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Quantitative Assessment of Nitrogen and Phosphorus Contents in Hyderabad City Sewage and Fuleli Canal Water

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Fulleli canal takes off from left bank of river Indus at Kotri barrage and passes through Hyderabad city, where untreated and partially treated city sewage is added. Five samples from sewage and seven samples along Fuleli canal were collected for three years at an interval of 4 to 6 weeks. These samples were analysed for nitrogen (organic, ammonia, nitrite, nitrate) and phosphorous (ortho, condensed and total phosphate). The variation in the concentration of total nitrogen ranged from 22.6 to 99.2 mg L^{-1} and 4.4 to 42.8 mg L^{-1} and phosphorous ranged 2.6 to 44.1 mg L^{-1} and 0.041 to 15.94 mg L^{-1} in sewage and along Fuleli canal respectively. The amount of nitrogen and phosphorous added to Fuleli canal from sewage water were calculated to 316.2 and 85.3 tons/month.

Key words: Fulleli canal, Nitrogen, Phosphorous, City sewage.

Introduction

Fuleli canal emerges from the left bank of River Indus at Kotri barrage and travels through Hyderabad city that has a population of about 2.0 million. Most of the sewage of old Hyderabad city and industrial liquid effluents end in Fuleli canal. It travels about 20 km from Hyderabad city, followed by 70 km towards Sajawal to provide the water for agricultural purposes and as a source of surface water in the region Dewani *et al* (1994) has described the impact of sewage and industrial effluents on the variation of chemical oxygen demand and residues in the Fuleli canal. Moreover, a study on metal contents in Fuleli canal and Hyderabad city sewage has also been carried out (Dewani *et al* 1997; Ansari *et al* 1999). Nitrogen and phosphorous are important nutrients and their enrichment in waters for long time may cause eutrophication. An increase in unicellular green and blue green algae and floating filamentous algae is observed (Hutzinger 1976; Schindler 1978) particularly in slow moving water that reduces the penetration of light and restrict reoxygenation of water (Dix 1981). In water and waste water nitrogen exists mainly in four forms i.e. organic ammonia, nitrite and nitrate as well as nitrogen gas, which are biologically interconvertible and are components of nitrogen cycle. As the relative concentration of different forms give a useful indication of the nature of the strength of samples. Due to high organic and ammonia nitrogen in water to be unsafe and pollutant (Tebbutt 1981). The phosphorous present in surface in the form of ortho phosphates, condensed phosphates and organic bound phosphate and sewage water may be soluble or insoluble phosphates. Different forms of phosphates also present in the industrial waste water, domestic sewage, soaps, detergents and fertilizers, but the inorganic orthophosphate play a dynamic role in an aquatic ecosystem (Triveds and Gurdeep 1992).

The present work examines different forms of nitrogen and phosphorous in Fuleli canal and sewage water and also evaluates quantitatively. The effect of sewage added on the balance of nitrogen and phosphorous in Fuleli canal, to evaluate the polluting effects of city sewage on Fuleli canal water.

Materials and Methods

Twelve samples, seven along Fuleli canal and five from sewage water, before entering in the Fuleli canal were collected (Fig 1). In Fuleli canal sample (I) was collected near Akhund village, the point of exit of Fuleli canal from Kotri barrage, before the entry of any sewage water. Four samples were collected from the canal in between the entry point of sewage water near (2) CIA center (3) Shakhi pir road near Liaquat colony (4) Bhatti village near Fateh Textile Mills and (5) Darya Khan village. Sample (6) was collected near village Ponho Kilhi, where it reaches Hyderabad city limits and sample (7) was collected from Hosri bridge near behar colony about 5-6 km away from Hyderabad city. Five samples from sewage were collected from (I) Cantonment board waste pumping station (II) Kali mori open sewerage line near Govt. College. (III) Sewerage channel near old power house (IV) Darya Khan Panhwar pumping station and (V) site area pumping station,

