REMOVAL OF ORGANICS FROM COLOURED WATER
PHASE 1 REPORT

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PHASE ONE REPORT

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SUMMARY

I OBJECTIVE

To investigate the production of disinfection by-products during the treatment of coloured water and to define suitable, cost effective, methods for their removal or control with due regard to other organic compounds, such as colour and pesticides, and inorganic material such as iron, manganese and aluminium.

II REASONS

The presence of disinfection by-products and synthetic organic compounds, such as pesticides, in drinking water derived from coloured sources may pose a health risk to the consumer and exceed regulated water quality parameters. Dissolved air flotation and 2 stage filtration has been identified as the most likely process to be used for treatment of upland coloured water; this process requires investigation and optimisation with respect to the trace organics of concern.

III CONCLUSIONS

(i) The three stage pilot plant is capable of producing water of high quality and modelling full scale treatment.

(ii) There is an optimum coagulation pH for colour removal; the pH is dependent on the coagulant used, 4.6 for ferric and 5.5 for alum.

(iii) There is a minimum coagulant dose required to achieve a given colour removal, the dose is dependant on raw water quality; operating at or close to the minimum dose makes final water quality sensitive to changes in raw water quality.

(iv) Mutagenic activity and other chlorination by-products are either absent or present at very low levels in the raw water; they are generated by chlorination.

(v) Operating under conditions that maximises colour removal minimises the potential formation of trihalomethanes (THM) during post treatment disinfection. Other chlorination by-products, including mutagenic activity and organic chlorine, are lower when colour removal is high.

(vi) Of the coagulants examined, ferric produced water of the best overall quality. The use of LT31, an organic coagulant, produced water with particularly high THM. There was no benefit in using flocculation aids for treating the raw water used in the tests.

IV RECOMMENDATIONS

To minimise the production of chlorination by-products the coagulation process should be operated to maximise colour removal. This can be best achieved by using ferric sulphate and operating at the optimum pH, with a dose above the minimum required for adequate colour removal.

V RESUMÉ

A series of tests, examining the coagulation-clarification stage of a three stage treatment stream, has been carried out as the first phase of a 3 phase experimental programme. The details and results of each test are provided and conclusions have been drawn.

CONTENTS

SECTION 1 - INTRODUCTION

This report details the results obtained from running a three stage dissolved air flotation (DAF) water treatment pilot plant for the removal of organics from upland water. It contains all the results obtained from the first phase of a three phase experimental programme. A full description of the pilot plant, its operation, and the three phases of the experimental programme are given in the first interim progress report[1]. This report describes the first phase of the experimental programme.

Because of the large number of results involved, tables of results have not been included within the main body of this report but have been appended to this report.

SECTION 2 - EXPERIMENTAL DETAILS

2.1 PROGRAMME

Phase 1 of the experimental programme was designed to investigate the coagulation process. The pilot plant was operated with one stream as the control, and one stream as the trial. The control stream was operated under fixed conditions, whilst the conditions of the trial stream were varied.

Two coagulants, alum and ferric, were studied in depth. Other coagulants and flocculation aids were looked at only briefly. The variables investigated were: coagulation pH, coagulant dose, coagulant type, and the use of flocculation aids. It was also possible to observe the effects of varying raw water quality on the performance of the control.

The programme was divided into five trials:

(a) effect of coagulation pH and coagulant dose using alum;
(b) effect of coagulation pH and coagulant dose using ferric;
(c) effect of coagulant type;
(d) effect of flocculation aids;
(e) effect of raw water quality.

In each trial, only the coagulation conditions were varied. The conditions for the filtration stages of both streams were fixed with the primary (1°) rapid gravity filters (RGFs) operating at a pH of 6.5, and the secondary (2°) RGFs at a pH of 9.0. The inter-filtration chlorine dose was manually set to give a free residual of 0.1mg/l after each 2° RGF.

A summary of the coagulation conditions for trials A and B is given in Table 1, and for trials C and D in Table 2.

After the completion of the alum trials, the control stream was always operated with ferric as the coagulant at a constant coagulation pH. The ferric dose was kept constant for long periods of time, only being altered when required by the changing raw water quality. It was, therefore, possible to observe what effect the changing raw water quality had on the final water quality.

Further details of each trial are given in the Appendix.

Table 1 - Coagulation conditions for trials A and B

TRIAL	COAGULANT (both streams)	COAGULANT DOSE		COAGULANT pH	
		TRIAL	CONTROL	TRIAL	CONTROL
a i)	Alum	1.3	1.2	Varied	5.6 to 5.8
a ii)	Alum	Varied	1.2	5.6 to 5.8	5.6 to 5.8
b i)	Ferric	2.0 to 2.1	2.3 to 2.4	Varied	4.8 to 5.1
b ii)	Ferric	Varied	2.3 to 2.4	4.6 to 4.8	4.6 and 4.8

Note: For both trials, there was a slight difference (~10%) between the trial and control stream coagulant doses.

Table 2 - Coagulation conditions for trials C and D

TRIAL	CONTROL STREAM		TRIAL STREAM					
	FERRIC	COAG.	COAGULANT			CHLORINE	FLOC AID	
	DOSE	pH	TYPE	DOSE	pH	DOSE	TYPE	DOSE
c)	3.8 4.0	4.6 4.8	Alum	1.9 1.9	5.4 5.4	- -	-	- -
c)	4.0 3.9	4.7 4.7	Chlorinated Copperas	3.8 3.9	4.7 4.6	3.3 3.8	-	- -
c)	4.0 4.0	4.6 4.7	LT31	5.1 5.1	4.7 6.7	- -	-	- -
d)	3.7 3.8	4.6 4.8	Ferric	3.4 3.6	4.7 4.6	- -	LT25	0.1 0.5
d)	2.7 3.7	4.7 4.7	Ferric	2.3 3.5	4.7 4.7	- -	LT22	0.1 0.6

2.2 SAMPLING AND ANALYSIS

At the end of each experimental run, samples were collected from points in each stream and were assayed for a selection of water quality determinands. The determinands divide into groups, listed below:

INORGANIC DETERMINANDS
pH
Iron
Aluminium
Manganese
1° RGF Headloss Development Rate
Turbidity

ORGANIC DETERMINANDS
Colour: true colour is that measured after filteration through a 0.5μm membrane and is given for raw and DAF water only, all other colours are apparent
UV absorption
TOC (total organic carbon)
Pesticides
Bacteriological Quality (Plate counts and Coliforms)

DISINFECTION BY PRODUCTS
Chlorine Demand
THMs (trihalomethanes)
AOX (organic halide)
Mutagenic activity.

Details of each determinand and its analysis are given in the first interim progress report[1].

Disinfection by-products were assayed for in chlorinated samples, either process chlorinated as for the 2° RGF filtrates or hand chlorinated. Hand chlorination was carried out in the laboratory where sufficient chlorine was added to a sample at time 0 to provide a free residual of 0.5 $\pm$ 0.05mg/l at time 30 minutes.

The free chlorine in the samples collected for THMs and AOX was quenched with sodium thiosulphate at the time of collection. This eliminates variations in the time taken between chlorination and analysis.

The measure of disinfection by-products is, therefore, an indication of a water's potential, under standard conditions, to form chlorination reaction products. The levels found in distribution would be a reflection of this potential but would depend on operational circumstances.

2.3 PILOT PLANT CONTROL AND OPERATION

Some of the more pertinent observations and problems encountered during the work are summarised below.

(i) **Coagulant Dose**

Problems with coagulant dose were rare. The main problem was associated with the two coagulant dosing pumps: when set at the same settings, the two pumps dosed at different rates. Although the two stream coagulant doses were rarely equal, they were always within 10% of each other. Once a trial was underway, and the coagulant doses were within 10% of each other, it was preferable to maintain constant dose, rather than trying to get the two doses exactly equal.

(ii) **Coagulation pH**

At first, there were some problems in controlling the coagulation pH. This was due to the automatic pH control, which had problems with the weakly buffered water. Better control of the coagulation pH was achieved by manually setting a constant caustic dose. This gave pH control to within ±0.2 pH units. Later, automatic and manual control were combined: the bulk of the caustic was dosed manually, and a small caustic dose was dosed by the automatic system. The pH probes, which had originally been located just after the in line mixers, were moved to the first flocculation tanks. This gave control to ±0.1 pH units.

(iii) **1° RGF Operation**

The 1° RGF pH was controlled to 6.5 ±0.3 pH units. At first some problems with sampling were experienced, and these turned out to be due to filters backwashing. These problems were solved by reference to headloss sight tubes on the 1° RGFs, which allowed the operator to see if a filter had recently backwashed.

(iv) **2° RGF Operation**

The 2° RGFs developed very little headloss, so sight tubes were an unreliable indicator of backwashing times. However, the 2° RGFs could be programmed always to backwash at night. The 2° RGF pH was controlled to 9.0 ±0.3 pH units.

The free chlorine residual after the 2° RGFs was difficult to control because the chlorine demand and 2° RGF pHs are interdependent. It also took a long time for a filter to reach steady state, especially if doses were changed by a large amount. Nevertheless, the free residual was generally maintained between 0.04 and 0.17mg/l.

(v) **DAF Operation**

There were no significant operational problems; some changes in the characteristics of the DAF float were apparent.

(a) The float produced with alum was lighter in colour than that produced by ferric, the consistencies were roughly equal.

(b) The float produced with LT31 was very much thicker than that produced with ferric, and caused drainage problems.

(c) When using LT22 as a flocculation aid, the float was about the same thickness as when using LT31.

(d) When using LT25 as a flocculation aid, the float was thicker than when using ferric, but not as thick as when using LT22 or LT31.

SECTION 3 - RESULTS

In all figures, the curves drawn are the interpretation of the operator, and are not based on statistical curve fitting.

3.1 RAW WATER QUALITY AND ITS EFFECT ON TREATED WATER QUALITY

This section describes the variation of the raw water quality during phase 1 of the experimental programme. For each determinand, the results for the raw water and the control stream final water are shown. By comparing the two, the effect of raw water quality on final water quality can be seen.

Figure 1 shows the raw water pH. The pH remained constant at 5.6 until May after which it began to change, eventually increasing steadily to 6.3.

Figure 2 is a plot of colour against time. Both the apparent and true raw water colour, as well as the control stream final water colour are shown. It can be seen that the raw water true colour decreased steadily from February until June, after which it increased steadily until September. However, the raw water apparent colour increase was erratic from June until September. Apparent colour is affected by turbidity and Figure 3 shows turbidity decreasing steadily until June, and then increasing very erratically until September. Sudden increases in turbidity were generally associated with periods of heavy rain, which were rare during an exceptionally dry Summer. Although these downpours were very quick to affect raw water turbidity (and consequently raw water apparent colour), they were much slower to affect raw water true colour.

Figure 2 shows that the final water colour approximately follows the raw water colour. The influence of raw water colour on final water colour is shown very clearly at the end of June, beginning of July. At this time, the raw water apparent colour increased sharply for one week, and then fell again. However, both the raw water true colour and the final water colour increased for both of these weeks. After this increase in final water colour, it was necessary to increase the control stream ferric dose, which resulted in the final water colour decreasing. Figure 3 shows that the high final water colour was also associated with turbidity.

Figure 4 shows a plot of raw water total and filtered iron, and final water total iron concentrations. Figures 5 and 6 show plots of aluminium and manganese for the same samples. From these plots, it can be seen that the raw water iron and manganese followed closely the raw water colour. However the raw water aluminium decreased steadily throughout the duration of the programme. The increase in pH may have led to precipitation of aluminium in the reservoir or a decrease in its leaching from the catchment.

Figure 7 shows a plot of raw water and final water TOC against time. Again, the shape is the same as for colour. However, three of the TOC values (for both samples) during March were extremely high. This increase was not matched by increases in other determinands and may be due to analytical error.

Figure 8 shows a plot of raw water (apparent and true) and final water UV absorbance against time. The shape of the plot is very close to that found for colour.

Figure 9 shows a plot of raw water and treated water chlorine consumption. There are two plots for treated water. One is the consumption measured during the laboratory assessment of the chlorine demand of the 1° filtered water, the other is the chlorine consumption of the 2° filtered water. The second value includes the chlorine consumed for manganese oxidation during 2° filtration, and that consumed during the laboratory assessment of chlorine demand.

Figure 9 shows that the raw water chlorine demand followed closely the raw water colour. It also shows that the final water chlorine demand broadly followed the raw water chlorine demand. The chlorine demand of the treated water at both sample points was similar.

Figure 10 shows a plot of chlorinated raw water and treated water THMs against time. Two final water plots are included. One is of water which has only been chlorinated during 2° filtration (i.e. for manganese removal), the other is of the hand chlorinated final water. The results show a consistent concentration of 5-10µg/l in the 2° filtered water; hand chlorination increases this by varying amounts which reflect changes in the chlorinated raw water.

Figure 11 shows a plot of chlorinated raw water and final water AOX potential plotted against time. There are two plots for final water, one with, and one without hand chlorination. The results for raw water are very similar to the results for colour. The final water AOX concentrations seem to have an inverse or no relationship to the raw water AOX.

Figure 12 shows a plot of the hand chlorinated final water mutagenicity against time. The levels of TA98 activity are low with pH7 showing an increase in July; the levels of TA100 are more variable, and higher. Neither activity shows a clear relationship with any other determinand.

Raw water mutagenicity was measured once. The results are given in Appendix A, Table Ai20 and show that raw water contains some TA 98 activity, without the addition of chlorine; TA 100 activity is only present after chlorination.

3.2 CORRELATIONS BETWEEN PARAMETERS

In this section, some of the values of the different determinands are compared.

Figure 13 shows a plot of colour against UV absorbance. The figure shows samples taken during the whole experimental programme, and these samples are grouped as apparent colour and true colour for raw and DAF treated water. It can be seen that there is a very good correlation between colour and UV, and that all the samples for true colour lie on the same straight line and for apparent colour on a slightly different straight line. This reflects greater reduction in colour than in UV absorbance by membrane filtration indicating that turbidity may have a greater influence on colour measurement than on UV absorption. The plots does not pass through the origin indicating that a proportion of the UV active material is not coloured. A similar correlation is found for samples taken after primary and secondary filters.

Figure 14 shows a plot of TOC against apparent UV absorbance. The plot shows results from the raw water, and both final waters. The figure shows a reasonable correlation between the two determinands, although there is more scatter than in Figure 13, especially for the final waters. Three sets of results have been omitted. These sets were all obtained during March when, for some reason, the values for TOC were unusually high.

Figure 15 shows a plot of THMs against chlorine demand and Figure 16 shows a plot of THMs against AOX; both figures show results from chlorinated raw water and chlorinated filtered waters from the control stream. There are positive correlations but there is also considerable scatter. Further analysis of the results is required to identify the causes of the scatter and to examine the relationship between multiple parameters, such as TOC, chlorine demand and disinfection by-products.

3.3 EFFECT OF TREATMENT ON INORGANIC DETERMINANDS

3.3.1 Metals

The final water iron, aluminium and manganese concentrations were normally below the EC guide levels (0.05, 0.05 and 0.02mg/l respectively).

However, if the coagulant dose were too low, or the coagulation pH were not correct, high final water coagulant residuals (up to 1mg/l with ferric, or 0.5mg/l with alum) could result. High final water coagulant residuals always coincided with high final water colours. High coagulant residuals were only obtained when the pilot plant was run at extreme conditions.

3.3.2 Headloss Development Rate

The headloss development rate in the 1° RGFs was usually between 50 and 60mm/hr. Assuming that these rates could be applied to full scale filters with an available head loss development of 1.8m, then these filters would need backwashing every 30 hours. This would mean that the filters could be routinely backwashed once a day with no operational difficulties.

When there was very high carry-over from the DAF due to high coagulant dose or inappropriate pH leading to poor flocculation conditions, then the headloss development rate increased up to about 100mm/hr. If the high carry-over was caused by a low coagulant dose, resulting in insufficient coagulation, then the headloss development rate was very low and the coagulant residuals in the final water were high.

There was no appreciable difference in headloss development rate between using alum, ferric, or chlorinated copperas, as coagulant. Neither was there an appreciable difference in headloss development rate when using ferric as a coagulant with or without floc aids. However, using the polymeric coagulant LT31 resulted in a reduction in headloss development by about one third.

3.3.3 Turbidity

Unless the pilot plant was run with exceptionally poor coagulation conditions, the final water turbidity was always less than the EC guide level (0.4 NTU). In fact, the great majority of the final water turbidities were 0.1 NTU or less.

3.4 BACTERIOLOGICAL QUALITY OF TREATED WATER

During the first part of the experimental programme (February to April 1989), standard plate counts at 22°C and 37°C of the final water were always within the EC guide levels without hand chlorination. However, during the later part of the experimental programme (May to September 1989), some of the colony counts for the non-hand chlorinated final water were above the EC guide levels; hand chlorination brought the colony counts below the EC guide level.

The only coliform count occurred after there had been two days continuous rain after a long dry period. This also coincided with a trial stream run with a very low ferric dose. The non-hand chlorinated trial stream final water for that day had a total coliform count of 2. The control steam (higher ferric dose), and hand chlorinated trial stream, had zero coliform counts.

