IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 13, Issue 4 Ser. I (April. 2019), PP 54-69
www.iosrjournals.org

Monitoring of Nitrogen and Phosphorus Forms in some Water Canals in Delta Region, Egypt

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Abstract: *Water pollution is one of the widest problems all over the world and has been extensively studied. One of the most widespread, costly and challenging environmental problems is nutrient pollution, which caused by leaches excess nitrogen and phosphorus to the water. The pollution intensity mainly depends on the anthropogenic activities in the studied area. So, surface water samples collected from eight different locations in middle and west delta regions (i.e., Gharbia and Beheira governorates, respectively). Water canal samples were collected monthly and different forms of nitrogen and phosphorus in these samples were determined including the dissolved ammonia nitrogen (N-NH_3), nitrite nitrogen (N-NO_2), nitrate-nitrogen (N-NO_3), total nitrogen, dissolved phosphorus and total phosphorus. The obtained results showed that there is a significant difference between the means of the collected samples from different sites and dates. The interaction between them in all studied parameters was also recorded. The concentration values of nitrate-nitrogen were higher based on the CCME limit for aquatic life and Egyptian law limits for drinking water in all samples from different locations and time. In addition, dissolved ammonia nitrogen concentration exceeded the limit of WHO for drinking water, whereas dissolved phosphorus and its total were within standard limits.*

Keywords: *Nitrogen, phosphorus, Surfacewater, Egypt.*

Date of Submission: 12-04-2019 Date of acceptance: 27-04-2019

I. Introduction

In Egypt, the river Nile is the lifeline that supplies water to tens of millions of people. Nile water sharing agreement with Sudan allocates to Egypt 55.5 billion cubic meters (BCM) per year. The second source of water in Egypt represents in the groundwater, which is located in the Western Desert and Sinai. This groundwater is characterized as a non-renewable source and the amount of annual extraction of them within the limits of 0.5 BCM per year[1,2]. On the other hand, the average rainfall is 1.5 BCM per year. However, rain falls in the winter, which is not enough for water needs. As a result of the increased population, water per capita has fallen. Egypt's status is below the level of water poverty and the country is suffering from water deficiency. Due to the water scarcity and its pollution, a major problem has been led to the use of non-conventional water resources. These non-conventional water resources include agricultural drainage water, desalinization of brackish groundwater and treated municipal waste-water [3,4].

In recent years, there has been an increasing interest in eutrophication phenomenon[5]. Phosphorus plays a key role in the eutrophication of surface waters[6], where the elevated concentration of phosphorus in canals leads not only to increase the vegetative growth of plants but also the change of the dominant plant species. This phenomenon has led to an increase in the proliferation of planktonic and epiphytic and epibenthic algae and follow-on in shading of higher plants[7]. On the other hand, many forms of nitrogen can be found in the environment of surface water[8]. These forms of nitrogen include nitrates (the most polluted form), ammonium hydroxide and nitrite, which are transformed through many chemical and biological processes[9]. Nitrogen sources vary in water from agrochemicals, human and animal wastes, landfills, sewage leaks, industrial wastes, application of waste-water for irrigation, etc. Most nitrogen is produced as nitrate from the aerobic decomposition of organic nitrogenous matter. Nitrate is one of the essential nutrients of plants, where it enters in the synthesis of proteins and nucleic acids. However, contamination of drinking water with nitrates causes many serious health problems such as blue baby syndrome. Anyway, WHO advises a maximum permissible limit of 50 mg L^{-1} for nitrate in drinking water[10]. Several studies have shown the high levels of pollution in the waters of Rosetta and Damietta branches compared to Nile waters due to a deficiency of water flow and increased human activities in this areas[11,12,13].

The current study aims to compare the levels of the pollutant of various nitrogen and phosphorus forms in two adjacent geographical regions in Delta Egypt. These sources include four canals in Gharbia, which characterized by clay soil and do not mix the water canal with agricultural drainage water. The other four canals are characterized by sandy soils and mixing water with agricultural drainage water.

II. Materials and Methods

2.3 Study Area and Sampling Sites

Water samples were monthly collected from March 2014 to February 2015. The samples collected from four sites in West (Beheira governorate) and four locations in Middle Delta regions (Gharbia governorate). Samples collected from Gharbia governorate include Mit Hebeish AlBahreyah, Nafya and Mahalat Menouf (along El-Kased canal) and also from Achenawai (from Sobtaas canal, which is a branch of El-Kased canal). Whereas, water samples collected from Beheira include Shubra Oseim, Al Tairyyah and Alqam (Along the Behery Rayah) and Markaz Badr (at Nassery Rayah, which is a branch from Behery Rayah). All details about the sampling sites and their description, as well as the latitude and longitude, are shown in Table (1) and Abdallah et. al (2019)[14].

2.4 Water Sampling and Analysis

Water samples from the surface layer were collected in polyvinyl chloride bottles and the samples immediately were transferred to the laboratory in an ice tank box. Total phosphorus (TP) and total nitrogen (TN) were estimated for non-filtered water samples. Part of the samples is filtered immediately upon arrival at the laboratory to estimate the concentration of different forms of nitrogen (i.e., ammonia nitrogen, nitrate, and nitrate) and phosphorus (i.e., total dissolved phosphorus ions and total phosphorus).

Table 1: Location of the study samples sites in West and Middle Delta regions

No.	Region	Location of the Sample site	Detailed location	Latitude (N)	Longitude (E)
1.	Gharbia	Achenawai	Achenawai, Sobtaas canal	30°48'17.83"N	31° 2'38.10"E
2.		Mit-Hebeish AlBahreyah	Farouk Bridge	30°46'28.69"N	31° 1'8.59"E
3.		Mahalat Menouf	Bridge of Sibirbay Park	30°49'10.75"N	30°59'32.50"E
4.		Nafya	Kafr Abou Dawoud Bridge	30°45'0.68"N	31° 1'27.90"E
5.	Beheira	Al Tairyyah	Al Tairyyah train station	30°37'39.83"N	30°46'52.50"E
6.		Markaz Badr	ElMhulat Bridge	30°36'12.01"N	30°42'47.62"E
7.		Shubra Oseim	entrance of Shubra Oseim Kom Hamada Road	30°42'49.28"N	30°42'52.51"E
8.		Alqam	Alqam youth center	30°32'52.47"N	30°48'31.82"E

Nitrogen-nitrate was determined using the UV-spectrophotometric screening method[15], which is based on the direct estimation of NO_3 ion by measuring the sample absorption of UV radiation at a wavelength of 220 nm (OD_{220}) after being developed with a standard hydrochloric acid 1 N to eliminate the interference by calcium carbonate. But, organic matter may absorb UV radiation at this wavelength. So, the sample absorption is measured at 270 nm (OD_{270}) and the sample absorption is corrected by the following equation,

Corrected sample absorption = sample OD_{220} - (2 × sample OD_{270})

Nitrite was appraised by the method of Gonçalves et al. (1998)[16], which depends on the react NO_2- ion directly with Safranin in acidic media and measured the resulting color at 610 nm. By taking 5 mL of the sample and add 0.25 mL sulfuric acid 6 N and 0.5 ml Safranin 0.001 M. Ammonia was assessed by salicylate method[17], which is based on the Berthelot reaction and measured at 660 nm wavelength spectrophotometrically. The total nitrogen (TN) determination depends on the digestion of the sample in acidic media (sulfuric acid) in the presence of a strong oxidizing agent (Hydrogen peroxide H_2O_2) and some catalysts to convert all the organic and inorganic nitrogen into an ammonium sulfate $(NH_4)_2SO_4$ so the samples were digested by the micro-Kjeldahl method.

The concentration of phosphate ions (PO_4^{3-}) in water samples was measured using the ascorbic acid method[18]. The estimate of total phosphates is based on the digestion of the sample in a strongly acidic medium to convert all organic and inorganic phosphorus into orthophosphate. 200 ml samples were concentrated to 20 ml (by evaporating) and digested using sulfuric acid (5ml + 1ml nitric acid). The samples were heated until near the sample dryness and the product was dissolved in a 1N Nitric acid. The total phosphorus was then determined by the above-mentioned ascorbic acid method. All chemical used for chemical analysis were laboratory analytical grad, and distilled water was redistilled water Obtained from the Central Laboratory Tanta University. All canal water samples were evaluated as indicators of water quality (Table 2).

2.5 Statistical analysis

Microsoft Excel 2010 was used to calculate the range, mean and standard deviation for all sampling sites and sampling dates. Program of SASS (version 9.2) was also used for statistical analysis of the results obtained using analysis of one-way ANOVA analysis ($p < 0.05$). Detection of differences among the means for locations and dates significantly was done by Duncan's multiple range tests.

