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EFFECT OF INTENSIVE AGRICULTURAL ACTIVITIES ON SURFACE AND GROUND WATER CONTAMINATION WITH NITRATES

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ABSTRACT

The ability to measure and monitor accumulation of nitrates from different agricultural activities in surface and groundwater would be useful to meet water quality guidelines. Over the last twenty years, there has been a dramatic shift in the structure of agricultural activities in the sandy soils of the north coast of Nile Delta, Egypt, but that was coupled with great environmental contamination. In particular, substantial surface and groundwater contamination has resulted from the espousing of agricultural systems demanding large inputs of fertilizers and irrigation water with inherited physical properties of coarse textured soils and shallow water tables. In addition, animal production has evolved to confine a large number of animals on a few farms resulting in more production of manures within a relatively small geographic area. Water table piezometers were installed at selected locations include all traditional crop growing sites differently fertilized with mineral fertilizers, poultry manures, fish farming wastes and farmyard manure. Water samples for examining nitrate were collected from water table piezometers and main surface drains over one year period in areas with different and intensive agricultural activities.

Results of this study showed that nitrate concentrations in surface and ground water increased steadily under intensively farmed sandy soils of Nile Delta, Egypt. Results also indicated

significant relationship between intensive agricultural activities and water courses contamination. All intensive agricultural activities caused higher nitrate concentrations in the surface and groundwater. Fish farming activity and its wastes added to the soils increased nitrate concentrations in surface and ground water in comparison to other agricultural activities. Highest nitrate concentrations were found in these areas with excessively irrigated and well-drained soils in winter. Concentrations of NO_3-N in all groundwater samples were above the recommended level of drinking water for human (10 mg/l), but far below the recommended level of drinking water for livestock (100 mg/l). Concentrations of NO_3-N in all surface drain water samples nearly reached the recommended level of drinking water for livestock, reflecting high risk of environmental contamination in the studied area.

INTRODUCTION

North coast region of El-Dakhahlia Governorate (located in Nile Delta, Egypt) became a major area for intensive agricultural activities such as fish, animal and poultry farming or crop production. There is a general agreement for the importance of understanding the fate of N in soils treated with organic and inorganic fertilizers for both plant nutrition and managing the potential risk of NO_3^-–N leaching (Correa, *et al.*, 2006). Leaching of nitrate could be a serious problem in the northern coast area of the Nile Delta, because of inherent high annual rainfall (exceeding 160 mm), sandy texture and shallow water table.

Researches carried out worldwide over the last decade clearly showed that nitrate concentration in the surface and ground water could be directly related to agricultural land use (Spalding *et al.*, 2001and Stites and Kraft, 2001). Nitrate leaching was reported after excessive applications of inorganic fertilizers (Lea-Cox and Syvertsen, 1996). Application of organic wastes was also reported to cause leaching of NO_3-N into groundwater (Daliparthy *et al.*, 1995). Ground-water contamination is one of the major environmental problems as it is a critical resource and in some parts of the country is the only source of drinking water. According to the drinking water quality standard the NO_3-N level of 10 mg/l is considered the maximum permissible level for human, and 100 mg/l is the maximum for live stock (USEPA, 1987). Nitrate-N is reduced to NO_2^- in human intestine and it can cause methemoglobinemia in infants if NO_3^- is present in a sufficient quantity in drinking water (Hearing, *et al.*, 2000). There are numerous reports about ground water contamination. Gromly and Spalding (1979) found nitrate concentrations exceeded the US Environmental Protection Agency drinking water standards of 10 mg/l N in 183 of the 256 ground-water samples collected from parts of Buffalo, Hall and Merrick counties in Nebraska. Comparison of isotopic nitrogen values suggested that the primary source of contamination in most wells was from N fertilization. Stites and Kraft (2001) determined nitrate loading rate of groundwater under irrigated vegetable fields, and found that nitrate-N loading was 56 to 60% of the available N or 66 to 70% of fertilizer N and sweet corn nitrate loading was about normal, but potato nitrate loading was probably 50% greater than the normal because heavy rain provoked extra fertilizer application.

In Egypt, groundwater is a vital resource and is used for many purposes, including public and domestic water supply systems, irrigation and livestock watering, as well as industrial, commercial, mining and thermo-electric power production (El-Tahlawi, 2004). Because of the rapid population growth and the increased consumption of water in agriculture, industry, domestic use, etc., it is expected that Egypt will rely to some extent on groundwater to develop the projects such as East Oweinat (El-Tahlawi, 2004).