3.5 EFFECT OF TREATMENT CONDITIONS ON ORGANIC DETERMINANDS

This section details the results for colour, UV absorbance, and TOC. In all of the experiments, the results for UV absorbance followed exactly the same trends as the results for colour. Therefore, only the results for colour and TOC are described below. Seven sets of samples taken between 21 February and 11 July were analysed for atrazine and simazine. None of the samples registered a concentration of pesticide above the quoted limit of detection of 0.1 μg/l; it was decided that no more samples would be taken routinely for pesticide analysis after 11 July.

3.5.1 Effect of Coagulation pH

(a) Alum

Figure 17 shows the effect of coagulation pH on DAF treated water colour using alum as a coagulant at a dose of 1.2-1.3mg/l. The figure shows the results for both apparent and true colour, and includes results from both the trial stream and the control stream.

The results for apparent colour show an optimum coagulation pH of about 5.5. Small deviations ($\pm$ 0.5 pH units) make very little difference to the DAF treated water apparent colour. However, if the coagulation pH is increased above 6.5, or reduced below 4.5, the DAF treated water apparent colour deteriorates considerably. The results for true colour follow a similar trend, but are very much lower and do not deteriorate at the higher pH.

Figure 18 shows the effect of coagulation pH on RGF treated water using alum as a coagulant. The figure shows the results from both the trial stream and the control stream, and includes results from both the 1° RGFs and the 2° RGFs. There is some vertical scatter in the results from the control stream due to changing raw water quality during the test but the results indicate that coagulation pH has had less effect on RGF colour than on DAF colour. This is probably because the pH adjustment prior to the 1° RGFs compensated for variations in DAF treated water quality resulting from an inappropriate coagulation pH.

During this trial, there was a wide variation in TOC concentration between different runs. However, each set of results should be consistent within itself, allowing comparisons between the trial stream and control stream. Figure 19 therefore shows a plot of the difference between the trial stream TOC and the control stream TOC against coagulation pH. When operating at comparable pH the trial stream removed marginally more TOC than the control stream, this may reflect the fact that the coagulant dose was slightly greater in the trial stream. The results indicate that at low coagulation pH final water TOC was higher, but above pH 4.7 there was little effect.

(b) Ferric

Figure 20 shows the results of DAF treated colour plotted against coagulation pH when ferric was used as the coagulant. The figure shows two plots; one for apparent colour, the other for true colour, the results from the control stream and trial stream have been plotted.

The results for apparent colour in Figure 20 show a clear optimum pH of 4.9. This is lower than the optimum pH observed with alum. The results for true colour follow the same trend as the results for apparent colour, but are all much lower.

Figure 21 shows the results for RGF colour plotted against coagulation pH. The results from all four RGFs are included in the figure. The optimum coagulation pH for RGF colour is about 4.6, which is slightly lower than that for DAF true colour (4.9).

The increased RGF colour observed at higher coagulation pHs was associated with turbidity breakthrough; the pH adjustment for the 1° RGF had less compensating effect than indicated for alum.

Figure 22 shows the results for RGF TOC plotted against coagulation pH. During the period of this trial the raw water TOC varied from 3.34mg/l to 4.68mg/l (see Figure 8 - May). Because of this raw water TOC variation, the results in Figure 22 have, again, been plotted as the difference between the trial stream TOC and the control stream. The trial stream usually removed less TOC; TOC removal was greatest with a coagulation pH of 4.4-5.0.

3.5.2 Effect of Coagulant Dose

(a) Alum

The raw water colour and TOC for one run was much higher than the other four runs and results from this run have been omitted from the results.

Figure 23 shows a plot of DAF colour plotted against alum dose when the coagulation pH was 5.6-5.9. Increasing alum dose, to around 2.0mg/l, decreases DAF colour down to a minimum value; once this minimum value has been reached, there is no advantage, for colour removal, in further increasing the alum dose.

Figure 24 shows a plot of RGF colour plotted against alum dose. Results from all four RGFs are included. The plot shows the same trend as for DAF colour. Increasing alum dose decreases RGF colour down to a minimum value.

Figure 25 shows a plot of final water TOC plotted against alum dose. Increasing alum dose increases TOC removal.

(b) Ferric

Figure 26 shows the results for DAF colour plotted against ferric dose. Results from both the trial stream and the control stream are included. The plot shows the same trend as was observed with alum. Increasing ferric dose decreases colour down to a minimum. Further increasing the ferric dose once the minimum has been reached results in no further reduction in colour.

As was observed with alum, the gradient of the inclined section of the plot is much steeper for apparent colour than for true colour. This would indicate that colour can be coagulated at a relatively low dose and be removed by the 0.45μ membrane but for flocculation and subsequent removal, a higher dose is required.

Figure 27 shows a plot of RGF colour plotted against ferric dose. Results from all four RGFs are included. The figure shows the same trend as Figure 26: increasing ferric dose decreases colour down to a minimum.

Figure 28 shows a plot of RGF TOC plotted against ferric dose. During the trial there was variation in raw water quality, which has caused vertical scatter in the control stream results; it should be noted that the scatter occurs on the inclined section of the plot. Thus when the ferric dose is below or close to the minimum for colour removal, treated water quality can be extremely sensitive to changes in raw water quality. The results on the flat portion of the curve where ferric dose is greater than the minimum show that the treatment process is more resistant to changing raw water. Thus to ensure consistent treated water quality it is necessary to operate with either good feed-forward control of the coagulant dose or a dose greater than the minimum required.

3.5.3 Effect of Coagulant Type and Flocculation Aids

The levels of colour and TOC in the control and trial stream for each of the tests comparing ferric with an alternative coagulant are given in Table 3. For each comparison there are two sets of results, corresponding to two tests.

Table 3 - Effect of coagulant type/flocculation aids on organic parameters

COAGULANT	DAF COLOUR (Hazen)				RGF COLOUR (Hazen)				FINAL TOC	
	APPARENT		TRUE		1° RGF		2° RGF		mg/l	
Alum	8	8	2	3	2	2	2	3	3.51	3.05
Ferric	18	13	1	2	1	2	1	2	2.88	2.92
Copperas	17	13	1	0	3	1	3	1	3.60	3.20
Ferric	17	13	2	1	2	1	2	1	3.06	3.10
LT31	14	15	4	6	6	6	4	6	3.51	3.64
Ferric	18	13	2	3	3	3	3	3	2.47	2.83
Ferric + LT25	17	22	3	2	3	3	4	3	3.26	1.94
Ferric	17	15	4	2	3	3	4	3	3.07	2.01
Ferric + LT22	17	18	3	3	4	3	4	3	2.15	2.04
Ferric	18	14	3	3	5	3	5	3	2.33	2.02

(a) Alum v Ferric

Dose: Alum 1.0-1.8mg/l, Ferric 3.1-3.6mg/l

pH : Alum 5.4, Ferric 4.7.

The DAF apparent colour was much lower when alum was used as the coagulant which was associated with lower turbidities (1.9 compared to 3.9), Ferric floc is also coloured when compared to the alum floc. The

DAF true colour, RGF colour and TOC are all slightly less with ferric than with alum. This is probably a reflection of the lower coagulation pH which can be used with ferric.

(b) Copperas v Ferric

Dose: Copperas 3.1-3.6mg/l + 2.5mg/l Cl, Ferric 3.9
pH : Copperas 4.6, Ferric 4.6.

There was no difference in DAF apparent colour between using ferric and chlorinated copperas. However, chlorinated copperas produced a slightly lower DAF true colour. This may have been due to partial bleaching by the chlorine (added for oxidation), or possibly may have been caused by chlorine changing the coagulant solubility, the effect, however, is small. In the first run the prechlorination dose was slightly low and was probably not great enough to produce full oxidation of ferrous to ferric. This may explain why, in that run, the results for RGF colour and TOC were marginally worse for copperas than for ferric. In the second run, when the chlorine dose was higher, copperas and ferric gave similar results.

(c) LT31 v Ferric

Dose: Ferric 3.2, LT31 5.1mg/l
pH : Ferric 4.6, LT31 4.7 and 6.7.

With LT31, there is little, or no, difference in DAF apparent colour between using ferric and LT31. However, the DAF true colour, RGF colour and TOC results are all worse with LT31.

(d) Ferric + LT25 v Ferric

Dose: Ferric 3.1-3.3mg/l + 0.12mg/l LT25
pH : 4.6-4.8.

a) Alum Doze 1.9 ~~[illegible]~~
Ferric Doze 3.8 - 4.0

b) Copperas 3.8 - 3.9 + 3.3-3.8 Cl
Ferric 3.9 - 4.0

c) Ferric 4.0

d) 3.4 - 3.8 + 0.12 / 0.5

e) 2.3 - 3.7 + 0.12 / 0.6

One of the runs using LT25 flocculation aid produced higher DAF apparent colour than ferric alone. This was caused by inefficient float removal due to drainage problems, the results for the other run show no difference. The results for DAF true colour, RGF colour and TOC show that there is no difference between using ferric alone or in conjunction with LT25 as a flocculation aid.

(e) Ferric + LT22 v Ferric

Dose: Ferric 2.7-3.7mg/l + 0.5-0.6mg/l LT22
pH : 4.6

The results for LT22 show no difference in DAF treated colour. However, for the first run, both ferric doses were low due to changes in raw water quality caused by the falling reservoir level. In addition due to dosing problems the trial stream dose was about 15% lower than the control. Nevertheless the results for RGF colour and TOC from the trial stream, using LT22, are slightly lower than those from the control, operating with ferric alone. This suggests that LT22 could be used to partially replace ferric as a coagulant. The second run, where the ferric dose had been increased, shows that there was no advantage in using LT22 when the primary coagulant dose was great enough.

Note: Taste was not objectively analysed for, but the following subjective comments can be made:

(i) Water treated by LT31 had a very unpleasant taste. Although the taste is extremely difficult to describe, the closest adjective is probably astringent.

(ii) The water treated with LT25 as a flocculation aid had a similar taste to water treated with LT31. However, the taste was very much milder with LT25, and thus not particularly unpleasant. LT22 did not produce any noticeable tastes.

3.6 DISINFECTION BY-PRODUCTS

The concentrations of disinfection by-products are those present in either the 2° filtered water or in the hand chlorinated water at the time of sampling. THMs and AOX samples are quenched, mutagenicity activity is measured on an extract obtained by passing unquenched water through a resin bed over a 16 hour period. They reflect the residual chlorine levels, pH and contact time of the test method (0.5mg/l, 9.0, and 30 minutes, respectively).

During the whole of this experimental programme, there was a wide variation in the raw water's potential to form THMs during hand chlorination (Figure 10). In the following discussion the effects of process variants on THM potential have generally been expressed as a % difference between the trial stream and the control stream. When THM concentrations have been used they are as total THMs, for all samples the greatest proportion (>90%) of THMs was chloroform.

3.6.1 Effect of Coagulation pH

(a) THMs

Figure 29 shows the effect of coagulation pH on THM formation when using alum or ferric. For both coagulants an optimum pH can be discerned, this optimum is the same as that found for colour removal: 5.5 for alum and 4.6 for ferric.

(b) AOX

Table 4 shows the concentrations of AOX obtained during the test on coagulation pH before and after hand chlorination of the 2° RGF water. Lower levels of AOX in the hand chlorinated samples are associated with a lower coagulation pH, the effect is when ferric is used. There is no apparent effect of pH when alum is used. The levels are comparable, but lower, with levels of 60μg/l found under similar test conditions using lowland river water[2].

Table 4 - Effect of coagulation pH on AOX

COAGULANT		COAGULANT	AOX (µg/l)	
TYPE	DOSE (mg/l)	pH	2° RGF	2° RGF Hand-Cl
Alum	1.3	4.8	19.7	25.7
	1.2*	5.8	14.7	28.3
Alum	1.3	6.4	22.4	25.5
	1.2*	5.8	20.2	32.7
Ferric	2.0	4.4	15.6	16.4
	2.3*	5.1	19.1	31.6
Ferric	2.0	5.6	14.0	34.5
	2.3*	5.0	17.7	47.0

* control stream

(c) Mutagenic Activity

Table 5 shows levels of mutagenic activity obtained during the tests on coagulation pH. There seems to be no clear effect of coagulation pH on mutagenic activity. The activities are of comparable magnitude to those found on lowland waters[2]. As with lowland waters, TA 100 activity is greater than TA 98 activity, and TA 100 activity at pH 2 is much greater than at pH 7.

Table 5 - Effect of coagulation pH on mutagenic activity

COAGULANT		COAGULANT	TA 98		TA 100	
TYPE	DOSE	pH	pH 2	pH 7	pH 2	pH 7
Alum	1.3	4.8	1.86	2.92	16.32	11.33
	1.2*	5.8	2.84	2.98	13.52	11.81
Alum	1.3	6.4	3.11	3.34	15.28	5.37
	1.2*	5.8	3.30	2.34	17.59	9.05
Ferric	2.0	4.4	3.69	3.55	30.12	17.38
	2.3*	5.1	4.52	3.79	29.13	19.25
Ferric	2.0	5.6	3.16	6.69	24.61	13.02
	2.3*	5.0	2.27	4.52	22.04	14.67

* Control N.B. All values are slope values

3.6.2 Coagulant Dose

(a) THMs

Figure 30 shows the effect of coagulant dose on THM formation. The results do show that, for both coagulants, a reduction in the THM production as the coagulant dose was increased in the trial stream. There appears to be no extra benefit in operating at very high coagulant doses.

(b) AOX

Table 6 shows the effect of coagulant dose on AOX formation. Generally increasing coagulant dose decreased AOX formation.

Table 6 - Effect of coagulant dose on AOX

COAGULANT		AOX (µg/l)		
TYPE	DOSE	1° RGF Hand-Cl	2° RGF	2° RGF Hand-Cl
Alum	1.7 0.7*	22.3 33.1	20.0 27.0	29.2 39.2
Alum	0.7 1.2*	35.1 20.4	18.4 16.5	33.2 29.3
Ferric	3.7 2.4*	64.6+ 33.8	22.7 16.6	29.1 43.6
Ferric	5.8 2.4*	23.8 25.7	N.A 19.4	18.1 26.9

* Control + The reason for the high value is not known.

(c) Mutagenic Activity

Table 7 shows the effect of coagulant dose on mutagenic activity. The results show little effect of coagulant dose, although pH 7 activity was reduced slightly by the higher dose.

Table 7 - Effect of coagulant dose on mutagenic activity

FERRIC DOSE	TA 100		TA 98	
(mg/l)	pH 2	pH 7	pH 2	pH 7
3.7	24.90	4.72	4.14	5.12
2.4*	21.12	9.36	3.16	7.25

* Control N.B. All values are slope values.

3.6.3 Effect of Coagulant Type and Flocculation Aid

Table 8 - Effect of coagulant type/flocculation aids on THM production

COAGULANT	TOTAL THMs ($CHCl_3$) µg/l					
FLOC AID	1° RGF + Cl		2° RGF no Cl		2° RGF + Cl	
Alum Ferric	12.20 (11.16) 19.63 (9.92)		7.65 (6.97) 5.88 (5.14)		14.64 (13.57) 9.25 (8.13)	
Copperas Ferric	59.10 33.41		24.66 8.20		62.66 38.30	
LT31 Ferric	13.61 3.47	24.68 12.79	1.46 1.41	18.04 7.95	40.20 27.93	27.93 12.96
Ferric + LT25 Ferric	26.10 12.71	14.21 18.96	8.62 11.05	10.73 9.73	15.85 16.32	19.34 18.89
Ferric + LT22 Ferric	13.06 12.36	11.47 11.47	3.60 3.05	9.19 7.53	14.42 13.04	13.76 14.96

(a) THMs

Table 8 shows the effect of coagulant type and floc aids on total THM production.

The total THM and chloroform production in the 2° filtered waters, before and after hand chlorination are greater with alum than with ferric, but the 1° RGF total THMs are greater with ferric due to due to an unexplained high concentration of dibromochlormethane; the results for chloroform are consistent, and show more chloroform with alum than with ferric.

Chlorinated copperas led to the formation of more THMs than ferric. Much of this is probably due to the presence of chlorine in the flocculators and DAF, where the chlorine has a long contact with organic material in the raw water, a conclusion supported by the levels of THM in the 2° RGF prior to hand chlorination.

The use of LT31 led to the formation of more THMs than ferric. The use of LT31 also resulted in higher concentrations of colour and TOC in the final waters, which may partly explain the increased THM production with LT31. However, it may be that the polymer itself is a significant THM precusor and that it is present in the final water.

Although there are some differences in THM production between waters treated with ferric only or with ferric and LT25, there are no consistent trends. The use of LT22 with ferric made no difference to THM production.

(b) AOX

Table 9 gives AOX concentrations in the hand chlorinated 2° RGF waters for each test. The results indicate more AOX is produced when using LT31 than when using ferric. The results for copperas are inconsistent since the hand chlorinated 1° RGF water with copperas has less AOX than with ferric, but the hand chlorinated 2° RGF water with copperas has more AOX than with ferric. The use of LT25 or LT22 had no effect.

