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for information

Effects of the Tolo Harbour Effluent Export Scheme on the Water Quality of Kwun Tong Typhoon Shelter, Victoria Harbour and Tolo Harbour

Introduction

The Tolo Harbour Effluent Export Scheme (THEES) was implemented to remove the nutrient input to the eutrophic Tolo Harbour from the Shatin and Tai Po Sewage Treatment Works. Under the scheme, the treated effluent from the two sewage treatment works is diverted to the Kai Tak Nullah in the Victoria Harbour catchment in two stages. Stage I, involving the effluent from the Shatin plant, commenced operation on 19 April 1995. Stage II, involving the effluent from the Tai Po plant, commenced operation on 20 March 1996. Due to technical problems, only a part of the total flow from the two plants has been discharged to Kai Tak Nullah (Table 1).

2 In order to assess the changes in water quality in the Kwun Tong Typhoon Shelter, Victoria Harbour and Tolo Harbour after the commencement of THEES, a water quality monitoring programme, involving the establishment of 14 monitoring stations in the field, was initiated by EPD in June 1993. At each sampling station and depending on the water depths, water samples were collected either bi-weekly or monthly at two or three water depths: 1 m below the surface (surface), mid-water (middle) and 1 m above the sea bottom (bottom), for analysis of various physico-chemical parameters. The locations of the sampling stations are shown in Figure 1. Table 2 lists the water quality variables measured by the monitoring programme.

Data Analyses and Results

3. The assessment of changes in water quality with the implementation of THEES is based on a comparison of the water quality measured before and after the commissioning of Stage I of the scheme at each of the sampling stations. The data obtained before the start of the scheme were treated as the background or control data while those obtained afterwards were taken to be the post-commissioning data. As many of the determinands might have seasonal fluctuations, only background and post-commissioning data from the same month of the year were used in the statistical test involving a pair-wise comparison of the data. The details of the statistical procedure used are described in the footnote[1] below.

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[1] *The dataset for each variable was first divided into two subsets: one for the period before the start of the scheme (i.e. from 20 April 1994 to 18 April 1995) and the other after the start of the scheme (i.e. from 20 April 1995 to 18 April 1996). The Wilcoxon Matched-Pairs Signed-Ranks Test was then applied to the matched pairs of data from the two subsets of data to determine if the two subsets were different at a statistically significant level of $p = 0.05$. The null hypothesis tested was that the THEES makes no significant impact on the water quality variable tested.*

4. Tables 3 and 4 summarise the test outcomes for the key determinands in Victoria Harbour and Tolo Harbour respectively. An upward arrow indicates that the post-commissioning data were significantly higher in magnitude than the control and a downward arrow indicates the reverse. Figures 2 and 3 show some representative time trend plots of significant key variables in Tables 3 and 4.

Kwun Tong Typhoon Shelter

5. It is apparent that the implementation of THEES, although not in full flow condition, was accompanied by a significant change in the water quality of the typhoon shelter (Table 3). Changes at the sampling station KTS1 were particularly prominent. The surface and middle water layers experienced a decrease in ammoniacal nitrogen (the un-ionised form is potentially harmful), total inorganic nitrogen, total nitrogen and biochemical oxygen demand (BOD, a measure of the biodegradable organic content in the water). Accompanying the decrease in ammoniacal nitrogen was an increase in nitrite nitrogen at the surface water layer of KTS1. A similar decrease in the total nitrogen was also observed at the sampling station KTS4. In addition, a decrease in suspended solids in the surface and middle water layers at KTS4 were found. Water transparency has improved at both stations. The overall picture is one of significant improvement, but this may have been brought about by other activities that have taken place over roughly the same period, notably declaration of the Victoria Harbour Water Control Zone (Phase I and Phase II) and rectification of expedient connections.

