The Agha Jari Formation: A Potential Source of Ammonium and Nitrate Nitrogen Fertilizers

A. R. Yazdian[1] and S. A. Kowsar[2]

ABSTRACT

Nitrogen deficiency ranks right behind water shortage as the second-most constraint to crop production in the coarse-loamy sand of the Gareh Bygone Plain (GBP) in southern Iran. Since better resource utilization is essential for wise energy management, contrary to reported cases, surface water pollution by N maybe a boon in the GBP. The Agha Jari Formation (AJF), in which the Bisheh Zard Basin (BZB) has been formed, contains anomalously high concentrations of NO_3^- and NH_4^+ in its calcareous sandstone, siltstone and marl components. As about 60% of our irrigation water is supplied through underground resources and are heavily over-exploited, the artificial recharge of groundwater (ARG) is actively pursued in Iran. Therefore, a major proportion of the ephemeral discharge of the BZB is spread over 1365 hectares of sedimentation basins and recharge ponds of the ARG system in the GBP. These basins and ponds are covered with improved rangeland, and eucalyptus (*Eucalyptus* spp.) and acacia (*Acacia* spp.) plantations. Therefore, it is expected that some of the geological-N dissolved in floodwater, and also carried by the suspended load, will reach the groundwater and supply the plants coming in contact with the water and/or sediment. Moreover, as both NO_3^- and NH_4^+ are considered pollutants of groundwater, the relative abundance of each should be determined, so that possible remedial measures can be designed and implemented. To study the origin of N in the BZB, and to investigate the fate of the dissolved and adsorbed N as it travels from the watershed to the root zone, 13 rock samples, 5 floodwater samples and 81 soil samples were collected and analyzed for NO_3^- and NH_4^+. The NO_3^--N concentration was lower than that of NH_4^+-N in most of the samples: 5.1 vs. 9.6 mg kg^{-1} in rocks, 13.4 vs.17.4 mg L^{-1} dissolved in floodwater, 1.3 vs.4.3 mg kg^{-1} carried by the suspended load, and 10.6 vs.15.5 mg kg^{-1} in the 0-125 cm soil profile. Assuming that the mean annual inflow of the GBP-ARG system is 7 million m^3, we receive 89.4±52.4 kg ha^{-1} yr^{-1} of NH_4^+-N and 68.7± 24.6 kg ha^{-1} yr^{-1} of NO_3^--N, of which some furnishes the vegetative cover with N. A part of what remains may reach the watertable after passing through the vadose zone.

INTRODUCTION

Nitrogen, an essential plant nutrient, is deficient in the soils of some arid and semi-arid lands; therefore, application of N-containing synthetic fertilizers to cropland is a common agronomic practice in such environments. Utilization of nonrenewable, dwindling resources for production of fertil-izers is not prudent in a world facing an energy crisis: 1.7m^3 of natural gas, or 1.1 liters of petroleum, is used to manufacture 1 kg of N (Anon., 1980; Liang and McHughen, 1987). Therefore, the subsistence farmers are unable to meet the costs of increased inputs due to the very high price of N- fertilizers.

[1] Tarbiat Modarres University, Tehran, Islamic Republic of Iran.
[2] Fars Research Center for Agriculture and Natural Resources, P. O. Box: 71365-458, Shiraz, Islamic Republic of Iran. Phone: +98711-2296091, and +98711-6274506; Fax: +98711-7205107; e-mail: <kowsar@farsagres.ir>

Legumes have been supplying N to their companion or subsequent crops from time immemorial. Unfortunately, they cannot supply more than 50% of the N needs of the current high N-demanding varieties with N_2 from symbiosis even under the best of circumstances (Heichel and Barnes, 1984); therefore, other economical N sources are needed.

