THE EFFECTS OF AMMONIA IN DISCHARGES FROM HOGSMILL VALLEY SEWAGE TREATMENT WORKS ON THE WATER QUALITY OF THE RIVER THAMES AT TEDDINGTON

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1. <u>Summary</u>

This report examines the effects of ammonia in discharges from Hogsmill STW on the quality of the River Thames at Teddington. Data from the automatic water quality monitoring station at Teddington for the period between 1987 and 1989 were used, and the performance of Hogsmill STW was assessed using data for the same period supplied by Thames Water Utilities PLC. Several objectives were set and the relevant investigations were undertaken. Results were used to define those areas in which the works had the greatest effect on the River Thames. Such a study can be used to augment other available information when assessing and reviewing discharge consent standards and conditions for Hogsmill STW.

2. Introduction

The aims of this study were to investigate and assess the effects of ammonia in discharges from Hogsmill Valley Sewage Treatment Works (STW) on the quality of the River Thames at Teddington. Various objectives of study were set at the start of the project and the relevant investigations were undertaken. These objectives were as follows:

A. To ascertain whether a significant relationship exists between the ammonia concentrations in the STW'S final effluent and those in the River Thames at Teddington.

B. To demonstrate that there is a diurnal pattern of ammonia concentrations in the final effluent from the STW and that this pattern is replicated in the Thames at Teddington after a time of travel of ammonia between the confluence of the Hogsmill River with the River Thames at Kingston and the River Thames at Teddington.

C. To calculate and compare loadings in the effluent from the STW's with those in the River Thames at Teddington.

D. To investigate the effect of ammonia concentration on levels of dissolved oxygen (D.O.) in the River Thames at Teddington.

E. To indicate the effects of storm sewage discharged from the STW on the ammonia concentrations in the River Thames and its subsequent effects on the levels of D.O. in the river.

F. To examine the levels of toxic unionised ammonia in the River Thames at Teddington in relation to the discharge of total ammonia in the STW's final effluent.

Data for the three year period between 1987 and 1989 were available for the purpose of this study.

3. Objectives : Methods and Results

The six objectives prepared for this investigation were considered singularly and methods of analysis and results are given below.

3.1 Objective A: Relationship between ammonia concentration in Hogsmill Valley STW Final Effluent and in the River Thames at Teddington.

Statistical analysis was used to establish the existence of a significant relationship. A regression line of daily ammonia concentrations in the final effluent, and mean ammonia concentration in the Thames at Teddington was plotted for those days where flows at Teddington were less than 20 cumecs and rainfall was less than 2 mm. Data were tested statistically and a significant relationship was found to exist. A positive correlation was found indicating that as the ammonia concentrations in the effluent increases, the ammonia concentrations in the River Thames increases.

3.2 Objective B: Comparison of Diurnal Patterns of Ammonia in the Hogsmill Valley STW's Final Effluent and in the River Thames at Teddington.

To compare the diurnal patterns of ammonia in the final effluent and in the River Thames, certain days were selected which had fulfilled the following criteria:

(a) Flows at Teddington were less than 20 cumecs for several consecutive days and were fairly constant throughout the period so that fluctuations which may have caused interferences in the comparison were eliminated.

(b) The days had no, or minimum rainfall (less than 3 mm).

(c) No storm sewage entered the river from Hogsmill Valley STW on the day in question.

Consecutive day periods were chosen so that diurnal patterns could be demonstrated and compared. Examples are given below:

I	03.10.87	to	06.10.87
II	25.11.88	to	28.11.88
III	19.09.88	to	23.09.88

These periods are presented graphically in Figs. 1-6. For each period a graph of diurnal ammonia concentrations in the final effluent and a graph of diurnal ammonia concentrations in the River Thames has been plotted.

These graphs clearly demonstrate the influence of the final effluent from Hogsmill STW on the River Thames. A diurnal pattern, showing peaks and troughs, of ammonia is evident in the final effluent from Hogsmill STW, and this pattern is replicated in the Thames after a time of travel of ammonia between the confluence of the Hogsmill River with the Thames, and the monitoring station at Teddington. The time-scale of the River Thames diurnal pattern has been adjusted to take the travel time into account so graphs can be compared. The time of travel can be calculated from the flow of the river and distance travelled by:

$$\text{Velocity of Water} = \frac{\text{Flow of river}}{\text{cross-sectional area (i.e. width x depth)}}$$

$$\text{and Time of Travel} = \frac{\text{Distance Travelled}}{\text{Velocity of Water}}$$

3.3 Objective C: Calculation of Loadings of Ammonia in the Final Effluent and in the River Thames at Teddington

The loadings of ammonia were calculated and compared to verify whether or not Hogsmill STW were responsible for the majority of the ammonia loadings in the Thames at this point. Table 1 gives some examples of the loadings for various days for which data was analysed.