Table 9 - Effect of coagulant type on AOX formation

COAGULANT	AOX µg/l	
	1° RGF + Cl	2° RGF + Cl
Alum	32	27
Ferric	30	20
Copperas	25	41
Ferric	31	32
LT31	58	43
Ferric	26	25
Ferric + LT25	18	25
Ferric	25	27
Ferric + LT22	21	22
Ferric	22	26

(c) Mutagenic Activity

Table 10 gives mutagenicity levels in the hand chlorinated 2° RGF water for each test. These results show that slightly more mutagenic activity is produced in both bacteria strains when water was treated with alum than when it was treated with ferric. There is virtually no difference in TA98 activity between waters treated with ferric and water treated with chlorinated copperas, or LT31. However, the TA 100 activity with both chlorinated copperas and with LT31 is worse than that produced by ferric. This is in agreement with previous observations, where TA 100 activity has been sensitive to the effects of chlorine, but TA 98 activity has not[2]. Floc aid had no apparent effect.

Table 10 - Effect of coagulant type on mutagenic activity formation

TYPE OF ACTIVITY Slope Value				
COAGULANT	TA 100		TA 98	
	pH 2	pH 7	pH 2	pH 7
Alum Ferric	19.4 14.9	9.2 8.4	5.1 3.9	7.3 5.9
Copperas Ferric	19.5 11.4	8.0 6.0	3.7 2.4	4.5 5.0
LT31 Ferric	26.6 18.8	13.6 8.4	2.9 2.4	4.7 4.1
Ferric + LT25 Ferric	13.9 12.9	9.6 8.9	2.7 3.3	3.1 4.5
Ferric + LT22 Ferric	10.7 12.4	10.5 7.7	2.4 2.3	3.2 3.3

SECTION 4 - CONCLUSIONS

(i) The 3 stage pilot plant was capable of producing water of very high quality.

(ii) There is an optimum coagulation pH for colour removal. This is 4.6 when the coagulant is ferric and 5.5 when the coagulant is alum.

(iii) There is an optimum coagulant dose, which is dependent on raw water colour. The optimum ferric dose is approximately twice the optimum alum dose (in terms of mg/l of metal).

(iv) The optimum coagulation pH and coagulant dose for colour removal appear to be the optimum coagulation pH and coagulant dose for reducing the formation of THMs, and to a lesser extent, AOX.

(v) For equimolar alum and ferric doses, ferric produced water with lower levels of colour, TOC, and disinfection by-products.

(vi) Chlorinated copperas produced water with equal levels of colour and TOC when compared to water produced by ferric. However, the water had higher levels of disinfection by-products due to the reaction of chlorine with raw water.

(vii) The organic coagulant, LT31, produced worse quality water than ferric in terms of colour, TOC and disinfection by-products.

(viii) The use of flocculation aids with the optimum primary coagulant dose made no difference to the quality of the final water.

(ix) Some mutagenic activity (TA 98) was present in raw water but chlorination was responsible for the production of most activity.

SECTION 5 - REFERENCES

1. ATTENBOROUGH A and WALKER I. Removal of Organics from Coloured Water; Interim Progress Report No. 1. WRc Contract No. 3024.

2. HYDE R A, WALKER I, RIDGWAY J and DENNY S. Organics Removal from Lowland Surface Waters; Interim Progress Report; October 1988, WRc Report 759-S.

SECTION 6 - ACKNOWLEDGEMENTS

The authors would like to thank the supply staff of North West Water, Eastern Division for their willingness to help whenever asked.