Nitrogen associated with certain geological formations of plutonic, sedimentary and metamorphic origins (Stevenson, 1959; Strathouse *et al*., 1980; Dahlgren, 1994) offer a viable alternative to this pressing problem. This becomes doubly attractive where the floodwater used for irrigation emanates from watersheds formed in the N-bearing outcrops. The discharge of such catchments usually carries dissolved N, and also the N-containing suspended load. The exceptional, verdant growth of eucalyptus and acacia trees and range plants in the coarse-loamy sand of the Gareh Bygone Plain (GBP)'s artificial recharge of groundwater (ARG) systems attests to an N source carried by the floodwaters. There is absolutely no farming on the watershed, and the relatively small amount of livestock manure in the catchment could not supply the transported N. Therefore, the Agha Jari Formation (AJF), in which the Bisheh Zard Basin (BZB) that discharges the ephemeral floodwater diverted into the systems has been formed, was probably the source rock.

Geologic-N occurs in rocks of different ages and in various forms and amounts. Stevenson (1959) reported on the presence of fixed NH_4^+ in silicate minerals contained in Paleozoic shales and granite rocks. Power *et al*. (1974) discovered exchangeable NH_4^+ in the Paleocene shale, which contained 40-70% montmorillonitic clay and up to 15% $CaCO_3$, at depths >10 m in North Dakota and eastern Montana. Above 10 m, NH_4^+ was nitrified *in situ*. They attributed the paucity of NO_3^- below 10 m to the lack of nitrifying bacteria and a probable lack of O_2. Boyce *et al*. (1976) detected up to 87mg kg^{-1} NO_3^- at a depth of about 7m, which continued to an unknown depth in excess of 30m

in the Pleistocene loess of arid western Nebraska. Strathouse *et al*. (1980) reported the presence of high ammonium concentrations and high charge smectite in the Ortigalita Creek Basin of the San Joaquin Valley, California. Nitrate-N concentration approached 4.8mg g^{-1} in a rock sample from a recent Tertiary unit. Moreover, they discovered up to 1.2 mg g^{-1} of organic N in the Cretaceous sediments of the Cantua Creek Basin in the same valley. These high concentrations of N were considered a geochemical hazard in California. Complete eradication of vegetation in the Klamath Mountains of northern California was the result of oxidation of NH_4^+ released from the mica schist bedrock and the generation of high levels of nitric acid (Dahlgren, 1994).

Tertiary sedimentary rock outcrops cover a vast area of western Iran. The runoff from some of these areas is used in the ARG projects. These rocks may contain N. If these rock outcrops contain N, we need to know the form and concentration of each N compound. Thus we can better optimize their utilization and reduce their potential hazard (s) through management practices. The objectives of the study reported here were i) to discover the source and extent of NO_3^- and NH_4^+ containing rocks in the AJF, ii) to quantify the concentration of dissolved and suspended load- carried NO_3^- and NH_4^+ in the floodwater of the BZB of the GBP, Fasa, Iran, and iii) to quantify the concentration of NO_3^- and NH_4^+ in the root zone of the sedimentation basins and a recharge pond in an ARG system.

MATERIALS AND METHODS

Site Location and Description

The study area (28° 38' N, 53° 55' E) is located 200 km southeast of Shiraz, Iran in the 192 km^2 BZB, and on the debris cone formed by the Bisheh Zard River that drains the basin (Figure 1). The BZB is a north west-southeast trending syncline formed by

the tectonic movements of the Zagros Mountain Ranges during the Mio-Pliocene time in the AJF. This formation consists of rhythmically interbedded calcareous sandstones, and slightly weathered, gypsum-veined red marls and gray to green siltstones (James and Wynd, 1965). Scattered patches of the Plio-Pleistocene Bakhtyari Formation, a cherty conglomerate, also occur in the BZB. A more detailed geologic and geomorphic description of the watershed has been given by Kowsar (1991).

The Agha Jari and Bakhtyari Formations are relatively impervious; a rainfall with an