Therefore, studies should be focused on surface and ground water quality in the north coast area of Nile Delta, Egypt to attract attention to such area and to monitor the mass loading rate of nitrate in the surface and groundwater due to intensive agricultural activities. This could lead to predict groundwater quality and to meet the quality goals. Thus, the objective of this study was to evaluate the contribution of certain agricultural activities to surface and groundwater nitrate contamination.

MATERIALS AND METHODS

Description study site:

The study was made on the 15th of May at Agricultural Association near Gamasa seaside, El-Dakhahlia Governorate, located in the north coastal part of Nile Delta, Egypt. This area represents one of the newly reclaimed sandy soils in north Nile Delta, Egypt. Layout of the research and distribution of piezometers in the studied area are shown in Fig. 1. The agricultural land use was predominantly cropping, with a major portion devoted to cereal, alfalfa and vegetable production, poultry, fish and animal farming. The studied site comprised an area of about 4 km^2 (approximately 1000 feddans) of coarse textured, 90% sand, extremely well-drained and containing 1 to 2% organic matter in the uppermost layer. The topography of the site was level with slopes of less than 3 % (Idris, 2004 and Khater, 2002).

The annual precipitation has an average of 200 mm, with rare probability of more than 250 or less than 160 mm. Approximately 100% of the annual precipitation fall in winter between November through February. The soil water table depth ranges normally from 1.5 to 2.5 m. Most of the soils are extremely sand that allows an annual ground-water recharge of approximately 40 cm (Hefny and Shata, 2004). This site was chosen after several studies have been reviewed and personal communications made with the authorities and local farmers to carry out this work and to provide an overview of the surface and groundwater quality problems in the Nile Delta, Egypt (Khater, 2002; Idris, 2004 and El-Tahlawi, 2006).

The studied fields were managed by their individual land owners who applied different irrigation regimes (surface, furrow and drip irrigation) and N management practices. The irrigated crop rotation in the area consisted of rice or corn followed by alfalfa or wheat.

The irrigated vegetable rotation in the area consisted of tomatoes or potatoes twice a year depending on market price expectations. Field operations frequently begin as early as March or October depending on the agricultural season, with broadcasting animal manures (poultry, fish farming wastes and cattle manures). Samples of fresh manures were taken to determine N, P and K using standard methods (Page, *et al.*, 1982). As shown in Table 1, N, P and K vary greatly among manure sources.