Victoria Harbour and Eastern Buffer Water Control Zone

6. There have been no systematic changes in the water quality of Victoria Harbour or the Eastern Buffer Water Control Zone since the commissioning of the scheme, that could confidently be ascribed to the effects of the discharge. Total phosphorus and *E.coli* levels seem to have increased at the station KTS5 immediately outside the typhoon shelter but this is more likely to be due to the proximity of the Kwun Tong sewage screening plant and our success in diverting illegal discharges in the Kwun Tong area back to the mains sewerage. The scattered declines in levels of nitrogen are welcome but are unlikely to have been due to the discharge.

Tolo Harbour

7. Table 4 shows that with the exception of scattered increases in levels of total phosphorus, there is a consistent pattern of widespread and systematic decline in nutrients throughout much of Tolo Harbour compared with the period immediately before commissioning of the scheme, despite the fact that only partial removal of the plants' discharge has been achieved. The forms of nitrogen showing reductions include ammoniacal nitrogen, total inorganic nitrogen and total nitrogen. There were also some isolated reductions of suspended and total volatile solids levels at a few of the monitoring stations.

8. Very little change, excepting a decrease in ammoniacal nitrogen and an increase in nitrite and BOD in the bottom waters, was found at the monitoring station TM2 which is located closest to the old sewage outfall of the Shatin Sewage Treatment Works. There are various possible explanations for this, such as the shallowness of the location coupled with interactions between the overlying water and the sediment, or TM2's proximity to the mouth of the Shing Mun River

in addition to the fact that the outfall still carries the bypass flow.

Conclusions

9. Since the implementation of the Tolo Harbour Effluent Export Scheme in April 1995:

(i) there has been an improvement in water quality of the Kwun Tong Typhoon Shelter, although this may have been brought about by factors other than the Tolo effluent;

(ii) there has been no material change to the water quality of Victoria Harbour or the Eastern Buffer, certainly none that could be ascribed to the Tolo effluent; and

(iii) there has been a decline in levels of nutrients in much of Tolo Harbour.

10. We conclude therefore that the Tolo effluent has had no deleterious impact on the new receiving waters (and may have contributed to an improvement in the Kwun Tong Typhoon Shelter) and that the partial removal of the effluent from Tolo has already made a significant contribution to the lowering of the nutrient levels in this water body.

Water Policy & Planning Group
Environmental Protection Department
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Table 1: Estimated Volumes of Effluent since 19 April 1995 upto July 1996 (source: Drainage Services Department)

Effluent Flow Pathway	Commencement Date	Volume (TCM)
Shatin STW to Kai Tak Nullah	19 April 1995, after Stage I of THEES	35,000
Shatin STW to Tolo Harbour as bypass	19 April 1995, after Stage I of THEES	53,000
Tai Po STW to Shatin STW	20 March 1996, after Stage II of THEES	1,100
Tai Po STW to Tolo as bypass	20 March 1996, after Stage II of THEES	8,000

Notes:

1. TCM stands for "thousand cubic metres"
2. the design capacity of Shatin STW is 205 TCM/day and that for Tai Po STW is 80 TCM/day
3. The monthly mean effluent flows during April 1994-April 1996 from Shatin STW and Tai Po STW are 182 TCM/day and 74 TCM/day respectively

Table 2 List of water quality variables measured at the sampling stations

Determinands		Unit	Sampling Depth
Physical and Aggregate Properties	Dissolved Oxygen [1]	mg/L & % saturation	Depth Profiling
	Salinity [1]	ppt	Depth Profiling
	Temperature [1]	°C	Depth Profiling
	pH[1]	-	Depth Profiling
	Turbidity [2]	mg/L	Depth Profiling
	Secchi Disc Depth [2]	m	---
	Suspended Solids [2]	mg/L	S, M, B
	Total Volatile Solids [2]	mg/L	S, M, B
Aggregate Organic Constituents	BOD_5[3]	mg/L	S, M, B
Microbiological Examination	Faecal Coliform [4]	cfu/100ml	S, M, B
	Escherichia coli [4]	cfu/100ml	S, M, B
Nutrients & Inorganic Constituents	Nitrite Nitrogen [5]	mg/L	S, M, B
	Nitrate Nitrogen [5]	mg/L	S, M, B
	Ammoniacal Nitrogen [5]	mg/L	S, M, B
	Total Kjeldahl Nitrogen (soluble, soluble & particulate) [5]	mg/L	S, M, B
	Ortho-phosphate [5]	mg/L	S, M, B
	Total Phosphorus (soluble & particulate) [5]	mg/L	S, M, B
	Silica (as SiO_2) [5]	mg/L	S, M, B
Biological Examination	Chlorophyll-*a* [5]	mg/L	S, M, B
	Phaeo-pigment [5]	mg/L	S, M, B