Typic Haplocalcids. Detailed descriptions of the soil present on the debris cone are reported elsewhere (Kowsar, 1991; Naderi *et al.*, 2000). The altitude of the site ranges from 1585m in the BZB to 1140 m above the mean sea level in the lowest sedimentation basin. The average annual rainfall and Class A pan evaporation of the closest weather-station to the site are 243 and 3200-mm, respectively (Pooladian and Kowsar, 2000). The depth of watertable at the site was >20m in 1996, when the reported study was implemented.
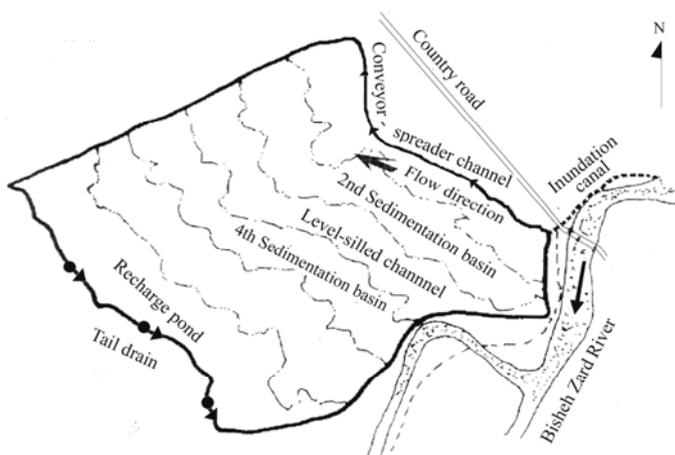

Figure 2. A 1:25000 reproduction of the map of the artificial recharge of groundwater system used in this study in the Gareh Bygone Plain.

intensity of 5mm h^{-1} and a duration of 1h causes runoff from the basin. The highest runoff coefficient obtained for the BZB has been 56% that occurred on 3 December 1986, when the maximum recorded intensity was 13 mm h^{-1}. There are a few seepage springs in the basin with the flow of <3 L s^{-1}, whose unpotable discharge is used by the livestock.

The debris cone is covered with a layer of drifting, fine sand ranging in thickness from a few mm to several cm. The soil of the site has been classified as a coarse-loamy, over loamy skeletal carbonatic (hyper) thermic

The Artificial Recharge of Groundwater System

Each ARG system consists of an inundation canal, a conveyor-spreader channel, three to six level-silled channels, three to five sedimentation basins, and a recharge pond (Figure 2). Water enters the inundation canal through an inlet and flows into the conveyor-spreader channel. This channel is a very long stilling basin that dissipates most of the kinetic energy and impulse force of the flowing water. The water runs over the spilling sill of this channel as sheet flow on a

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very long front. After filling the first sedimentation basin and leaving some of the suspended load behind, a clearer water enters the second sedimentation basin through the gaps installed in the embankment of the level-silled channel. This process is repeated 3-5 times until the clear water flows into the recharge pond. It is essential to realize that the infiltrating water percolates through the vadose zone and eventually reaches the watertable. To maintain a high rate of hydraulic conductivity through the root channels, and to utilize the portion of soil water that uselessly evaporates, sedimentation basins and recharge ponds are planted to river red gum (*Eucalyptus camaldulensis* Dehnh.), cooba (*Acacia salicina* Lindl.) and quail bush [*Atriplex lentiformis* (Torr.) Wats.]. More details may be found elsewhere (Kowsar, 1991, 1998; Kowsar *et al.*, 1996).

Rock Sampling

Thirteen surface rock samples, each weighing 1 to 2 kg, were collected on 25 July 1995 on the southern flank of the BZB on the S340W transect from the axis of the syncline to the western bluff. These samples consisted of the three main rock types of the basin, namely marls, sandstones and siltstones. Sampling was based on the abrupt change in the outcrops. We cleared the alluvium or decomposed rock material from the outcrop surface in order to collect samples that were not exposed to the recent atmospheric conditions. The distance between the sampling sites was measured to the closest meter for future reference. The samples were placed in the properly marked plastic bags. As a small shower on the afternoon of 24 July 1995 had damped the rock surface, the samples were placed on plastic sheeting for air drying in the shade within six hours after collection.

Soil Sampling

Each of the five sedimentation basins and

one recharge pond of the ARG system was divided into four roughly equal sections. A hole was drilled with a 3cm diameter screw type auger at the center of each section, and a composite sample was taken from 0 - 25, 25 - 75 and 75-125cm of each hole. Moreover, nine samples were also collected from the same depths from the outside of the ARG system as the control. Sampling was performed on 4 and 5 January 1996. The samples were collected in 15×30cm labeled plastic bags and transported to the laboratory in Shiraz and air dried for 30 days in the shade.