Figure 1 Raw Water pH vs Time

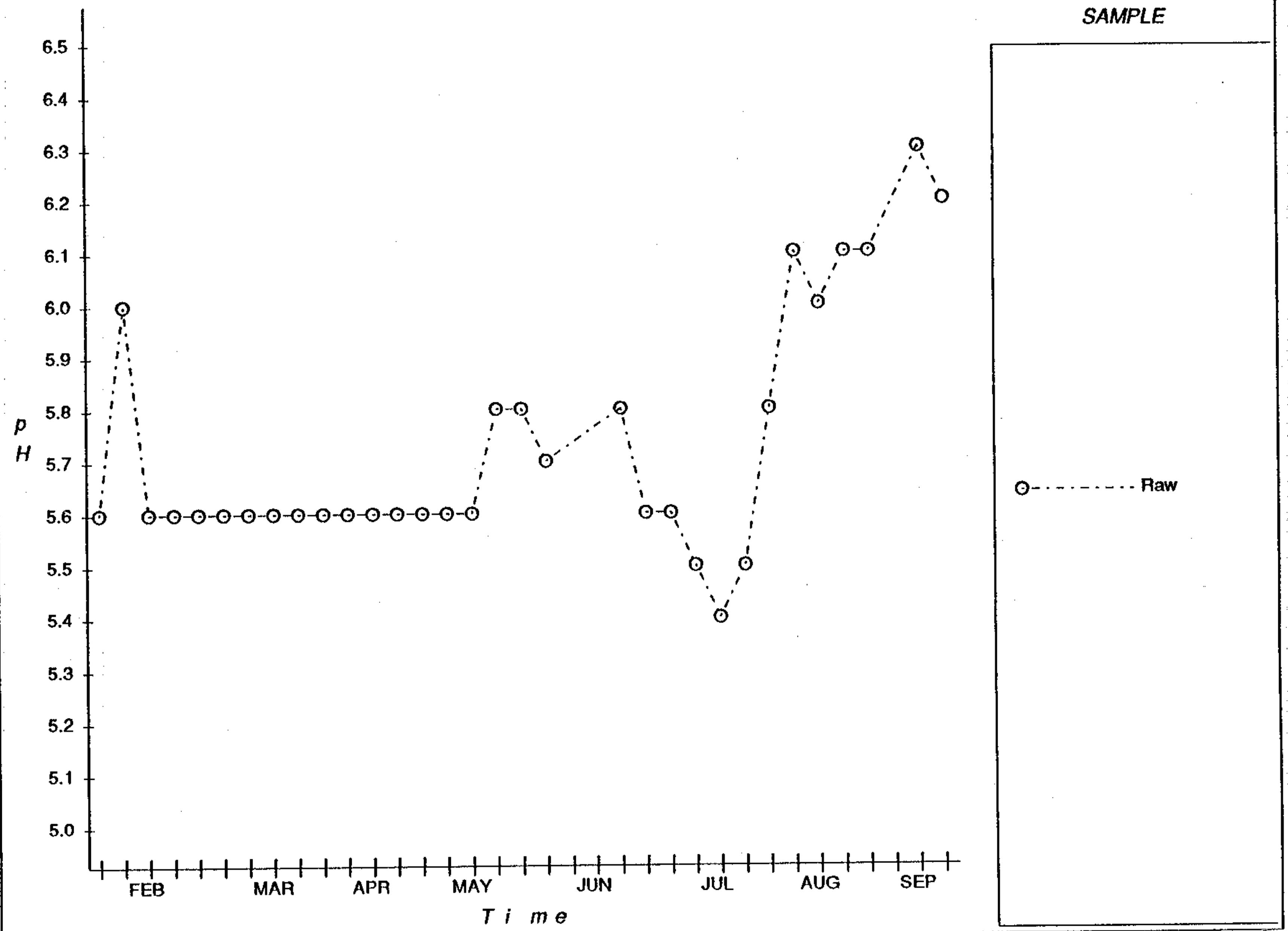


Figure 2 Colour vs Time

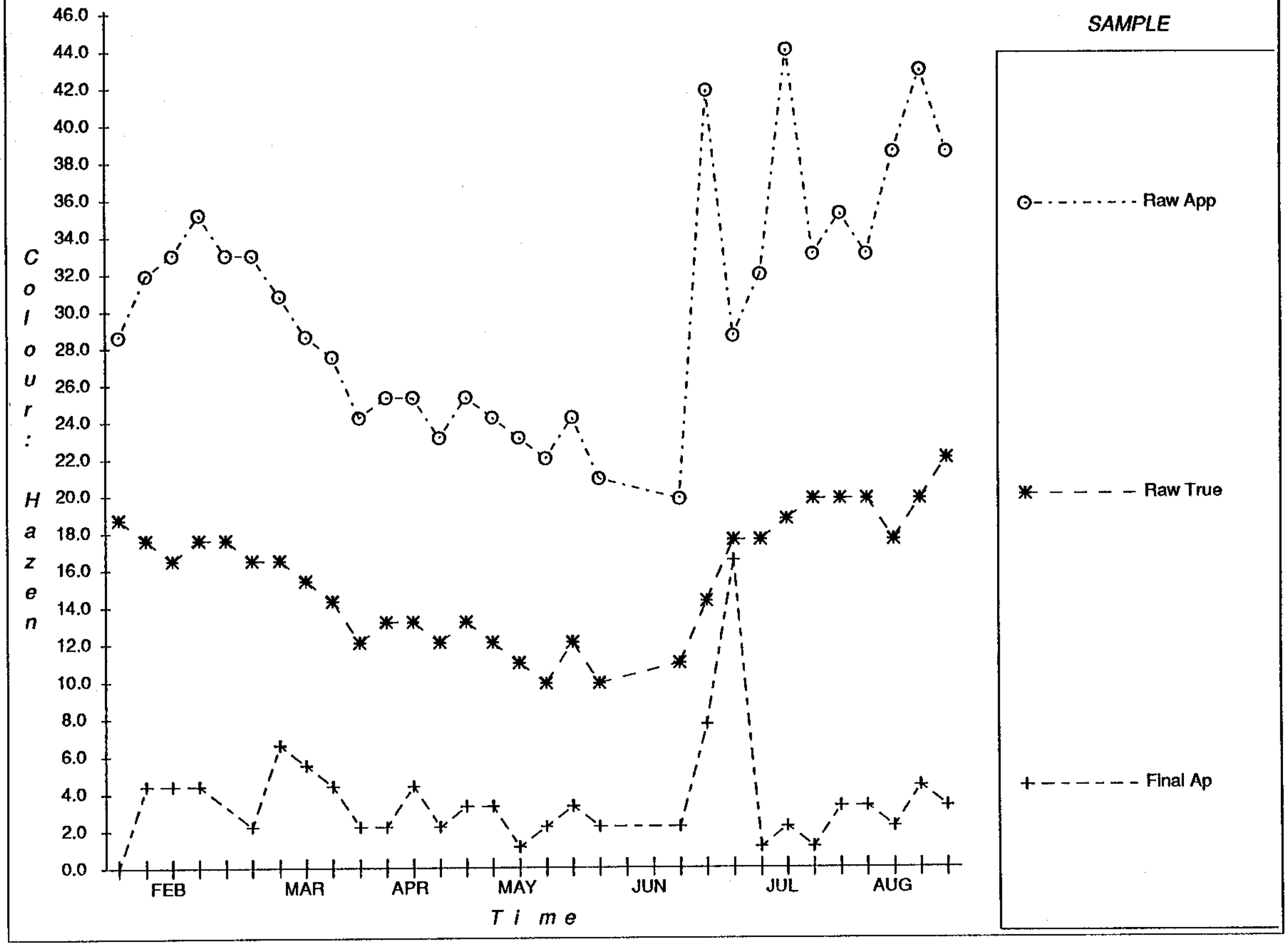


Figure 2 Colour vs Time

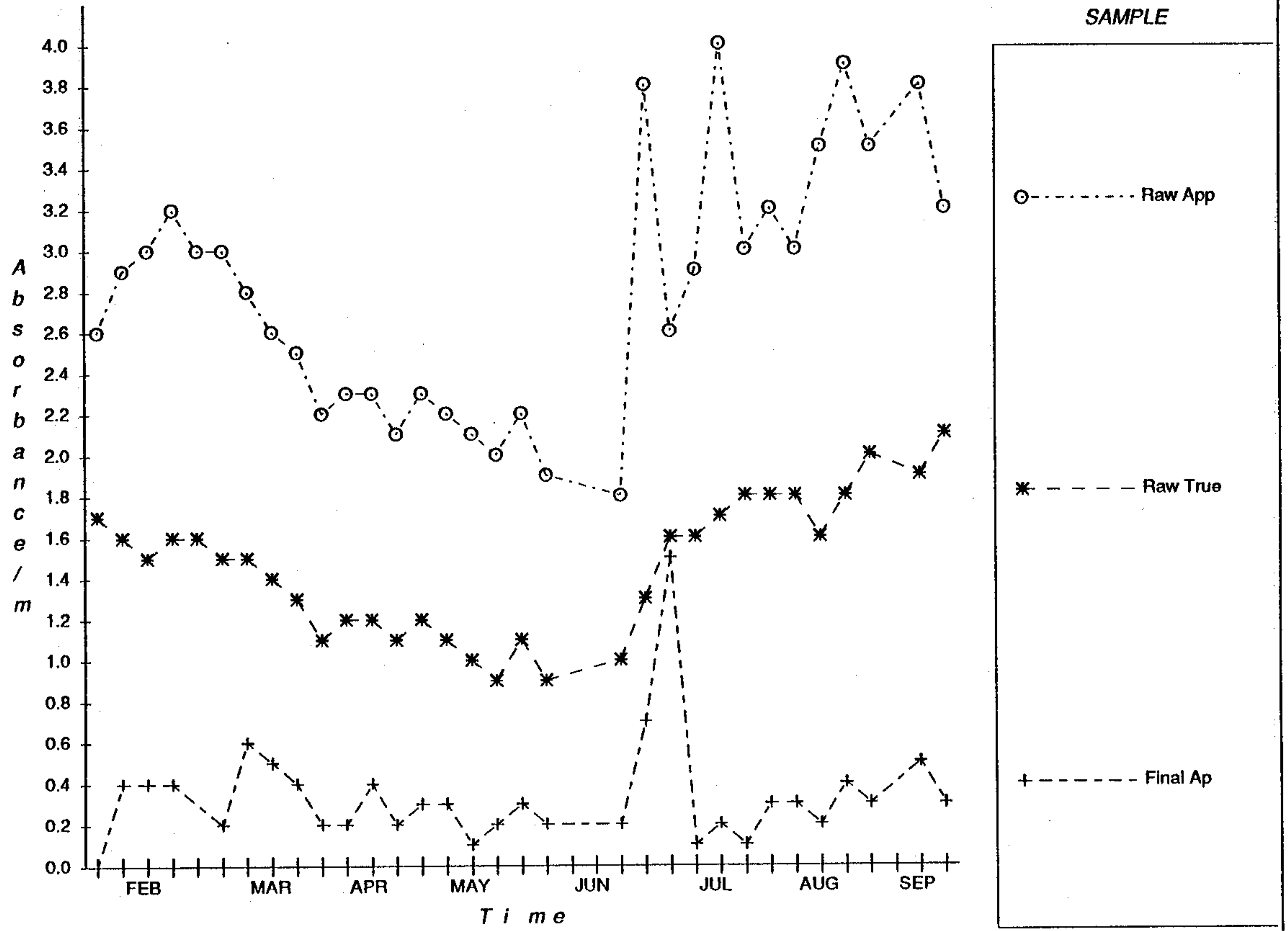


Figure 3   Turbidity vs Time

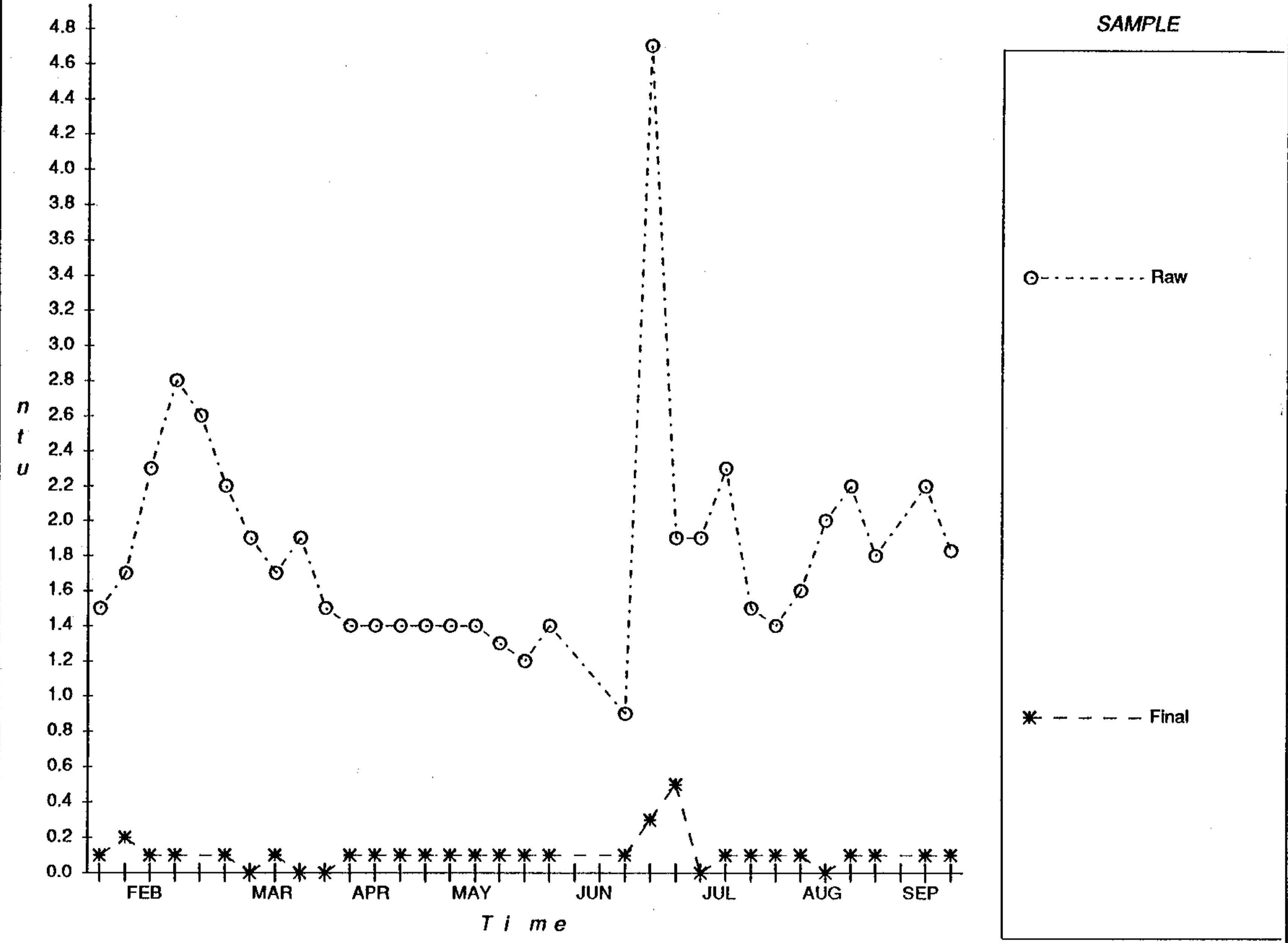


Figure 4 Iron vs Time

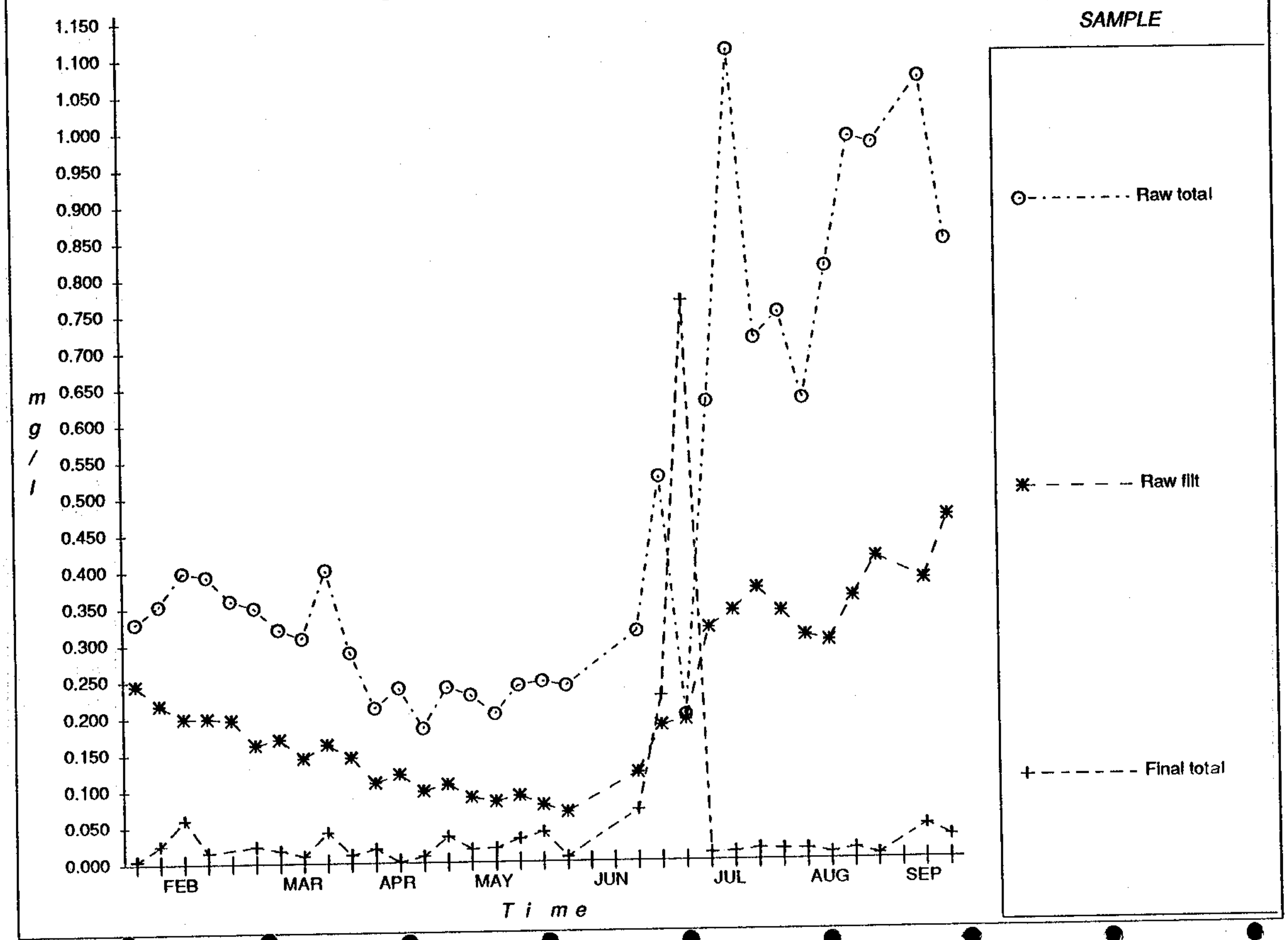


Figure 5 Aluminium vs Time

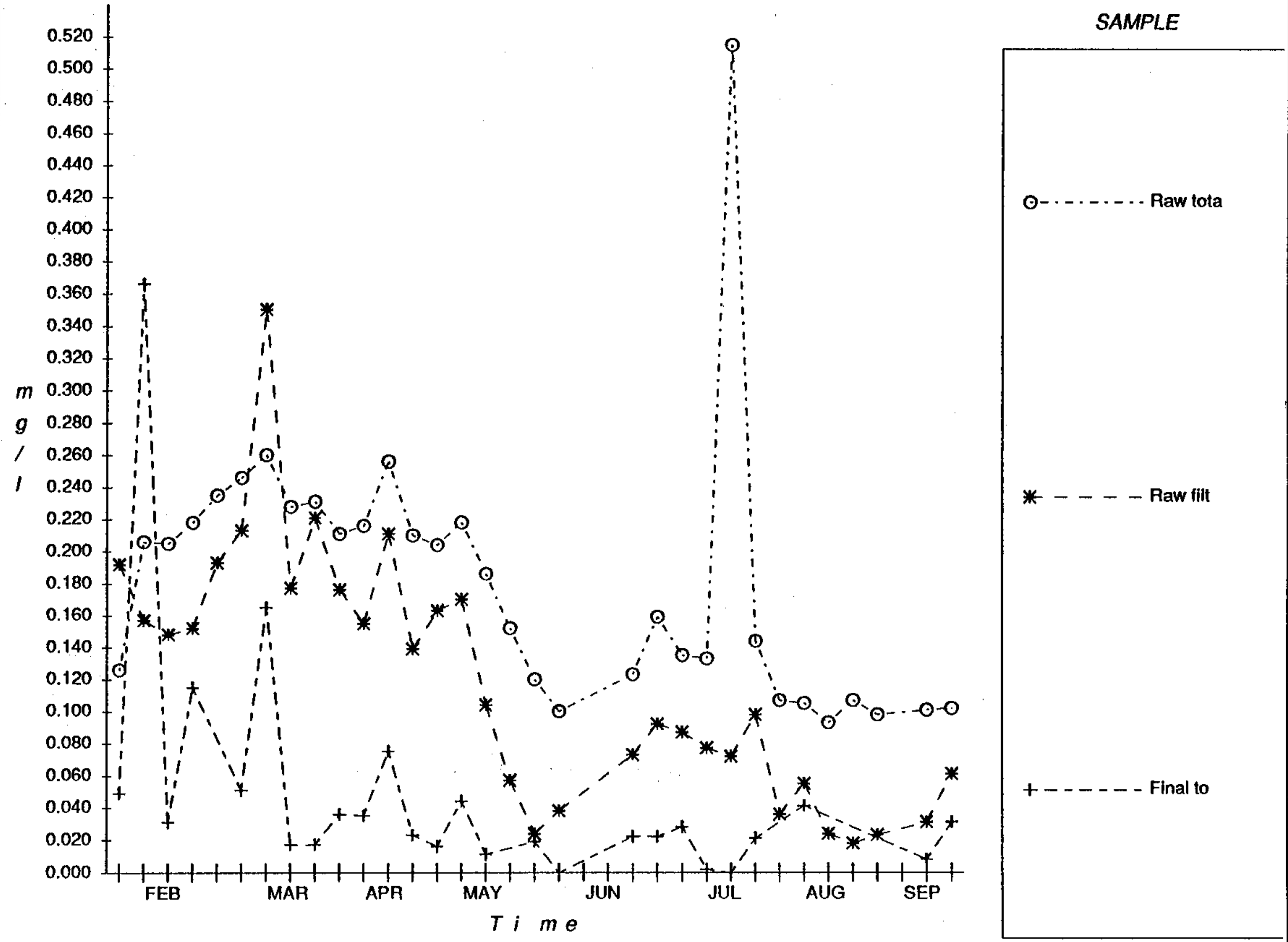


Figure 6   Manganese vs Time