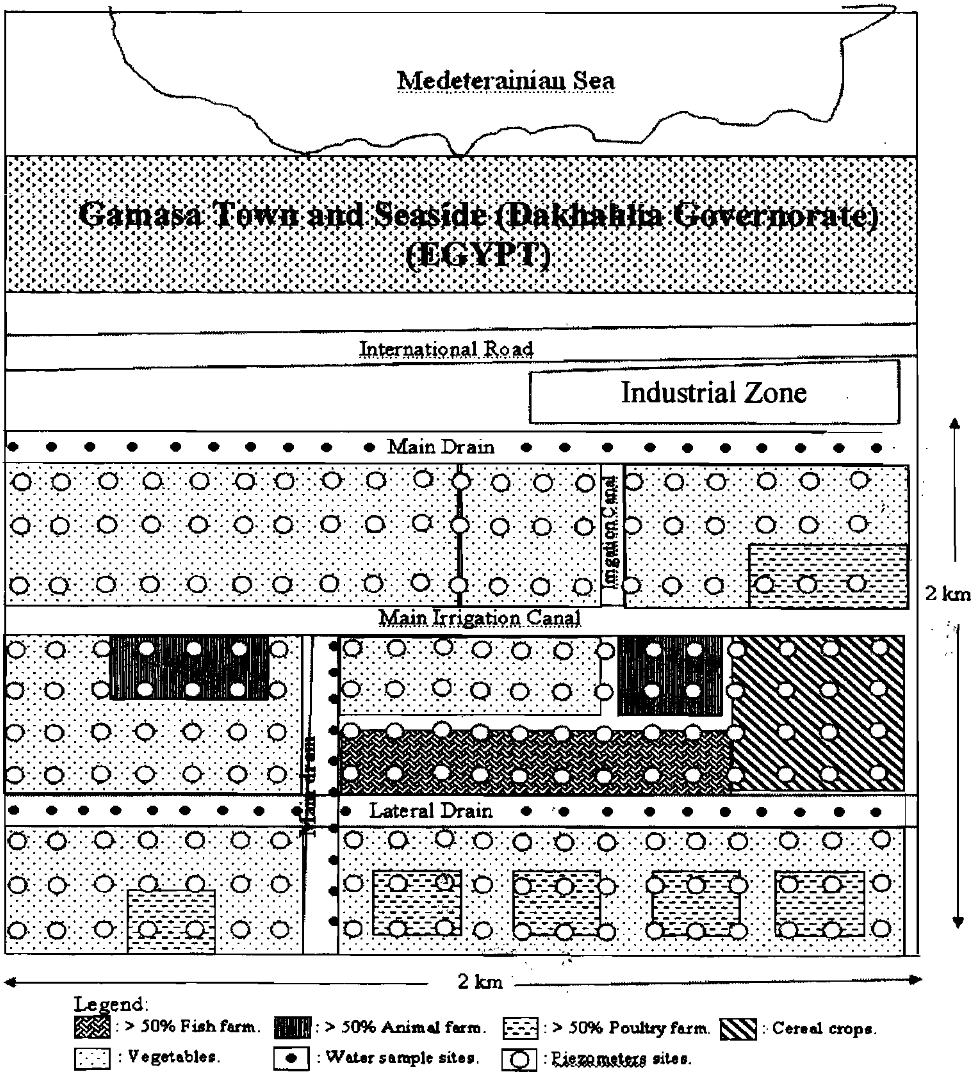

Fig. 1: Layout of the research area location and piezometere sites.

Table 1: Averages of N, P and K in animal manures (kg/ton).

Animal type	N	P	K
Cattle	**13.8**	**1.9**	**3.9***
Poultry	**16.6**	**3.6**	**5.4**
Fish	**15.5**	**6.3**	**4.4**

* Values are of fresh manures without storage, drying and handling losses.

Mineral fertilizers were applied after planting and two to three additional times, during the growth season, by hand and with irrigation water in the case of drip irrigation. Depending on weather and type of crop, irrigation water was applied about 20 to 30 times per year. In general, plant nutrients for crops were applied as mineral fertilizers, poultry, fish farming and farmyard manures or mixtures of mineral and one of aforementioned organic fertilizers. Nitrogen application levels ranged from 200 to 250 kg ha^{-1} for cereal crops and 350 to 450 kg ha^{-1} for vegetables. Organic fertilizers application levels ranged from 5 to 10 ton ha^{-1} for cereal crops and 10 to 20 ton ha^{-1} for tomatoes and potatoes production. The major mineral nitrogen fertilizers were ammonium nitrate (33.5% N) and urea (46% N). Higher levels of organic and inorganic nitrogen fertilizers were applied to vegetables under drip irrigation systems.

Experimental instrumentation, sampling and nitrate analysis:

From September 2005 to October 2006, an intensive ground-water monitoring study was conducted to evaluate nitrate leaching rate. Land uses in the sampling were intensive animal, fish and poultry production, cereal crops, alfalfa, tomatoes and potatoes. The studied area had at least 20 poultry houses, 20 cattle farms and 10 fish farms (at least 10 feddan each). For an area to be classified as cereal, alfalfa or vegetables grown, over 50% of the this area was in this cropping system. The field area sampled, number of samples, the major added fertilizers and irrigation regime and the main agricultural activities are presented in Table 2.

Table 2: Major fertilizing regimes and main agricultural activities in the sampling areas.

Field area and samples No.	Piezometer number	Major added fertilizer	Major irrigation regime	Major agricultural activity
250 feddan (200)*	1 – 50	Poultry and mineral	Drip irrigation	Poultry and vegetables
250 feddan (200)	51 - 100	Fish wastes and mineral	Surface irrigation	Fish farming, field crops
250 feddan (200)	101 - 150	Poultry, animal, mineral	Furrow irrigation	Poultry, Animal, vegetables
250 feddan (200)	151 - 200	Animal wastes, mineral	Surface irrigation	Animal farming, field crops
Main drains (200)				

* Samples number.

Areas selected for sampling that had document evidence of high nitrate concentrations in the ground and surface water and piezometeres were distributed almost equally inside and nearby each certain agricultural activity. The purpose of selecting these areas of certain agricultural activity was to determine the major cause of nitrate contamination. The impact of different agricultural activities on water quality was assessed with piezometers (PVC pipe of 10 cm diameter), which permits water sampling from as many as 200 wells throughout the water table of the studied area. The study area was instrumented in September 2005 with a total of 200 piezometers to the depth of water table (1.2 to 2.5 m) in each field of sampling areas. Within each agricultural activity field, the piezometers were separated by 100 x 200 m and aligned as far as we could handle along the studied site (1000 feddan).

Groundwater was sampled 4 times a year (22^{nd} of December 2005 after 22^{nd} of March 2006 22^{nd} of June 2006 and 22^{nd} of September) at four month intervals. At the same time, additional 50 samples of surface drainage water were collected 4 times from the main drains distributed equally throughout the studied area. Water samples were collected in polyethylene bottles, kept on ice until they were frozen in the laboratory, then analyzed for NO_3-N by automated colorimetery (APHA, 1995). Linear regression analyses were completed for significant effects of each agricultural activity and year seasons on the concentrations of nitrate in the surface and ground water samples.