FIG 2: DIURNAL AMMONIA CONCENTRATIONS - HOGSMILL VALLEY STW EFFLUENT
3.10.87 - 6.10.87

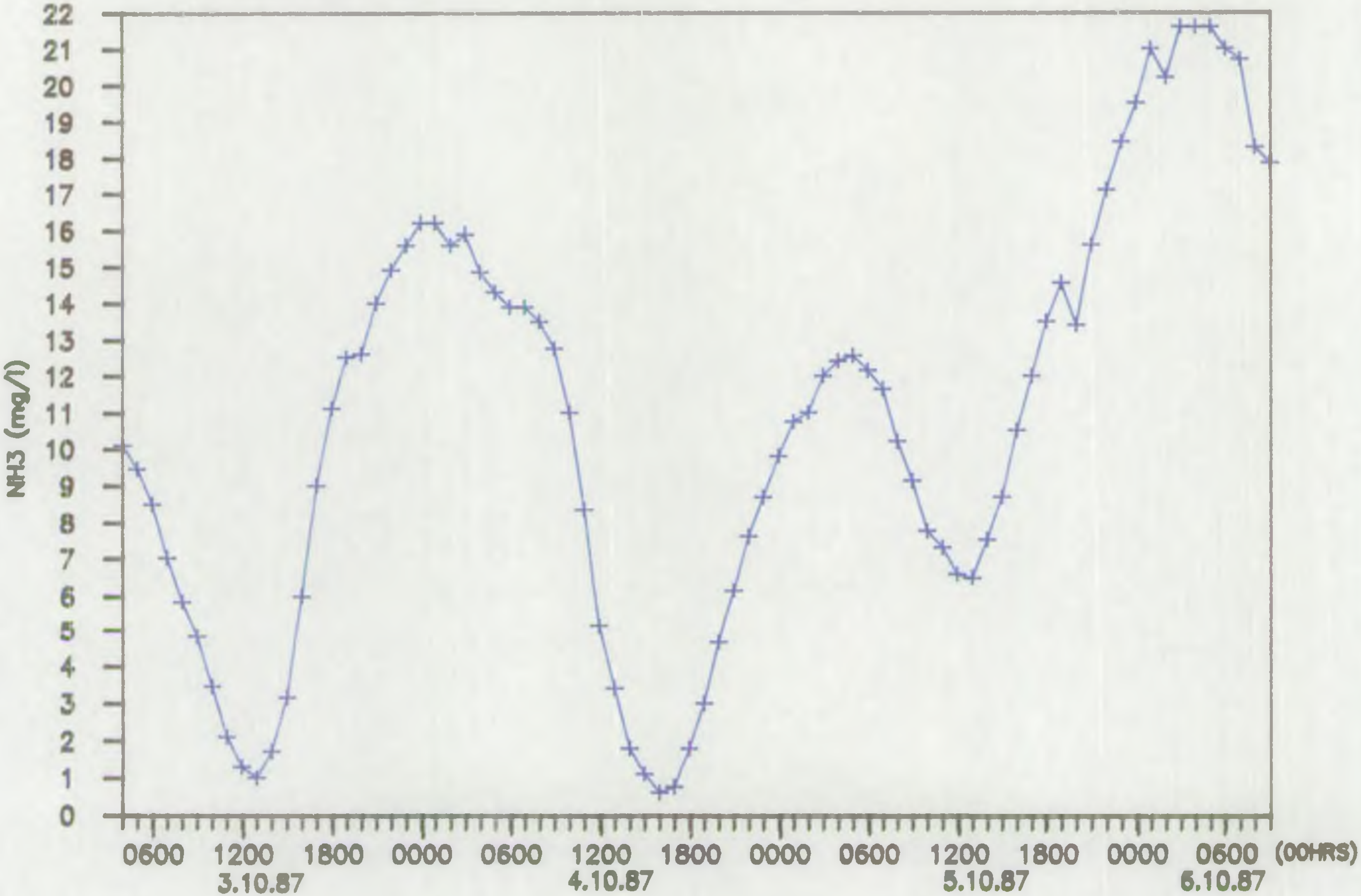


FIG 4: DIURNAL AMMONIA CONCENTRATIONS – HOGSMILL VALLEY STW EFFLUENT 25.11.88 – 28.11.88

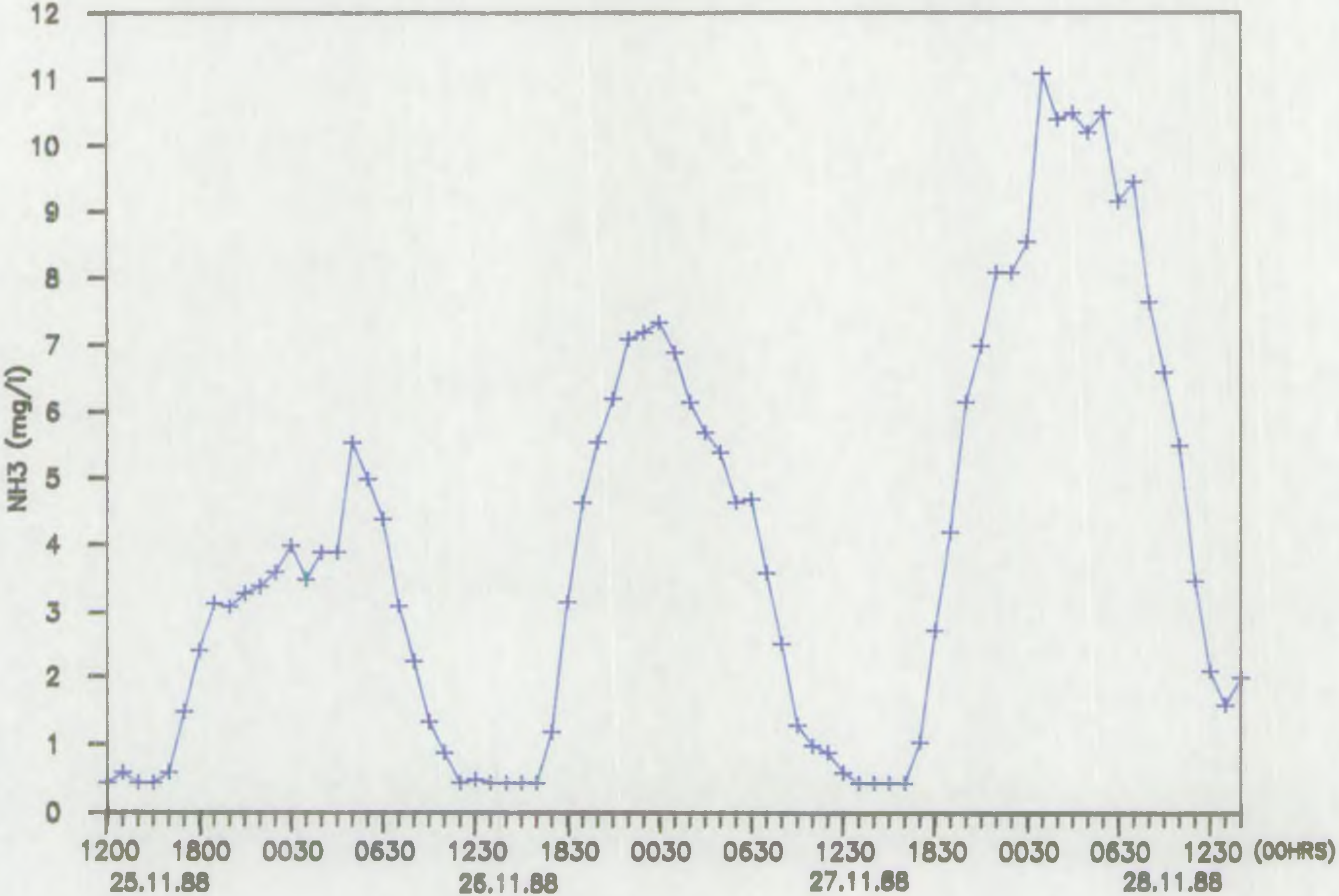
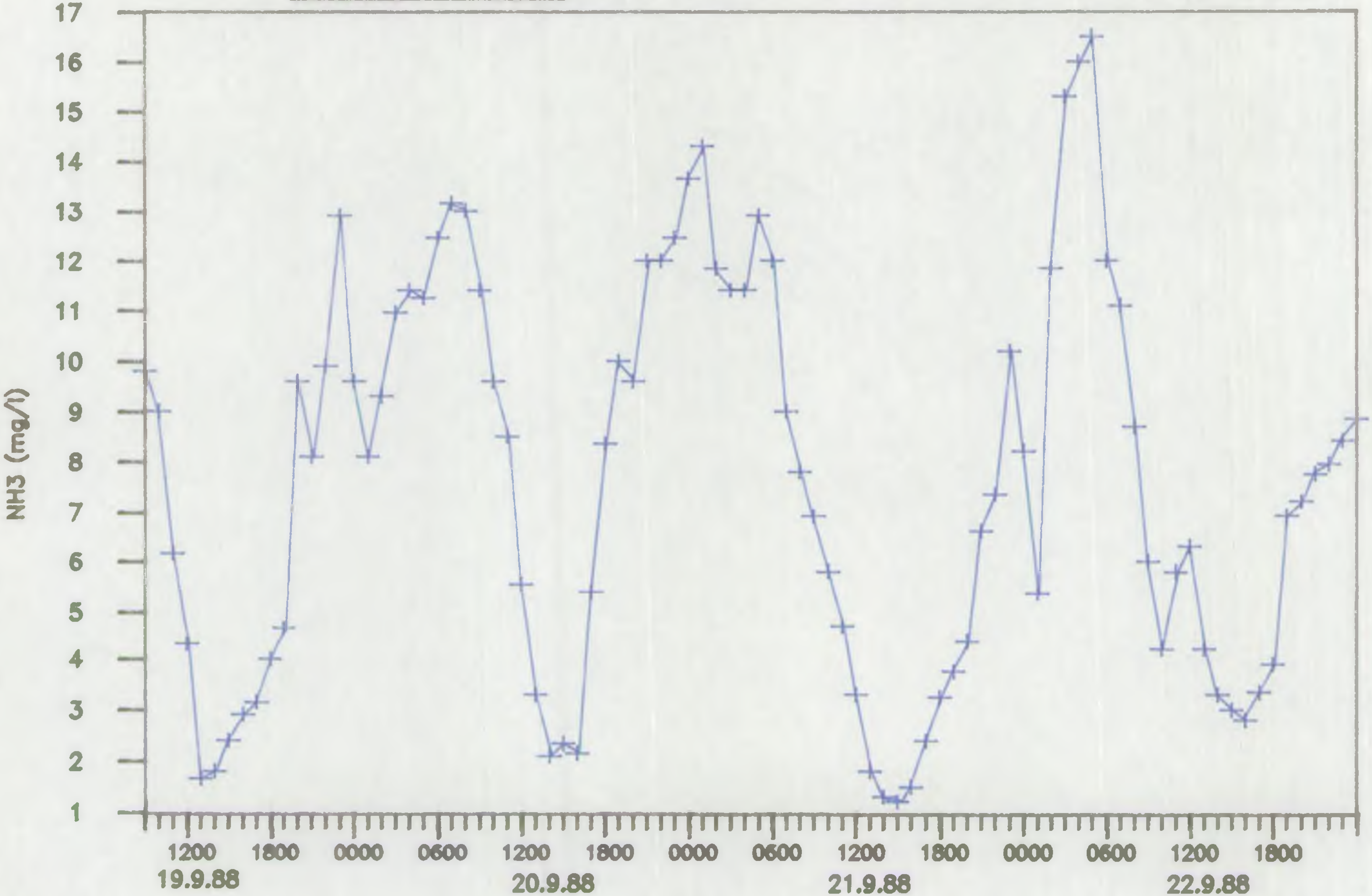


FIG 6: DIURNAL AMMONIA CONCENTRATIONS - HOGSMILL STW EFFLUENT 19.9.88 - 22.9.88



Loadings were calculated using the following equation:

$$\text{Loadings of } NH_3 (Kg/d) = \text{Mean daily flow } (m^3/d) \times \text{Mean } NH_3 \text{ in solution } (Kg/m^3)$$

The daily loadings in Hogsmill Valley STW's final effluent were calculated from the mean flow of the effluent from the works and the ammonia content of the effluent. For loadings at Teddington, the mean flow gauged at Teddington were used and mean daily ammonia concentrations at Teddington were calculated from data.

The results in Table 1 show that the loadings in the final effluent and in the Thames are very similar. In a majority of cases shown here, the loadings in Hogsmill STW's final effluent are greater than in the Thames indicating that Hogsmill STW is responsible for most of the ammonia in the Thames at Teddington. On regression and correlation analysis a significant positive correlation between the loadings in the effluent and mean loadings in the River Thames was established. Therefore a strong relationship exists and results point to greater evidence that Hogsmill STW affects the River Thames at Teddington.

It must be pointed out that "mean" loadings were calculated for the River Thames, as shown in Table 1. This was done to enable better comparison of the loadings at both locations. By taking into account the time of travel of ammonia between the confluence of the Hogsmill River with the River Thames, and the River Thames at Teddington, loadings had to be calculated for the relevant days covering the travel time. Therefore, temporal errors were eliminated by taking a mean of these loadings.

3.4 Objective D: Investigation of the Effects of Ammonia Concentrations on Levels of D.O. in the River Thames at Teddington.

This investigation was undertaken using data collected over the summer months of 1989 because of the dry conditions experienced over this period. The study of D.O. levels was carried out in several stages, as described below:

TABLE 1 COMPARISON OF AMMONIA LOADINGS IN HOGSMILL STW FINAL EFFLUENT AND RIVER THAMES AT TEDDINGTON

Date	NH3 Loadings (Kg/d) At:-			Time of Travel of NH3 (hours)
	Hogsmill	Teddington (Mean)	Difference	
03.10.87	615.85	527.39	88.46	15.47
04.10.87	482.40	556.42	-74.02	15.16
05.10.87	609.84	685.58	-75.74	12.63
06.10.87	627.76	627.53	00.23	16.14
19.09.88	475.57	373.25	102.32	14.53
20.09.88	413.88	390.88	23.00	16.76
21.09.88	313.91	353.61	-39.70	18.09
22.09.88	381.76	361.58	20.18	16.13
23.09.88	339.41	369.58	-30.17	12.03
06.02.89	662.34	760.49	-98.15	10.69
07.02.89	647.28	558.49	88.79	17.26
08.02.89	472.46	484.45	-11.99	19.72
12.02.89	397.49	412.13	-14.64	16.44
13.02.89	481.28	400.46	80.82	16.93
14.02.89	425.90	469.07	-43.17	14.29
27.06.89	949.16	885.05	64.11	15.16
28.06.89	480.71	676.05	-195.34	19.20
04.09.89	121.44	108.00	13.44	37.89
05.09.89	92.53	84.81	7.72	32.08
06.09.89	88.20	78.78	9.42	28.58

3.4.1 Diurnal Patterns of D.O.

In order to assess the effects of ammonia on D.O., it was deemed necessary to establish the existence of a diurnal pattern of D.O. in the River Thames at Teddington. Data was examined for days where ammonia concentrations in the Thames were at baseline levels of 0.2 mgl^{-1}, so that any diurnal changes in D.O. were evident.

Figs. 7 and 8 represent two periods over which ammonia concentrations were minimal. Diurnal patterns of D.O. are clearly visible in these graphs. Daytime maxima of 85-100% occur between the hours of 13.50 and 19.50 and night time minima occur in the early hours of the morning (03.50 - 08.50 hours), where D.O. levels fall to between 65-75%. This D.O. pattern appears to be the normal pattern for those days where there is little or no rain, where river flows are less than twenty cumecs and where there is a long duration of sunshine throughout the day.

3.4.2 Fluctuations in D.O. in the River Thames at Teddington with Fluctuating Ammonia Concentrations

It has been established, vide supra, that a diurnal pattern of D.O. exists where ammonia levels in the River Thames are constant at low concentrations and environmental conditions are constant. These results can be used as a background picture to investigate the effects of fluctuating ammonia concentrations (away from baseline), and changes in weather conditions.

Two examples of periods where fluctuations in ammonia concentrations and/or environmental conditions are shown to have an effect on D.O. are considered below.

A. Example 1 : 9.9.89 - 20.9.89

Ammonia concentrations and D.O. percentage saturations for this period are graphically presented in Figs. 9, 10 and 11. Fig. 9 shows the period between 9.9.89 and 12.9.89. As can be seen the D.O. levels no longer demonstrate a diurnal day-maximum, night-minimum pattern. This is because between 9.9.89 and 12.9.89, there was a total absence of recorded sunshine