Note: Depth profiling - measurements are taken at 1m interval from the water surface to 1m above the seabed

S - 1m below water surface
M - mid-depth of water column
B - 1m above seabed

1 - To study the oceanographic conditions of marine water
2 - To study the transparency and light penetration of marine water which relate to the appearance and aesthetic value of a waterbody
3 - To study the organic pollution of marine water
4 - To study the bacterial condition of marine water and to indicate faecal pollution
5 - To study the eutrophic condition of marine water as a consequence of pollution by sewage, livestock wastes, industrial wastes, rural and urban runoff: total nitrogen = TKN/SP + NO_2 + NO_3; total inorganic nitrogen = NO_2 + NO_3 + NH_4

Table 3 Result of the Wilcoxon Matched-Pairs Signed-Ranks test for the comparison of samples taken in Kwun Tong Typhoon Shelter and Victoria Harbour before and after THEES

Determinand	water depth	Kwun Tong		Victoria Harbour			Eastern Buffer	
		KTS1	KTS4	KTS5	VM1	VM2	EM1	EM2
Dissolved Oxygen	surface	-	-	-	-	-	-	-
	middle	-	-	-	-	-	-	-
	bottom	-	-	↘	-	-	-	-
5-day Biochemical Oxygen Demand	surface	↘	-	-	-	-	-	-
	middle	↘	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-
Secchi Disc Depth		↗	↗	-	-	-	-	-
Turbidity	surface	-	-	-	-	-	-	-
	middle	-	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-
Suspendend Solids	surface	-	↘	-	-	-	-	-
	middle	-	↘	-	-	-	-	-
	bottom	-	-	-	-	↘	-	-
Total Volatile Solids	surface	-	↘	-	-	-	↘	-
	middle	↘	↘	-	-	-	↘	-
	bottom	-	-	-	-	-		-
Ammoniacal Nitrogen	surface	↘	-	-	-	-	-	-
	middle	↘	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-
Nitrite Nitrogen	surface	↗	-	-	-	-	-	-
	middle	-	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-
Nitrate Nitrogen	surface	-	-	-	-	-	-	-
	middle	-	-	-	↘	-	-	-
	bottom	-	-	-	↘	-	↘	-
Total Inorganic Nitrogen	surface	↘	-	-	-	-	-	-
	middle	↘	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-
Total Nitrogen	surface	↘	↘	-	-	-	-	-
	middle	↘	↘	-	↘	-	-	-
	bottom	-	-	-	-	-	↘	↘
Ortho-phosphate	surface	-	-	-	-	-	-	-
	middle	-	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-
Total Phosphorus	surface	-	-	↗	-	-	-	-
	middle	-	-	↗	-	-	-	↗
	bottom	-	-	-	-	-	-	-
Faecal Coliform	surface	-	-	↗	-	-	-	-
	middle	-	-	↗	-	-	-	-
	bottom	-	-	-	-	-	-	-
E. coli	surface	-	-	↗	-	-	-	-
	middle	-	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-
Chlorophyll-*a*	surface	-	-	-	-	-	-	-
	middle	-	-	-	-	-	-	-
	bottom	-	-	-	-	-	-	-