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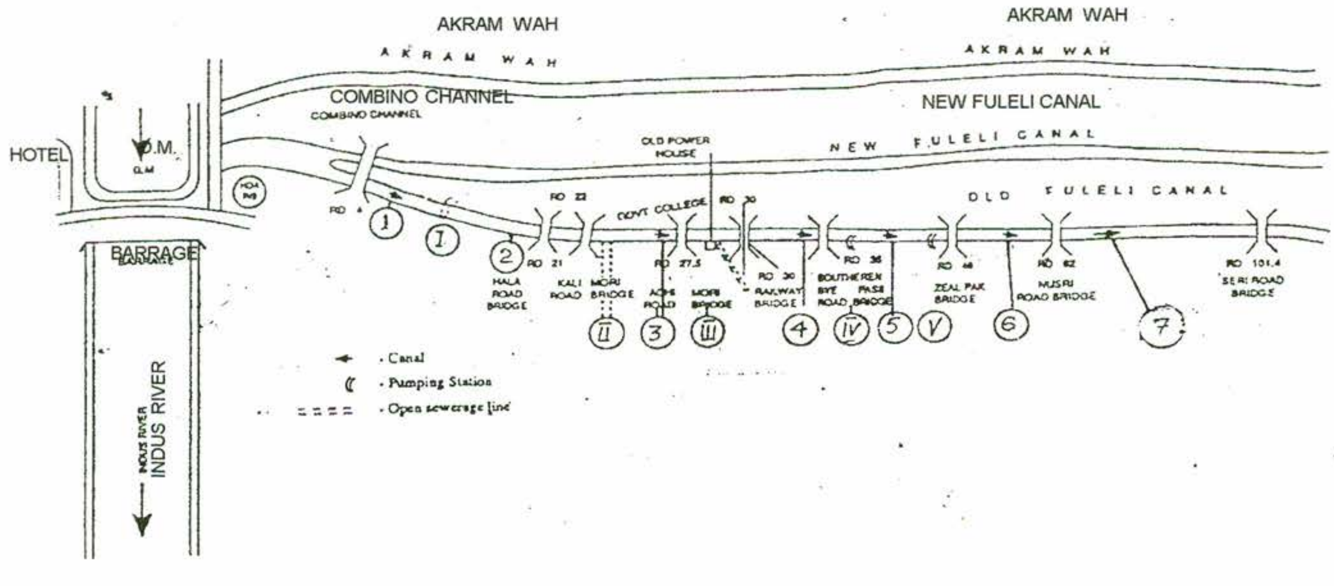

Fig 1. Map of study area of Fuleli canal showing sampling stations of Fuleli canal and sewage water.

near Nara jail. Grab sampler was used for the collection of the samples from the sewage lines. However due to extremely high pressure it was not possible to collect a cross section of the flow or from the middle of the flow, but was possible to penetrate a few cm in the flow of water and sample was collected.

Two to four sub samples from Fuleli canal were taken from the middle of the bridges; where it was not possible, the sample was collected 3-4m from the side of the canal. Periodical sampling was done at an interval of 4-6 weeks and practice was made 17 times. Samples were transferred to 2.5L pre washed glass bottle, rinsed with the sample several times. Analysis of nitrogen and phosphorous was made in laboratory immediately after the collection of the sample. If prompt analysis was not possible, the sample was acidified to pH 1.5-2.0 with sulfuric acid (1N) and stored just above the freezing point. Nitrite was preserved by adding 40 mg L^{-1} $HgCl_2$ and stored at 4°C. Nitrate, nitrite, ammonia and orthophosphate were determined by spectrophotometry using Hitachi 220 spectrophotometer. Nitrate was determined by using brucine sulfate as derivatizing reagent (APHA 1976). Nitrite was determined by diazotized sulphanilic acid with N-(1-napthyl) ethylenediamine dihydrochloride (APHA 1976) and ammonia was determined by phenate method (Rossum and Vilarruz 1963). Organic nitrogen together with ammonia was determined by micro-Kjeldahl method (Morgan *et al* 1957; Rossum and Vilarruz 1963). Subtraction of ammonia determined by the phenate method from the Kjeldahl nitrogen gave organic nitrogen. Orthophosphate was determined by the reduction of phosphomolybdate to molybdenum blue with ascorbic acid. Acid hydroxylable phosphorus gave condensed phosphorous (APHA 1980). Average water discharge in Fuleli canal was obtained from the records of control room Kotri barrage. The quantity of water discharge was calculated from the relation, Q=AxV, where A=area and V=Velocity of water. Area of the water body was obtained by multiplying average depth and breadth. The depth of the water was measured by sounding rod and velocity with Velptometer. Quantity of water discharge of sewage calculated using the relation.