FIG 7: DIURNAL DISSOLVED OXYGEN % SATUARATION – R. THAMES, TEDDINGTON

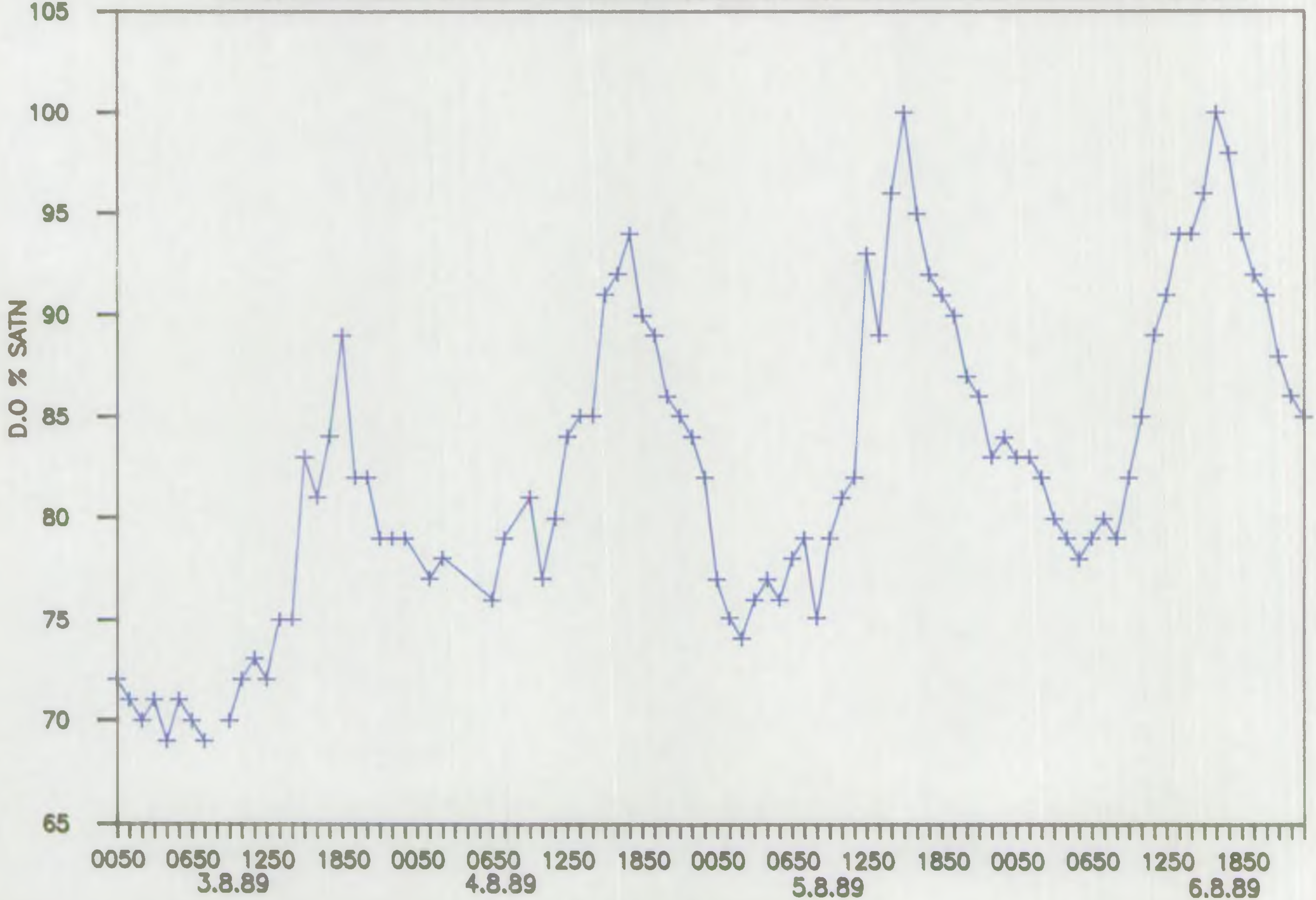
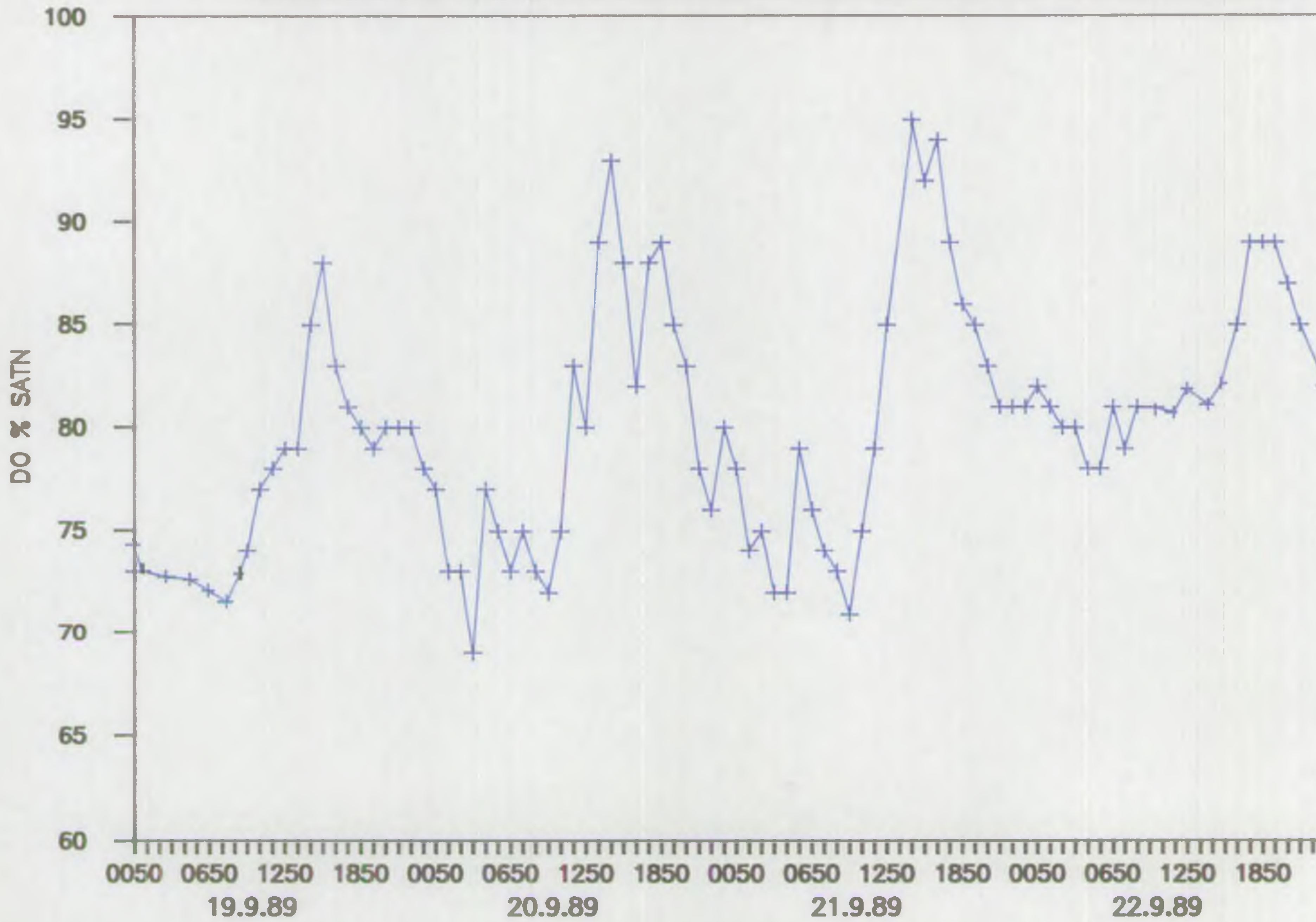


FIG 8: DIURNAL DISSOLVED OXYGEN % SATURATION – R. THAMES, TEDDINGTON



hours. The D.O. saturations are constant and show a flattening of the previously observed diurnal pattern when high illumination was recorded. On 9.9.89 and 10.9.89 the D.O. levels fluctuated little between 70% and 80%. Over this time ammonia concentrations are at baseline levels of 0.2 mgl^{-1} and flows for the whole period are less than 20 cumecs. On 11.9.89 and 12.9.89 the ammonia concentrations increase very slightly above baseline levels. D.O. levels are seen to drop down to between 60% and 70% but this cannot be conclusively tied with the ammonia concentrations and can probably be accounted for by the continual low level and duration of sunshine. For 12.9.89 and 13.9.89 the hours of sunshine had only increased to 0.2 hours and this has had the effect of keeping D.O. levels flattened and at a low level of below 70%.

After 13.9.89 (Fig. 10) the level and duration of sunshine increased only slightly until 18.9.89 after which the sunshine hours increased up to 6.9 - 10.9 hours (Fig. 11). The slight increase in sunshine has caused the appearance of a diurnal pattern of D.O. but this pattern is not marked and daytime levels are still below 70% with night-time minima of greater than 55%. Ammonia increased on 14.9.89 and 15.9.89 up to and exceeding 0.4 mgl^{-1} but the D.O. levels at this point in the River Thames did not appear to decrease as a result.

From 17.9.89 to 20.9.89 (Fig. 11), a diurnal pattern of D.O. is re-established. However, over this period the ammonia concentrations were seen to increase dramatically which was a result of high loadings of ammonia in the final effluent from Hogsmill STW (loadings in the final effluent increased from 188 Kg/d on 15.9.89 to 566.4 Kg/d on 18.9.89, causing loadings to increase at Teddington). As can be seen, D.O. levels do not decrease with the increase in ammonia. Minima of D.O. saturation are above 55% with daytime maxima between 70% and 80%. It must be pointed out that daytime maxima are not as high as demonstrated in Figs. 7 and 8, which may be due to the high ammonia concentrations but these levels of ammonia do not cause the D.O. to drop lower than the minima resulting from the absence of sunshine. It is therefore apparent that environmental conditions such as the level of the sun's irradiation are fundamental in determining the saturation of D.O. in the River Thames at Teddington.