1. Sample size ranges from 12 to 24
2. ↗ represents an increase in level of the determinand after the commissioning of THEES (statisically significant at $p < 0.05$)
3. ↘ represents a decrease in level of the determinand after the commissioning of THEES (statisically significant at $p < 0.05$)
4. - represents no significant change in level of the determinand after the commissioning of THEES ($p > 0.05$)

Table 4 Result of the Wilcoxon Matched-Pairs Signed-Ranks test for the comparison of samples taken in Tolo Harbour before and after THEES

Determinand	water depth	Harbour subzone			Buffer subzone		Channel subzone	
		TM2	TM3	TM4	TM5	TM6	TM7	TM8
Dissolved Oxygen	surface	-	-	-	-	-	-	-
	middle	X	-	-	X	-	-	-
	bottom	-	-	-	-	-	-	-
5-day Biochemical Oxygen Demand	surface	-	↗	-	-	-	-	-
	middle	X	-	-	X	-	-	-
	bottom	↗	↗	-	-	-	-	-
Secchi Disc Depth		-	-	-	-	-	-	-
Turbidity	surface	-	↗	-	-	-	-	-
	middle	X	-	-	X	↗	-	-
	bottom	-	-	-	-	-	-	-
Suspendend Solids	surface	-	-	↘	↘	-	-	-
	middle	X	-	-	X	-	-	↘
	bottom	-	-	↘	-	-	-	-
ɹtal Volatile Solids	surface	-	-	-	-	-	-	-
	middle	X	-	-	X	-	-	↘
	bottom	-	-	↘	-	-	-	-
Ammoniacal Nitrogen	surface	-	-	↘	↘	↘	↘	-
	middle	X	↘	↘	X	-	-	-
	bottom	↘	-	-	-	-	-	-
Nitrite Nitrogen	surface	↗	-	-	-	-	-	-
	middle	X	-	-	X	-	-	-
	bottom	-	-	-	-	-	-	-
Nitrate Nitrogen	surface	-	-	-	-	-	-	-
	middle	X	-	-	X	-	-	-
	bottom	-	-	-	-	-	-	-
Total Inorganic Nitrogen	surface	-	-	-	↘	↘	↘	-
	middle	X	↘	-	X	-	-	-
	bottom	-	-	-	↘	-	-	↘
Total Nitrogen	surface	-	-	↘	↘	↘	↘	↘
	middle	X	↘	↘	X	↘	↘	↘
	bottom	-	-	↘	↘	↘	-	↘
Ortho-phosphate	surface	-	-	↘	↘	↘	↘	↘
	middle	X	↘	↘	X	-	-	↘
	bottom	-	-	-	↘	-	↘	↘
ɹtal Phosphorus	surface	-	↗	-	-	-	-	-
	middle	X	-	-	X	↗	↗	-
	bottom	-	-	-	-	-	↗	↗
Faecal Coliform	surface	-	-	-	-	-	-	-
	middle	X	-	-	X	-	-	-
	bottom	-	-	-	-	-	-	-
E. coli	surface	-	-	-	-	-	-	-
	middle	X	-	-	X	-	-	-
	bottom	-	-	-	-	-	-	-
Chlorophyll-*a*	surface	-	↗	-	-	-	-	-
	middle	X	-	-	X	-	-	↗
	bottom	-	-	-	-	-	-	↗

1. Sample size ranges from 17 to 24
2. ↗ represents an increase in level of the determinand after the commissioning of THEES (statisically significant at $p < 0.05$)
3. ↘ represents a decrease in level of the determinand after the commissioning of THEES (statisically significant at $p < 0.05$)
4. - represents no significant change in level of the determinand after the commissioning of THEES ($p > 0.05$)
5. X no measurement for the determinands was taken at this water depth