Floodwater Sampling

Floodwater samples were collected in 750cm^3 clean glass bottles, each containing 5 cm^3 of concentrated H_2SO_4 to prevent microbial denitrification. The runoff-producing storm related to this study started at 17:30 on 3 January 1996 and continued for 2 days. The mean flow rate for this 48 h event was 25m^3 s^{-1}. The first floodwater sample was collected at 08:30 on 4 Jan. 1996, 10cm below the surface at the Bisheh Zard River crossing. Four other samples were also collected at the same depth, 4-5m from the streamside, upstream towards the BZB at different locations. Each bottle was immediately closed with a tight fitting plastic cap and stored in a refrigerator below 4°C.

Determination of Nitrogen

Exchangeable and soluble NH_4^+ and NO_3^- were determined by the semi-micro – Kjeldahl method (Bremner and Mulvaney, 1982), expressed as mg L^{-1} for floodwater samples and as mg kg^{-1} for the suspended load, soil and rock samples. Organic N, fixed NH_4^+, and nitrite were not determined. Concentration of the dissolved NH_4^+ and NO_3^- was measured in 10 cm^3 samples after passing through Whatman filter paper No. 42. The same analyses were performed on the turbid floodwater. The difference in the

concentrations of NH_4^+ and NO_3^- in the filtered and turbid floodwater was assigned to the suspended load. The sediment concentration of each sample was measured by passing a 100 cm^3 aliquot of turbid floodwater through the filter paper after shaking the bottles vigorously. By dividing the amount of NH_4^+ or NO_3^- in the suspended load by the weight of the respective sediment, their concentrations in mg kg^{-1} were calculated. The values were then converted to N concentration using appropriate factors (14/18 and 14/62 for NH_4^+ and NO_3^-, respectively).

Statistical Analyses

Analysis of the variance in the flood derived soil N data assumed a split-plot experimental arrangement with NO_3^--N and NH_4^+-N content as the main plots, five sedimentation basins and one recharge pond as the subplots, and the three sampling depths as the sub-subplots. Duncan's multiple range test (MRT) was used to compare the means at the p=0.01 and p=0.05 probability levels. The MRT was also used to compare the NH_4^+-N and NO_3^--N concentrations of the soil of the flooded area as compared to those of the control. The MSTAT-C (1991) program and a personal computer were utilized in performing these analyses.

RESULTS AND DISCUSSION

The NH_4^+-N and NO_3^--N contents of the rock samples along the 2700-m transect did not follow a definite trend going from the older to the younger strata (Table 1). This is in contrast with the findings of Strathouse *et al.* (1980) at Cantua Creek, California. This is mainly due to the different geological settings of the two places. The NH_4^+-N concentration ranged from 3.1 to 34.1 mg kg^{-1} with a mean of 9.6±7.9 mg kg^{-1}. The NO_3^--N concentration ranged from 1.8 to 19.6 mg kg^{-1} with a mean of 4.9± 4.7 mg kg^{-1} (Table 1). The ratio of NH_4^+-N concentration to that of NO_3^--N ranged from 0.27 to 13.6. Only in three samples out of 13 was the N concentration of NO_3^- higher than that of NH_4^+. As the NO_3^--N concentration of the rainfall 80km to the SE of Shiraz, a metropolitan area, was 0.3 mg L^{-1}, it was assumed that the NO_3^-–N content in the study area rainfall was insignificant relative to NO_3^--N from geologic materials.

The concentration of dissolved NH_4^+-N in floodwater ranged from 10.1 to 33.4 mg L^{-1} with a mean of 17.4 ± 10.2 mg L^{-1}. The concentration of dissolved NO_3^--N in floodwa-

Table 1. Sampling sites, lithology and concentration of ammonium and nitrate- N in the Bisheh Zard Basin.