Table 2: Water studied parameters and their Guidelines used in comparison

Parameter	Drinking water		Irrigation	Aquatic life
	EMH (2007)[19]	WHO (2011)[20]	(FAO 1994)[21]	(CCME 2007)[22]
NH_3-N (mg 1^{-1})	0.45	0.2	5	1.37
NO_2-N (mg 1^{-1})	0.005	0.9		0.06
NO_3-N (mg 1^{-1})	10	11	10	2.93
TDP PO_4-P (mg 1^{-1})			2	
TP (mg 1^{-1})	1	-	-	-

TP: total phosphorus TDP: total dissolved phosphorus
CCME: Canadian Council of Ministers of the Environment
EMH: Egyptian Ministry of Health

III. Results

3.1 Nitrogen contents

The nitrogen content in the collected water samples was estimated by ascertainment the ammonia nitrogen (NH_3^+) nitrite (NO_2^-), nitrate (NO_3^-) ions and the total nitrogen (TN). Results were recorded in Table (3a) and proved in Fig. (1, 2, 3 and 4). The results obtained showed that in all studied parameters there were significant differences among the means of sample collection sites and their dates as well as the interaction between studied variables.

3.1.1 Ammonia-nitrogen (NH_3-N)

The values of N-NH_3 at all locations and all times exceeded the maximum WHO limits[20] of NH_3-N content for drinking water (0.2 mg N L^{-1}) except the February sample of Al Tairyyah (0.193 mg L^{-1}). All samples also exceeded the maximum limit of Egyptian Environmental Protection Law[19] for drinking water (0.45 mg L^{-1}) except for the following samples: Alqam (February, January and December); Al-Tairyyah/ (December, February and July); Markaz Badr/(January and December); Shubra Oseim/ (February, January, November and August); Mahalat Menouf/December and Nafya/ (December, October and April). While most of the samples did not exceed the limits set for the concentration of NH_3-N by the CCME[22] (1.37 mg L^{-1}) except for the following samples: Markaz Badr/(September and August); Shubra Oseim/ September; Mahalat Menouf/September; Achenawai/August and Nafya/August. While there is no sample exceeded the limits established by the FAO for the irrigation water content of N-NH_3 (5 mg L^{-1}). There was a difference in the values of NH_3 content with ranging values from 0.193 to 1.848 mg L^{-1}. August's month had the highest of N-NH_3 content (1.082 mg L^{-1}), while the lowest values were recorded in December (0.337 mg L^{-1}). Achenawai site recorded the highest N-NH_3 content (0.921 mg L^{-1}), while Al-Tairyyah site recorded the lowest value of the NH_3 content (0.551 mg L^{-1}). The annual average of N-NH_3 content in Gharbia governorate was higher than that of Beheira governorate, where they scored 0.712, 0.632 mg L^{-1}, respectively (Fig 1).

3.1.2 Nitrite (NO_2-N)

The values of NO_2 content exceeded the maximum concentration limits of NO_2 specified by CCME[22] (0.006 mg NO_2-N L^{-1}) as well as that set by Egyptian law[19] (0.005 mg L^{-1}) for drinking water. Whereas, the NO_2 content values ranged between 0.017 and 0.415 mg L^{-1}. There was a discrepancy among the values recorded for NO_2 Conc. The highest NO_2 conc. values recorded in July (0.302 mg L^{-1}) while the lowest value recorded in January (0.080 mg L^{-1}). The sample collection site at Mit Hebeish AlBahreyah recorded the highest NO_2 content (0.202 mg L^{-1}), while Al Tairyyah site recorded the lowest NO_2 content (0.133 mg L^{-1}). From the annual average, NO_2 content in Gharbia was higher than in Beheira governorate, (0.178 and 0.168 mg NO_2-N L^{-1}, respectively), (Fig. 2).

3.1.3 Nitrate (NO_3-N)

All sample values were lower than those set by the Egyptian law[19]and WHO[20] for drinking water, as well as the limits for irrigation water by FAO or the boundaries of CCME[22]. There were distinctions in NO_3 concentration values, where these values ranged between 0.057 and 0.609 mg NO_3-N L^{-1}. The maximum NO_3 content recorded in July (0.431 mg L^{-1}), while the lowest value recorded in February (0.100 mg L^{-1}). The highest NO_3 content recorded at the Mahalat Menouf site (0.261 mg L^{-1}) while the lowest nitrate value was recorded at Alqam (0.222 mg L^{-1}). The average of the two governorates was very close (with 0.249 and 0.225 mg L^{-1}, for Gharbia and Beheira governorate, respectively), (Fig. 3).

3.1.4 Total nitrogen (TN)

There is no legal limit for the concentration of the total nitrogen (TN) in water. The TN is the sum of all nitrogen forms (nitrous nitrogen, nitrite, nitrate and organic or bio-nitrogen). There were variances in the values of TN concentration where the values ranged between 1.23 and 12.8 mg N L^{-1}. The highest values of TN concentration were recorded in September (9.12 mg L^{-1}), whereas the lowest values were recorded in December (2.58 mg L^{-1}). Achenawai site recorded the highest concentration of TN (7.44 mg L^{-1}), while Al-Tairyyah site recorded the lowest value (5.26 mg L^{-1}). From the annual average, the TN concentrations for Gharbia governorate were higher than the average values of Beheira governorate (6.11 and 5.64 mg L^{-1}, respectively), (Fig. 4).

3.2. Phosphorus content

The Phosphorus content in the collected water samples was estimated by ascertainment the total dissolved phosphorus (TDP) ions and total phosphorus (TP). Results were recorded in Table (3b) and proved in Figures (5 and 6). The results obtained show that in all studied parameters there were significant differences among the means of sample collection sites and dates as well as the interaction between studied variables.

3.2.1 The total dissolved phosphorus (TDP)

The value of any samples did not exceed the maximum TDP content determined by FAO[21] (2000 μg P L^{-1}). There was a significant variation in the values of TDP content where values ranged between 1.897 and 33.404 μg L^{-1}. The maximum values of TDP content were recorded in September (9.12 μg L^{-1}), while the lowest values were recorded in December and January (4.767 and 5.326 μg L^{-1}, respectively). Achenawai site recorded the highest value of TDP content (14.14 μg L^{-1}), while Al Tairyyah site had the lowest value (6.00 μg L^{-1}). The annual average value of Gharbia governorate was higher than that of Beheira governorate (11.50 and 7.21 μg L^{-1} respectively), (Fig. 5).

3.2.2 Total phosphorus (TP)

The value of any samples did not exceed the maximum TP content determined by Egyptian law[19] (1000 μg P L^{-1}) for drinking water. There was a significant variation in the values of TP content where the values ranged between 12.87 and 259.05 μg P L^{-1}. The maximum values of TDP content were recorded in September (174.21 μg L^{-1}), while the lowest values were recorded in January (55.64 μg L^{-1}). The highest content of the TDP was recorded in Achenawai sample site (169.86 μg L^{-1}). While Al-Tairyyah sample site recorded the lowest value (82.81p μg L^{-1}). The annual average values of TP content in Gharbia governorate were higher than that in Beheira governorate (129.99 and 106.01 μg L^{-1}, respectively), (Fig. 6).

IV. Discussion

From the previous data, it could infer that all forms of nitrogen increase in hot months (August, July, July and August) and decrease at the winter months (December, January, February, and December) for NH_3-N, NO_2-N, NO_3-N, and N, respectively). The same trend could observe in the case of phosphate, where the maximum values recorded in August while the minimum values recorded in December and January for TDP and TP, respectively. With taking into consideration all forms of nitrogen and phosphorus, the contaminations of nitrogen and phosphorus increased in June, July, and August and decline in December and January (Fig. 7).

The obtained results confirmed those ofRadwan (2005)[23]for Nile river and some drains; Mohamed (2005)[24]for Abu Za'baal ponds; Ali (2008)[25] for lake Manzala and Ali et. al (2014)[26] for the Nile river near Mansoura city. In contrast,ElBouraieet. al (2011)[27] observed increasing of ammonia concentration from El-Rahawy and Al-Moheet drains, especially during winter. It could observe that in all studied sites had the following order for the concentration of inorganic nitrogen forms NH_4> NO_3> NO_2 (Fig. 9). Four basic biological processes control the concentration of nitrogen forms and the ratio between them: (1) nitrogen-fixation is a process which converts atmospheric nitrogen to ammonia (NH_3) or one of the affined nitrogen compounds. (2) Ammonification is a one-way chemical reaction that microorganisms mineralize amino acids and yields ammonia (NH_3). (3) Nitrification is an operation that ammonia (NH_3) oxidized to nitrite (NO_2) and nitrate (NO_3). It involves two groups of micro-organisms Nitrosomonas, which oxidizes NH_3 to NO_2 and water, and subsequently, Nitrobacter oxidizes the NO_2 ions to NO_3. (4) Denitrification is the process where nitrate reduced and ultimately produces molecular nitrogen (N_2). Facultative anaerobic bacteria accomplish denitrification as respiration that reduces oxidized forms of nitrogen to oxidize the organic matter in an anoxic environment.