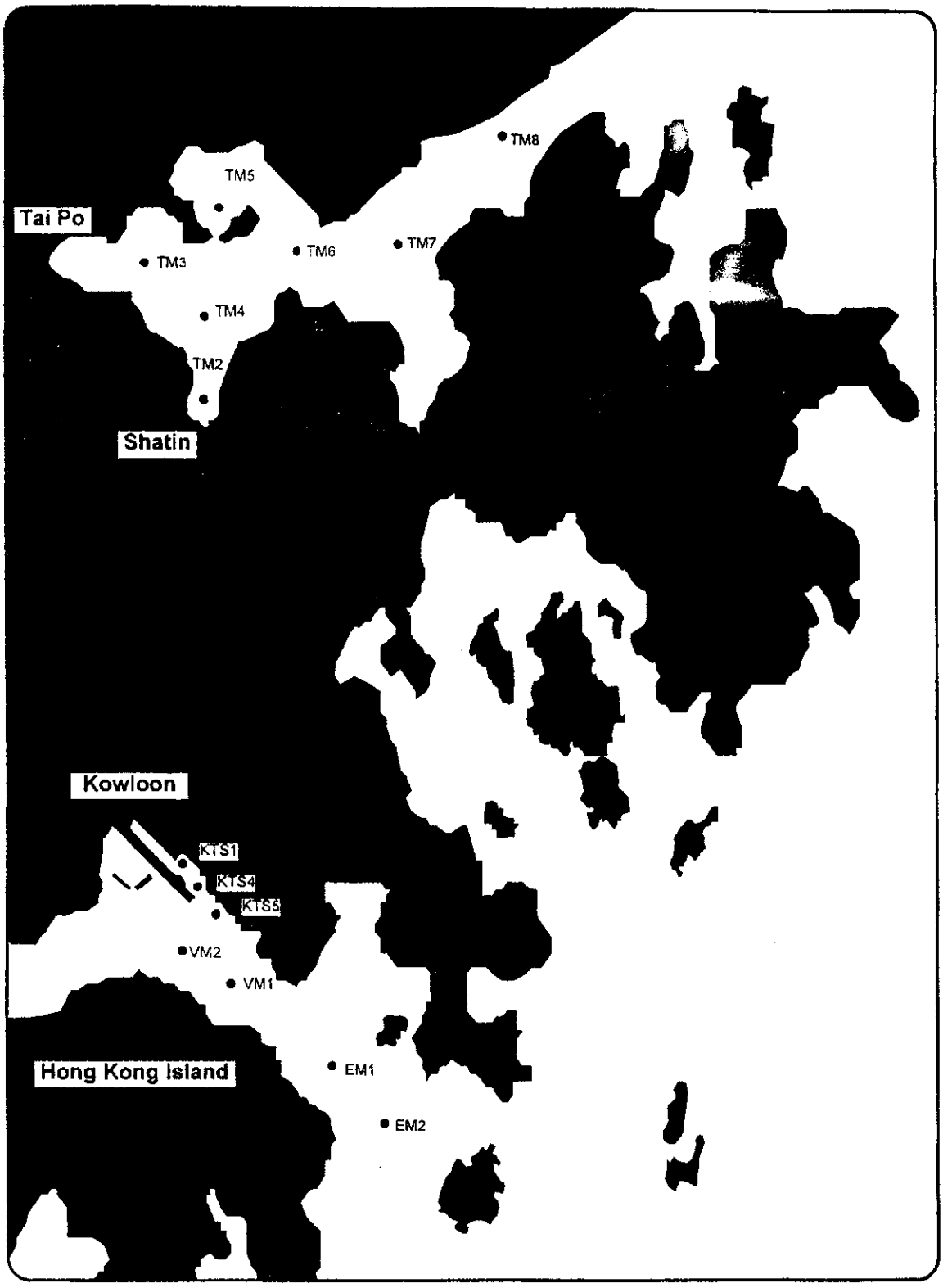

Figure 1 Locations of the monitoring stations at Kwun Tong Typhoon Shelter, Victoria Harbour and Tolo Harbour