$$Q=\{(B\text{x}D)\text{x}\tfrac{s}{t}\}$$

Where B=Breadth and D=Depth of drain. S=Specified distance in drain and t=Time taken by water for specific distance. For trapezoid drain Q was calculated from the relation:

$$Q=[\{\tfrac{(T+B)}{2}D\}\tfrac{s}{t}]$$

T=Top width of water level and B=Bottom width of the drain. Time of flow of water over a specified distance and depth of the channel were calculated at the site. For the sewage ponds where the pumps are lifting the waste water and introducing in the canal the discharge was estimated from the capacity of the pumps, diameters of pipe and the average operating hours of pumps. In order to calculate the load of nitrogen and phosphorous by the Fuleli canal and sewage water, the amounts in mg L^{-1} were multiplied with one to convert to (g m^{-3}).

Total load in tons/month=Concentration (g m^{-3})xaverage water discharge (m^3 s^{-1})x60x60x24x30x0.000001=Concentration (g m^{-3})xaverage water discharge (m^3 s^{-1})x2.592. The water discharge in cu.sec^{-1} was multiplied by 0.028 to convert into m^3 s^{-1}.

Results and Discussion

The water samples collected from sewage and Fuleli canal were analyzed for the contents of nitrogen and phosphorous and results are summarized in Tables (1-4).

Nitrogen contents in sewage water. The organic nitrogen is the first stage of nitrogenous organic matter present in sewage. A significant variation in its contents was observed at different sewage stations due to varying composition of sewage water. Sampling stations II and III contributed highest concentration of organic nitrogen, with average values of 49.25 and 47.27 mg L^{-1}, because these are open drains flowing through thickly populated areas of the city with enriched organic matter. The range of organic nitrogen was from 12.86 to 75.78 mg L^{-1} with following descending order in sewage water.

II~III>>IV>V~I

Ammonia-nitrogen followed similar trends as that of organically bound nitrogen with highest average values of 24.45 mg L^{-1} at sampling station II and lowest 8.67 mg L^{-1} at sampling station V. The level of ammonia nitrogen is ranged between 6.5-35.5 mg L^{-1} in sewage water (Table 1). The ammonia nitrogen in sewage water is due to the decomposition of organic nitrogen or from excretory products found in the sewage water. Nitrate nitrogen was in a range from 0.65 to 5.9 mg L^{-1} with highest average of 2.84 mg L^{-1} at sampling station III and lowest of 1.48 mg L^{-1} at station V. Nitrate contributed 1.57-5.44% to the total nitrogen contents of sewage water, in contrast to 61.7-70.4% by organically bound and 26-33.7% by ammonia nitrogen. Nitrite was found absent in waste water sample during study period, because it is thermodynamically unstable in anoxic waters (Dix 1981). The nitrogen contents indicate that highest average of total nitrogen (75.75%) was disposed off by station II, while total variation was in the range 22.6 to 99.2 mg L^{-1}.

Phosphorus contents of sewage water. Orthophosphate was the dominant form of the phosphorous found in sewage which ranged between 3.11 and 34.61 mg L^{-1}, with highest average of 15.96 mg L^{-1} at station II and lowest mean of 6.71 at station V. The orthophosphate phosphorous contributed 67.5 to 78.0% of total phosphorous contents. The level of condensed phosphate was maximum at sampling station I with mean value of 7.0 mg L^{-1} and mean minimum was 2.4 mg l^{-1} at station V (Table 2). The entire concentration of condensed phosphates varied within 0.66 and 12.1 mg L^{-1} and contributed 23.3 to 31.1% of total acid hydrolyzable phosphate. The concentration of acid hydrolyzable phosphate was related with orthophosphates and condensed phosphate with regression coefficient (r) 0.96 and 0.93 respectively. It indicated a similar pattern with a maximum average of 22.66 mg L^{-1} at station II and minimum average of 8.8 mg L^{-1} at station V. The overall range was observed within 4.4 and 42.8 mg L^{-1}.