The process carries out mainly by heterotrophic bacteria such as *Paracoccus denitrificans* and varied pseudomonads[9]. The balance between these processes depends on the amount of dissolved oxygen in the water and temperature. The amount of dissolved oxygen (DO) depends on the water temperature, salinity, and pressure. Gas solubility increases with decreasing temperature. Thus, the amount of oxygen absorbed in water decreases as temperature increases[9]. So, many researchers stated that the ammonia concentration increases during the hot period over cold seasons in oxic conditions[28,29,30]. They related the relative decrease in the ammonia concentration during cold seasons to the oxidation of the ammonia by oxygen-rich rather than consumption of ammonia by the phytoplankton organism. The nutrient content in the soil varies according to the agricultural season. This nutrient is characterized by a lack of water and fertilizer used in winter, whereas, in summer, agrochemicals increasingly used (fertilizers and pesticides) and the amount of water consumed also increases. The addition of fertilizer causes a gradual increase in this nutrient concentration in the soil. Water carries nutrient to surface water systems through (1) overland flow, (2) unsaturated flow, and (3) groundwater flow. Overland flow is the most direct path for water transportation, whereas underground flow is less direct because water flux obstructed by porosity constraints and soil permeability[23]. This explains the increase in nutrient (N and P) concentration in the summer months compared to the winter ones. Also, in high temperature, the increased nitrogen-fixing activity and the addition of fertilizer causes the growth of phytoplankton and the increase in photosynthesis. The phytoplankton is the main supplier to organic matter in the watercourse[32]. Increase temperatures also increase the organic matter decomposition[33], which increase the NH_3 content.

The percent of total inorganic nitrogen forms to total nitrogen ranged between 18.28 and 18.68 % (Fig. 9). On the other hand, the percent of total dissolved phosphor to total phosphorus had a wide range of 5.73 to 10.88%. Where, it ranged from 5.73 to 8.04 and 6:89 to 10.88 for Beheira and Gharbia, respectively. The average of Gharbia (8.89) was higher than Beheira (6.84%). Also, Shubhra Oseim is characterized by a high value (8.04) similar to the values of Gharbia sites (Fig. 11). So, the main source of pollution is an organic source. This may be because of agricultural and industrial activities, which discharge enormous quantities of untreated urban municipal, industrial wastewater and rural domestic wastes into the canals or agricultural drains. Although the level of pollution in Beheira is less than that in Gharbia, the proportion of inorganic[34] phosphorus is less in Beheira meaning that Beheira had more organic pollutants.

On the other hand, the most contaminated site with NH_3-N, TN, TDP, and TP was Achenawai, while Mit Hebeish contains the maximum value of NO_2-N, while the highest NO_3-N concentrations were recorded in Mahalat Menouf. Furthermore, the Al-Tairyyah was the lowest polluted sites by NH_3-N, NO_2-N, TN, TDP, and TP. While Alqam were the lowest contaminated sites with NO_3-N. The most contaminated site with N was Achenawai and Markaz Badr, while Mit Hebeish AlBahreyah and Al-Tairyyah were the lowest contaminated sites in Gharbia and Beheira, respectively. The most contaminated site with P was Achenawai and Shubra Oseim, whereas Tairyyah and Mahalat Menouf were less contaminated sites in Gharbia and Beheira, respectively. But, for all forms of both N and P, it found that the most polluted sites were Achenawai and Shubra Oseim, while Tairyyah and Mahalat Menouf the lowest contaminated sites in Gharbia and Beheira respectively (Fig. 8). The values of all thoughtful parameters in Gharbia sites surpassed those in the Beheira sites. Thus, Gharbia sites are considered to be more polluted with phosphate and nitrogen than those in studied Beheira sites. As we clarified in our previous study[14], there are many environmental and geographical differences between the two studied regions. The two regions differ in crop system; soil texture (sand and clay soil); irrigation system (drip and flooding irrigation) for Beheira and Gharbia, respectively. Except for Shubra Oseim, which approximate the regions of the Gharbia in all characteristics, with open drains for both regions.

Soil texture is one of the most important factors influencing overland and groundwater flow because water flows obstructed by porosity constraints and soil permeability[23]. This affects the leaches of nutrients into different watercourses. Sandy soil also is characterized by low water and cation/anion holding capacity, increasing the chance of nutrient leaches[35]. There are many other factors that affect the rate and the total amount of leached ions like, soil nutrient exchange capacity; ion adsorption; the total irrigated water and fertilizer rate and its form and solubility[36].

Both regions had the same source of water (Rosetta branch), where over 3×10^6 m^3 daily of untreated or partly treated municipal, industrial wastes and agricultural drainage water discharge on it[38]. It could be noticed that both regions suffer from low water quality. Not only Beheira regions receive agricultural drainage water from many drains (i.e., El-Umoum, El-Nasr-3, El-Rahawy, Tharwat, Zarkon Abu-Almatamir, and Edko drains) but also in order to satisfy its water needs[38]. As a result, Beheira canals supposed to be more polluted than the Gharbia canals. However, according to the various measurements, Gharbia was more polluted by phosphate and nitrogen. This may be due to the application of drip irrigation in Beheira regions. Drip irrigation system reduces overland flow and may stop it completely, whereas surface irrigation increases the runoff and the leaches of nutrients into watercourses. This confirms the proposition, that Shubra Oseim site, which uses surface irrigation, is the most polluted site with phosphorus and nitrogen. The same manner could be observed when the water quality in the selected region is studied. Concerning Gharbia region, it was recorded higher values of COD, UV_{254} and chloride ion (Cl^-) content higher than those recorded in the Beheira[14]. Shubra Oseim was the most polluted site in Beheira.

On the other hand, the ratio of TDP to TP as a percent is low in Beheira sites compared to Gharbia, which indicates organic pollution, whereas Beheira regions suffer from the lack of sanitation in most of its districts. So, untreated sewage wastes discharged into drains and canals (in officially or unofficially manner). Therefore, Markaz Badr is the most contaminated site with nitrogen and phosphorus. The most polluted site was Achenawai in all studied sites, due to the discharge of industrial waste, in addition to the problems of sanitation and leaches of nutrients into the different watercourses, which mentioned earlier.

V. Conclusion

It could be concluded that there is an urgent need to address the safety problems caused by water pollution. This kind of pollution is a growing public health concern worldwide. This pollution can be extremely harmful to human beings and other living things. This study has been conducted to monitor the possible effects of water pollution. It is found from this study that both studied regions (Gharbia and Beheira) suffer from high concentrations of nitrogen pollutants including organic and inorganic, especially ammonia (NH_3). The recorded values exceeded the limits allowed by the WHO. On the other hand, the contamination levels of phosphorus compounds within the limits allowed. However, it is observed that the percent of the organic component in nitrogen and phosphorus pollutants is high. Results from earlier studies demonstrate a strong and consistent association between anthropogenic activities and this pollution. It is noteworthy that the level of total pollution in Beheira regions is low compared to the regions of Gharbia. This is due to using drip irrigation systems in Beheira regions. However, the level of organic pollution in the regions of Beheira is higher than the counterpart in Gharbia. That is may be due to the problems related to sanitation. Therefore, the study proposes to amend the irrigation system in Gharbia governorate to modern irrigation methods less polluting to the environment with attention to the problems of sewage treatment. To date, the monitoring of water pollution has not still been comprehensively investigated in Egypt and further studies are needed.