RESULTS AND DISCUSSION

From environmental point of view, nitrate accumulation should be avoided in water resources. Over the entire period of this study, nitrate concentrations in all surface and ground water samples collected from piezometers or main drains were consistently high regardless of the agricultural activity implemented or water table depth. This gives a clear indication of the impact of intensive agricultural practices executed in such areas on non-point source impacted surface or groundwater quality. The average and range of nitrate concentrations and the associated major agricultural activity of the land use in the sampling areas and main drains are presented in Table 3.

Table 3: Nitrate concentrations in water samples of the studied area.

Agricultural activities	No. of samples	Mean No. concentration (mg/l)	Number of samples Nitrate concentration (mg/l)			
			20 - 40	40 - 60	60 - 80	>80
Artificial fertilizers, Drip irrigation, poultry farming and Vegetables (ADPV)	200	47.36	143 (71.5)	52 (26)	5 (2.5) *	0.0 (0.0)
Fish wastes and fertilizers, Surface irrigation, Fish farming, field crops (FSFF)	200	54.4	34 (17)	55 (27.5)	111 (55.5)	0.0 (0.0)
Poultry, animal wastes and fertilizers, Furrow irrigation, Poultry, animal and Vegetables (PFPV)	200	46.7	136 (68)	49 (24.5)	15 (7.5)	0.0 (0.0)
Animal wastes, artificial fertilizers, Surface irrigation, animal farming and field crops (AASF)	200	50.06	66 (33)	94 (47)	40 (20)	0.0 (0.0)
Main drains water samples (MDWS)	200	63.22	11 (5.5)	43 (21.5)	26 (13)	120 (60)

* Numbers between brackets represent percent of the samples under each nitrate concentration category.

Nitrate in surface and ground water

In the north coast of the Nile Delta Egypt, increased nitrate concentrations in the surface and ground water samples revealed extensive nitrate leaching from sandy soils under different agricultural practices which is a real risk to be evaluated. In this area of Delta Egypt shallow water table was located in sandy soil, which is classified as an excessively well-drained soil (permeability of >16 cm h^{-1}) (El-Tahlawi, 2004). Thus, nitrates will leach as readily because of the low moisture-holding capacity and in the well-drained sandy soils, more loss of nitrates can be expected (Waddell, *et al.*, 2000).

Several sandy soil characteristics in combination with weather and agricultural activitie factors control the transformations of N as well as the movement of N and water in the soil (Waddell, *et al.*, 2000). As a result, these factors control the potential for leaching nitrate out of the root zone. Thus, the risks of N-leaching from the studied sandy soils are closely related to the form and level of applied nitrogen fertilizers reflecting the net nitrate production in soils (Smith and Cassel, 1991).

In this respect and exclusively based on nitrate concentrations reported in surface and ground water, fish farming activity represented the highest N-leaching potential to sandy soils. In contrast, the lowest risk under the conditions of the studied area was the application of organic and inorganic fertilizers in different combinations under drip irrigation systems. Surface and furrow irrigation systems are likely to show similar N-leaching risk when applied to sandy soils. However, the future changes in some physical and chemical characteristics of the soil as a result of different managements may further alter this scenario. From the results of this study, it appears that N leaching from such sandy soil is sensitive to land management practices, with the largest losses usually occur under high application rates of nitrogen fertilizers. However, Edis (1998) considered the infiltration of water generally as the dominant factor for the concentration of solute transported below a given soil layer. White *et al.* (1998) agreed and explained that in hot climates infiltration of water is the dominant factor for the movement of solute to depth.

Main agricultural activity:

Main agricultural activities in the studied area were intensive animal, fish and poultry production, cereal crops, alfalfa, tomatoes and potatoes. The monitoring piezometers were installed closer to or even inside each agricultural activity to determine if there was high nitrate concentrations in the water table or in the main drains around each agricultural activity. In general, none of the water samples collected from all different agricultural activity areas as well as main drains had an average nitrate concentration below 10 mg/l. The results revealed that nitrate concentrations values in all ground water samples collected from piezometers show that the average concentration was consistently high and the nitrate concentration in the deeper water table piezometers was slightly low. The regression analyses for nitrate concentrations in the water samples as affected by different agricultural management practices were highly significant ($P < 0.05$) and provided consistently high coefficient of determination (R^2) values. Regardless of the main agricultural management practice, water nitrate concentr-ation response were very similar with all R^2 exceeding 0.75 (Table 4).

