato, etc.), and the controlling methods. Engineering pamphlet No. 414. Sana Publishers, Agricultural Science Publishing. Soil and Water Institute. Tehran. Iran. 2005.
- [8] Maynard, D. N, A. V. Barker. Regulation of nitrate accumulation in vegetables. *Acta Horticulture*, 1979, 93: 123-159.
- [9] National Research Council. Nitrate and nitrite in drinking water. National Academy Press; Washington DC, 1995. p. 63.
- [10] Schlatter, C. Wieviel Nitrat verträgt der Mensch. *Landw. Forsch. Kongressband*. 1985, pp: 58-66.
- [11] Terbe, I., Kappel, N. and Tompos D. Investigation of nitrate accumulation in green pepper. *International journal of Horticultural Science* 2006, 12(1): 21-25.
- [12] Viragh, Z. A. nitrates a nitrit egeszsegugvi kockazatai., Az EU-s nitrat direktiva Szakmai Forum kiadvanya. Okt. 12. Godollo. 2004, pp:5-24.
- [13] Ward MH, de Kok TM, Levallois P, et al. Workgroup report: Drinking-water nitrate and health--recent findings and research needs. *Environ Health Perspect*. 2005;113(11):1607-1614. (PMC free article) (PubMed).
- [14] WHO (World Health Organization). Health hazards from nitrates in drinking water. WHO, Regional Office for Europe, Switzerland. 1993.