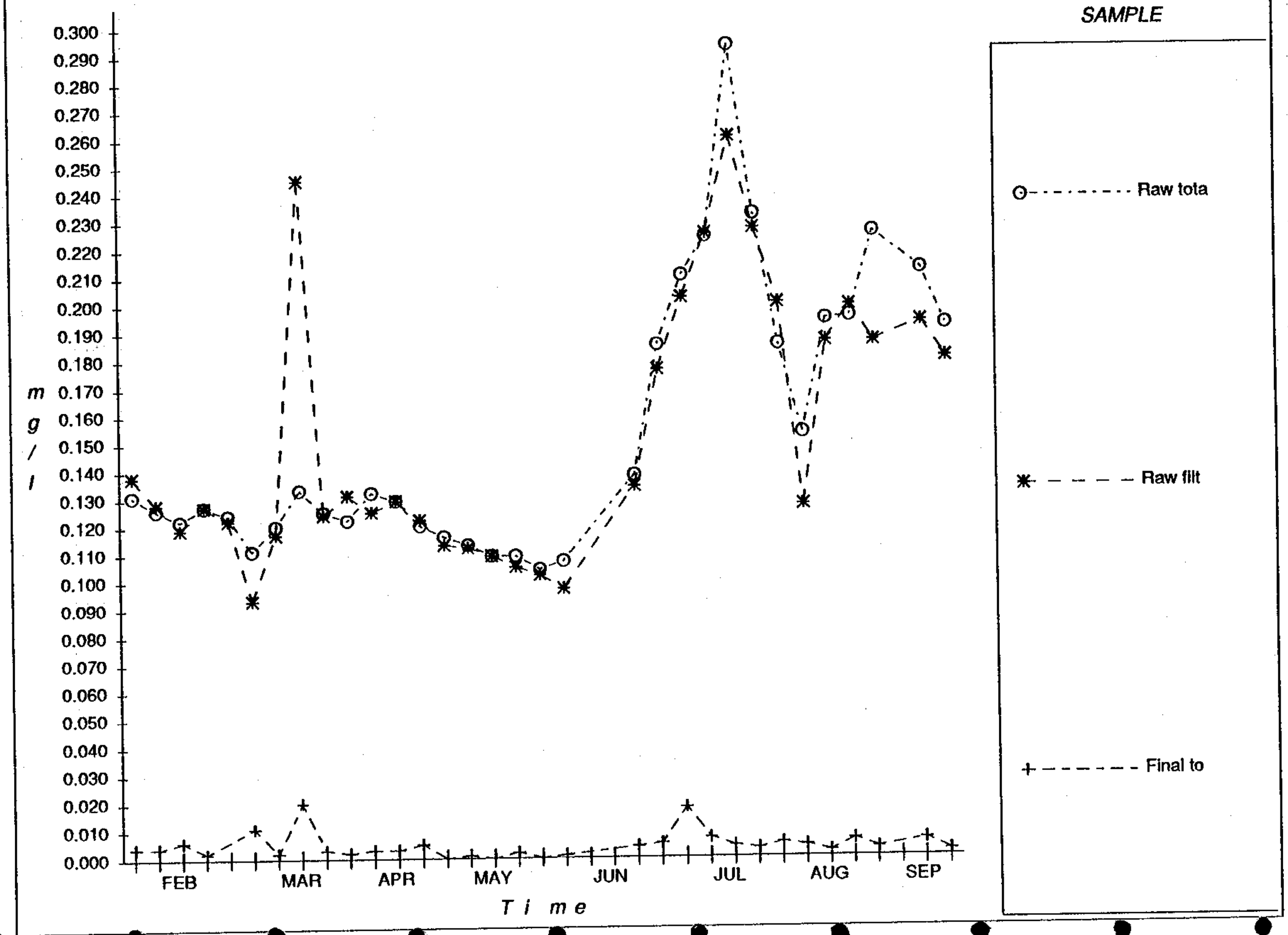


Figure 7 TOC vs Time

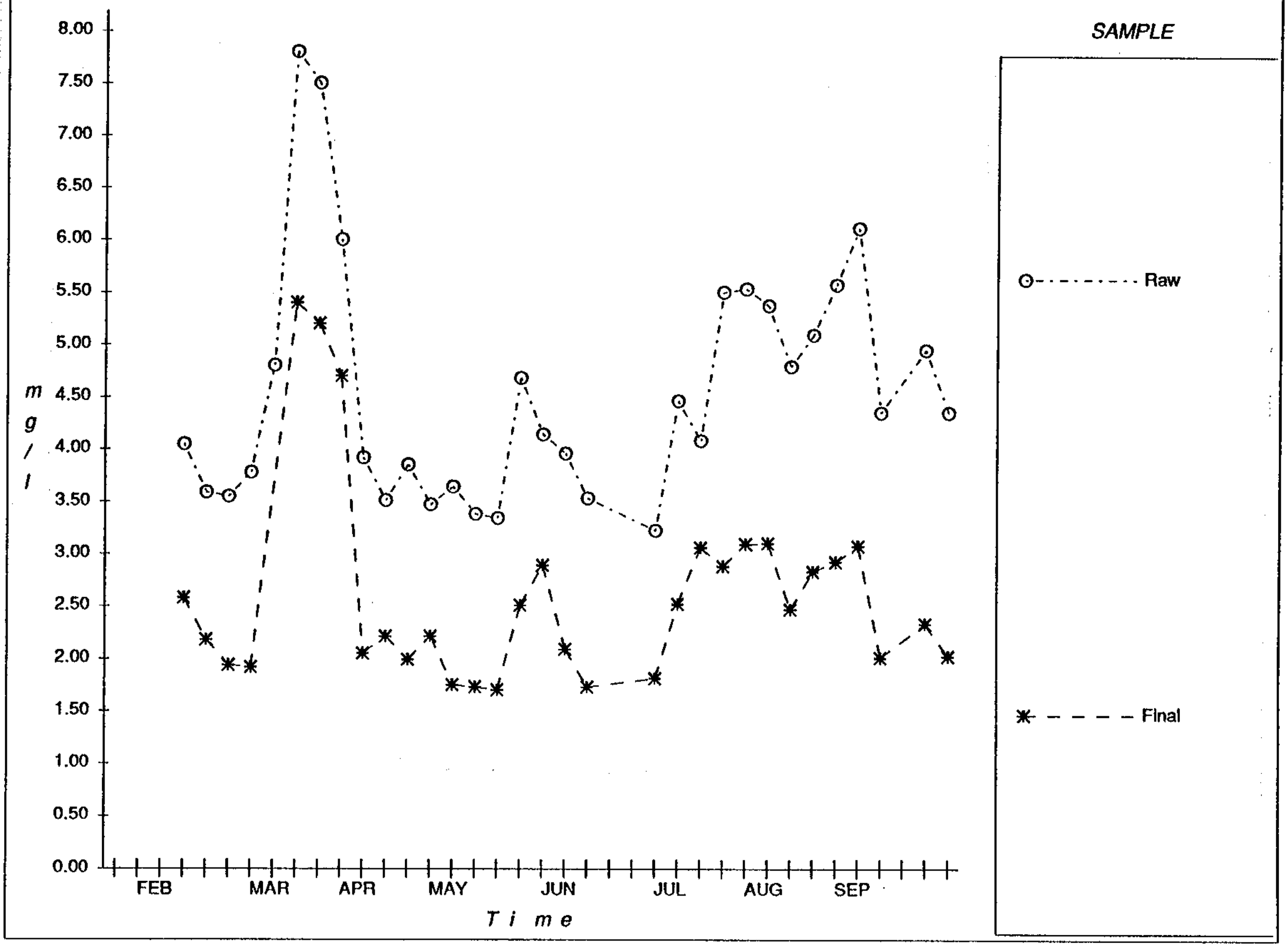


Figure 8 Uv absorbance(254nm) vs Time

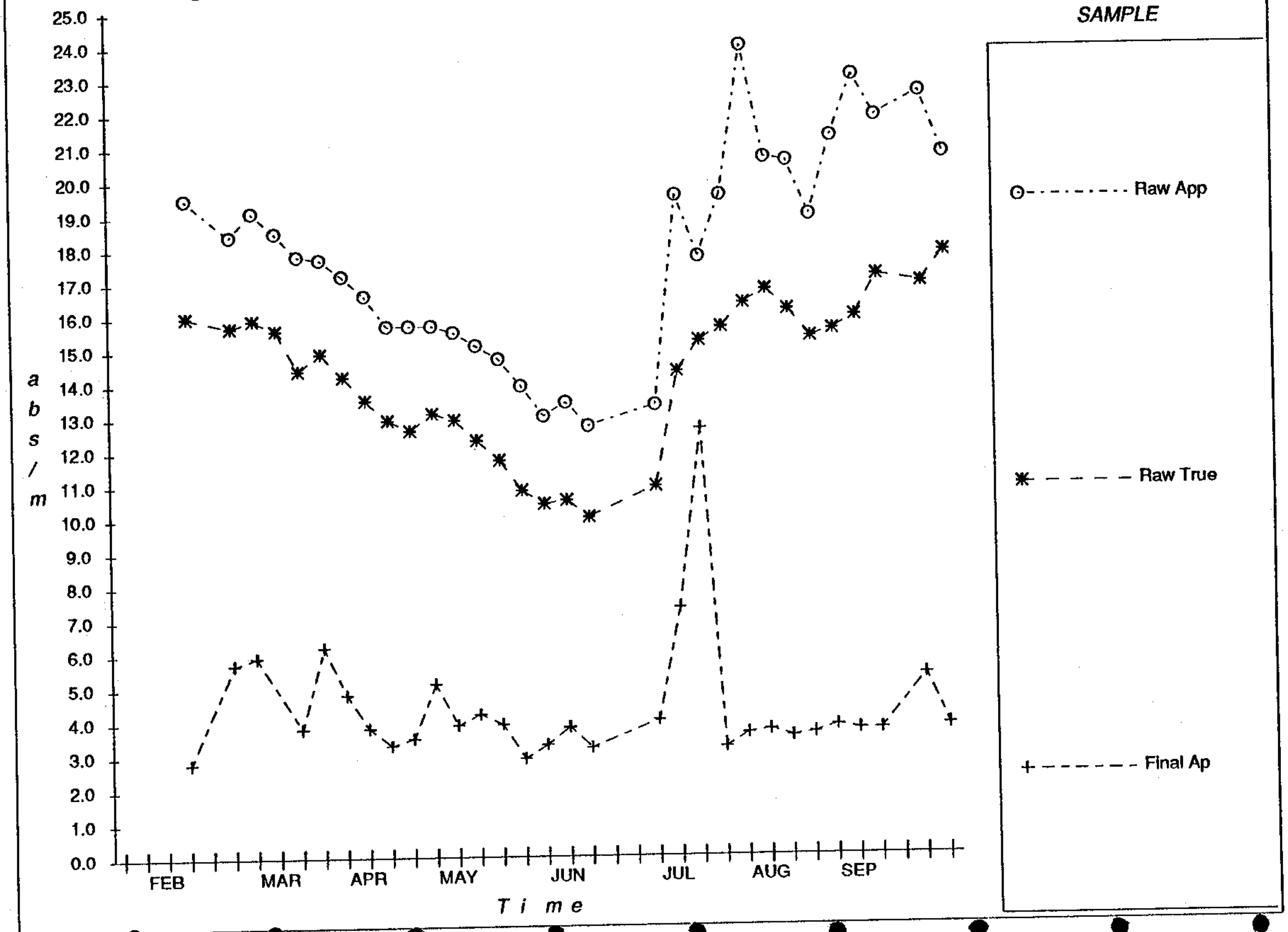


Figure 9 Chlorine demand vs Time

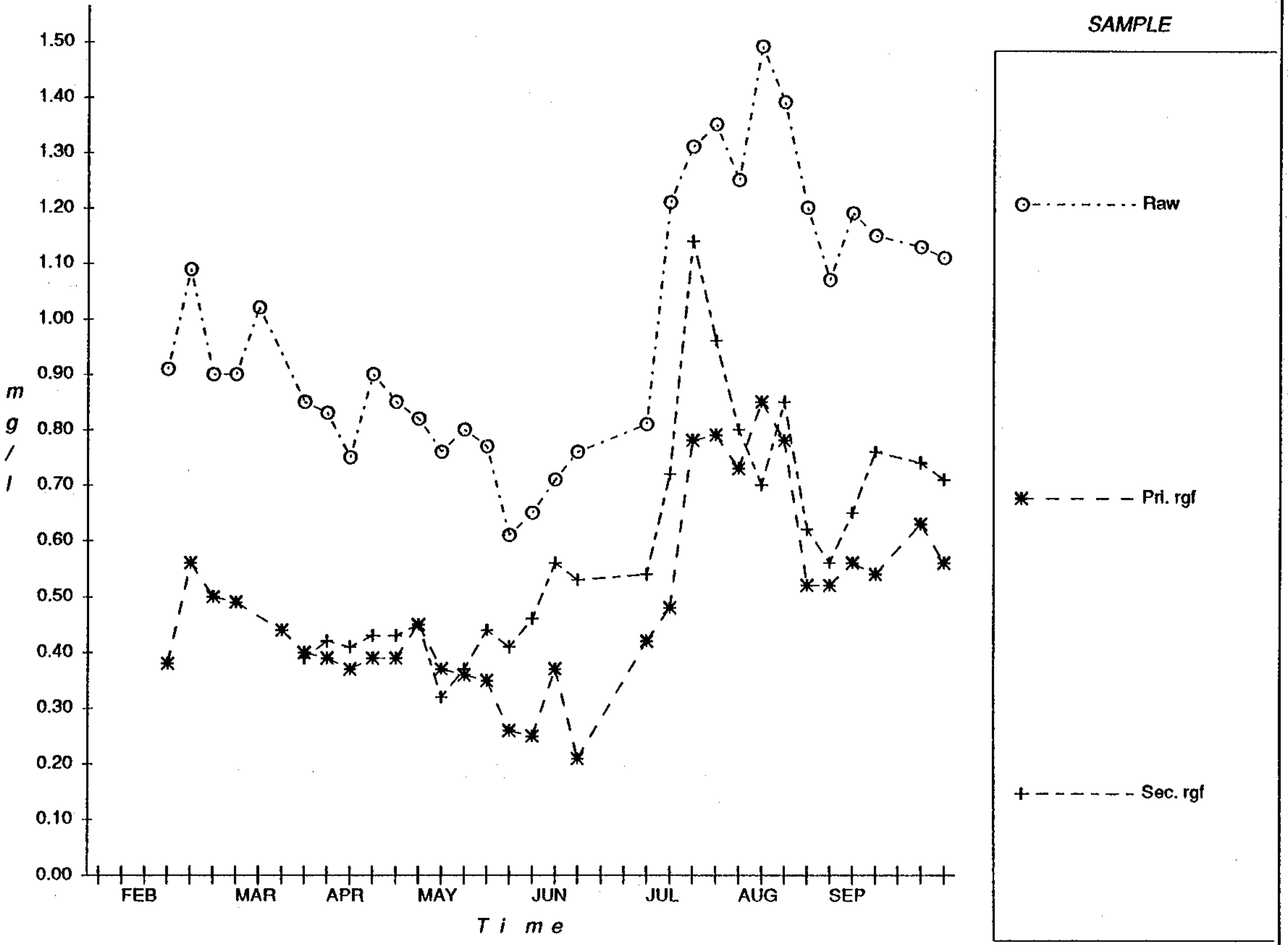


Figure 10 Total THM potential vs Time

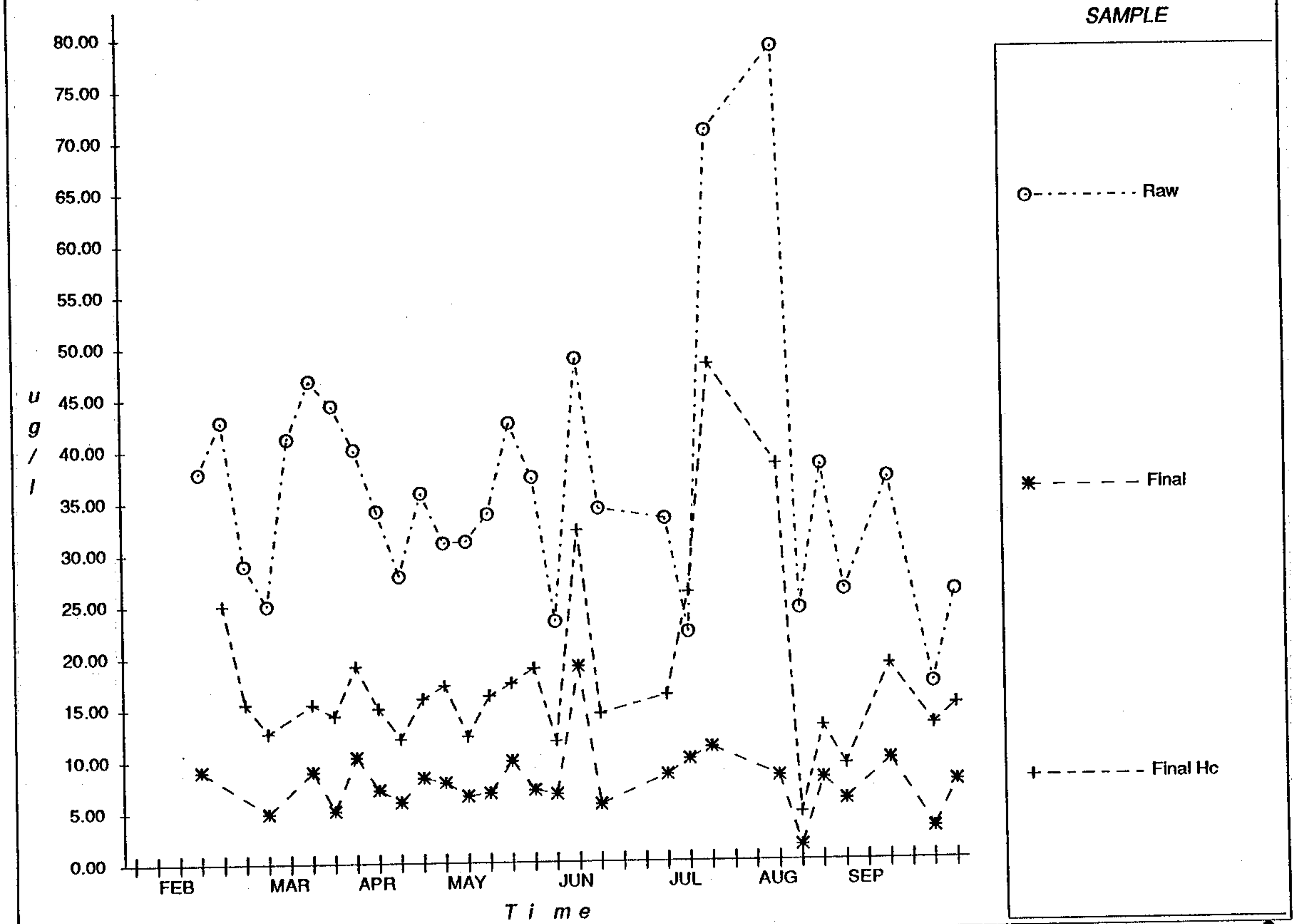


Figure 11 AOX potential vs Time

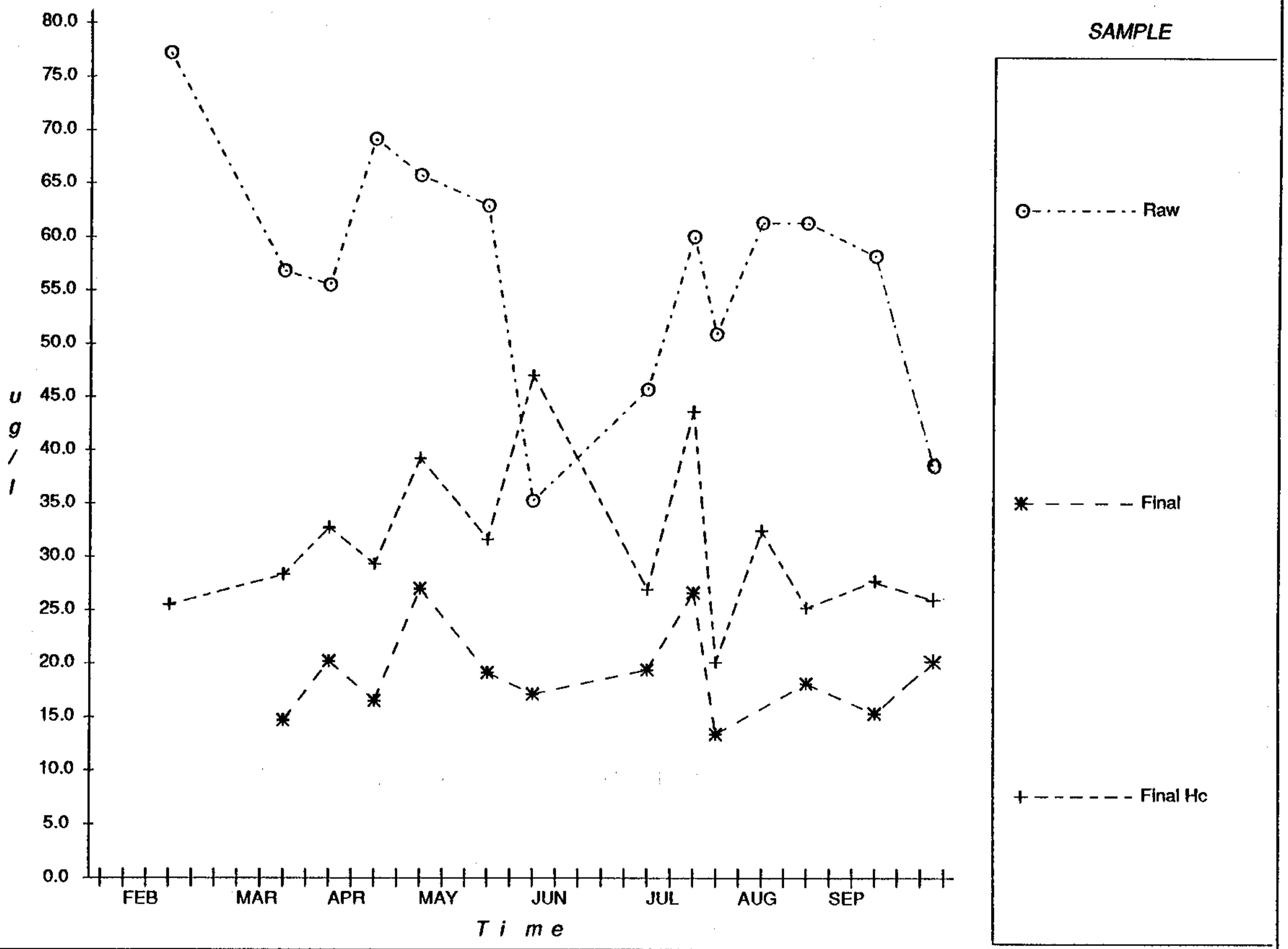


Figure 12 Mutagenicity vs Time