Table 4: Relationships of water nitrate concentrations (WNC) and different agricultural managements practices.

Agricultural management practices	Dependent variable	Regression equation	R^2
Irrigation Regimes (IR)	WNC for piezometers	WNC = 40.3 + 3.55 (IR)	0.945*
	WNC for main drains	WNC = 47.0 + 0.13 (IR)	0.796*
Four Year Seasons (YFS)	WNC for piezometers	WNC = 40.0 + 1.4 (YFS)	0.925*
	WNC for main drains	WNC = 67.0 + 0.14 (YFS)	0.969*
Nitrogen Management (NM)	WNC for piezometers	WNC = 63.0 + 0.04 (NM)	0.963*
	WNC for main drains	WNC = 68.0 + 0.76 (NM)	0.762*
Land Use Practice (LUP)	WNC for piezometers	WNC = 70.59 + 2.0 (LUP)	0.963*
	WNC for main drains	WNC = 73.0 + 2.3 (LUP)	0.881*

* Significant at 5% probability level.

The results revealed that in areas fertilized with organic and inorganic mixtures, drip irrigated and the main agricultural activity was poultry and vegetables production, 71.5% of the piezometers samples had average nitrate concentration of 31.9 mg/l. Only 26% of these water samples had average nitrate concentration of 45.7 mg/l and 2.5% had a nitrate concentration of 64.5 mg/l.

In contrast, areas of fish production farms and fertilized with fish wastes complemented with inorganic fertilizers had high nitrate concentrations compared to areas fertilized with inorganic fertilizers and animal or poultry manures. These areas had average nitrate concentration of 54.4 mg/l for total piezometers, while the other areas had average nitrate concentration of 47.36, 50.06 and 46.7 mg/l for poultry, animal and both mixed manures for crop production areas, respectively. It is worthy mentioning that, average nitrate concentration of piezometers instrumented within the fish farm areas (outside fish basins) was 75.6 mg/l, while the average concentration of piezometers located near the animal and poultry farms and their stockpiles were 55.3 and 53.5 mg/l, respectively. This might explain the relationship between high nitrate concentration and fish farming agricultural activity.

It appears that nitrate is moving through fish basins and soil profile to shallow water-table and adjacent drains. The farmer nearly fishes twice a year and when fish basins are empty the dredges liner will be taken out and this will be used as organic fertilizers. In winter, fish goes fasting and basin water nearly changed everyday so that seepage may occur in the presence of high amounts of fish food (poultry manures, biosolids and factory wastes such as macaroni, biscuits). If seepage is occurring at winter high nitrate concentrations in the monitoring piezometers would occur. The concentration of nitrate will depend upon how far the water sampler is from fish basins. This might explain why fish farming and surface irrigated areas have the highest nitrate concentrations compared to different agricultural activity areas. So, under the conditions of the studied area, if fish farms and irrigated fields are not operated properly they will have a serious impact on surface and ground-water quality in sandy soils.

Only few samples collected from main drains had nitrate concentrations above 80 mg/ liter^{-1}. Most of these samples were taken after winter from drains located in the direction of the drain water flow next to field crops and fish farms where fish wastes and urea fertilization under surface irrigation system were implemented. Approximately, 60% of the water samples collected from drains had average nitrate concentration more than 80 mg/l (Table 3). Only 5.5% of the water samples had average nitrate concentrations ranged from 20 to 40 mg/l. For all main drain water samples, the nitrate concentration nearly reached in most cases the drinking water standard of 100 mg/l for livestock.

Effect of different irrigation regimes:

A pilot study was conducted to observe the temporal changes in moisture contents over summer in some soil samples of the studied area under different irrigation regimes. The results of the temporal changes in soil moisture conditions under different irrigation regimes are shown in Fig. 2. The highest moisture differences existed between the surface irrigated fields compared to drip irrigated ones. Intermediate values were obtained with fields under furrow irrigation system. In the light of the pilot study data, the influence of different irrigation regimes had a significant effect upon changes in soil moisture contents over passing time so that the area under investigation was subject to different moisture conditions. This indicates that micro-organisms responsible for N mineralization are subjected to different moisture conditions. Therefore, the amount of N mineralized and nitrate subjected to leach from the applied fertilizers were expected to differ as a result of different irrigation regimes.

Generally, under different irrigation systems nitrate concentration in water samples was above drinking water standard of 10 mg/l. Nitrate concentrations in water samples were higher for surface or furrow irrigation treatments compared to drip irrigation treatment (Table 5). Drip irrigation was capable of applying water reducing leaching of nitrates in drip-irrigated fields compared to surface or furrow irrigation and ones. The results revealed that twenty five piezometers located within the drip irrigated area, which is completely vegetables, had average nitrate concentration of 25 mg/l. The average nitrate concentrations in water samples collected from vegetable areas surface or furrow irrigated were 45.6 and 31 mg/l, respectively.