Table (3a): The annual average (mg L^{-1} ± S.E) of nitrogen contents at investigated sits in the west and middle delta regions

Location	NH_3-N(mg L^{-1})	NO_2-N (mg L^{-1})	NO_3-N (mg L^{-1})	Total N (mg L^{-1})
Alqam	0.6 ± 0.06 e	0.19 ± 0.03 b	0.22 ± 0.04 d	5.44 ± 0.5 de
Al Tairyyah	0.55 ± 0.06 f	0.2 ± 0.04 a	0.23 ± 0.04 cd	5.26 ± 0.66 e
Markaz Badr	0.75 ± 0.13 b	0.16 ± 0.03 d	0.25 ± 0.04 ab	6.29 ± 0.96 b
Shubra Oseim	0.64 ± 0.12 d	0.2 ± 0.04 ab	0.2 ± 0.03 e	5.57 ± 0.81 d
Mahalat Menouf	0.69 ± 0.1 c	0.17 ± 0.04 d	0.26 ± 0.04 a	6.01 ± 0.67 c
Achenawai	0.92 ± 0.11 a	0.2 ± 0.04 ab	0.24 ± 0.04 bc	7.44 ± 0.87 a
Mit Hebeish AlBahreyah	0.64 ± 0.06 e	0.13 ± 0.03 e	0.24 ± 0.03 b	5.49 ± 0.43 e
Nafya	0.6 ± 0.1 e	0.18 ± 0.03 c	0.25 ± 0.04 ab	5.48 ± 0.68 de
Beheira	0.63 ± 0.03	0.19 ± 0.01	0.23 ± 0.01	5.64 ± 0.16
Gharbia	0.71 ± 0.02	0.17 ± 0.01	0.25 ± 0.01	6.11 ± 0.13

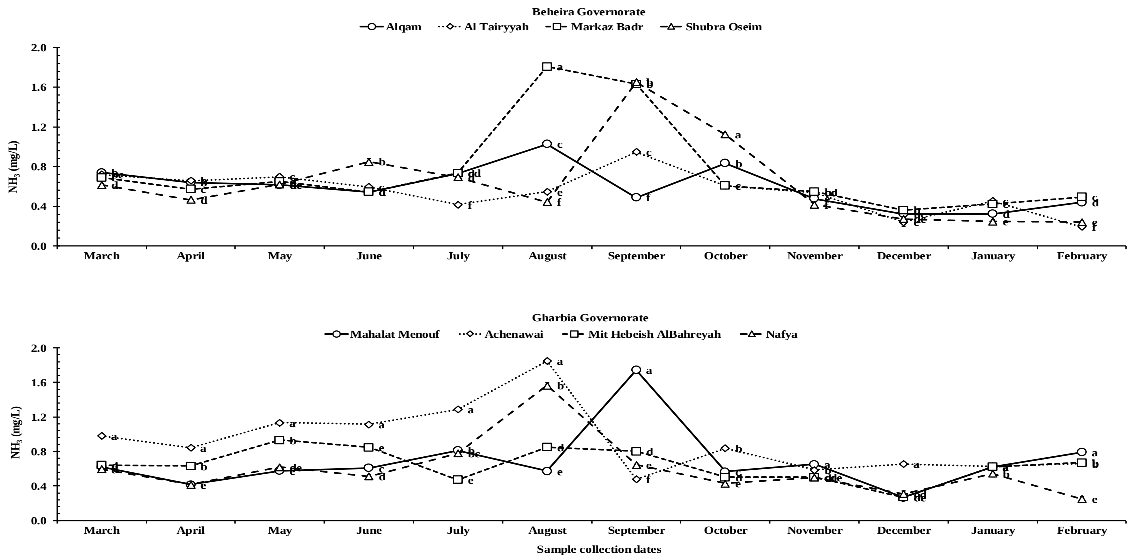
S.E: Standard error. Means followed by the same letter (s) are not significantly different (P= 0.95 level).

Table (3b): The annual average (mg l-l ± S.E) of phosphorus contents at investigated sits in the west and middle delta regions

Location	Total dissolved phosphorus (µg L^{-1})	Total phosphorus (µg L^{-1})
Alqam	6.85 ± 1.14 f	119.52 ± 8.71 b
Al Tairyyah	6.01 ± 0.75 g	82.81 ± 11.71 e
Markaz Badr	6.92 ± 1.07 f	109.15 ± 9.47 d
Shubra Oseim	9.05 ± 0.87 d	112.56±12.08 cd
Mahalat Menouf	7.84 ± 1.14 e	113.77 ± 14.93 cd
Achenawai	14.14 ± 2.08 a	169.86 ± 15.77 a
Mit Hebeish AlBahreyah	11.37 ± 1.88 c	120.21 ± 10.36 b
Nafya	12.64 ± 2.60 b	116.14 ± 13.95 bc
Beheira	7.21 ± 0.11	106.01 ± 1.48
Gharbia	11.50 ± 0.29	129.99 ± 1.52

S.E: Standard error. Means followed by the same letter (s) are not significantly different (P= 0.95 level)

A



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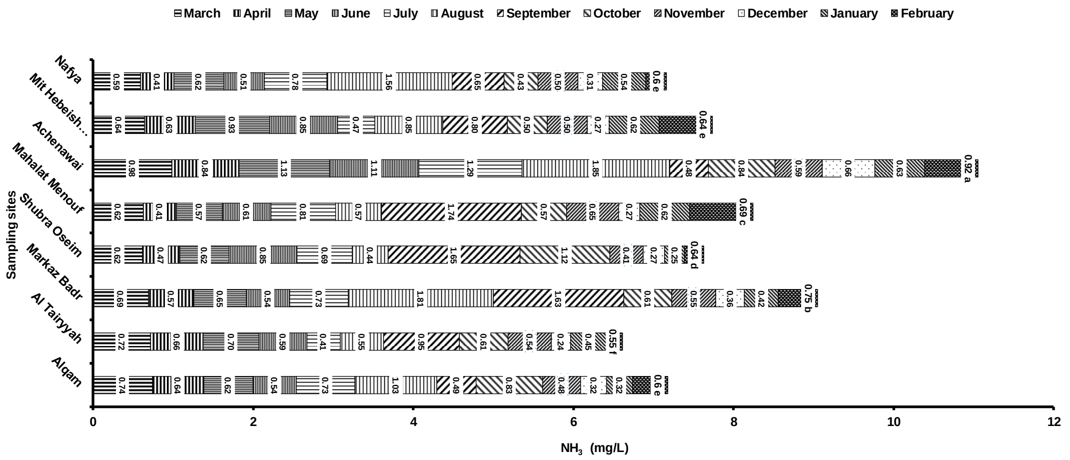

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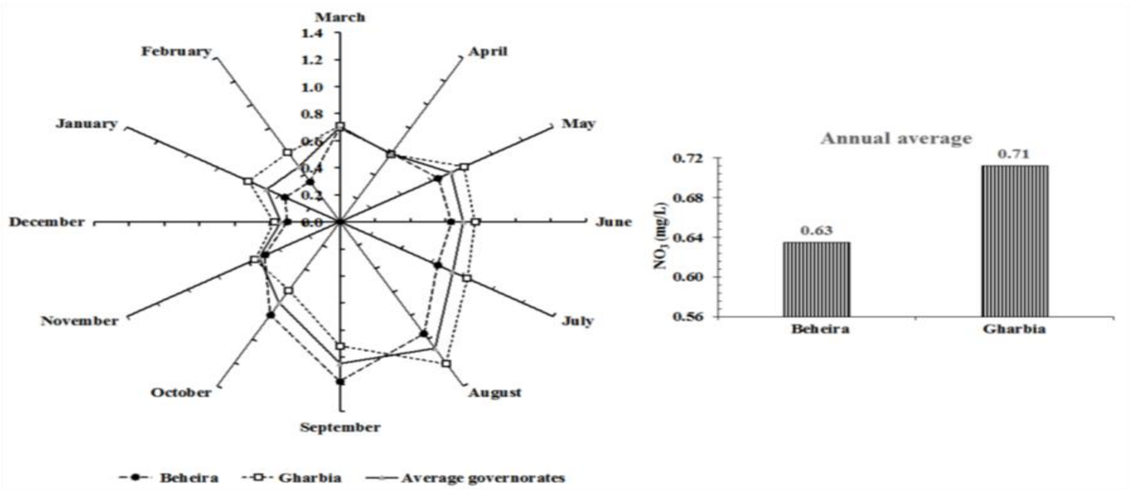


Fig. (1): Ammonia nitrogen N-NH_3 (mg L^{-1}) at investigated sites in the west and middle delta regions (A: Site monthly average; B: site average and the cumulative value of water parameter and C: region monthly averages and the annual averages)