final hand chlorinated

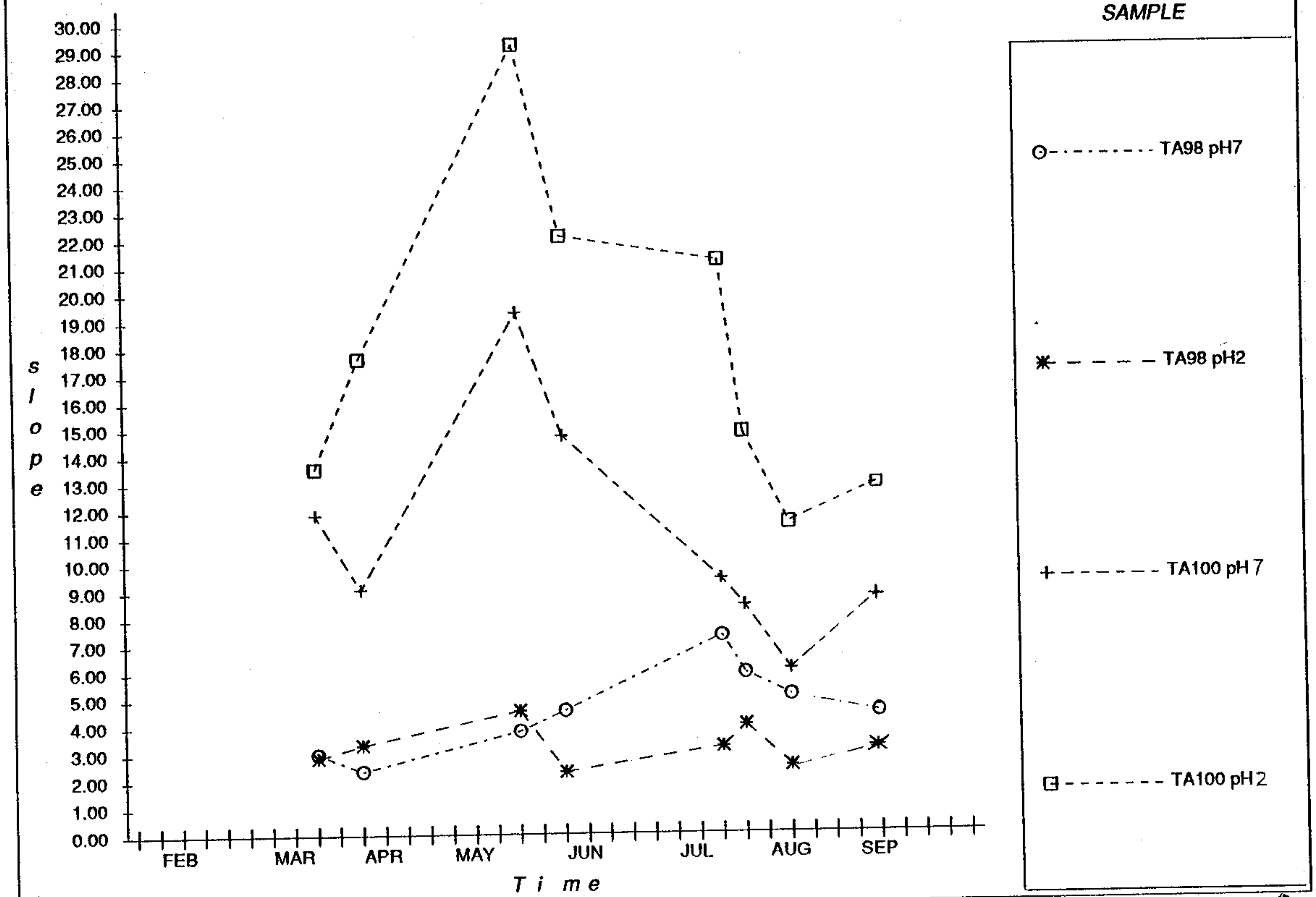


Figure 13 Colour vs uV Absorbance

o:apparent values. *: true values

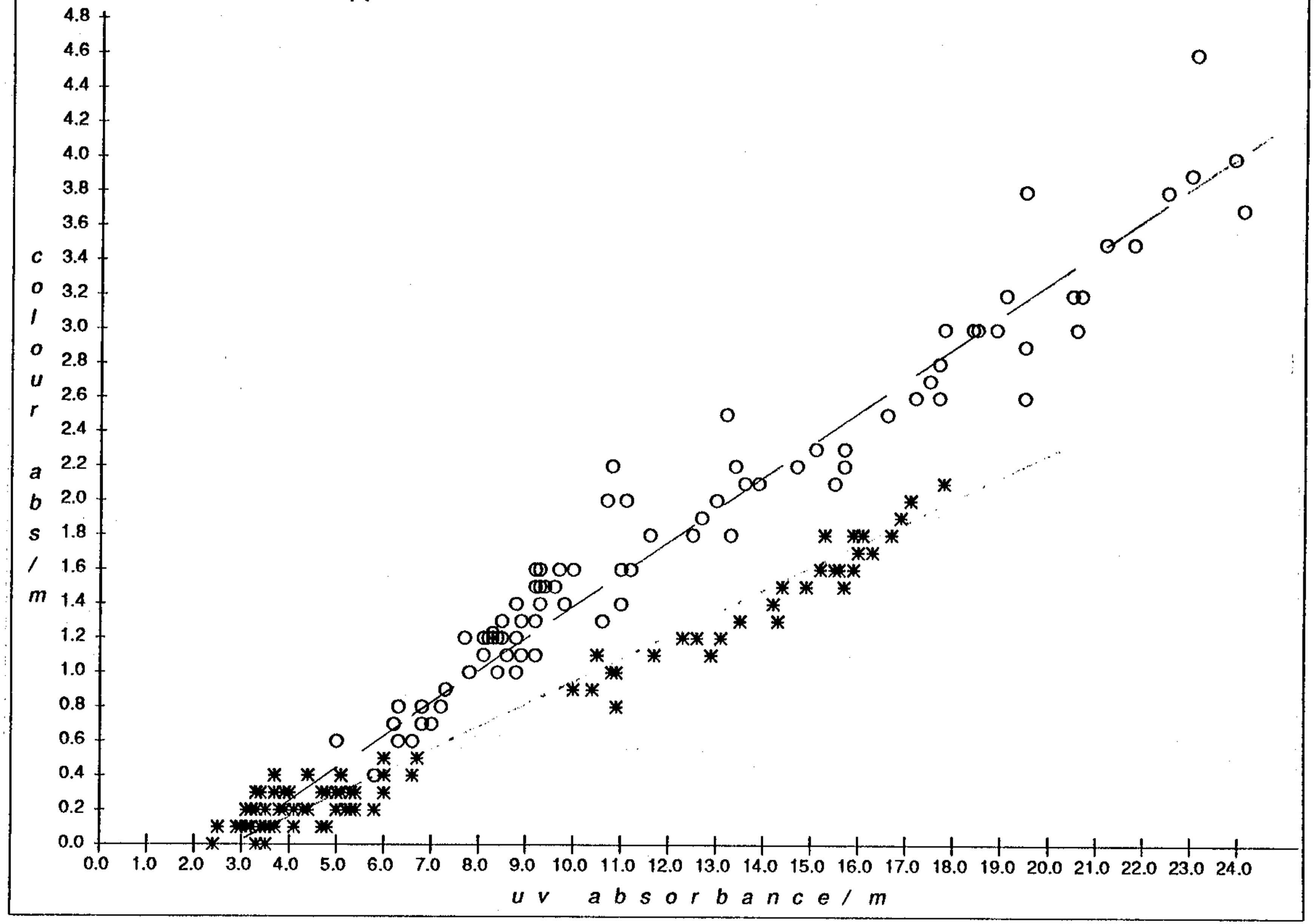


Figure 14 TOC vs uV Absorbance

o: raw water *:2' filtered water

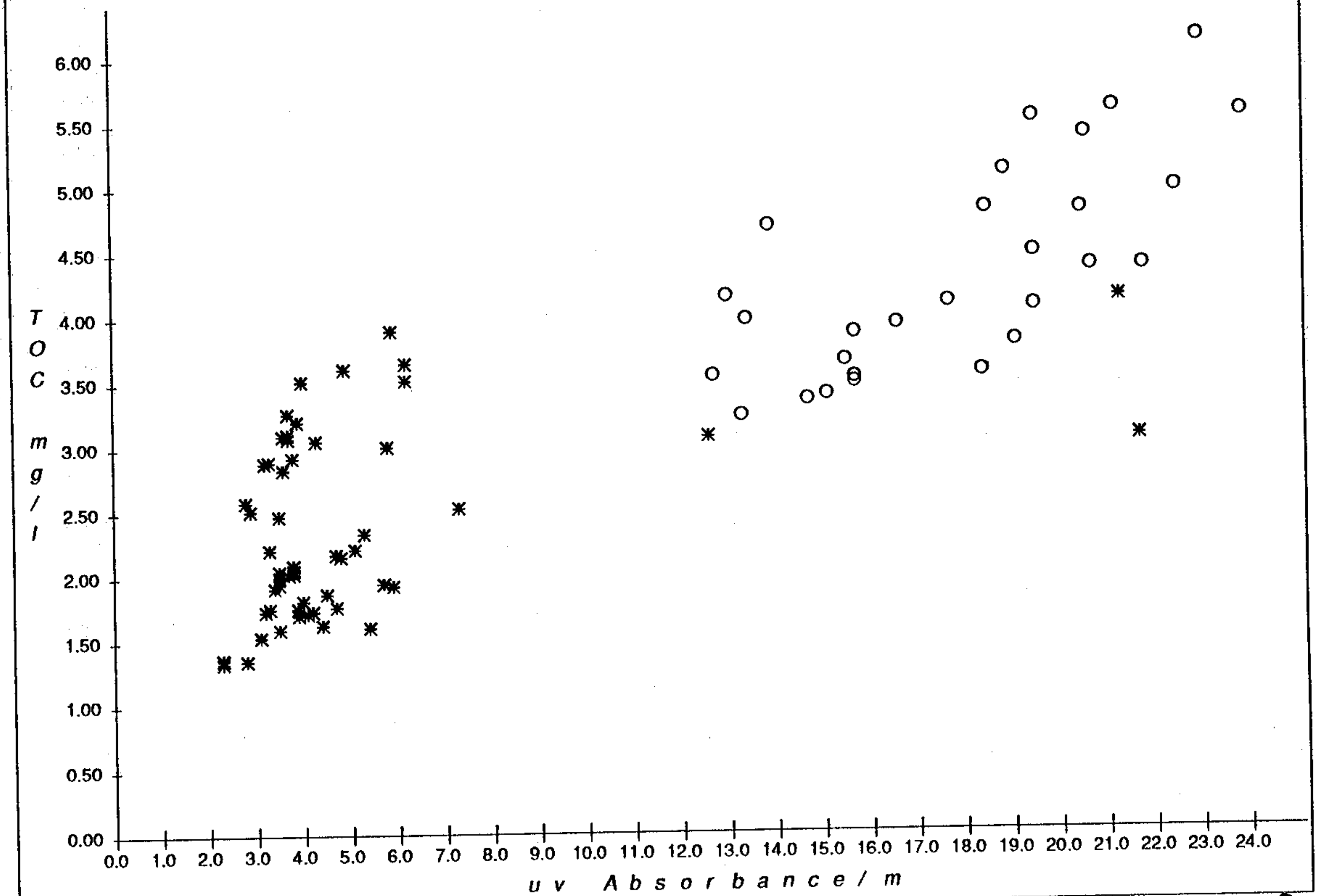


Figure 15 Total THM vs Chlorine Demand

o: raw water *:1' filtered water

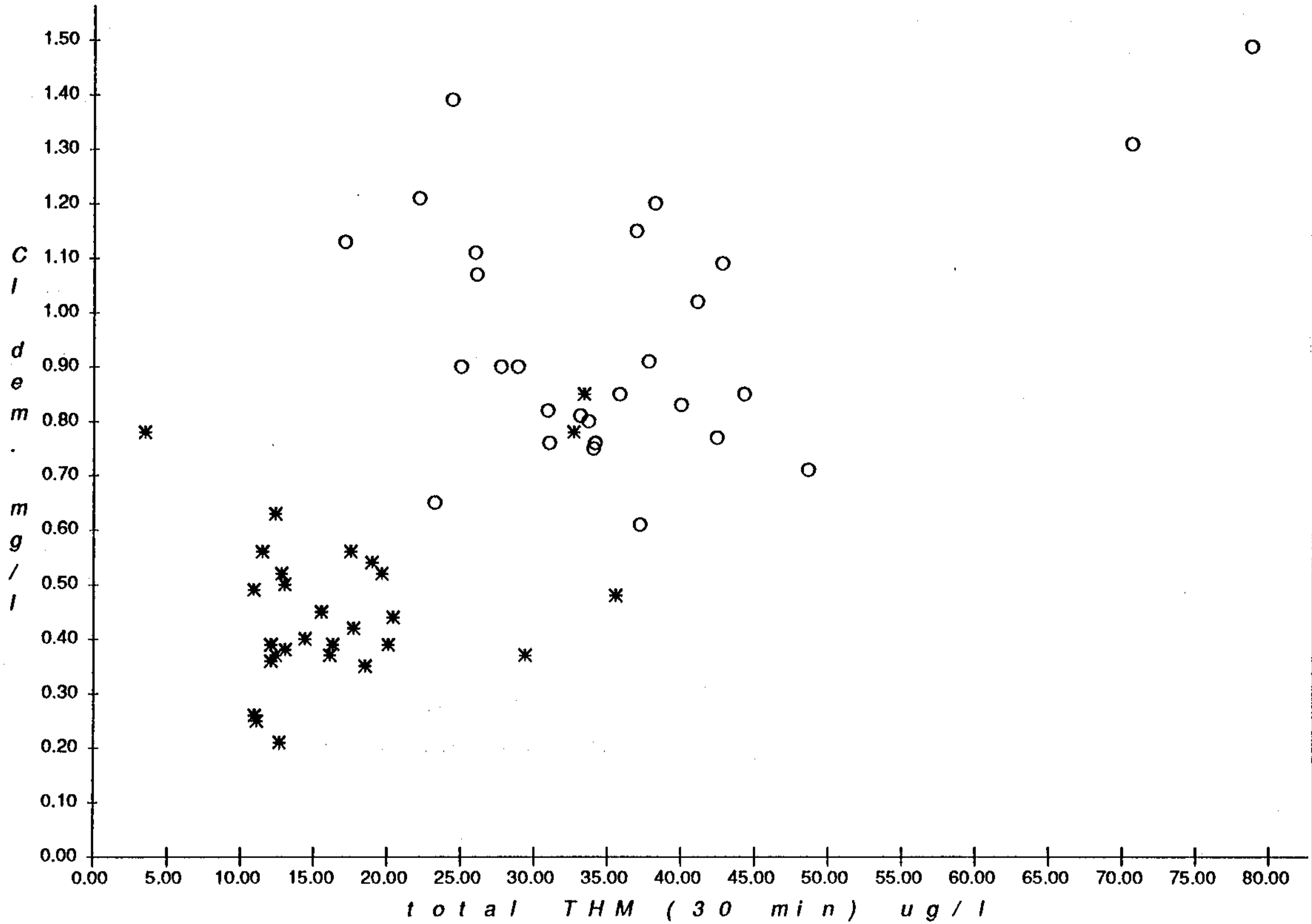
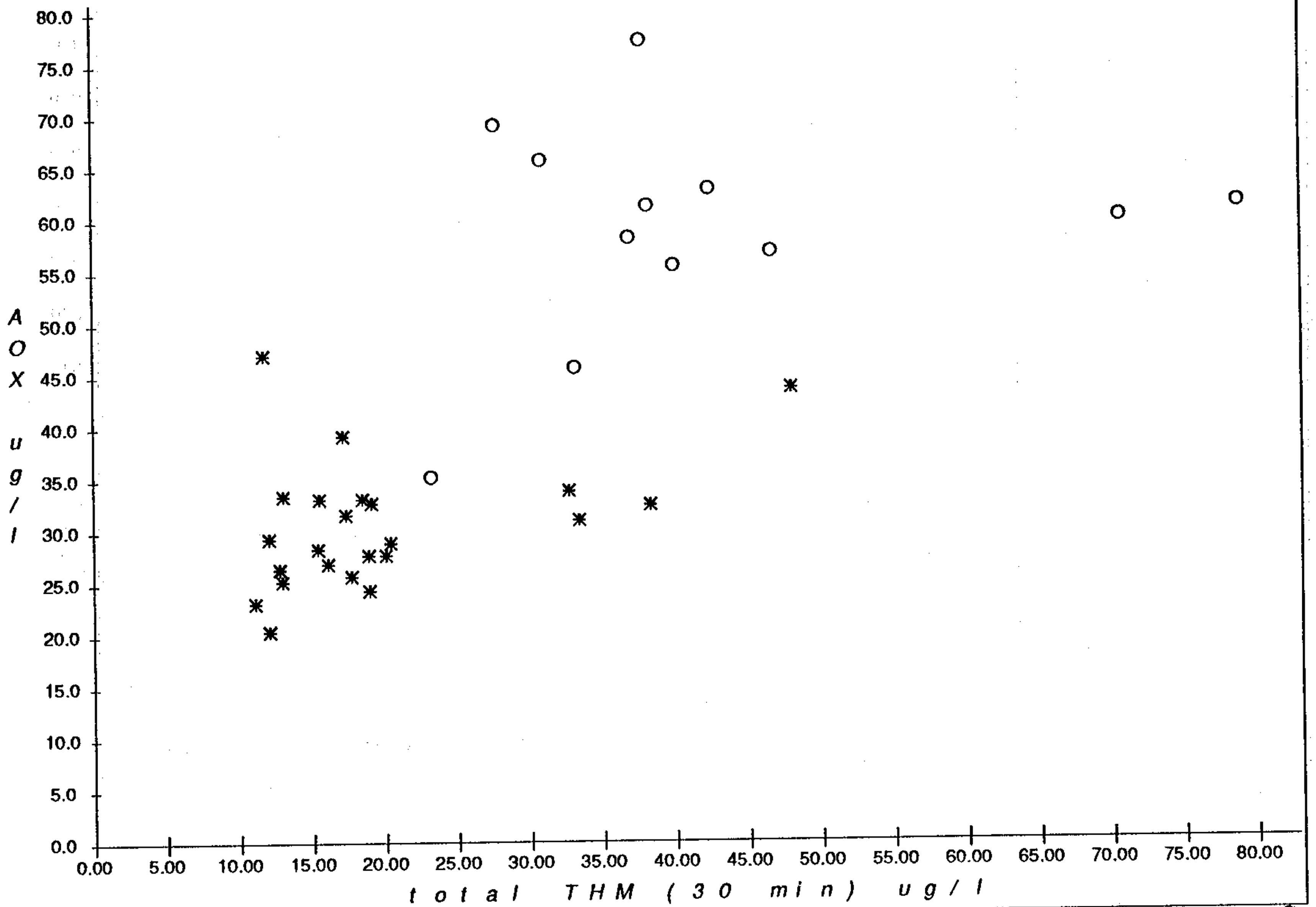