Distance from the axis of the syncline, m	Lithology	Concentration, mg kg^{-1}	
		NH_4^+-N	NO_3^--N
0	Marl	10.1	4.0
150	Sandstone	9.3	4 .5
400	Marl	6.9	1.8
600	Marl	4.6	3.2
1000	Marl	34.1	2.5
1300	Marl	5.4	19.6
1370	Marl	8.5	3.2
1450	Marl	11.6	4.0
1600	Marl	12.4	1.8
2100	Marl	3.8	6.8
2250	Marl	3.1	2.7
2650	Detritus	10.1	7.2
2700	Siltstone	5.4	2.2
Mean ± SD		9.6±7.9	4.9±4.7

Table 2. Sampling sites, and concentrations of suspended load, ammonium and nitrate –N dissolved in floodwater and carried by the suspended load.

Distance from the watershed outlet, m	Concentration in water, mg L^{-1}		Concentration in the suspended load, mg kg^{-1}		Conc. of suspended load, gL^{-1}
	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	
0000	10.87	17.32	14.01	0.67	2.328
1000	10.87	6.97	3.40	3.49	2.507
1600	10.10	11.25	0.87	1.01	4.433
2600	33.41	12.60	2.24	0.49	4.496
4700	21.75	18.90	1.07	0.62	5.070
Mean ± SD	17.4±10.2	13.4±4.8	4.3±5.5	1.3±1.3	3.76±1.25

ter ranged 7.0-18.9 mg L^{-1} with a mean of 13.4 ± 4.8mg L^{-1}. The concentration of NH_4^+-N carried by the suspended load ranged 0.9-14.0mg kg^{-1} with a mean of 4.3± 5.5 mg kg^{-1}. The concentration of NO_3^--N carried by the suspended load ranged 0.5-3.5mg kg^{-1} with a mean of 1.3±1.3mg kg^{-1}. It is interesting to note that while the mean NH_4^+ and NO_3^- concentrations in the rock samples were 0.69 and 0.36m moles kg^{-1}, respectively, their mean concentrations in the suspended load were 0.30 vs.0.09m moles kg^{-1}. This indicates that NO_3^- was 1.7 times more soluble than NH_4^+ under the existing conditions. The rate of NO_3^- dissolution of the suspended load did not correlate with the travel distance from the outlet of the BZB to the ARG system.

As the marl and siltstone components of the AJF contain gypsum, the floodwater contains 3.8 meq L^{-1} of SO_4^{2-} (Pooladian, 1995), and because SO_4^{2-} can replace NO_3^- (Singh and Sekhon, 1978), it is logical to assume that SO_4^{2-} replaces some NO_3^- from the surface of $CaCO_3$ in the suspended load. Therefore, while the NO_3^- concentration is reduced in the suspended load, it is increased in floodwater relative to the source rocks. Elucidation of this point requires further studies. Furthermore, although oxidation of NH_4^+ to NO_3^- was probable, its reduction to gaseous NH_3 was improbable due to the near- freezing temperatures during the flood occurrence.

The difference in N concentrations among the three depths in the sedimentation basins was significant at the 1% level. The highest concentrations of both NH_4^+-N and NO_3^--N in the soil were found in the 0-25cm layer at 16.7 and 12.4 mg kg^{-1}, respectively (Tables

Table 3. Ammonium-N concentration at three depths in the sedimentation basins, recharge pond and control, mg kg^{-1}.

Sampling site	0-25 cm	25-75 cm	75-125 cm	Mean[a]	
1st sedimentation basin	11.25	12.45	12.22	11.97 b	C
2nd sedimentation basin	15.90	12.22	18.08	15.42 ab	B
3rd sedimentation basin	13.20	11.85	13.03	12.69 b	C
4th sedimentation basin	14.00	11.65	9.70	11.78 b	C
5th sedimentation basin	26.05	17.08	14.37	19.17 a	A
Recharge pond	19.47	19.83	13.48	17.60 a	A
Mean	16.65a	14.18ab	13.48b	14.77ab	B
Control	12.98	10.11	7.54	10.18	C

[a]Means for the sedimentation basins and recharge pond followed by the same lower case letter or letters are not significantly different at the p= 0.05 level, based on the Duncan's multiple range test.
Upper case letters signify the difference between each basin or pond and the control : A and B= significant at the 1 and 5% levels, respectively; C= not significant.