FIG 9: PATTERNS OF TOTAL AMMONIA & DISSOLVED OXYGEN IN THE R. THAMES, TEDDINGTON

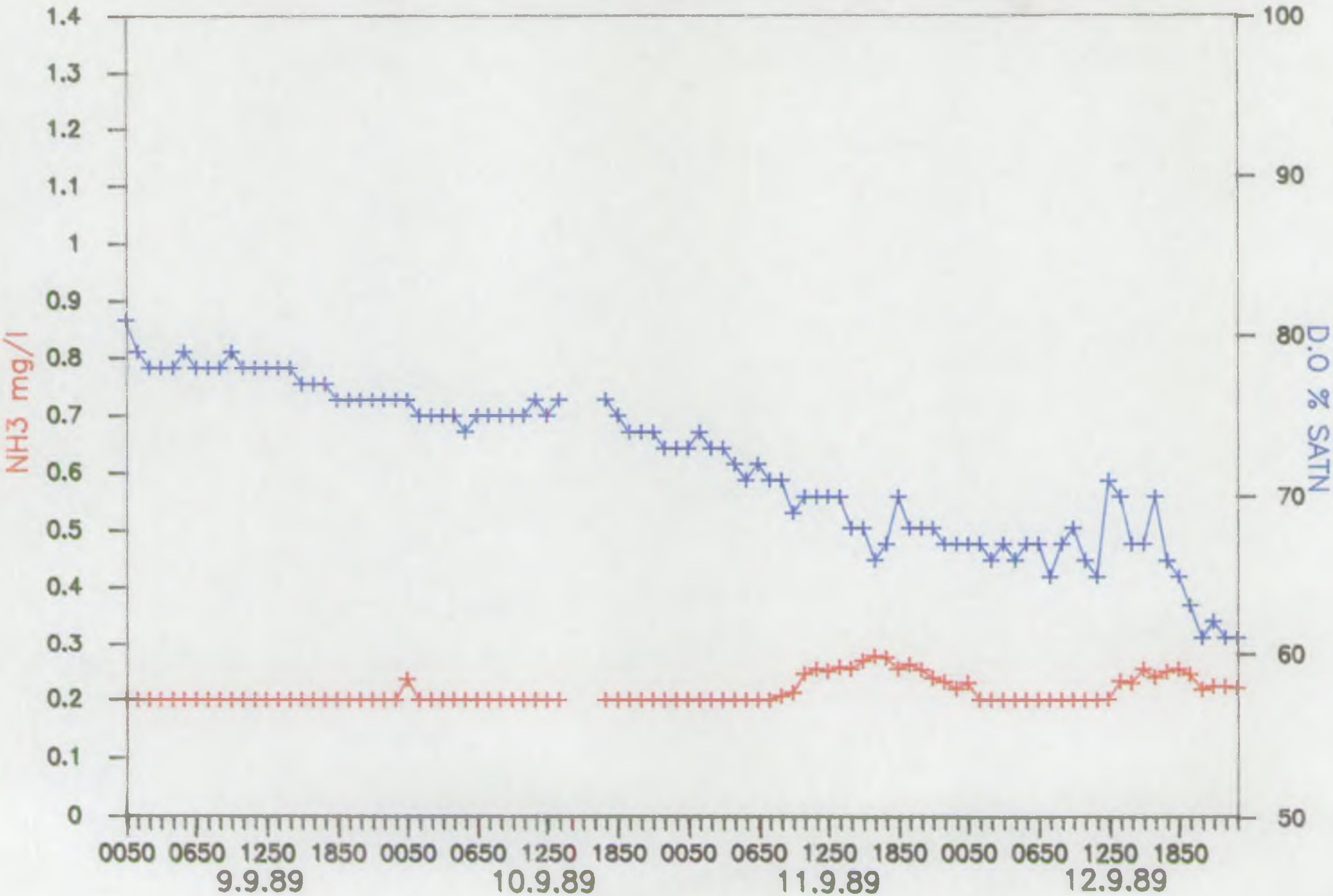


FIG 10: PATTERNS OF TOTAL AMMONIA & DISSOLVED OXYGEN IN R. THAMES, TEDDINGTON

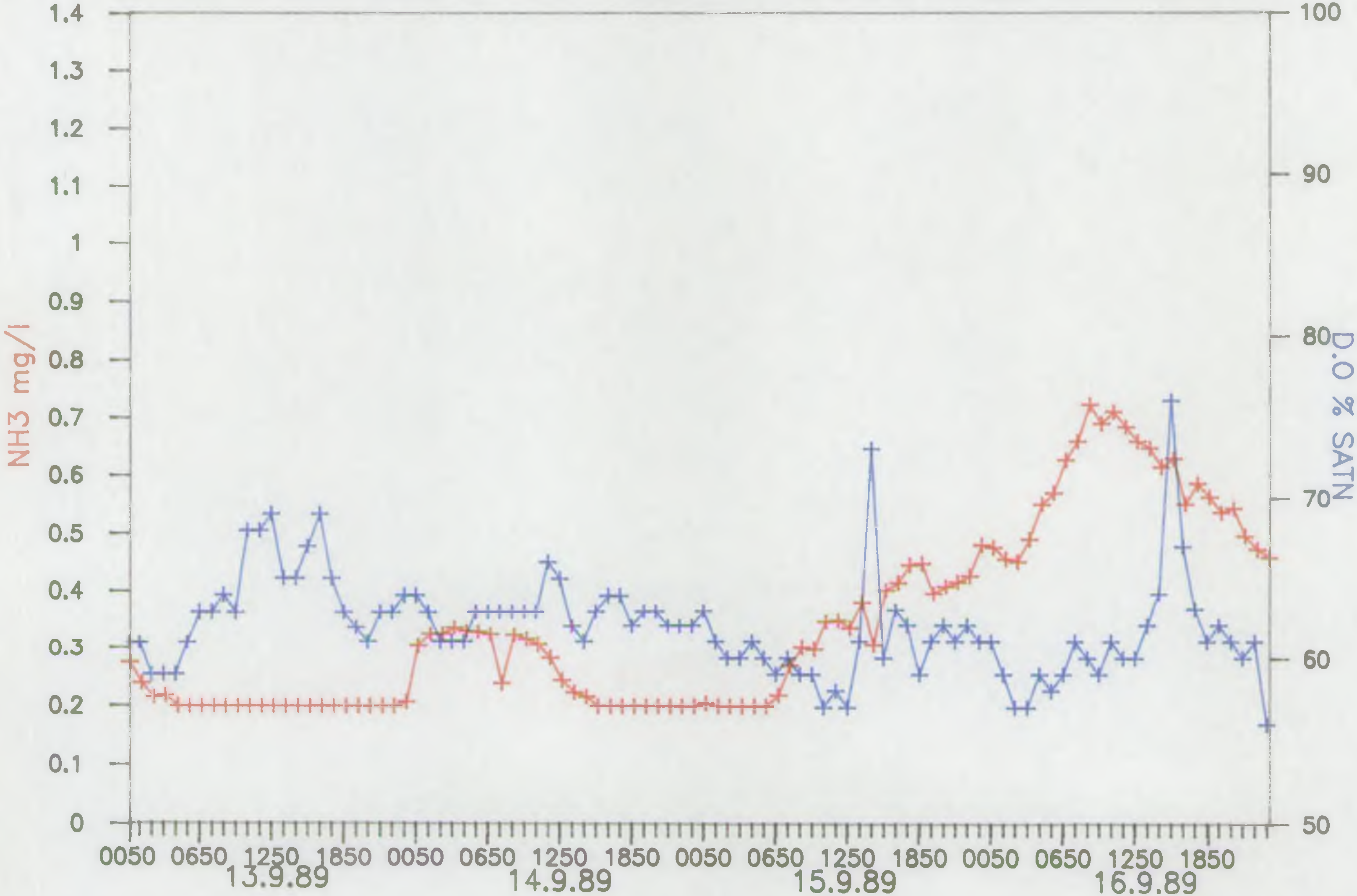
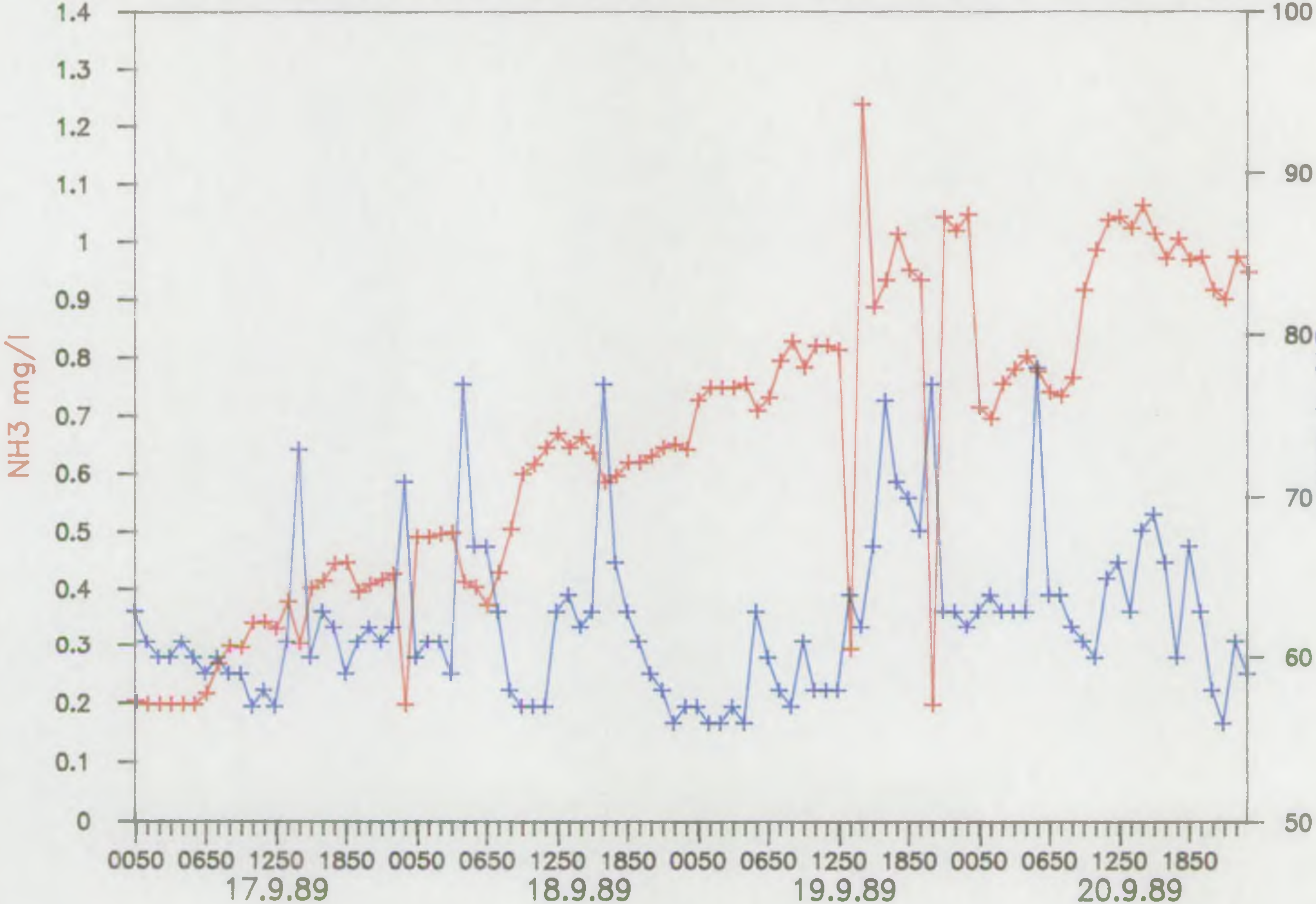


FIG 11: PATTERNS OF TOTAL AMMONIA & DISSOLVED OXYGEN IN R. THAMES, TEDDINGTON



B. Example 2 : 26.7.89 - 6.8.89

Results for ammonia concentrations and D.O. over this period have been plotted graphically in Figs. 12, 13 and 14.

The first period between 26.7.89 and 29.7.89 (Fig. 12) demonstrates the now familiar diurnal pattern of D.O. Levels of ammonia are at baseline and fluctuations of D.O. range from 110% during the day and down to 75-80% at night. The hours of sunshine over this period are very high (7.2 - 9.7 hours) causing the high daytime D.O. via the algal photosynthetic pathway.

On 30.7.89 (Fig. 13), the duration of sunshine fell to 2.8 hours, and 5.6 mm of rainfall were recorded in Central London. The diurnal pattern of D.O. for the day has changed dramatically because of the changed environmental conditions and the day maxima of D.O. has been flattened and there is no peak of oxygen evident on this day.