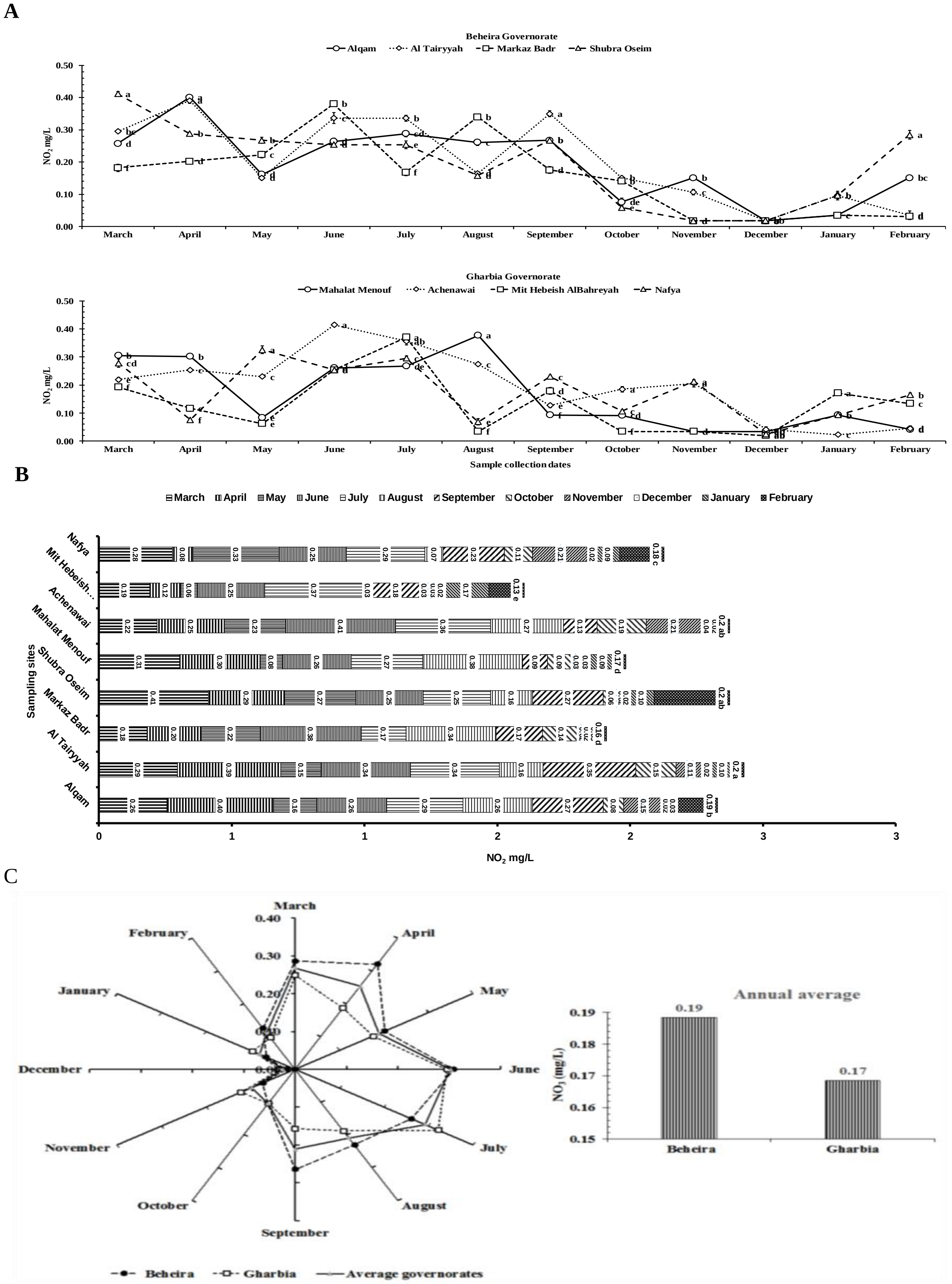


Fig. (2): Nitrites NO_2-N (mg L^{-1}) at investigated sites in the west and middle delta regions (A: Site monthly average; B: site average and the cumulative value of water parameter and C: region monthly averages and the annual averages).

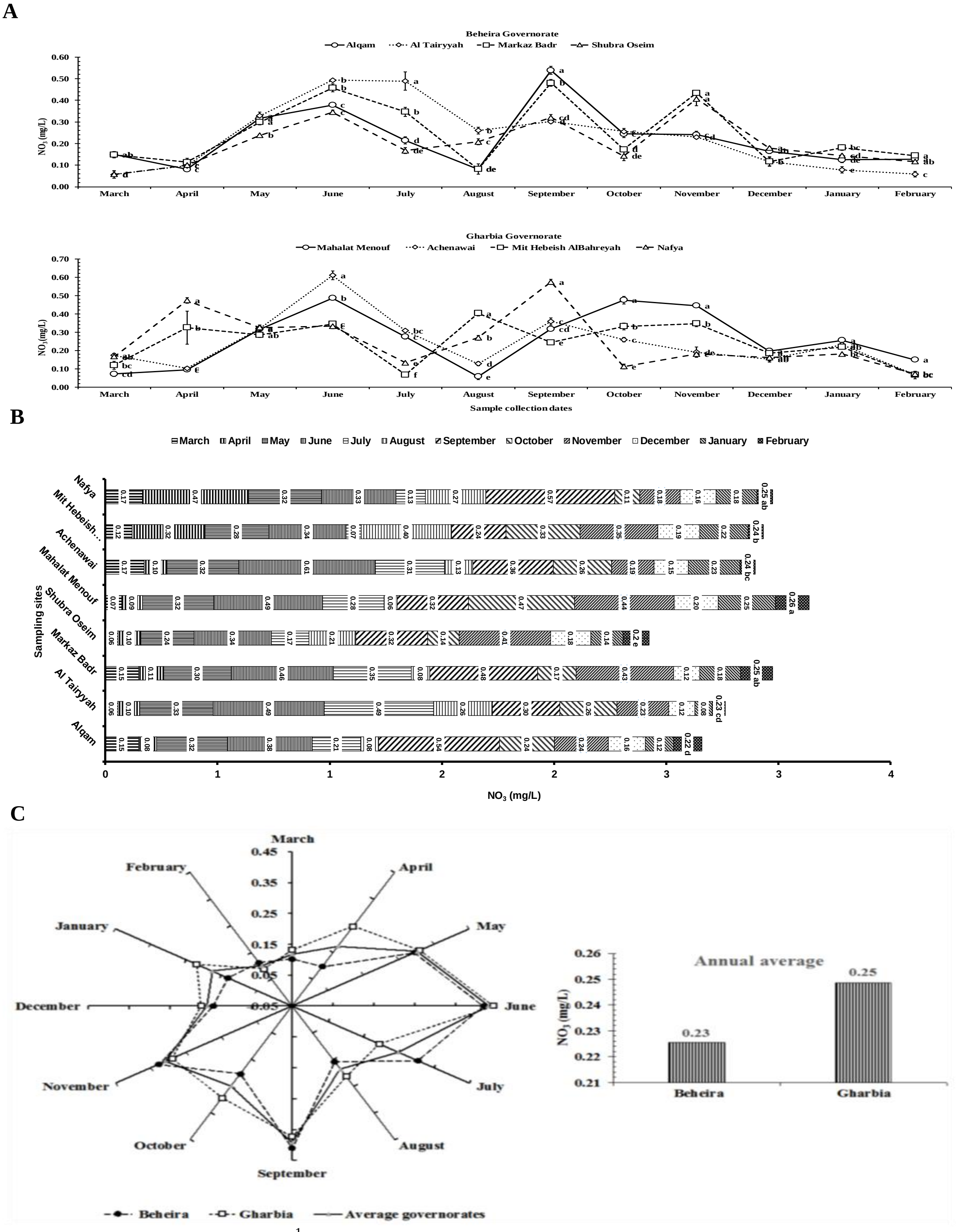
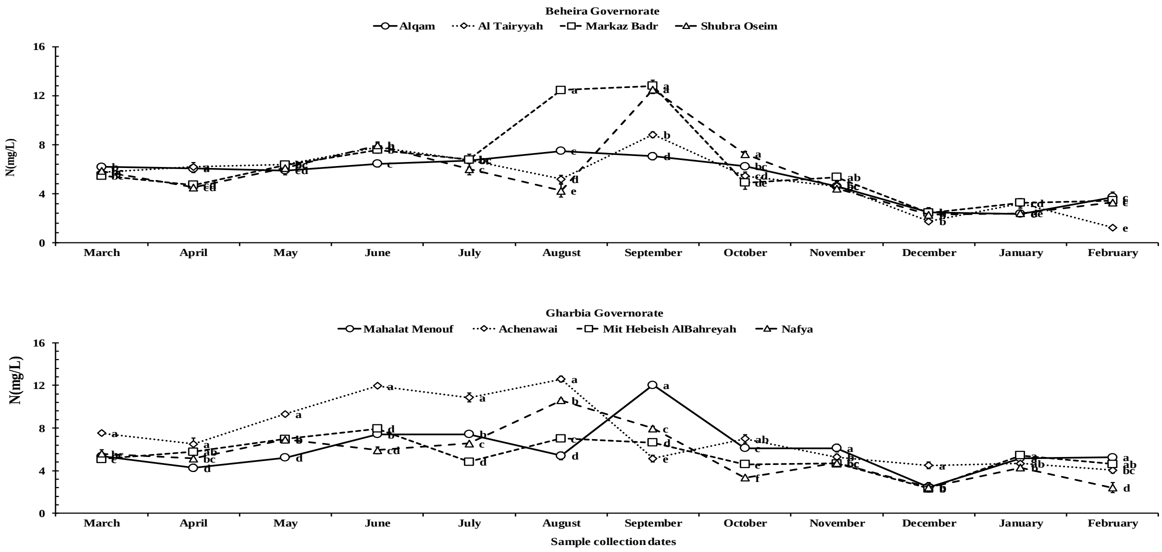
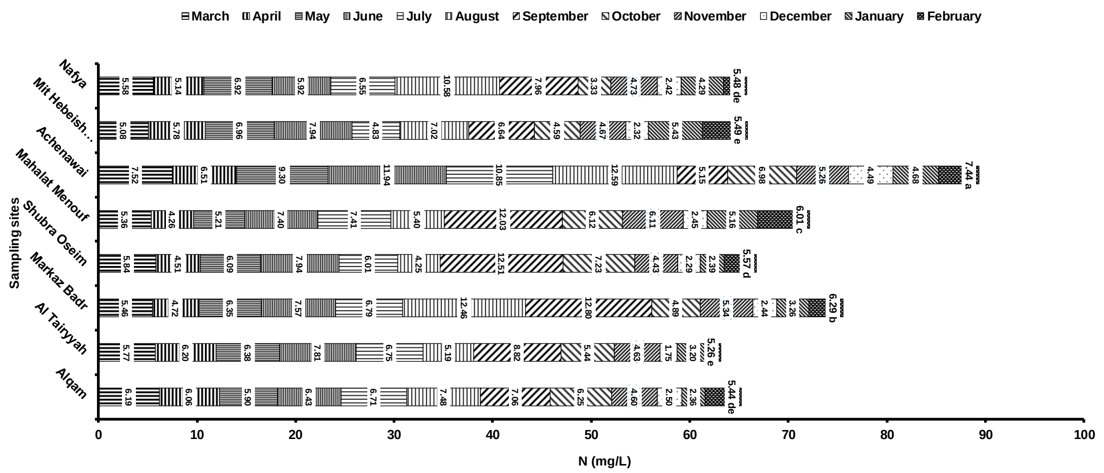