3 and 4). The lowest NH_4^+–N concentration was found at the 75-125 cm depth, and the lowest NO_3^--N concentration was detected at the 25-75cm depth. The interaction of depth × location of the sedimentation basins was significant at the 1% level. The highest concentration of NH_4^+-N was observed in the fifth sedimentation basin. The highest concentration of NO_3^--N was detected in the recharge pond and the second sedimentation basin. This may indicate that the prolonged detention time in the sedimentation basins favors dissolution of these ions from the suspended load.

It is noteworthy that the ratios between NH_4^+-N and NO_3^--N concentration in the soil profile in the recharge pond and the rock samples were equal at 1.8, while that of the control profile was 1.5. This indicates more leaching of NO_3^- in the recharge pond, as expected. The difference in the mean concentration of NO_3^--N (10.6 mg kg^{-1}) and NH_4^+-N (14.8 mg kg^{-1}) is significant at the 5% level.

The difference in the mean NO_3^--N concentration between the flooded and control plots was significant at the 1% level; this difference for NH_4^+-N was significant at the 5% level. This points to the long time leaching of nitrate in the control relative to the flooded area. Comparing the NH_4^+-N concentration in the five sedimentation basins and one recharge pond with that of the con-

trol, the concentration in the fifth sedimentation basins and the recharge pond were higher at the 1% level; for the second sedimentation basin the difference was significant at 5%.

There were no significant differences between the control and the first, third and fourth sedimentation basins. As the fifth sedimentation basin and the recharge pond receive the highest amount of water and clay, it is reasonable that they should show the highest concentrations of N. The second sedimentation basin with its flatter gradient receives more water and clay than the first, third and fourth sedimentation basins. This may indicate that not only the sediment-bound NH_4^+ is more abundant in the second sedimentation basin, but also some of the exchange sites on the clay suite in the lower depths were occupied by the previously dissolved NH_4^+.

The situation for NO_3^--N was somewhat different from that of NH_4^+-N; all of the sedimentation basins showed a highly significant difference with the control except the fourth one (Table 4). We cannot offer an explanation for this anomaly.

CONCLUSIONS

Contrary to the currently held belief in the U.S. and Europe, geologic - N in moderate

Table 4. Nitrate-N concentration at three depths in the sedimentation basins, recharge pond and control, mg kg^{-1}.

Sampling site	0-25 cm	25-75 cm	75-125 cm	Mean[a]	
1st sedimentation basin	11.50	10.25	10.25	11.00 ab	**
2nd sedimentation basin	15.20	7.52	11.25	11.32 a	**
3rd sedimentation basin	12.48	8.95	11.48	10.97 ab	**
4th sedimentation basin	8.08	7.55	7.55	7.72 b	ns
5th sedimentation basin	15.83	9.12	7.77	10.91ab	**
Recharge pond	10.97	12.80	10.15	11.31 a	**
Mean	12.35a	9.60b	9.85b	10.59ab	**
Control	6.93	7.15	6.61	6.88	ns

[a] Means for the sedimentation basins and recharge pond followed by the same lower case letter or letters are not significantly different at the p = 0.05 level, based on the Duncan's multiple range test.
Upper case letters signify the difference between each basin or pond and the control.
** Significant at 1% level, ns: non- significant.

concentrations should be considered a boon for the poor farmers. As the potential hazards of N have been documented (e.g., Spalding and Exner, 1993), however, one has to be wary of utilizing N-containing waters. The runoff of the AJF and, perhaps, other Mio-Pliocene formations in Iran contains geologic - N, and in most places, that is the only source of water available. Therefore, we have to accommodate our inspiration for development to such waters.

That the floodwater in the GBP contains anomalously high concentrations of NO_3^- and NH_4^+ may be a cause for concern. Based on the 1983-1988 data (Kowsar, 1991), the 1365 ha of the ARG systems in the GBP annually receive, on average 7 million m^3 of floodwater. The ARG systems received 4.3 million m^3 of floodwater in the event reported here. Assuming that the mean suspended load is 10 g L^{-1}, the ARG systems annually receive 302 ± 357kg NH_4^+-N and 88±82kg NO_3^--N from the suspended load, and 121800±71190 kg NH_4^+ –N and 93800± 33575kg NO_3^- –N dissolved in the floodwater. Should the turbid floodwater be distributed evenly over the 1365 ha of the ARG systems, each hectare will receive 89±52kg of NH_4^+-N and 69±25 kg of NO_3^--N which, at the upper end, seems excessive for growing small grains in a highly productive system, but rather high at the lower end in a marginal production system. Therefore, the financial rewards of utilizing nitrogen containing floodwater are enormous.