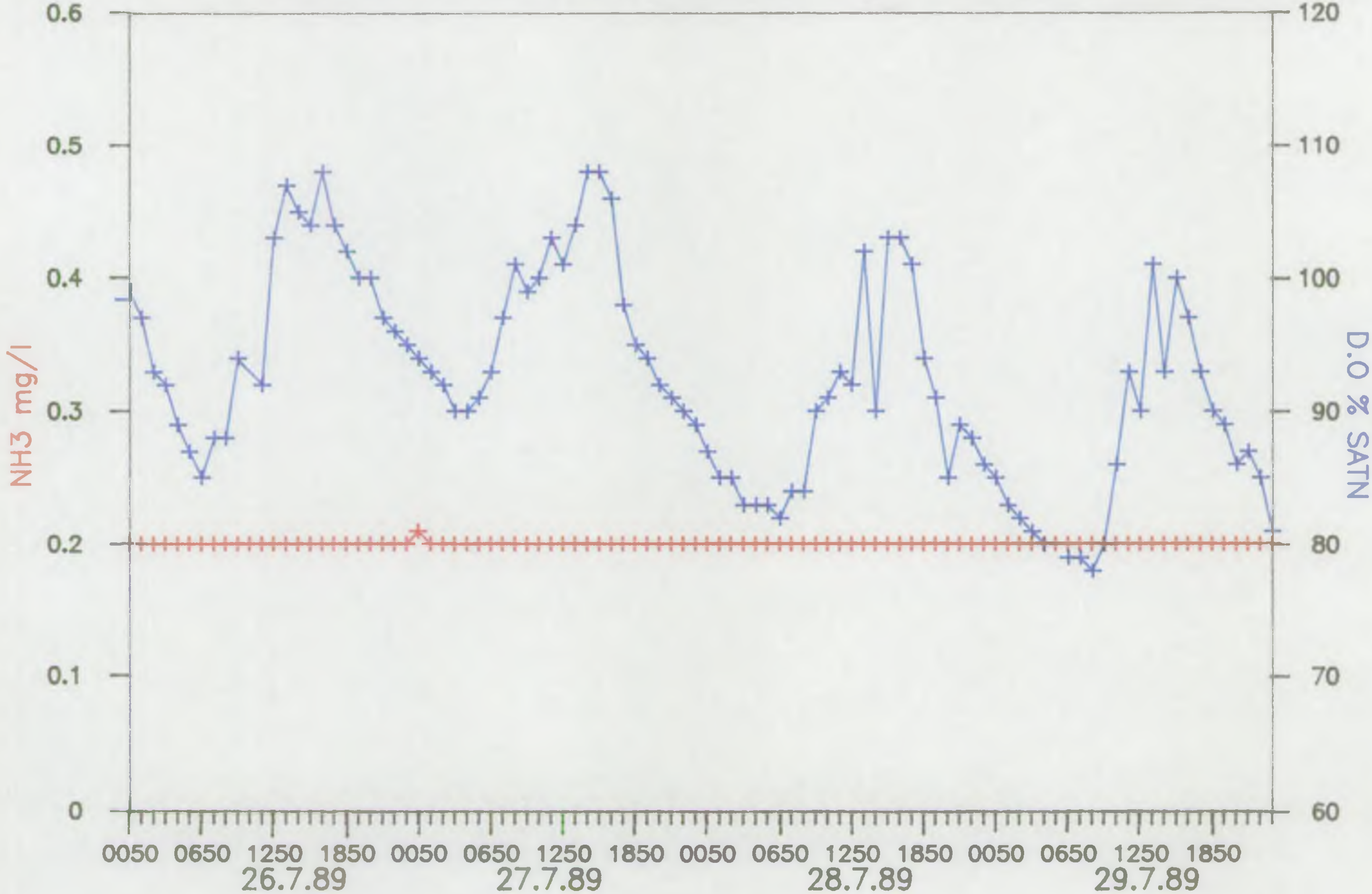
Hogsmill Valley STW discharged 18.10 mgl^{-1} of storm sewage ammonia into the Hogsmill River on 30.7.89. It was calculated that it would take 22 hours for the first flush of storm sewage ammonia to reach the River Thames at Teddington.

In Fig. 13 the ammonia concentrations in the River Thames are seen to increase up to 0.335 mgl^{-1} on 31.7.89 as a result of the storm sewage ammonia reaching Teddington. The D.O. saturation decreases to a level just above 60% at this time. The hours of sunshine are higher on 31.7.89 but the storm sewage has knocked the D.O. to this lower level. After 31.7.89, D.O. levels gradually recover although this process is slow at first. By 3.8.89 the sunshine levels are high and a diurnal pattern is fully re-established (Fig. 14).

3.4.3 Summary of Objective D

Investigation of the D.O. levels in the River Thames at Teddington over the summer months of 1989 has demonstrated some interesting effects. Flows of the River Thames over this period were low.

FIG 12: PATTERNS OF TOTAL AMMONIA & DISSOLVED OXYGEN AT R. THAMES, TEDDINGTON



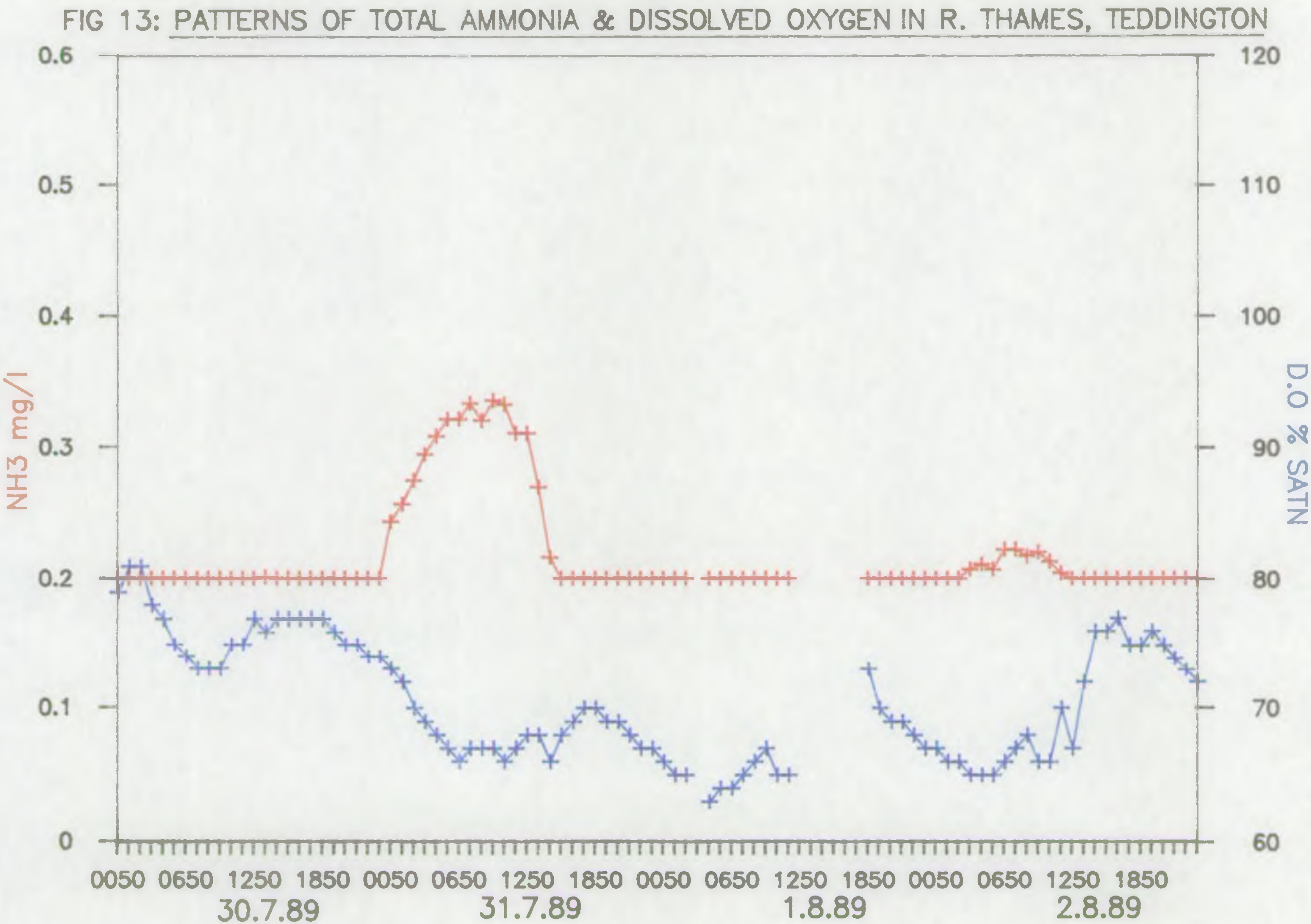
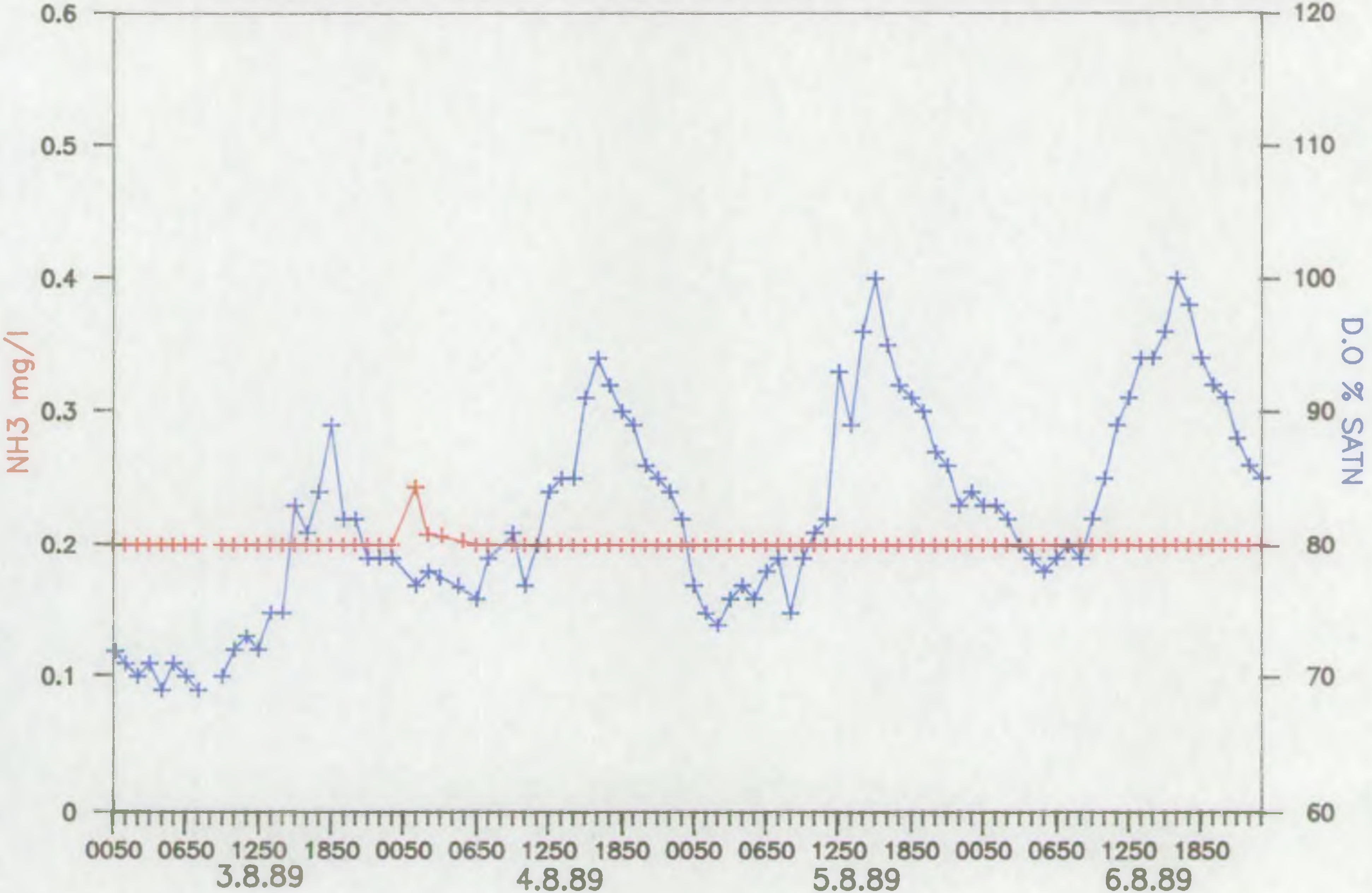


FIG 13: PATTERNS OF TOTAL AMMONIA & DISSOLVED OXYGEN IN R. THAMES, TEDDINGTON
0.6
0.5
0.4
0.3
0.2
0.1
0
NH3 mg/l
120
110
100
90
80
70
60
D.O % SATN
0050 0650 1250 1850 0050 0650 1250 1850 0050 0650 1250 1850 0050 0650 1250 1850
30.7.89
31.7.89
1.8.89
2.8.89

FIG 14: PATTERNS OF TOTAL AMMONIA & DISSOLVED OXYGEN IN R. THAMES, TEDDINGTON



It has been seen that the duration of sunshine has a marked effect on the level of D.O. in the Thames. Increased sunshine causes increased photosynthesis by algae in the river, in turn resulting in elevated daytime D.O. saturation. Low levels of sunshine cause the diurnal pattern of D.O. to be lost and oxygen levels decrease.