Fig. (3): Nitrate (NO_3-N) (mg L^{-1}) at investigated sites in the west and middle delta regions (a: Site monthly average; b: site average and the cumulative value of water parameter and c: region monthly averages and the annual averages).

A



B



C

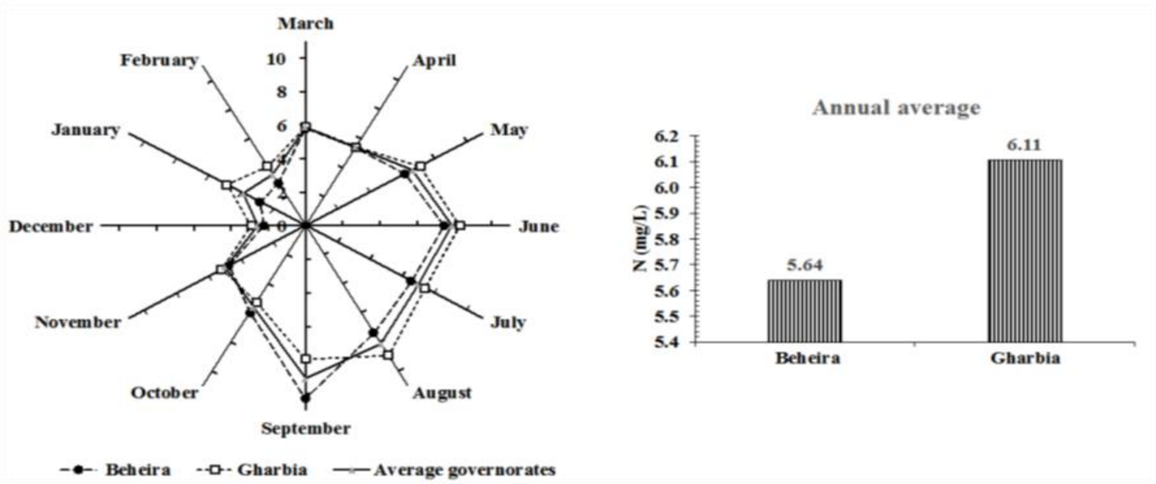


Fig. (4): Total nitrogen TN (mg L^{-1}) at investigated sites in the west and middle delta regions (a: Site monthly average; b: site average and the cumulative value of water parameter and c: region monthly averages and the annual averages).

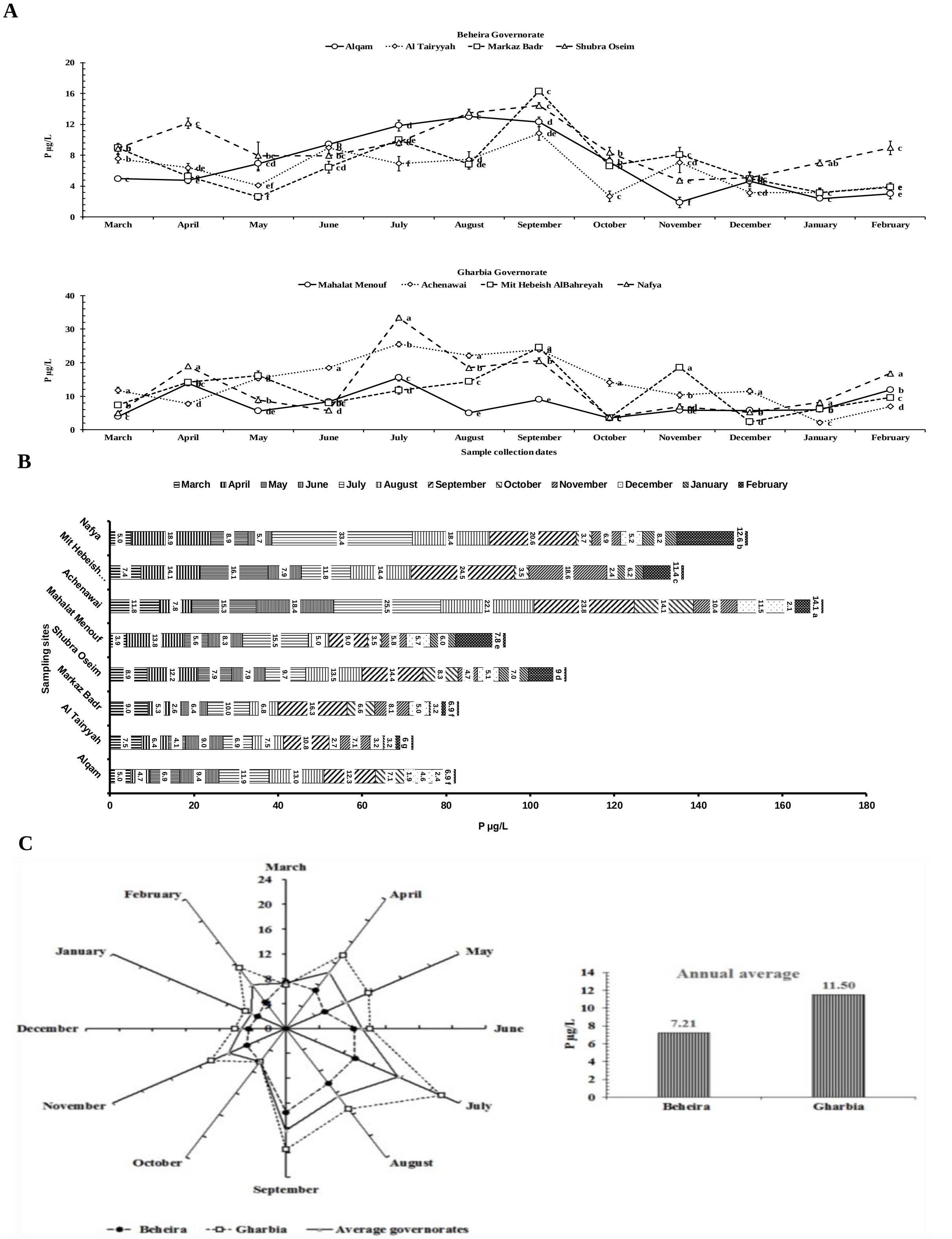
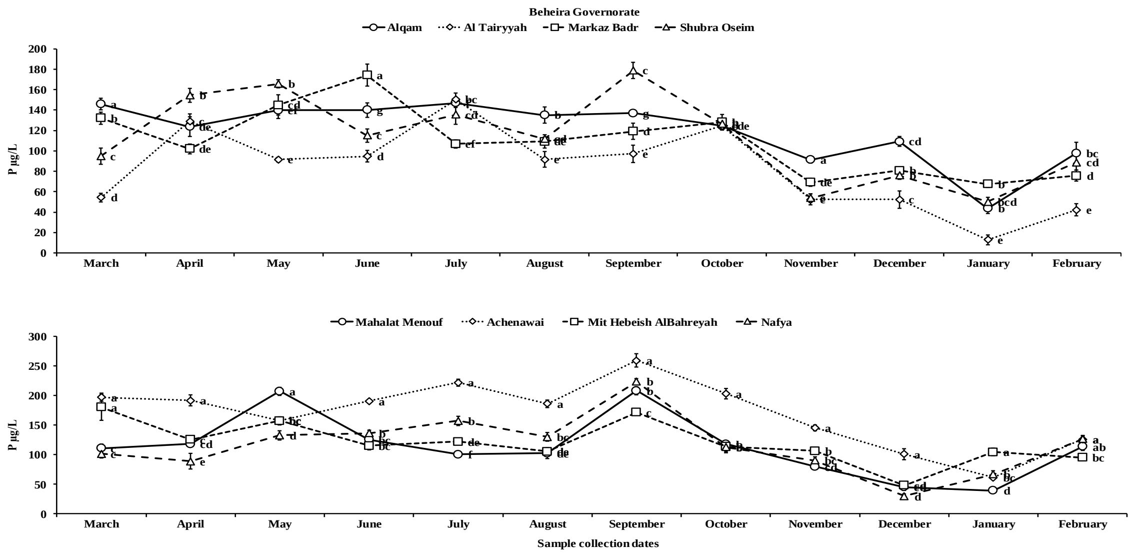
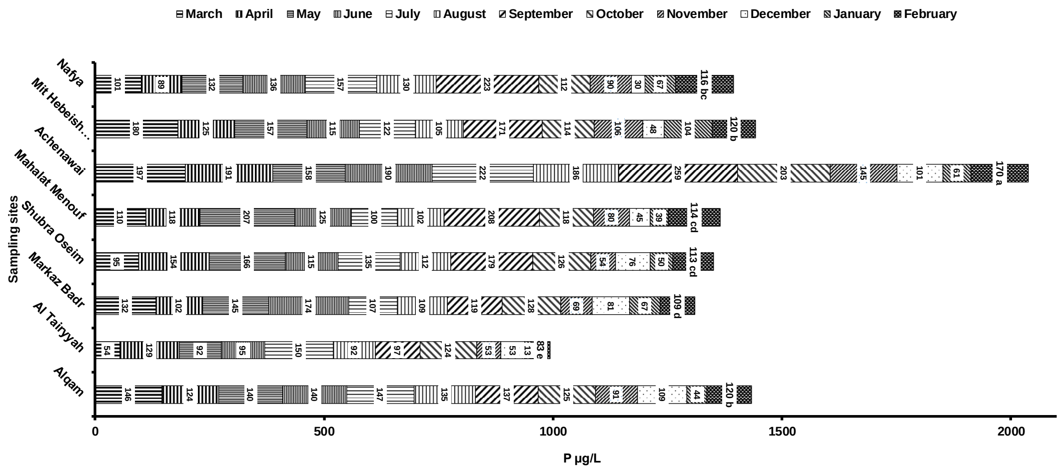