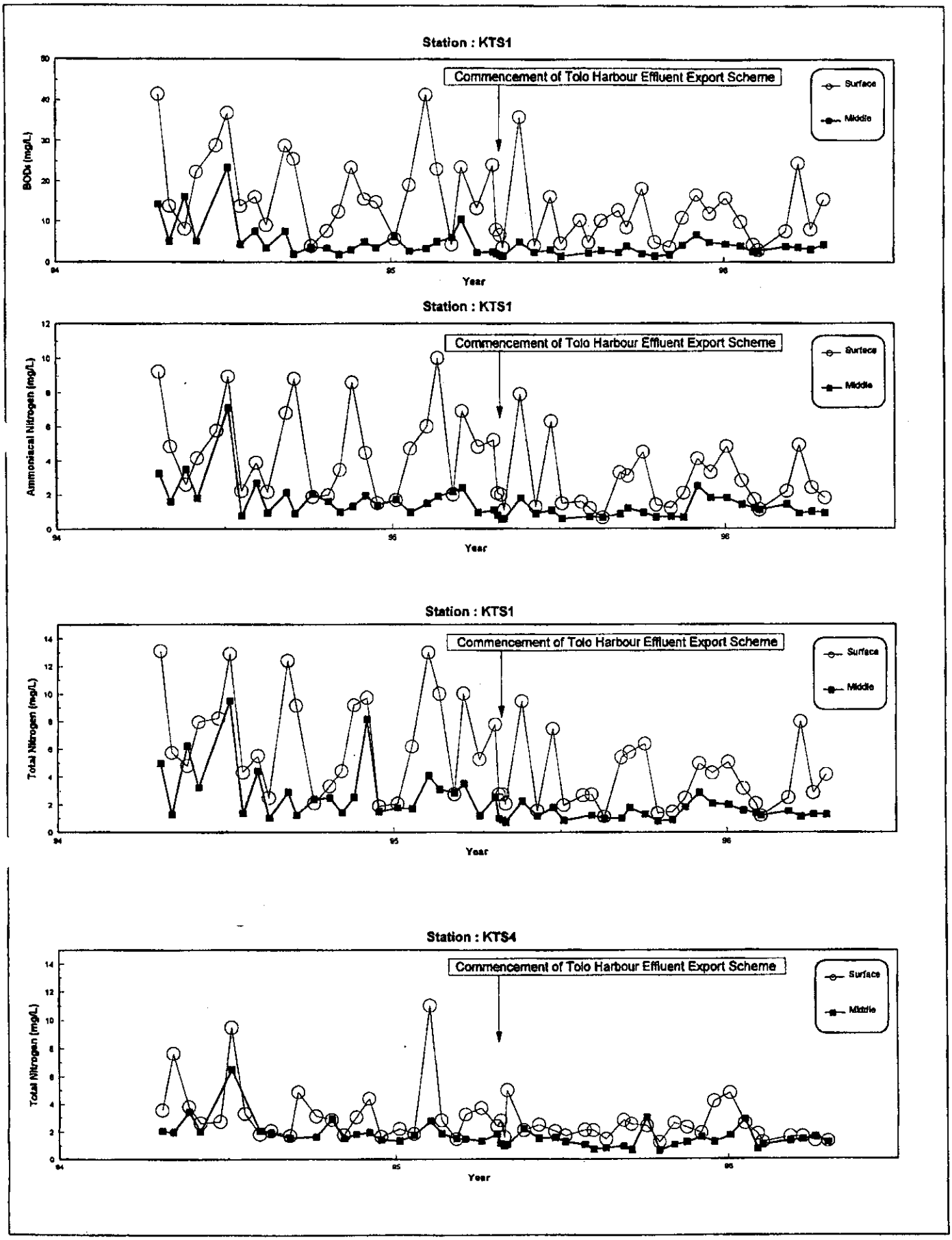

Figure 2 : Changes in 5-day biochemical oxygen demand, ammoniacal nitrogen and total nitrogen in various depths of the stations KTS1 and KTS4 in Kwun Tong Typhoon Shelter before and after the commencement of the Tolo Harbour Effluent Export Scheme