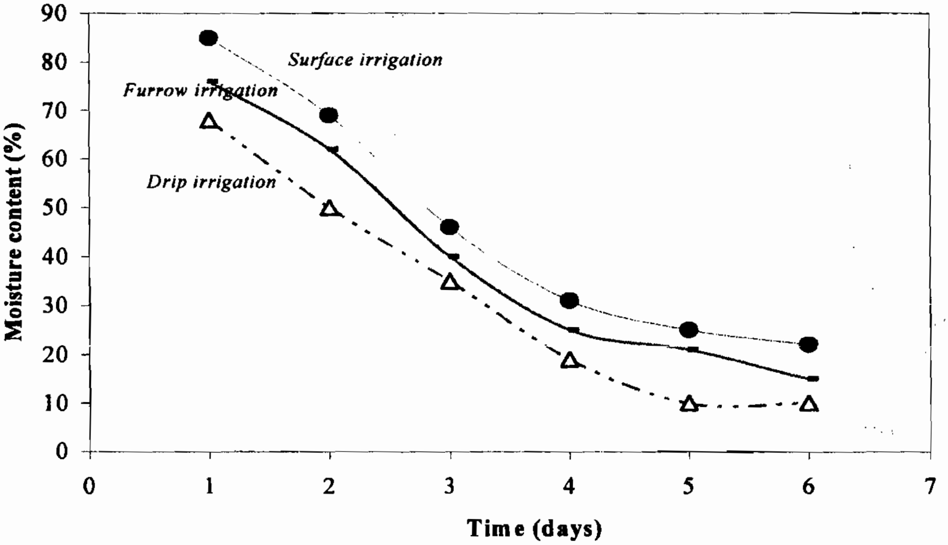

Fig (2). Temporal changes in soil moisture contents (%) under different irrigation regimes.

Table 5: Nitrate concentrations in water samples in areas under different irrigation regimes.

Irrigation regime	Number of samples	Concentration (mg/l)			
		Mean	Standard deviation	Range	
				Low	High
Surface irrigation	25	45.6	5.63	25.9	57.4
Furrow irrigation	25	31	5.19	22.6	45.3
Drip irrigation	25	25	3.11	15.1	39.2

Under the conditions of this study, different irrigation systems seemed to increase nitrate concentrations in this area. One possible explanation is that unforeseen rains in winter may cause significant water percolation reflected with high water table inside piezometers and in turn, nitrate leaching occurred even with proper irrigation management. So, proper irrigation management alone is not sufficient to reduce nitrate leaching when most rains might occur right after irrigation events. For such conditions, other treatments such as decreasing N inputs during winter as well as localized drip irrigation will be more effective in reducing N leaching. These results show that management practices used by land owners such as drip irrigation, organic and inorganic fertilizers and reduced N inputs through winter are effective means in decreasing nitrate leaching into groundwater compared with the other treatments. These results are in line with different previous studies (Myette, 1984 and Sexton *et al.* 1996). Myette (1984) showed that N concentrations in groundwater increased steadily under different irrigation regimes in intensively farmed sandy soils of central Minnesota, USA. Sexton *et al.* (1996) showed that even with the right amount of irrigation, significant nitrate leaching occurs when summer thunderstorms come soon after irrigation or fertilization.

Effects of fertilization systems:

Data were collected from monitoring piezometers located around or inside a field where different organic and inorganic fertilizers had been spread at least twice a year. Nitrate concentrations were higher in piezometers located below fields spread with fish wastes mixed with mineral fertilizers compared to fields spread with mixtures of inorganic and organic animal or poultry manures. There was no large difference in the nitrate concentration of the piezometers located below or near to fields spread with animal and poultry manures or their stockpiles. Always, nitrate concentrations were higher in piezometers located at the end of the field in the direction of ground-water flow than in piezometers located at the start of the field.

From the results of this study, it could be concluded that the application of organic N sources (other than fish wastes), such as animal or poultry manures, provide a good management to reduce N leaching in sandy soils. Manures applied can provide enough inorganic N to meet crop needs while mineralization of the organic fraction can contribute to later N demands (Sutton et al, 1985). Inorganic ammonium form of N presents another way to reduce N leaching compared to nitrate one as they are not mobile in soils; however rapid nitrification can occur in sandy soils, and thus increasing the potential for N leaching (Waddell *et al.*, 2000).