The effects of elevated ammonia concentration on D.O. concentration (which was the purpose of Objective D), have not been significantly demonstrated apart from those caused by storm sewage. Where Hogsmill STW performs poorly, and ammonia concentrations are high in the effluent, the effects on the River Thames oxygen saturation appear minimal. The level of sunshine has a much more prevalent effect, and even when there is no sunshine, ammonia concentrations are high and flows in the river are very low, the D.O. levels did not fall below 50%.

3.5 Objective E : The effects of Storm Sewage Discharged from the STW on the Ammonia Concentrations and D.O. levels in the Thames

As has been demonstrated in Fig. 13, storm sewage overflows from Hogsmill STW does appear to have a visible effect on ammonia concentrations in the River Thames at Teddington. Further examples of this effect, and the effect on D.O. levels are discussed below. Certain criteria were set for the days selected for investigation to eliminate, as best as possible, other factors that would unduly affect the results:

(i) Storm sewage overflow into the Hogsmill River from the works.

(ii) Flows at Teddington were less than 20 cumecs on days before storm sewage is discharged.

(iii) Rainfall was greater than 5 mm on the day.

For each day used as an example of the effects of storm sewage overflows, changes in weather conditions, river flows and the extent of storm sewage overflows were examined.

1. Example A : 7.7.89

Fig. 15, shows the ammonia concentration and D.O. saturation in the Thames. On 7.7.89, storm sewage was discharged from Hogsmill STW, which contained an ammonia concentration of 8.20 mgl^{-1}. Rain on 7.7.89 caused increased river flows at 03.50 hours and it is likely that storm sewage was discharged at approximately this time. The time of travel of the storm sewage ammonia from the confluence of the Hogsmill River with the River Thames at Teddington was calculated to be 09.03 hours. Therefore, a peak of ammonia would be expected in the River Thames at Teddington at approximately 12.50 hours. As shown in Fig. 15, a peak was visible between 12.50 - 14.50 hours which was caused by the storm sewage ammonia.

There were no recorded hours of sunshine on 7.7.89 which, until mid-day has caused the oxygen levels to be flattened and lower than recorded on the previous day. At the time of the peak in ammonia caused by the storm sewage the oxygen levels drops considerably, down to 65%. The first flush of storm sewage will have high levels of ammonia, high concentrations of suspended solids and a high BOD, and all three will cause the oxygen levels in the river to be depleted. In fact, the BOD of the storm water was 46 mgl^{-1} which is very high and will deplete D.O. markedly.

On 8.7.89, continued rain causes an increase in flow, so diluting the storm sewage, and causes the ammonia levels to fall to baseline levels. Oxygen levels are high, but have not returned to a normal diurnal pattern owing to a low level of sunlight.

2. Example B : 10.8.89

Results of ammonia concentrations and D.O. levels are presented in Fig. 16. On 9.8.89, ammonia concentrations in the Thames are at baseline level, and a diurnal pattern of D.O. is apparent, with a daytime peak of 100% and night time trough of greater than 70%.

This pattern alters dramatically on the 10.8.89, when storm sewage is discharged from the works with a flow of 27 tcmd and an ammonia concentration of 10.9 mgl^{-1}. There was heavy rain on this day, the heaviest falling between 08.00 and 11.00 hours. This indicates that the

FIG 15: PATTERNS OF AMMONIA & DISSOLVED OXYGEN IN R. THAMES, TEDDINGTON WITH STORM SEWAGE DISCHARGED FROM HOGSMILL STW ON 7.7.89

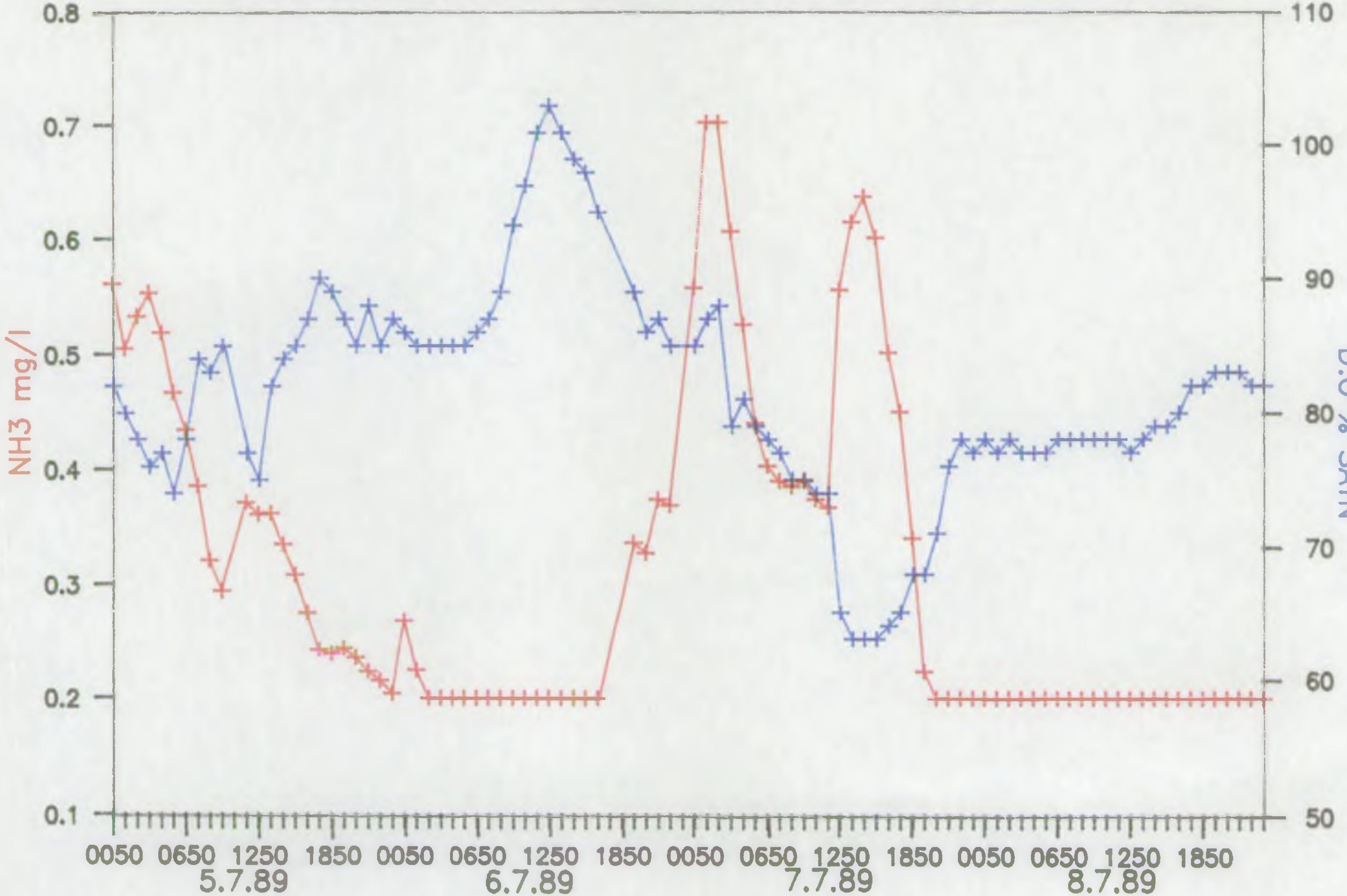
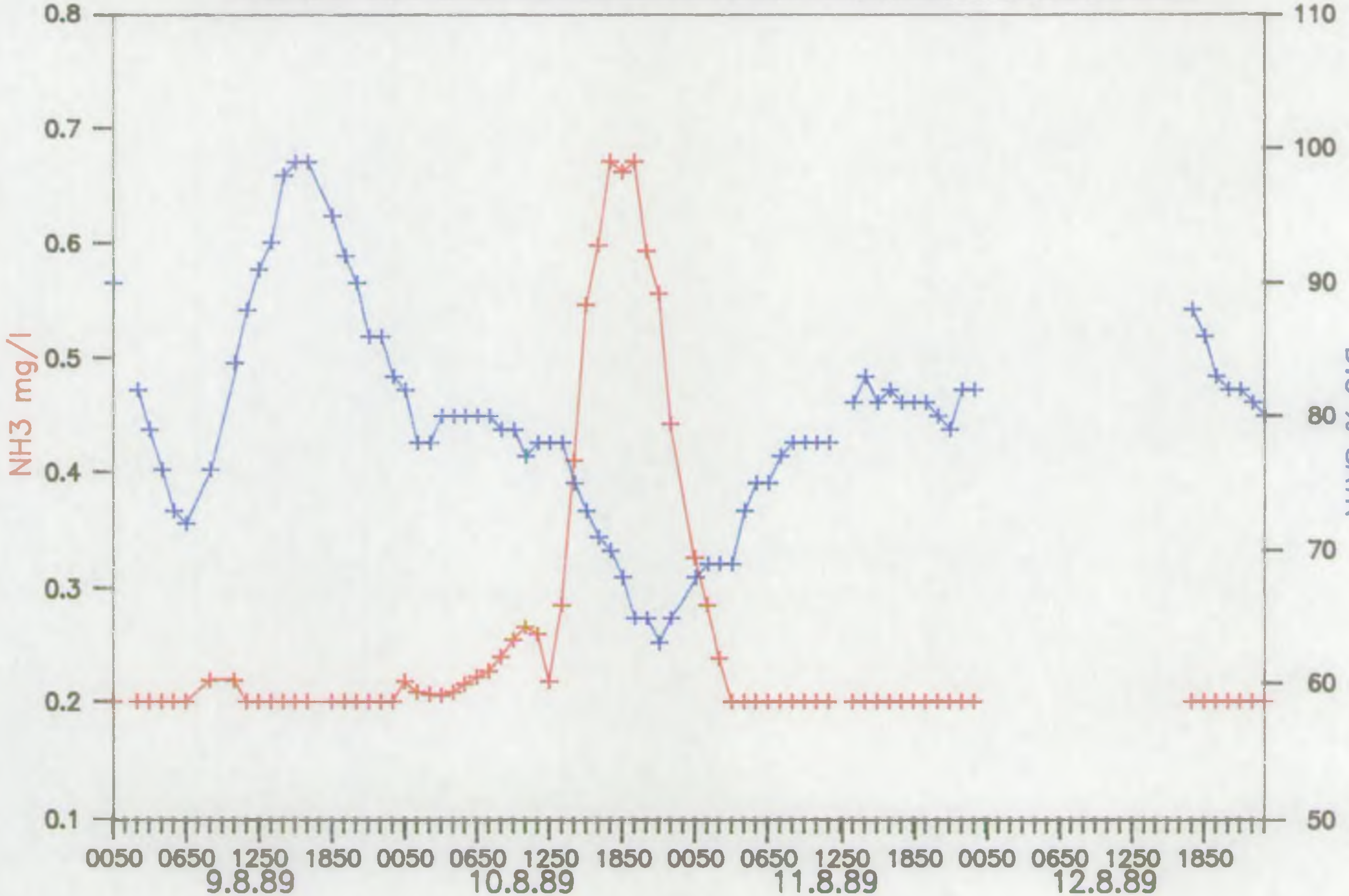


FIG 16: PATTERNS OF AMMONIA & DISSOLVED OXYGEN IN R. THAMES, TEDDINGTON WITH STORM SEWAGE DISCHARGED FROM HOGSMILL STW ON 10.8.89



likely time of storm sewage overflowing from the works will also be between 08.00 and 11.00 hours. The time of travel of ammonia was calculated at 7.71 hours. Therefore a peak of ammonia in the River Thames at Teddington would be expected between the estimated times of 15.45 and 18.45 hours. A peak of ammonia was seen between 16.50 hours and 20.50 hours which must have been caused by the first flush of storm sewage discharged from the works. Peaks of BOD and suspended solids would also coincide with this ammonia peak.