Table 1

Quantitative data of nitrogen fractions (mg l^{-1}) at different sewage sampling stations (n=10)

Sampling Stations	Kjeldahl Nitrogen: Organic Nitrogen	Kjeldahl Nitrogen: Ammonia-N	Nitrate-N	Nitrite Nitrogen	Total-N
I	23.25±4.2 (12.88-36.4) [61.7%]	12.7±2.5 (8.61-16.23) [33.7%]	2.05±0.76 (0.75-5.08) [5.44%]	N.D	37.63±4.42 (25.5-53.15)
II	49.25±6.6 (38.3-68.46) [65%]	24.45±4.42 (13.14-35.45) [32.2%]	1.19±0.59 (0.35-3.3) [1.57%]	N.D	75.75±7.3 (61.1-99.2)
III	47.27±7.3 (35.1-75.78) [70.45%]	17.9±3.85 (6.5-29.5) [26%]	1.91±.58 (0.65-3.95) [2.84%]	N.D	67.12±7.6 (48.24-89.11)
IV	30.50±3.7 (25.8-40.4) [62.78]	15.32±3.6 (7.8-25.2) [31%]	2.3±0.8 (0.72-5.9) [4.7%]	N.D	48.58±4.6 (37.02-60.98)
V	21.1±3.1 (13.68-28.1) [67.4%]	8.67±2.89 (7.79-20.13) [28%]	1.48±0.95 (1.13-4.5) [1.77%]	N.D	31.10±4.1 (22.66-45.41)

Mean ± confidence interval at 95% range (Min-Max) [ ] = % contribution.

Assessment of nitrogen and phosphorus in fuleli canal. The organic nitrogen in the Fuleli canal fluctuated between 0.4 and 35.4 mg L^{-1} with lowest mean concentration of 1.26 mg l^{-1} at sampling station 1, before entry of polluting material and highest mean of 8.7 mg L^{-1} was observed at station 4. There was positive was positive shift in base line after the addition of sewage water.

The contribution of organic towards total nitrogen was 66% at sampling station canal travels along the city, more sewage is added with higher organic nitrogen, high oxygen demand and low dissolved oxygen, with the result that denitrification process becomes dominant with low % of nitrate.

At sampling station 1 the seasonal variation of ammonia and nitrate was similar as discussed for organic nitrogen, but the sampling station 2 to 7 showed different behaviour for nitrate with water discharge (Fig 2), because either the nitrification of free ammonia or denitrification of nitrate processes are taking place in the canal water due to the addition of organic nitrogen rich sewage water.

The level of orthophosphate in Fuleli canal ranged between below the detection limit to 12.6 mg L^{-1} with lowest and highest mean concentration of 0.042 to 3.1 mg L^{-1} at sampling station 1 and 5 respectively (Table 4). There was a rise in the mean concentration of orthophosphate after the addition of the effluents and was dependent upon the volume and

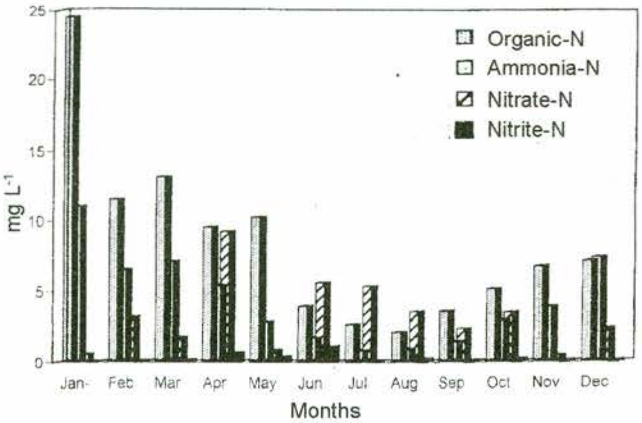

Fig 2. Seasonal profile of different forms of nitrogen at sampling station 2 to 7.

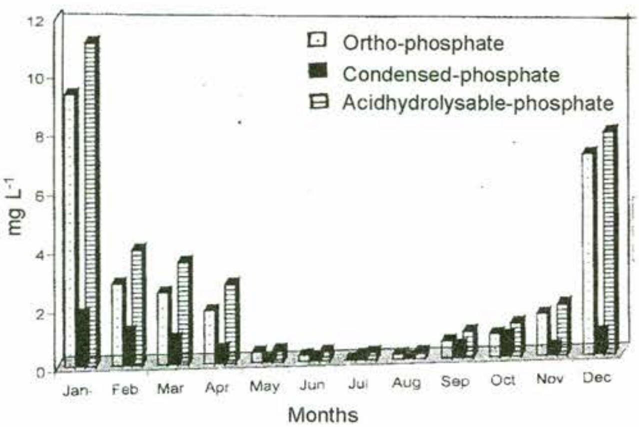

Fig 3. Seasonal profile of different forms of nitrogen at sampling station 3 to 7.