As the AJF covers 27680km^2 in the Zagros Mountain Ranges it may supply an enormous amount of N in the floodwater that will eventually be utilized for the production of food, forage, fiber and fuelwood. Therefore, characterization of N species is important in the basins. Determination of organic – N, fixed NH_4^+ and nitrite in the rocks of the Tertiary era is highly recommended.

ACKNOWLEDGEMENTS

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سازند آغاجاري: منبعي بالقوه براي تأمين كودهاي نيتروژنه آمونيومي و نيتراتي

ع. ر. يزديان و س. آ. كوثر

چكيده

پس از آب، كمبود نيتروژن مهمترين عامل محدود كننده كشاورزي در خاك شني گربايگان به شمار مي‌رود. بهره برداري از ذخاير پايان‌پذير نفت و گاز براي توليد كودهاي نيتروژني، با وجود ديگر منابع قابل دسترس، بخردانه نيست. از آن جا كه آبخيز بيشه زرد، كه از سيلاب آن در گربايگان بهره‌وري مي‌شود، در سازند آغاجاري به وجود آمده است، و مواد تشكيل دهنده آن داراي نيترات و آمونيوم مي‌باشند، سيلاب بيشه زرد حاوي مقادير معتنابهي نيترات و آمونيوم است. بدين ترتيب، آلودگي نيتروژني سيلاب را بايستي امتيازي بزرگ محسوب نمود. از ديگر سو، نيترات و آمونيوم از عوامل سرطان زا به شمار آمده، و معيارهايي براي غلظت مجاز آنها در آبهاي آشاميدني آمريكا و اروپا وضع شده است. نزديك به ٦٠ درصد آب آبياري ايران از منابع زيرزميني تأمين مي‌گردد. تغذية

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مصنوعي آبخوانها يكي از روشهاي مديريت منابع آب به شمار مي‌رود. از آن جا كه بخشي بزرگ از سيلاب بيشه زرد آبخوانها را انباشته و براي آشاميدن نيز مورد استفاده قرار مي‌گيرد، بايستي منبع و غلظت نيتروژن را در سيلاب، و دگرگوني‌هاي آن را هنگام جريان از سطح خاك به سوي آبخوان مطالعه كرد. در اين بررسي۱۳ نمونه سنگ آبخيز، ۵ نمونه سيلاب، و ۸۱ نمونه خاك رسوبگيرها و استخر, تغذيه مورد مطالعه قرار گرفتند. غلظت نيترات در بيشتر موارد از غلظت آمونيوم كمتر بود:۵/۱ در برابر۹/۶ ميلي‌گرم در كيلوگرم سنگ، ۱۳/٤ در برابر۱۷/٤ ميلي‌گرم در ليتر سيلاب،۱/۳ در برابر٤/۳ ميلي گرم در كيلوگرم مواد معلق، و۱۰/٦ در برابر۱۵/۵ ميلي گرم در كيلوگرم ۱۲۵-۰ سانتي‌متر خاك سطحي. چنانچه ميانگين سالانة سيلاب مهارشده در گربايگان ۷ ميليون مترمكعب بوده، و سيلاب به گونه‌اي يكنواخت در ۱۳٦۵ هكتار شبكه‌هاي تغذيه مصنوعي گسترش يابد، سالانه ۵۲/٤± ۸۹/٤ كيلوگرم در هكتار نيتروژن آمونيومي، و۶/ ۲٤±۶۸/۷ كيلوگرم در هكتار نيتروژن نيتراتي به شبكه‌ها رسيده، بخشي به وسيلة گياهان جذب شده، و قسمتي در آبخوان نفوذ مي‌كند.