The low level of sunshine on 10.8.89 can account for the flattening of the D.O. levels up to midday but after this time there is a dramatic decrease in the oxygen saturation which can be explained by the storm sewage affecting the river. On 11.8.89 and 12.8.89, the level of dissolved oxygen picks up with increased sunshine and dilution of the storm sewage.

3.5.1 Summary of Objective E

The results described above indicate that storm sewage is having an effect on the ammonia concentrations in the River Thames at Teddington. It would appear that the first flush of storm sewage is most detrimental to water quality. Levels of D.O. are seen to be initially affected by the loss of sunshine when the weather conditions deteriorate, but the arrival of storm sewage causes the D.O. to be severely depleted at Teddington. The storm sewage has been shown (graphically) to increase ammonia concentrations in the Thames. It will also increase the BOD and the concentration of suspended solids in the Thames. It is difficult to blame only one of these parameters for the dramatic depletion in D.O. It is likely that all these factors together are causing D.O. levels to decrease. The ammonia peaks in Figs. 15 and 16 are used as indicators of the effects of storm sewage from Hogsmill STW on the Thames. It has been conclusively shown that storm sewage has a detrimental affect by both increasing ammonia and decreasing D.O.

3.6 Objective F : Examination of Unionised Ammonia concentrations in the River Thames at Teddington

It has previously been established that the final effluent from Hogsmill Valley STW affects the quality of the River Thames at Teddington. When ammonia concentrations are high in the effluent, they have also been seen to be high in the Thames. Having already investigated the effects of ammonia concentrations on the D.O. levels, all that remains to complete the study is an examination of the levels of unionised ammonia. Unionised ammonia is the toxic part of the total ammonia. It is toxic to freshwater fish and invertebrates because it is uncharged and lipid soluble and therefore can permeate through membranes so affecting the vascular system, (Bauer et al, 1978).

The EEC Fishing Water Quality Directives give mandatory values of unionised ammonia for salmonids and cyprinids as 0.025 mgl^{-1} NH_3 (0.021 mgl^{-1} NH_3-N). EIFAC recommend a threshold concentration of 0.024 mgl^{-1} NH_3 and the EPA water quality standard is set at 0.02 mgl^{-1} NH_3 (Hellawell, 1988). These values for unionised ammonia are set in order to protect fish and invertebrate life. Above this concentrations, levels of unionised ammonia will be toxic to various species of fish and below it, sub-lethal effects on aquatic life may be observed with prolonged exposure.

Various environmental factors will affect the concentration of unionised ammonia. For example, with high pH and temperature, the proportion of unionised ammonia in solution will be greater, (EIFAC Technical Paper No. 11, 1970). The toxic effects of unionised ammonia may be greater after high peaks of ammonia such as storm sewage discharges, and it has been seen that fluctuating concentrations such as diurnal fluctuations, may be more toxic to aquatic life than constant concentrations.

The investigation into levels of unionised ammonia in the River Thames caused by Hogsmill Valley final effluent was carried out using data for the summer of 1989 only. Relevant data for interpreting the effects of the STW on levels of unionised ammonia in the Thames are plotted in Figs. 17, 18, and 19. These graphs tend to highlight trends which occurred over the summer months.