Table 2
Quantitative data of different forms of phosphorous ($mg\ L^{-1}$) at different sewage sampling stations

Sampling station	Different "Forms of Phosphorous" n=20 Total Acid Hydrolyzable Phosphorous	n=23 Ortho-Phosphate Phosphorous	Condensed Phosphate-Phosphorous
I		(67.48)	(30.25)
	11.47±2.46	7.74±1.36	3.47±1.12
	(4.95-24.5)	(3.11-20.25)	(0.68-11.49)
	[46.64]	[41.47]	[70.60]
II		(70.43)	(31.06)
	22.66±3.61	15.96±2.55	7.04±1.13
	(13.4-42.8)	(6.88-34.61)	(3.08-12.1)
	[34.78]	[37.21]	[36.38]
III		(77.67)	(28.6)
	(9.1-41.15)	(6.26-33.72)	(2.65-9.95)
	[40.85]	[41.13]	[44.11]
IV		(78.54)	(23.28)
	13.53±1.94	10.63±1.3	3.15±0.57
	(6.85-23.2)	(5.43-18.7)	(1.05-5.18)
	[31.87]	[28.51]	[39.87]
V		(75.85)	(27.5)
	8.85±1.78	6.71±1.47	2.44±.59
	(4.35-17.25)	(3.41-15.43)	(0.66-4.59)
	[46.54]	[50.8]	[51.63]

Mean ± confidence interval at 95% range (Min-Max) % contribution ( ) coefficient of variation c.v% [ ].

its concentration in sewage water. High mean concentration at station 5 could be due to high flux of waste water from sewage station IV. Orthophosphate contributed 26% of total phosphorous at sampling station 1, but contributed above 60% at sampling stations 2 to 6. The orthophosphate at sampling station 1 indicated peak values in months of July and August and the lowest concentration in November and January. The variation could be explained on the basic of phosphorous recycling process from sediments. The presence of ferric oxide in the oxidized layer of sediments has been often considered as the major factor in controlling phosphorous recycle, because of strong adsorption properties of these phases for phosphorous (Lijklema 1977; Nedwel and Brown 1982). In the month of July and August due to high temperature and high amount of suspended solids depletion of dissolved oxygen is observed (Dewani *et al* 1994) in water column. The adsorption capacity of sediments for phosphorous is thus destroyed and phosphate are released to over lying water (Banoub 1977; Fillas 1977), 4 and 22% at station 1 (Table 3). The seasonal variation of organic nitrogen at sampling station 1 was observed, with lowest values in the months of December and January, relating with low discharge, while highest concentration was observed in July, August, when there was maximum flow in the canal from the river. Remaining sampling stations of Fuleli canal registered peak values of organic nitrogen in months of low discharge due to low dilution factor and lowest in the month of highest discharge (Fig 2). The levels of ammonia nitrogen in Fuleli canal ranged between 0.17 and 12.04 $mg\ L^{-1}$, with average lowest of 0.081 $mg\ L^{-1}$ at station 1 and highest average 4.07 at sampling station 5 (Table 3). Increasing trends in the mean values of ammonia nitrogen were noted from sampling station 2 to 5. These are due to stress of sewage water and owing to the excretes of cattle's using canal water. The decline in the values of NH_4-N from sampling stations 6 to 7 could be due to settling of organic matter, loss of ammonia by volatilization and mixing of oxygen from atmosphere which possibly converted NH_4-N into oxidized nitrate-N (Table 3).