Fig. (5): Total dissolved phosphorus TDP (µg L^{-1}) at investigated sites in the west and middle delta regions (A: Site monthly average; B: site average and the cumulative value of water parameter and C: region monthly averages and the annual averages).

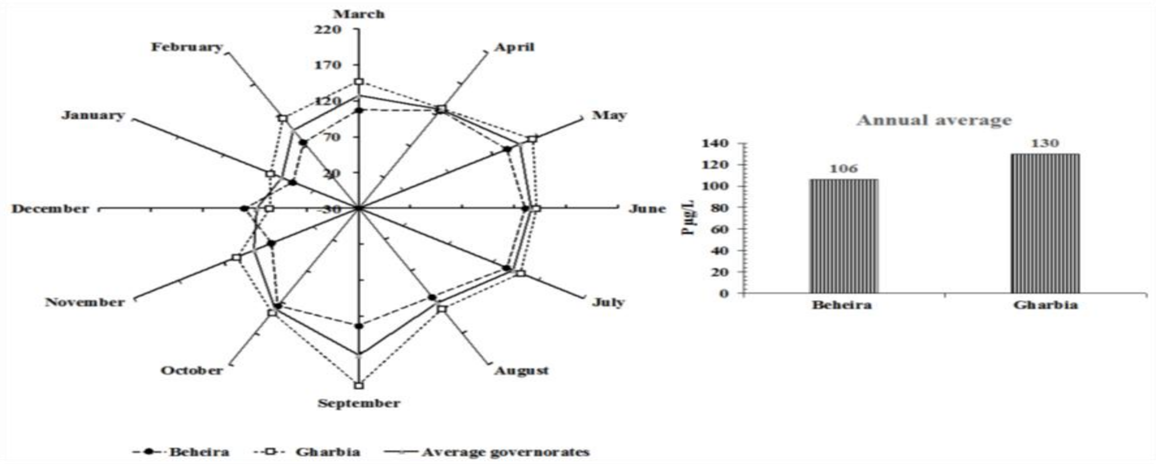
A


Beheira Governorate
Alqam
Al Tairyyah
Markaz Badr
Shubra Oseim
P µg/L
Mahalat Menouf
Achenawai
Mit Hebeish AlBahreyah
Nafya
P µg/L
March
April
May
June
July
August
September
October
November
December
January
February
Sample collection dates

B


March April May June July August September October November December January February
Nafya
Mit Hebeish...
Achenawai
Mahalat Menouf
Shubra Oseim
Markaz Badr
Al Tairyyah
Alqam
Sampling sites
P µg/L

C


March
April
May
June
July
August
September
October
November
December
January
February
Beheira
Gharbia
Average governorates
Annual average
106
130
P µg/L
Beheira
Gharbia

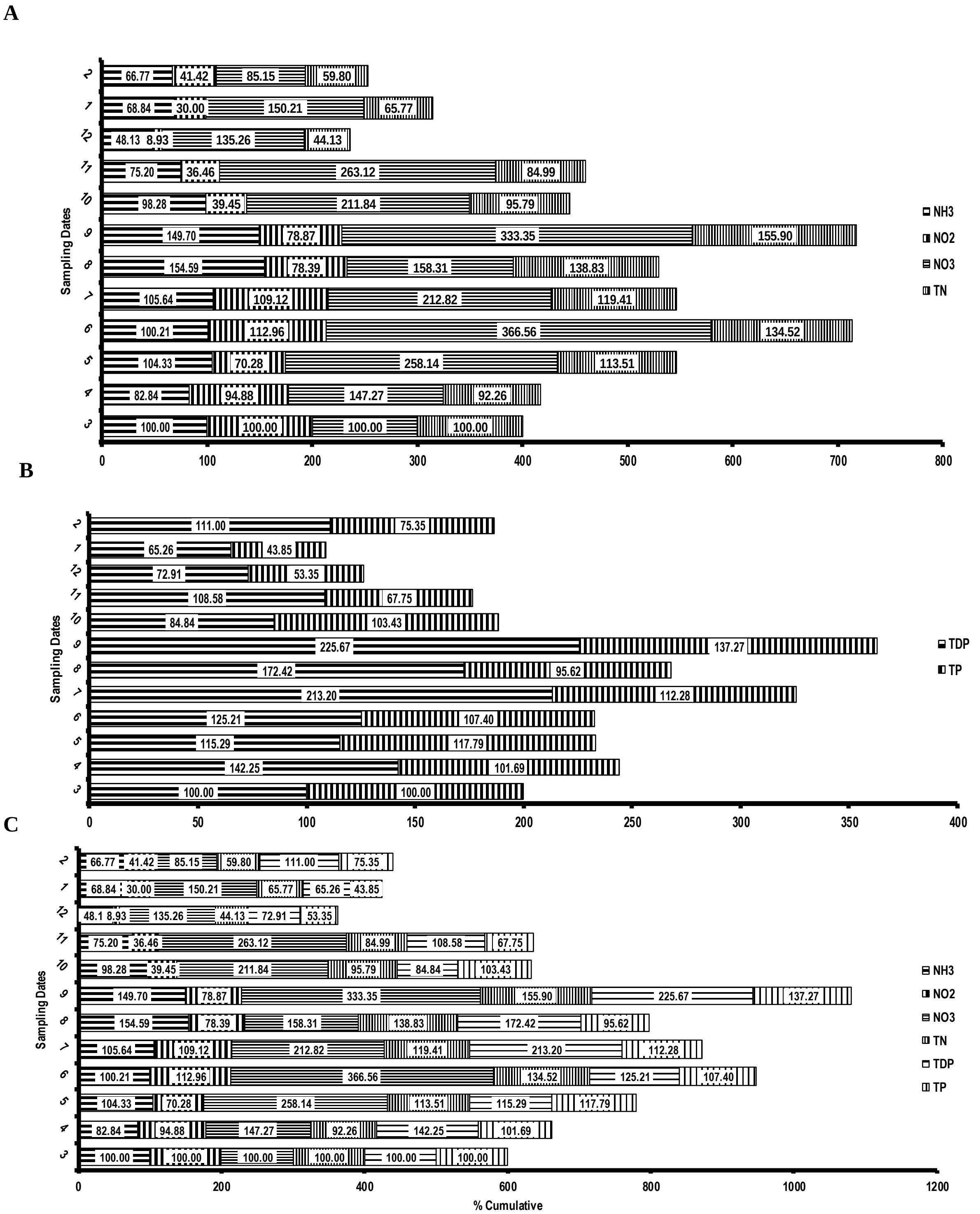


Fig. (7): Cumulative percentage of N and P contents at the specific sampling dates in the west and middle delta regions (A: N contents only; B: P contents only C: N+P contents).