Figure 16 Total THM vs AOX

o: raw water *:1'and 2' filtered water



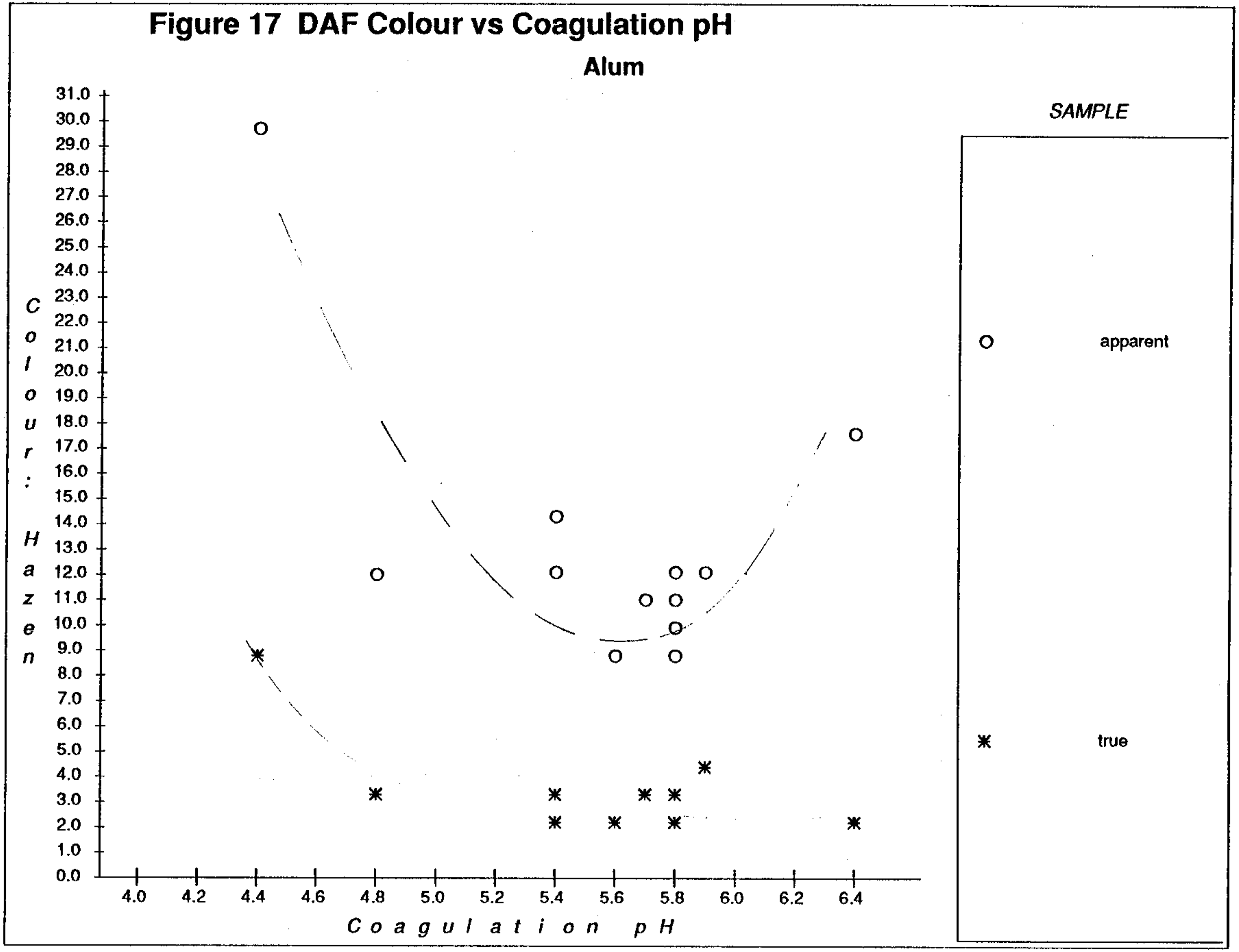


Figure 17 DAF Colour vs Coagulation pH
Alum
Colour: Hazen
31.0
30.0
29.0
28.0
27.0
26.0
25.0
24.0
23.0
22.0
21.0
20.0
19.0
18.0
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
Coagulation pH
SAMPLE
apparent
true