Table 3
Assessment of different fractions of nitrogen (mg L^{-1}) at Fuleli canal water

Sampling stations	Kjeldahl nitrogen (n=18) Organic-nitrogen	Kjeldahl nitrogen (n=18) Ammonia-N	Nitrate-N n-21	Nitrite-N n=21	Total-N
1	1.26±0.21 [22] (0.41-2.04)	0.80±0.22 [14] (0.17-1.47)	3.49±0.73 [62] (1.46-7.1)	0.27±.013 [0.47] (N.D-.083)	5.67±1.10 (2.6-10.1)
2	3.44±1.3 [37] (1.15-10.72)	1.94±0.71 [20] (0.46-4.95)	3.78±1.23 [41] (0.48-10.46)	0.186±0.15 [1.9] (N.D-1.25)	9.35±1.8 (6.85-18.2)
3	7.24±3.96 [52.4] (1.69-26.53)	3.4±1.39 [25] (0.6-11.2)	3.36±1.24 [24] (0.41-9.21)	0.185±14 [1.3] (N.D-1.04)	13.8±4.88 (5.63-37.72)
4	8.7±4.78 [66] (1.59-35.37)	3.11±1.20 [24] (0.75-7.1)	2.89±0.85 [22] (0.35-7.88)	0.14±.10 [1.1] (N.D-0.84)	13.05±5.4 (5.44-44.1)
5	6.38±3.5 [44] (1.45-28.31)	4.07±1.65 [28] (1.16-12.04)	3.57±1.74 [25] (0.36-12.93)	0.32±0.28 [2.1] (N.D-1.71)	14.48±4.8 (6.5-43.8)
6	4.41±3.31 [37] (1.15-28.65)	2.47±1.15 [21] (0.43-8.66)	5.1±1.63 [42] (1.1-14.33)	0.28±0.19 [2.3] (N.D-1.87)	12.17±4.17 (4.78-40.34)
7	4.2±3.4 [34] (1.08-29.54)	2.70±1.40 [22] (0.38-10.7)	5.54±2.00 [46] (0.97-16)	0.33±0.26 [2.7] (N.D-1.97)	12.05±4.41 (5.21-38.05)

Mean ± confidence interval at 95% range (Min-Max) % contribution [ ].

Table 4
Assessment of different forms of phosphorus (mg L^{-1}) at Fuleli canal water

Samp-ling stations	Different forms of phosphorus: Total n=20 acid hydrolyzable phosphorous	Ortho-phosphate phosphorous n-24	Condensed phosphate n=20
1	0.16±0.058 (.041-0.46) [74.2]	.042±0.028 (25.8) (N.D-0.21) [159.5]	0.11±0.040 (69) (0.031-0.31) [77.2]
2	1.15±0.90 (.094-6.6) [163.7]	0.68±0.52 (60) (0.054-4.91) [176]	0.49±0.34 (41) (0.05-2.79) [140.2]
3	2.21±2.02 (0.19-15.94) [190]	1.61±1.59 (71.8) (.048-11.34) [194]	0.75±0.55 (34) (.09-4.6) [154]
4	1.99±1.78 (0.28-14.96) [187.1]	1.28±1.15 (64.3) (0.13-11.19) [210]	0.78±.61 (39) (0.1-4.1) [168.5]
5	4.13±1.75 (0.77-14.25) [88.4]	3.1±1.26 (75) (0.45-12.61) [93.45]	1.01±0.39 (25) (0.22-2.99) [71.0]
6	1.82±1.37 (0.15-11.05) [157.1]	1.32±0.97 (72.5) (.065-9.27) [171.4]	0.48±0.19 (26.3) (.07-1.78) [84.8]
7	1.91±1.61 (0.22-13.18) [175.7]	1.22±1.24 (63.8) (.07-12.1) [236]	0.67±36 (35.1) (0.14-3.5) [118]

Mean ± confidence interval at 95% range = (Min-Max) [ ] = C.V ( ) = % contribution.

Nitrite is an unstable product of nitrification of ammonia or denitrification of nitrates. The concentration of nitrite largely depends upon the relative abundance of nitrifying and denitrifying bacteria and their activities. The variation of nitrite from below the detection limit to 1.91 mg L^{-1} in Fuleli canal is the result of both these processes. The lowest mean of 0.027 mg L^{-1} was found at sampling station 1 and highest mean of 0.32 mg L^{-1} was at station 5. The nitrite contributed less than 2% towards the total nitrogen, but its concentration at Fuleli canal crossed the safe limits recommended by EEC. (Rump and Krist 1992). The fluctuation in nitrate nitrogen was in the range of 0.35 to 16 mg L^{-1}, with average concentration of 2.89 mg L^{-1} at station 4 and 5.54 mg L^{-1} at station 7. Nitrate contributed 62% of total nitrogen at sampling station 1 as compared to 22% at station 4. The aerobic bacteria becomes more active in higher concentration of dissolved oxygen at sampling station 1, with higher % of nitrate.