Nitrate in surface and ground water

Effects of seasonal changes:

Nitrate concentration data confirm that seasonal changes in water quality brought about by different agricultural activities can be detected in surface and ground water and that the impact depth is correlated with certain agricultural activity. Over winter, NO_3^- levels were the highest in the groundwater samples (piezometers) and in drainage water samples, indicating that rainfall plus irrigation water flushed most of the mobile NO_3^- from the root zone into shallow groundwater and drains. Peak NO_3^- concentrations were pronounced in winter beneath surface irrigation fields and in the water samples from adjacent main drains. Over summer, NO_3^- levels were the lowest in ground and drainage water samples, indicating that high evapotranspiration rate occurred and the active plant absorb most of the mobile NO_3^- from the root zone. Intermediate values were recorded for autumn and spring seasons (Fig. 3).

Over winter, the high rainfall rate and additional irrigation for this sandy soils, excess water could drain from the soil profile only in November, December, January, and February. For nitrate leaching to occur, more water must infiltrate through the soil than that lost from the soil by evapotranspiration (Smith, *et al.*, 1998). Another crucial factor controlling nitrate leaching is rainfall timing with respect to mineral-N content present in soils when drainage occurs (Williams and Kissel, 1991). Martin, *et al.* (1991) considered that water drainage is the most important factor for nitrate movement and non-point source contamination of surface waters. Among the months when water infiltrates into the soil, January presents over twice as much water as drains in May and July, and over three times compared to August. From the weather point of view, winter represents the highest risk of nitrate leaching. Water percolation is also directly affected by soil water storage capacity (Williams and Kissel, 1991) and for that reason field capacity has to be taken into account.

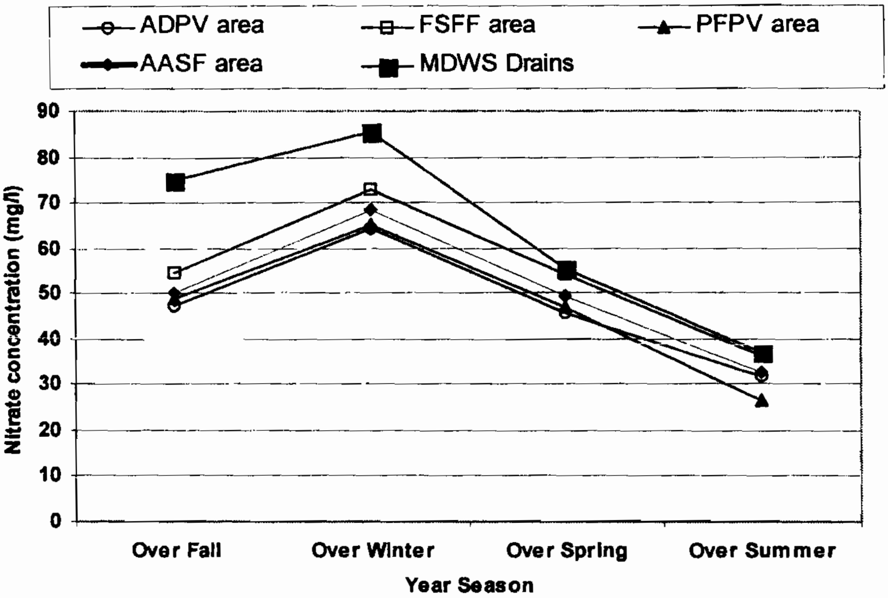

Fig. 3: **Seasonal means of surface and ground water nitrate concentrations as affected by different agricultural activities.**

The higher average of NO_3^- concentrations in winter was associated with both surface and furrow irrigation systems. This suggests that drip irrigation is vastly superior practice for controlling NO_3^- leaching. These results are in agreement with Spalding, *et al.* (2001), who stated that climatic conditions significantly affected NO_3^- concentrations in municipal wells and were significantly reduced during another very wet spring, and the higher NO_3^- concentrations were associated with furrow irrigation practice suggesting that centre-pivot irrigation is the superior for controlling water quality.

CONCLUSION AND RECOMMENDATIONS

Three conclusions may be drawn from the present data; first, nitrate concentrations in all surface and ground water samples collected from piezometers or main drains show that average nitrate concentrations were consistently high regardless of the agricultural activity implemented. Second, the agricultural activity of fish farming may represent the highest nitrogen leaching potential in sandy soils and peak NO_3^- concentrations were pronounced in winter beneath surface irrigation fields and in the water samples from adjacent main drains. Third, NO_3-N concentrations in all water sample fractions were well above the recommended level of 10 mg/l in drinking water for human, and below the recommended level of 100 mg/l in drinking water for livestock.