FIG 17: UNIONISED AMMONIA CONCENTRATIONS IN R. THAMES, TEDDINGTON JUNE - OCTOBER 1989

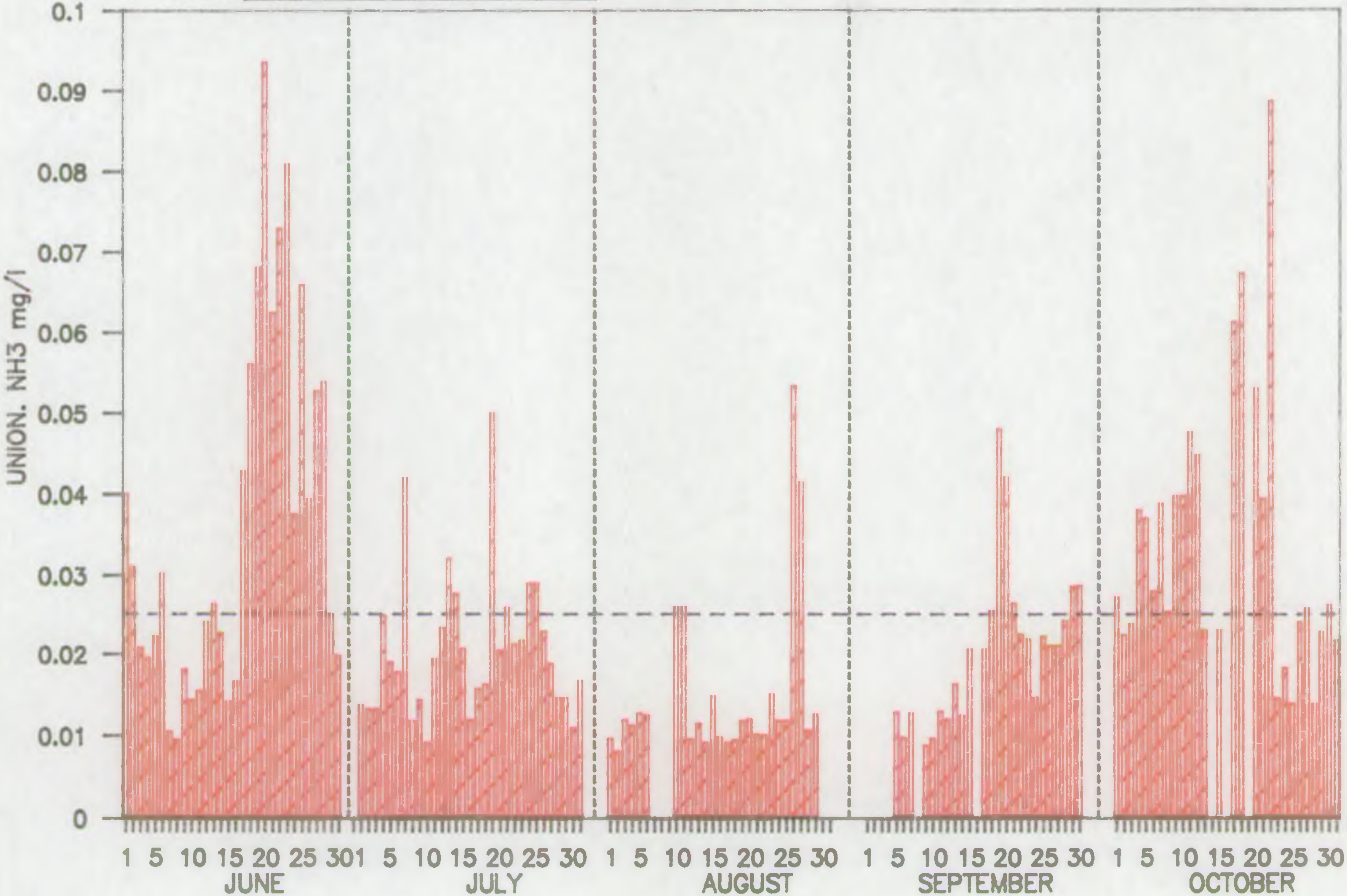


FIG 18: TOTAL AMMONIA CONCENTRATIONS IN HOGSMILL STW FINAL EFFLUENT JUNE – OCTOBER 1989

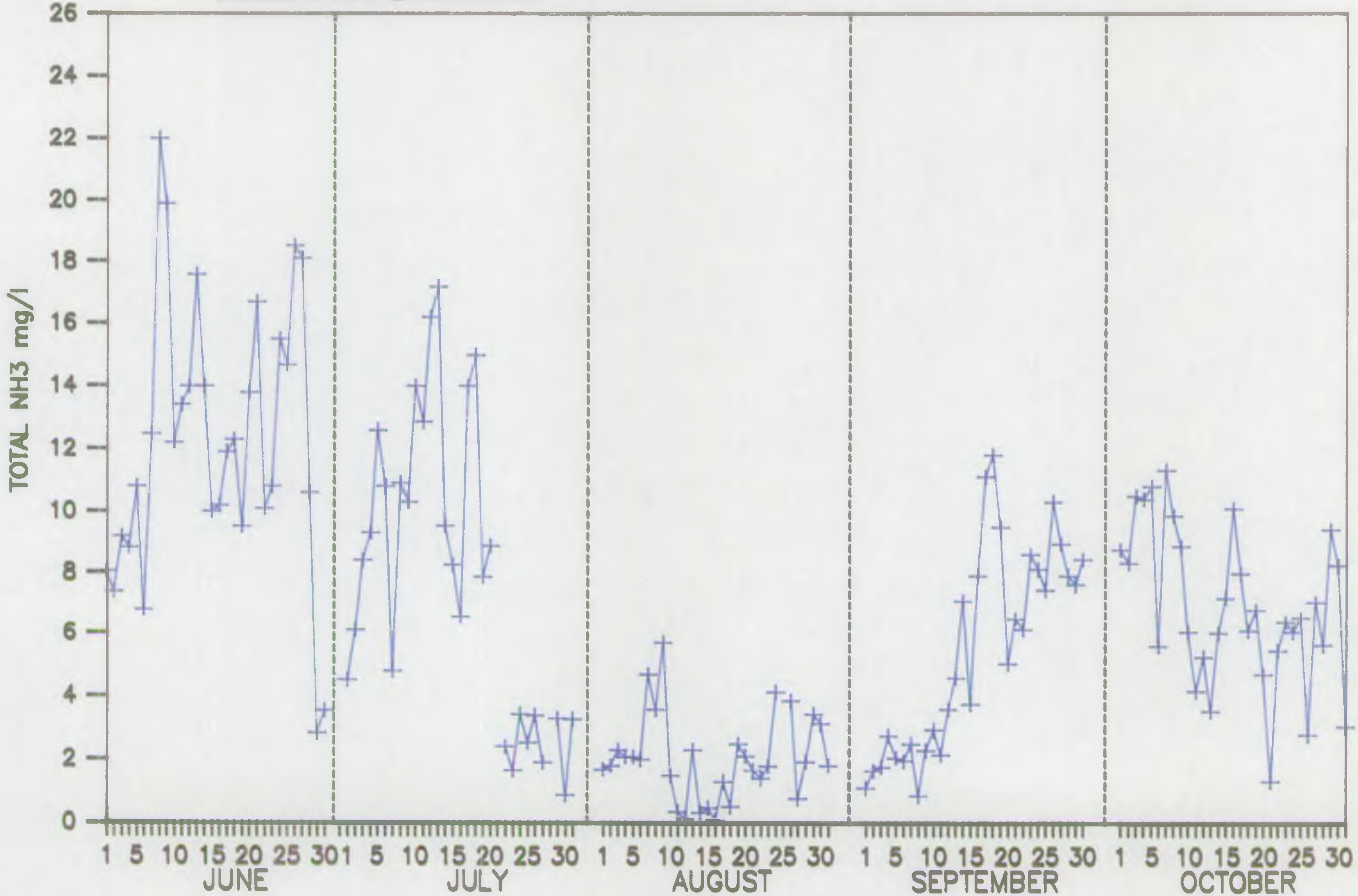


FIG 19: pH OF THE R. THAMES AT TEDDINGTON JUNE – OCTOBER 1988

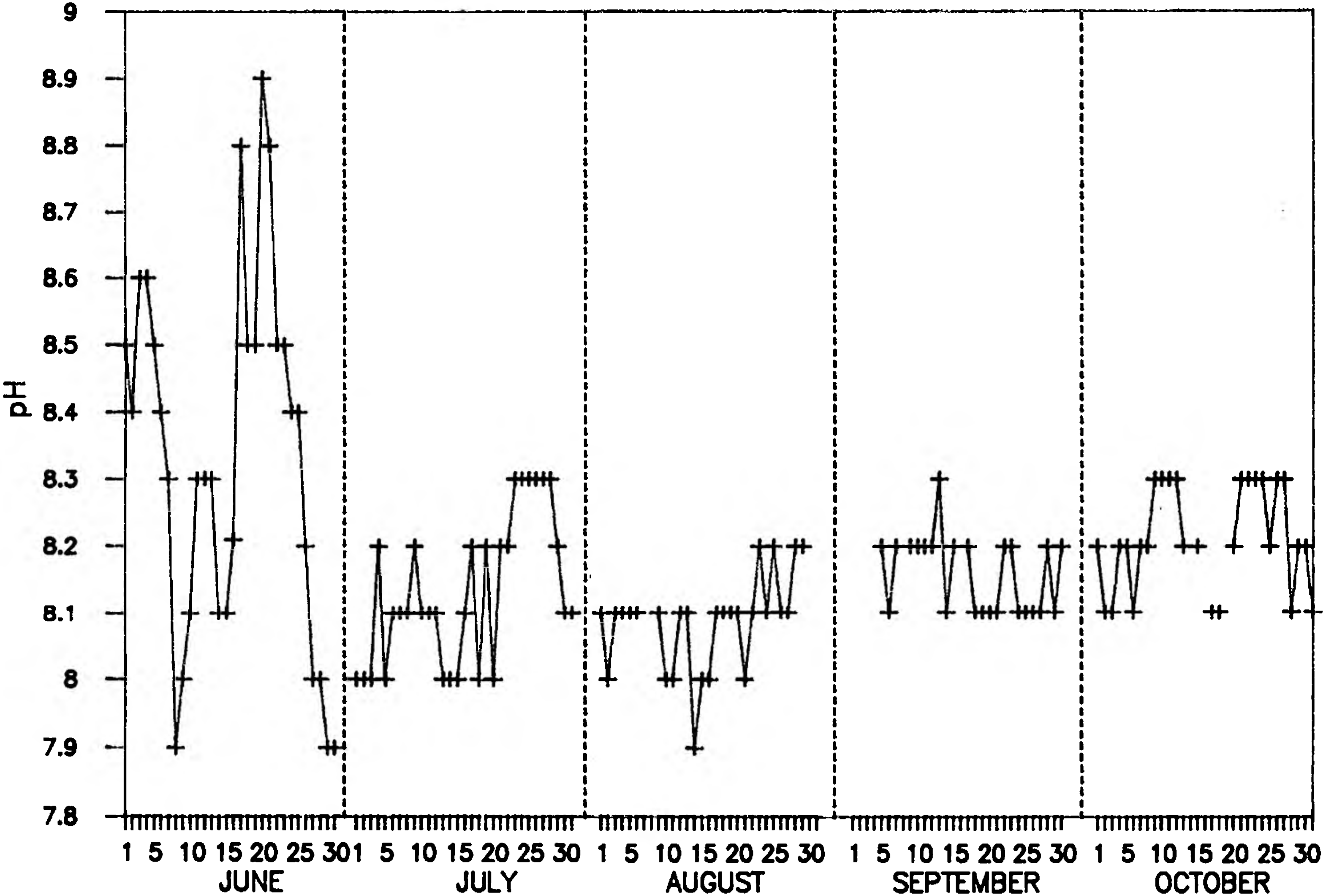


Fig. 17 shows the levels of unionised ammonia in the Thames at Teddington over the summer of 1989. It can be seen that highest levels were found in the second half of June and in October. Both these months had many days where unionised ammonia levels were higher than the EIFAC recommended threshold concentration of 0.025 mgl^{-1}. In fact, in June 1989, levels for sixteen days were higher than 0.025 mgl^{-1}, and twelve of these days were consecutive days (between 17.6.89 and 29.6.89). A majority of days in October had unionised NH_3 concentrations greater than threshold concentrations.

It is evident that for July, August and September the levels of unionised ammonia in the Thames were, on the whole, lower, although the recommended threshold for unionised ammonia was exceeded on several individual occasions in July and August. These excesses may be attributed to storm sewage from Hogsmill STW. For example, storm sewage was discharged to river on 6th July, 10th August and 25th/26th August. All these days show high levels of unionised ammonia. The Thames during August had the lowest concentrations of unionised ammonia apart from the two periods aforementioned when storm sewage was discharged from Hogsmill STW. In September water quality began to deteriorate towards the end of the month, especially around 17th/18th September.

The various fluctuations and changes in water quality with respect to unionised ammonia may be explained by looking at the total ammonia concentrations in the Hogsmill STW's final effluent and by considering changes in the water environment, especially pH which is known to have a great influence on the equilibrium of unionised ammonia in solution.

Fig. 18 presents graphically the concentrations of total ammonia in the STW's final effluent and Fig. 19 is a graph of the daily pH of the River Thames at Teddington. The ammonia levels in the final effluent demonstrate great changes in the performance of the STW and quality of the final effluent. The apparent trends shown in Fig. 18 appear to be quite similar to those seen in the unionised ammonia levels in the Thames (Fig. 17). The final effluent had the highest total ammonia concentrations in June and the beginning of July, with very low levels in August and the first half of September. From this time through until the end of October, total ammonia concentrations in the final effluent increased again.

Throughout the month of June the final effluent had very high levels of total ammonia which may solely have led to high unionised ammonia in the Thames. However, high levels of toxic ammonia were mainly restricted to the days after 15th June. From the 15th June until 26th June, the pH of the Thames was very high, ranging from 8.2 to 8.9. This is probably due to increased algal photosynthesis over this period. This increase in pH will have a great influence on the levels of unionised ammonia and this, combined with the poor quality of the final effluent, appears to be the explanation for prolonged high levels of toxic ammonia in the River Thames at Teddington. In the beginning of July, effluent ammonia levels were still fairly high but the pH had dropped to about 8.1, and this has caused very few days at this time to have unionised levels exceeding recommended concentrations.

The increased performance of the works during August and the beginning of September has led to low loads of ammonia in the final effluent and, consequently, levels of unionised ammonia in the Thames were lower. The pH in the Thames remained fairly steady at a moderate level of between 8.0 - 8.1 in August and in September the pH was only slightly higher at 8.1 - 8.2. These factors, along with an improved effluent quality, have resulted in the lower unionised ammonia concentrations in the Thames.

In September there was a deterioration in effluent quality from about the 14th September onwards. On the 17th and 18th the ammmonia concentration increased up to approximately 12 mgl^{-1} and subsequently there was an increase in unionised ammonia in the River Thames which exceeds the EIFAC threshold of 0.025 mgl^{-1}. The pH at this time was fairly steady (8.1-8.2), and it appears that, in this instance, the quality of the effluent is affecting the unionised ammonia levels irrespective of pH.

In October, the works were still producing effluent of a lower quality than that produced in August, causing higher levels of unionised ammonia for most of the month. Again there is not such a definite correlation with pH and unionised ammonia levels in the River Thames in October. Storm sewage from Hogsmill STW on 19.10.89 has caused unionised ammonia levels to increase dramatically around 20.10.89.

It becomes apparent that as the pH decreases and becomes more stable, its influence on unionised ammonia becomes less prevalent and a deterioration in effluent quality will directly influence the levels of unionised ammonia in the River Thames at Teddington.

3.6.1 Summary of Objective F

The level of total ammonia in the final effluent from Hogsmill Valley STW affects the level of unionised ammonia in the River Thames at Teddington. However, the pH of the water will greatly influence the levels of unionised ammonia and must be considered when looking at the effects of the STW on the River Thames. In June 1989, high pH and high effluent ammonia levels led to high levels of toxic unionised ammonia in the River Thames. In October, the pH was not as high in June, but concentrations of ammonia in the effluent were quite high which resulted in levels of toxic ammonia exceeding EIFAC recommendations.

It is therefore important that the quality of the effluent is maintained throughout the summer months at a fairly low concentration so that the influence of pH (and temperature) does not increase the amount of toxic ammonia in solution. If, for prolonged periods, levels of unionised ammonia exceed 0.025 mgl^{-1} as in June, lethal and chronic effects on the aquatic life of the river may result. Prolonged exposure of aquatic organisms to sub-lethal levels may result in reproductive and growth rate changes and cause histopathological effects such as gill lesions (Seager et al, 1988). It must also be noted that unionised ammonia in the River Thames is likely to fluctuate diurnally as do the total ammonia concentrations. Brown, Jordan and Tiller (1969) showed that fluctuating unionised ammonia concentrations may be more toxic than constant concentrations even at low sub-lethal concentrations.

3.7 Conclusions

Hogsmill Valley STW have, under this investigation, been shown to incur pronounced effects in the water quality apropos of ammonia concentrations in the River Thames at Teddington.

To conclude:

A. A well defined relationship has been established between the ammonia concentrations in the final effluent and those in the River Thames under dry weather conditions.

B. Diurnal patterns of ammonia in the effluent and in the River Thames at Teddington exhibit homogeneity and show conclusively that the pattern of ammonia in the Thames is heavily dependent on concentrations in the final effluent discharges from the works.

C. Similarities in ammonia loadings at both locations confirm the reliance of the Thames on the performance of Hogsmill STW.

D. Elevated ammonia concentrations do not appear to significantly decrease the levels of D.O. in the River Thames at Teddington. Conversely it has been seen that the level of the sun's irradiation is the main influence of D.O. levels, a reduction in which causes flattening of day time maxima.

E. Results of the investigation of the effects of storm sewage suggest that storm discharges from Hogsmill STW greatly influence water quality by causing disparate peaks of ammonia and by having a dramatic impact on D.O. levels on the River Thames at Teddington.

F. Poor performance of the STW, with reference to the concentrations of ammonia in the final effluent, has been shown to result in levels of unionised ammonia in the River Thames to be above EIFAC threshold recommendations, particularly when pH and temperature are elevated as in the summer months.

The effects of Hogsmill STW have been investigated and assessed in this study. It can clearly be deduced that the quality of the River Thames is most affected by the storm sewage discharges and by the effluent quality in terms of the levels of toxic unionised ammonia present in solution. Any changes in consent standards for the final effluent from the works would have to be made in the light of the possible effects of elevated unionised ammonia on the aquatic life in the River Thames at Teddington.

3.8 References

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