The seasonal variation at sampling stations from 3 to 7 was reciprocal to that of 1, with maximum value recorded in months of low discharge, while minimum observed in the months of peak discharge (Fig 4). The concentration of condensed phosphate fluctuated in the range 0.036 to 4.1 mg L^{-1} with mean lowest and highest concentration of 0.11 mg L^{-1} and 1.01 mg L^{-1} at sampling stations 1 and 5 respectively. But its proportion to the hydrolyzable phosphate was more than 60% at 1 and less than 40% at sampling station from 2 to 7 in the Fuleli canal. Acid hydrolyzable phosphate is the sum of ortho and condensed form was observed with average minimum and maximum concentration 0.041-15.94 mg L^{-1} (Table 4). The seasonal variation was identical to that of orthophosphate.

Total flux of nitrogen and phosphorus on Fuleli canal from Indus. Total flux of nutrients on Fuleli canal from river Indus were calculated from the concentrations of nitrogen and phosphorous at sampling station 1 and average monthly flow in Fuleli canal from Indus. The total nitrogen budget on Fuleli canal from river Indus was 1.05×10^4 tons and 2.07×10^4 tons annually during 1994 and 1995 respectively. Similarly the transport of phosphorous during 1994 and 1995 was observed 764.7 tons/annum respectively.

The greatest input of nitrogen and phosphorous was during high flow and minimum during low flow of water Fuleli canal.

Total nitrogen and phosphorus budget on Fuleli canal by sewage water and River Indus. The sewage water which was rich in nitrogenous organic matter and phosphorous mixed up with canal water and contributed significant quantity of nitrogen and phosphorous flux from different sewage stations depended upon the concentration and the volume of sewage water introduced in the canal. The estimated load of nitrogen from all sewage sources was 316.16 tons/month which amounts for major fraction of 66% for organic nitrogen, followed by 29.6% ammonia nitrogen and 3.3% nitrate nitrogen. The sewage sampling station III represented 42.97%, while lowest 2.18% of total nitrogen by station V. Similarly, the mean monthly input of phosphate concentration from the sewage sources under study was 85.13% tons/month, with highest percentage of 42.98% estimated from sampling station III and lowest of 2.06% contributed by station V. Total load of nutrients on Fuleli canal calculated by adding, contributed by the flow of water from River Indus and sewage water, amounted to 1964 tons/month and 159.1 tons/month for nitrogen and phosphorous respectively. The total load of nitrogen and phosphorous on Fuleli canal after it left Hyderabad city limit was calculated 1605 tons/month and 117.4 tons/month respectively assuming that there is no loss of water during flow through Hyderabad city. Thus the canal was deficit on the average by 359 tons/month nitrogen and 41.65 tons/month of phosphorous. These investigations reflected that sedimentation in the canal water accounted 26% removal of phosphorous and in the case of nitrogen 18.3% removal was shared to sedimentation and loss due to the volatilization of ammonia to atmosphere.

Conclusion

The work examined pre and post mixing of sewage water in Fuleli canal in terms of nitrogen and phosphorous contents. The sewage was loaded with organic nitrogen, ammonia and nitrate in the range of 12.86 to 75.86 mg L^{-1}, 6.5 to 35.4 mg L^{-1} and 0.65 to 5.9 mg L^{-1}. Similarly orthophosphate and condensed phosphate were in the range 3.11 to 34.61 mg L^{-1} and 0.66 to 12.1 mg L^{-1}. The estimated load of nitrogen and phosphorous from all the sewage sources were 316.16 and 85.31 tons/month respectively. There was a positive shift of nitrogen and phosphorous concentration along the Fuleli canal due to the addition of sewage water. Total load on Fuleli canal amounted to 1964 tons/month nitrogen and 159.1 tons/month phosphorous, calculated by adding contributed by the flow of water from River Indus and sewage.

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