From the results of this study, many intensive agricultural practices had been expanded in the sandy soils of north coastal area of Nile Delta, Egypt, with great environmental risks. In particular, substantial surface and groundwater contamination had resulted from coupling of different agricultural production systems demanding large inputs and leaving large organic wastes with a physical setting that consists of coarse sandy soils and shallow groundwater. This trend resulted in a huge supply of animal manure for disposal on a limited amount of land area. Intensive, long-term application levels of manures and inorganic fertilizers to soils in these regions contributed to frequent assurance that the quantity of nutrients relative to the assimilative capacity of cropping systems had grown out of balance. Thus, the area under investigation requires fundamental changes in agricultural practices that not only lead to water contamination but also are acceptable to land owners and regulators. Worldwide, future dependence on groundwater as an important source of drinking water is the major thrust for a sustained impetus to develop and implement more effective nitrogen and agricultural management strategies to reduce surface and ground water NO^-_3 contamination.

Even when a management strategy successfully reduces nitrate leaching, land owner acceptance largely depends on yield average. A land owner will always strive to maximize yield by combining land, water, fertilizers, labor and climate to produce crops in an optimal and efficient way. Because nitrate contamination of surface and groundwater from agricultural activities is an external effect, private decision making alone will not provide a desirable outcome. So, reducing nitrate contamination in areas with intensive agricultural practices will require some kind of government intervention to align the interests of land owners (the individuals) with boarder social interests (the public). In addition, animal manure sources under investigation contained more N than P (Table 1); consequently, nutrient management plans always base application rates on trying to balance fertilizer N with that removed by a crop. This management protocol will contribute to over application of P because plants have a much lower P that N nutritional requirements. Thus, research needed to be done to evaluate the transportation of P into surface and groundwater bodies in the area under investigation.

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تأثير الأنشطة الزراعية المكثفة على تلوث المياه السطحية والجوفية بالنترات

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تعتبر القدرة على قياس ومراقبة تراكم النترات فى المياه السطحية والجوفية من مختلف الأنشطة الزراعية مفيداً للمحافظة على شروط جودة المياه. توسعت حديثاً الأنشطة الزراعية المكثفة فى الأراضي الرملية للساحل الشمالي لدلتا مصر منذ سنة ١٩٩٠م ولكن مع حدوث تلوث بيئي كبير. على الأخص تلوث المياه السطحية والجوفية الناتج عن دمج أنظمه زراعية تحتاج إلى مدخلات كبيرة من الأسمدة ومياه الري فى أراضى لها صفات طبيعية موروثة من خشونة قوام وكذلك مياه جوفية سطحية. فقد جمعت عينات مياه لاختبار النترات فيها من بيزوميترات وكذلك من المصارف الرئيسية فى خلال عام من مساحات بها أنشطة زراعية مختلفة ومكثفه. فقد دُقت البيزوميترات فى مواقع للأنشطة الزراعية المختلفة التى تشمل مناطق لكل المحاصيل التقليدية المسمدة بأسمدة معدنية وبمخلفات الدواجن وبمخلفات المزارع السمكية وسماد المزرعة.

أوضحت نتائج هذه الدراسة أن تركيز النترات فى المياه السطحية والجوفية ازدادت بثبات تحت ظروف الأراضى الرملية المزروعة بكثافة فى دلتا مصر. بالإضافة إلى ذلك دلت النتائج على وجود علاقة معنوية بين الأنشطة الزراعية المكثفة وتلوث المصادر المائية. وأحدثت كل هذه الأنشطة الزراعية المكثفة تركيزات عالية للنترات فى المياه السطحية (مياه الصرف) والجوفية. كما أدت الزراعة السمكية ومخلفات مزارعها المضافة إلى الأرض إلى زيادة فى تركيز النترات فى المياه السطحية والجوفية بالمقارنة بمختلف الأنشطة الزراعية الأخرى. كانت أعلى تركيزات للنترات موجودة فى المساحات جيدة الصرف التى تُروى باستمرار فى خلال فصل الشتاء. كما كانت تركيزات النترات فى كل عينات المياه الجوفية أعلى من المستوى الموصى به فى

مياه الشرب للإنسان (١٠ ملليجرام/لتر) ولكن كانت أقل من المستوى الموصى به فى مياه الشرب للحيوانات (١٠٠ ملليجرام/لتر). ووصلت تركيزات النترات فى كل عينات المياه المأخوذة من المصارف السطحية تقريباً إلى المستوى الموصى به فى مياه الشرب للحيوانات لتعكس بذلك الخطر العالي للتلوث البيئي فى المنطقة تحت الدراسة.