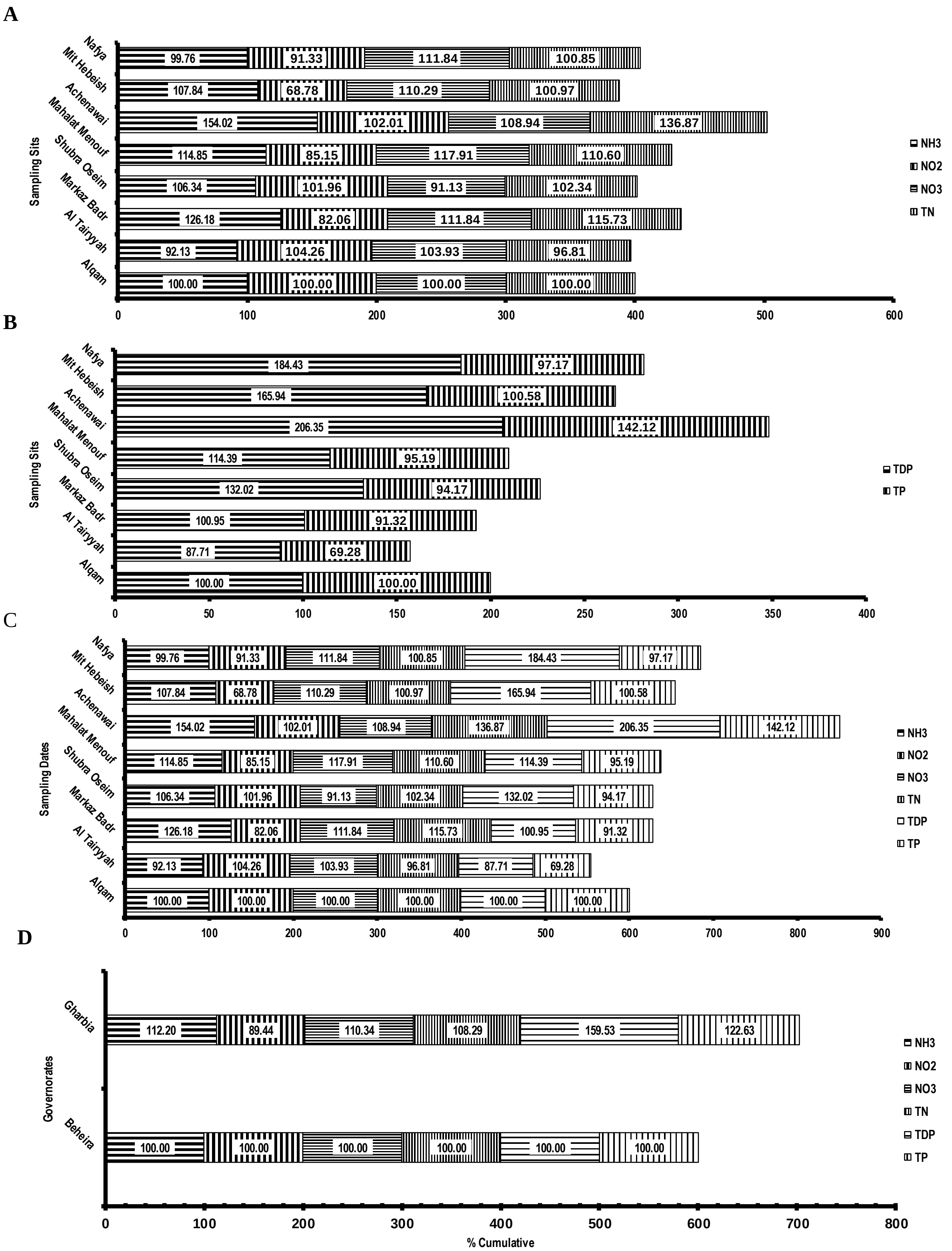


Fig. (8): Cumulative percentage of N and P contents at investigated sites in the west and middle delta regions (A: N only; B: P only; C: N+P and D: governorate annual averages)

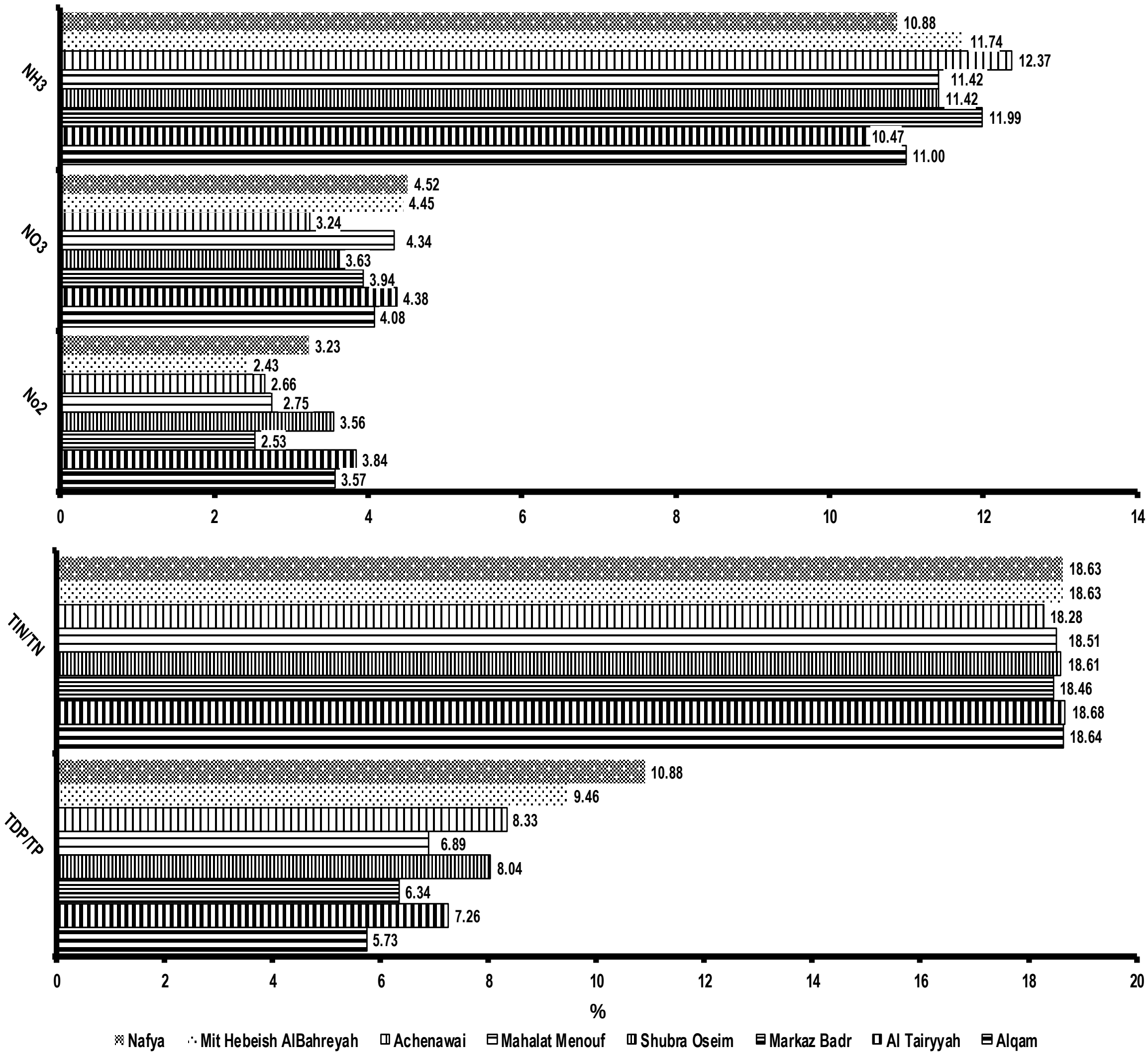


Fig. (9): The percentage of various forms of dissolved nitrogen to total nitrogen and the percentage of total dissolved nitrogen (TIN) to total nitrogen (TN) and also, dissolved phosphorus (TDP) to total phosphorus (TP). (a:%nitrogen forms/TN and b: TIN/TN and TDP/TP)

Acknowledgments

The author would like to prompt his utmost respect and appreciation to all sponsors and employees on "The research fund Tanta University" for their great provision to support this research. Which funded by the research fund Tanta University in the framework of the research project "Solar photo-catalytic degradation of environmental contaminants" under code: TU-01-13-08.

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