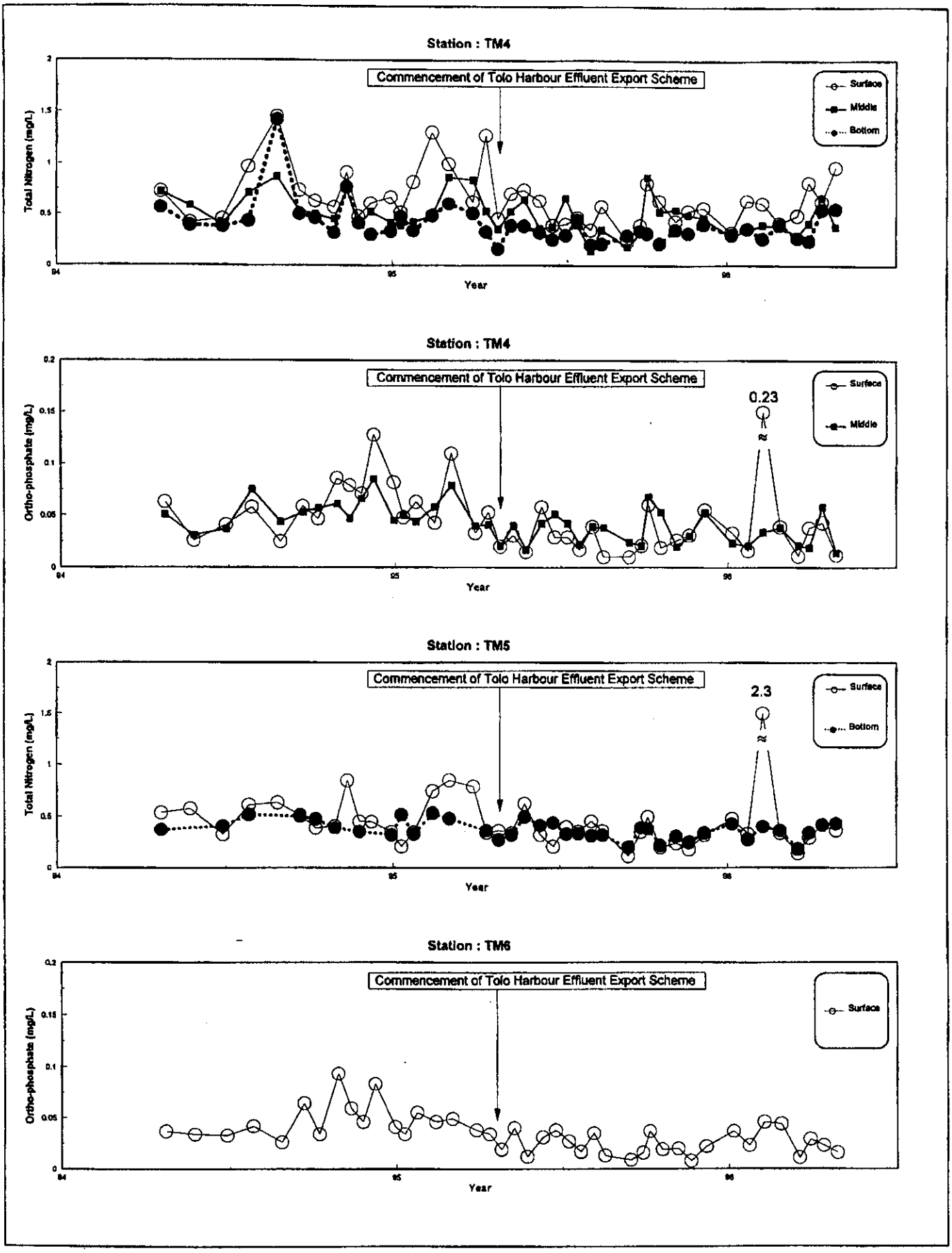

Figure 3 : Changes in total nitrogen and ortho-phosphate in various depths of the stations TM4, TM5 and TM6 in Tolo Harbour before and after the commencement of the Tolo Harbour Effluent Export Scheme