Figure 18 RGF Colour vs Coagulation pH

results from 1' and 2' rgfs, alum

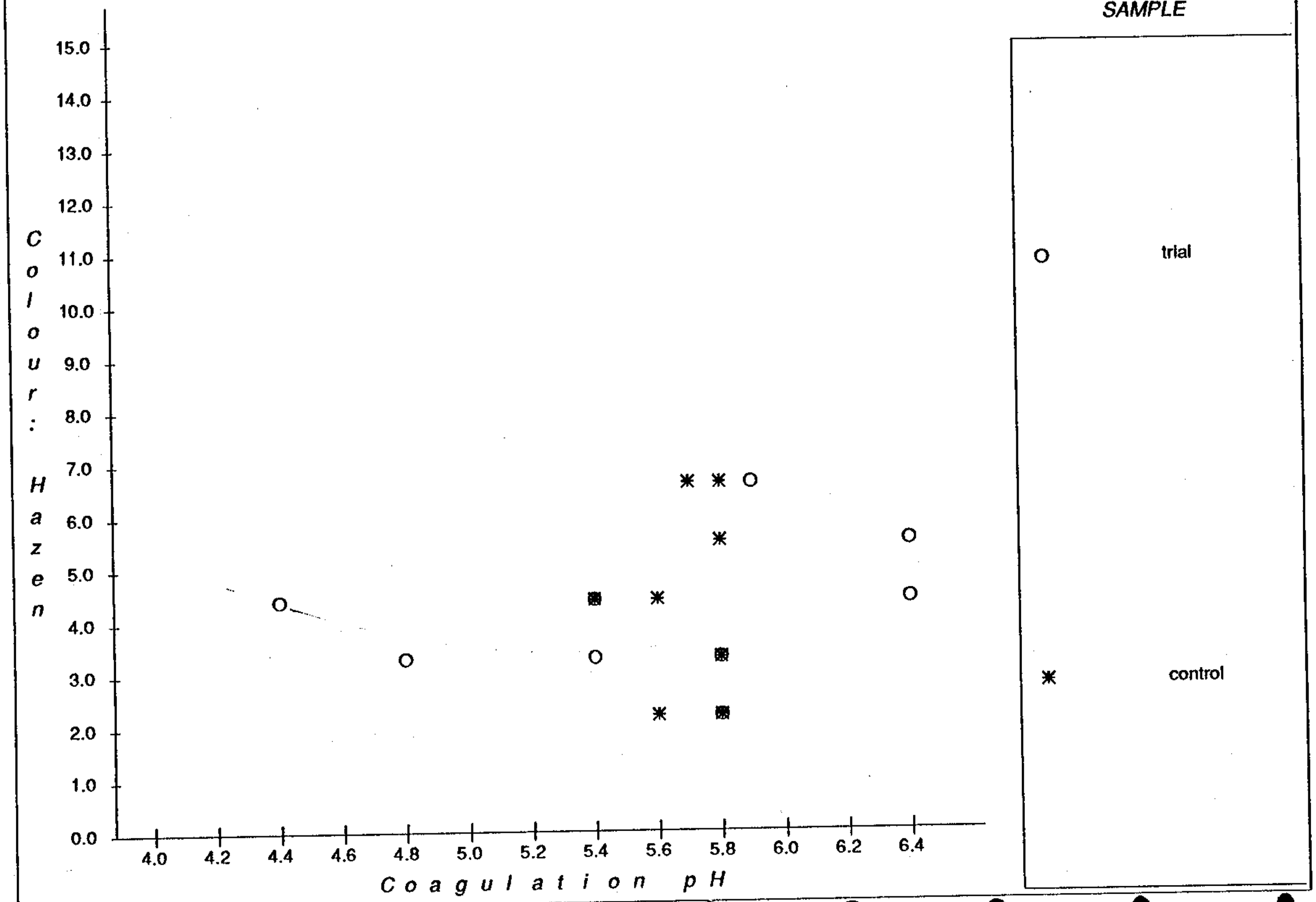


Fig. 19 TOC Removal vs Coagulation pH

TOC of 2' rgfs,(trial - control) Alum

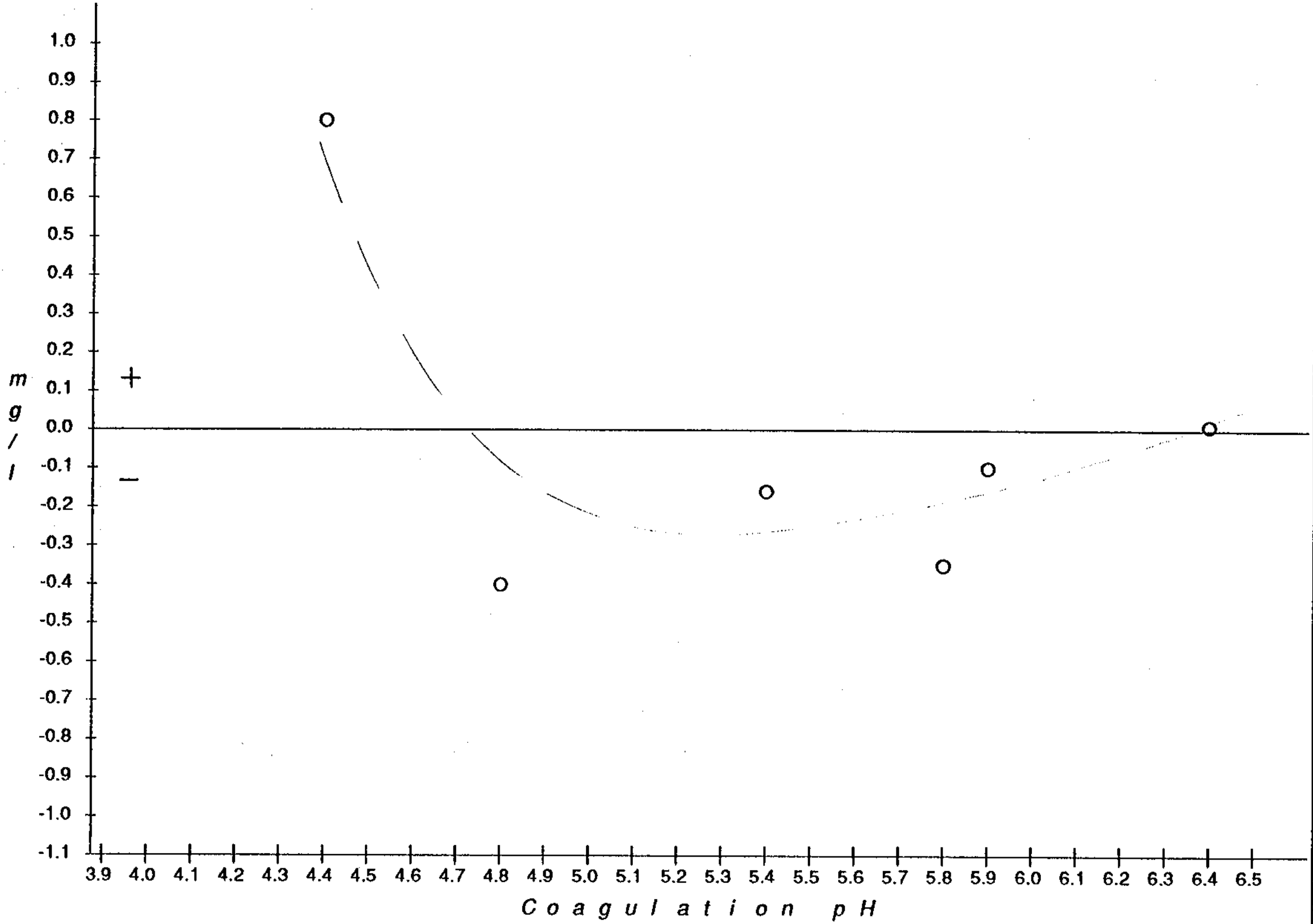


Figure 20 DAF Colour vs Coagulation pH

Ferric

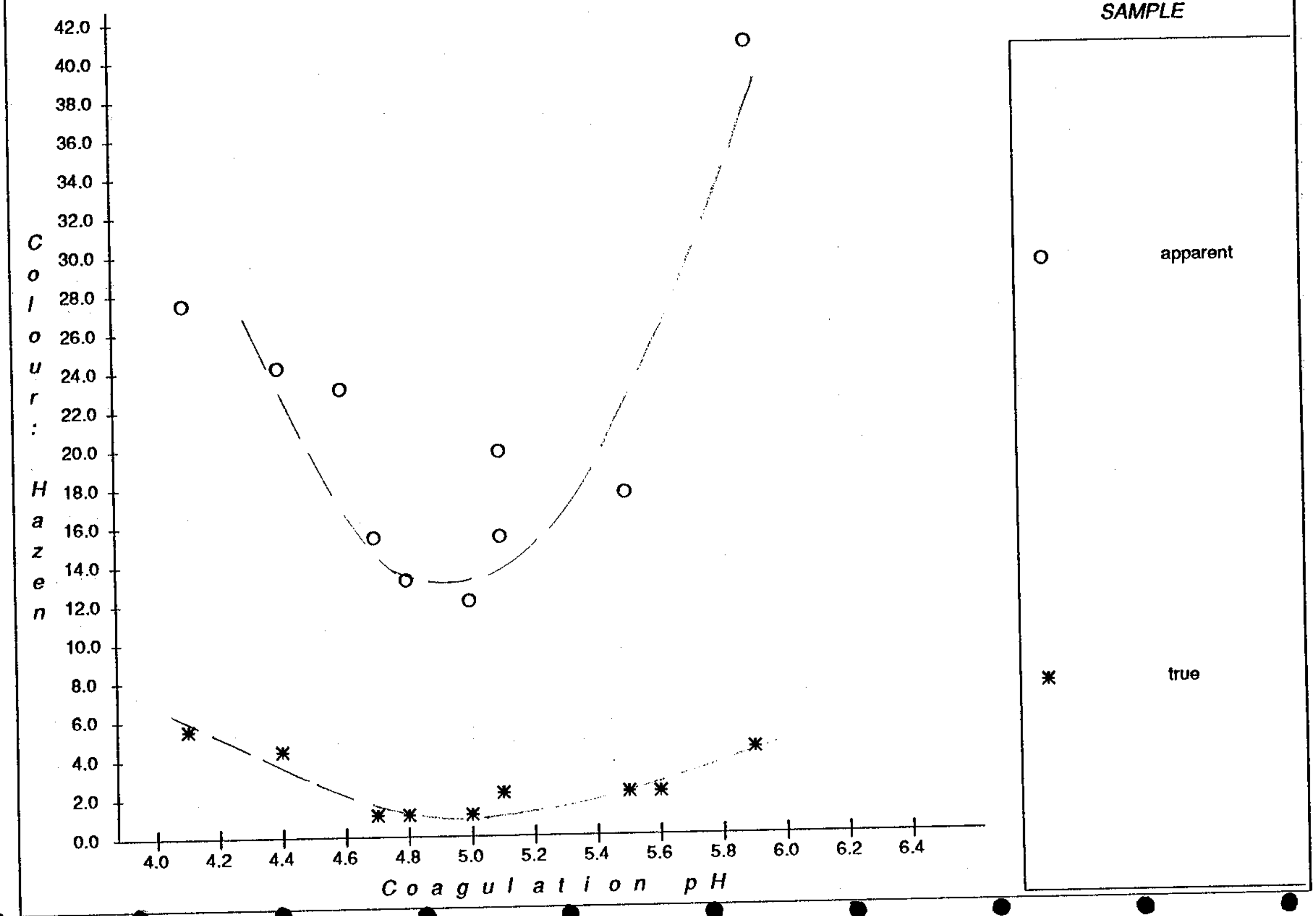


Figure 21 RGF Colour vs Coagulation pH

results from 1' and 2' rgfs, ferric

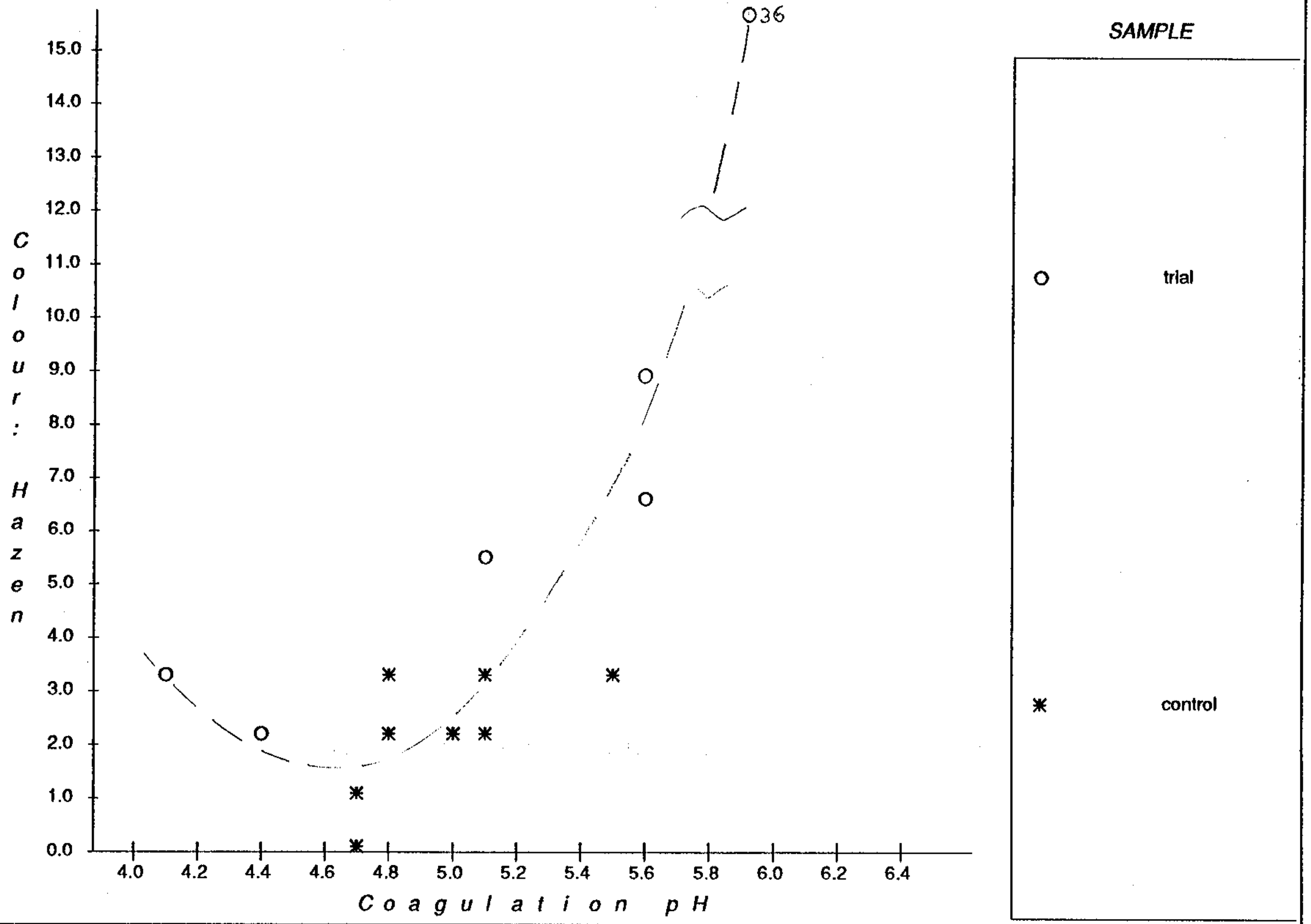


Fig. 22 TOC Removal vs Coagulation pH

TOC of 2' rgfs,(trial - control) Ferric

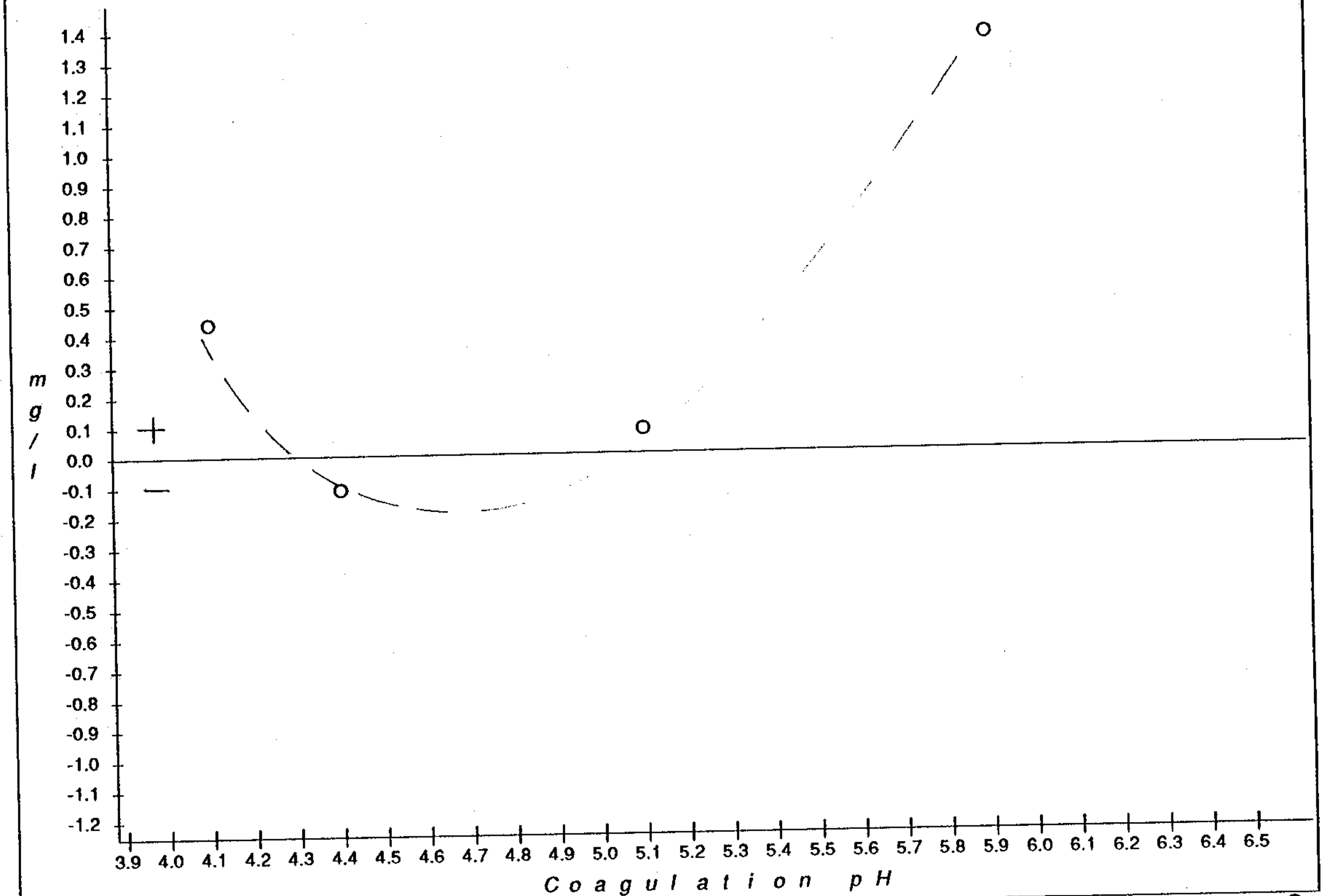


Figure 23 DAF Colour vs Alum Dose

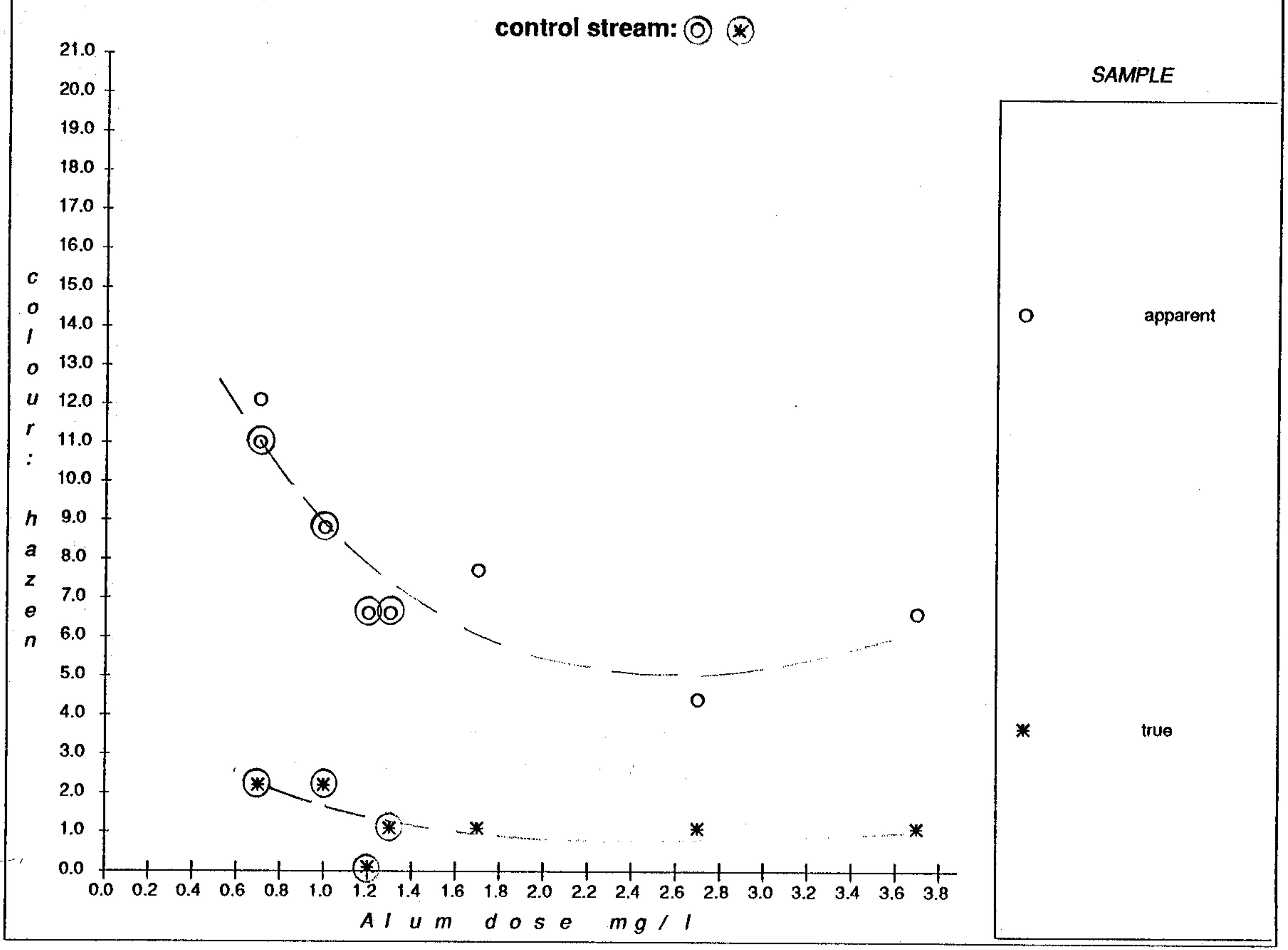


Figure 24 RGF Colour vs Alum Dose

results from 1' and 2' rgfs

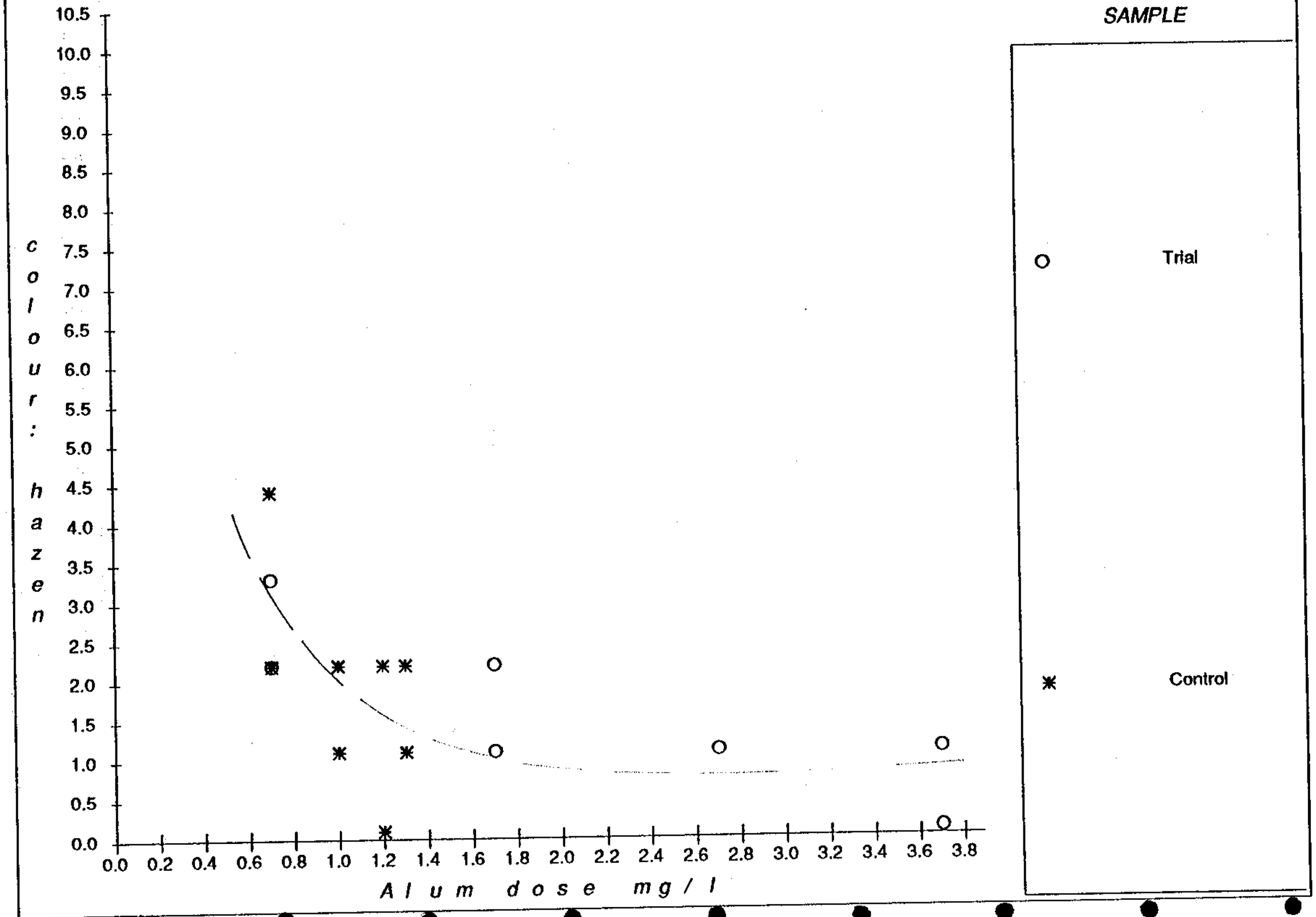


Figure 25 RGF TOC vs Alum Dose

results from 2' rgfs

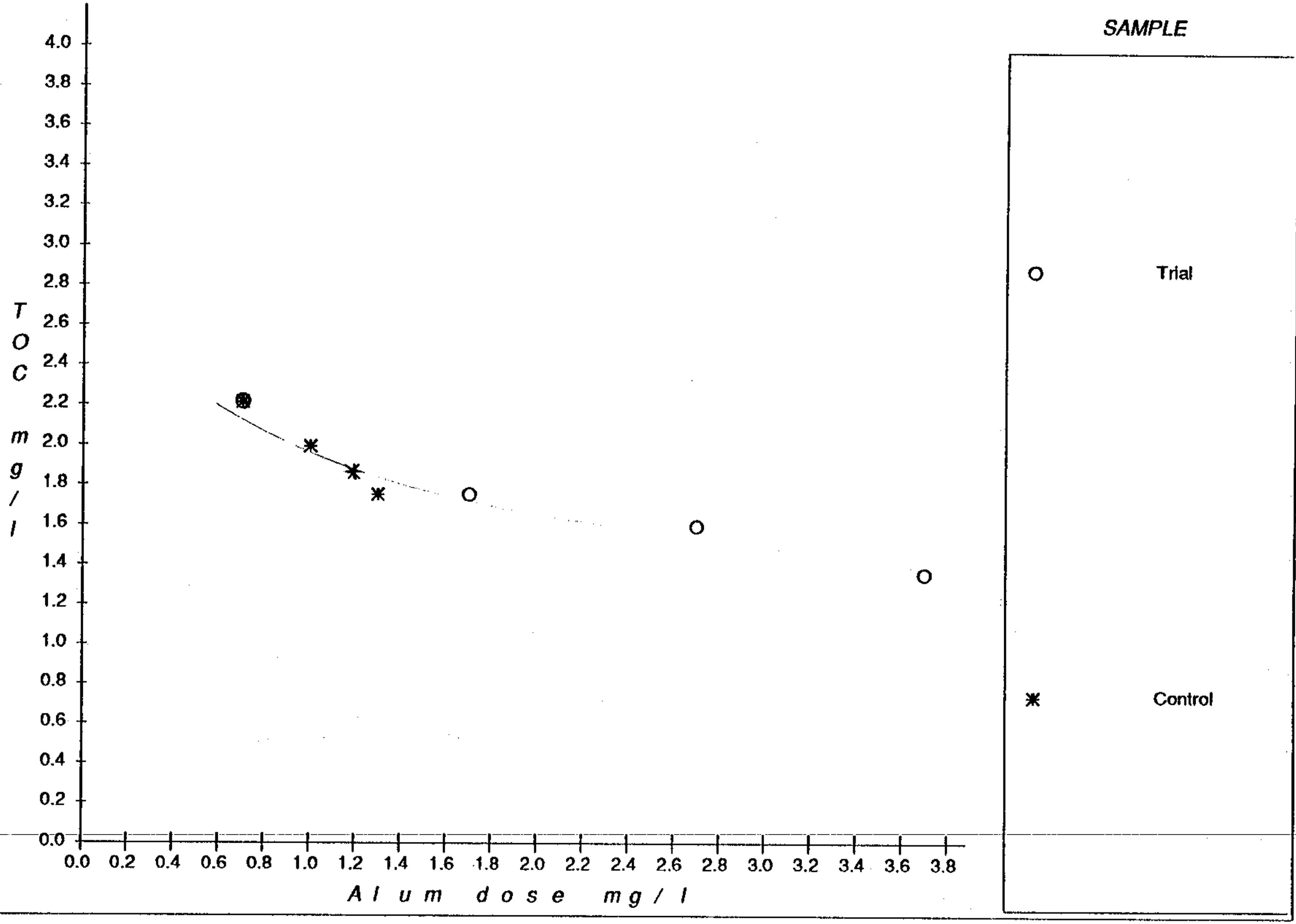


Figure 26 DAF Colour vs Ferric Dose

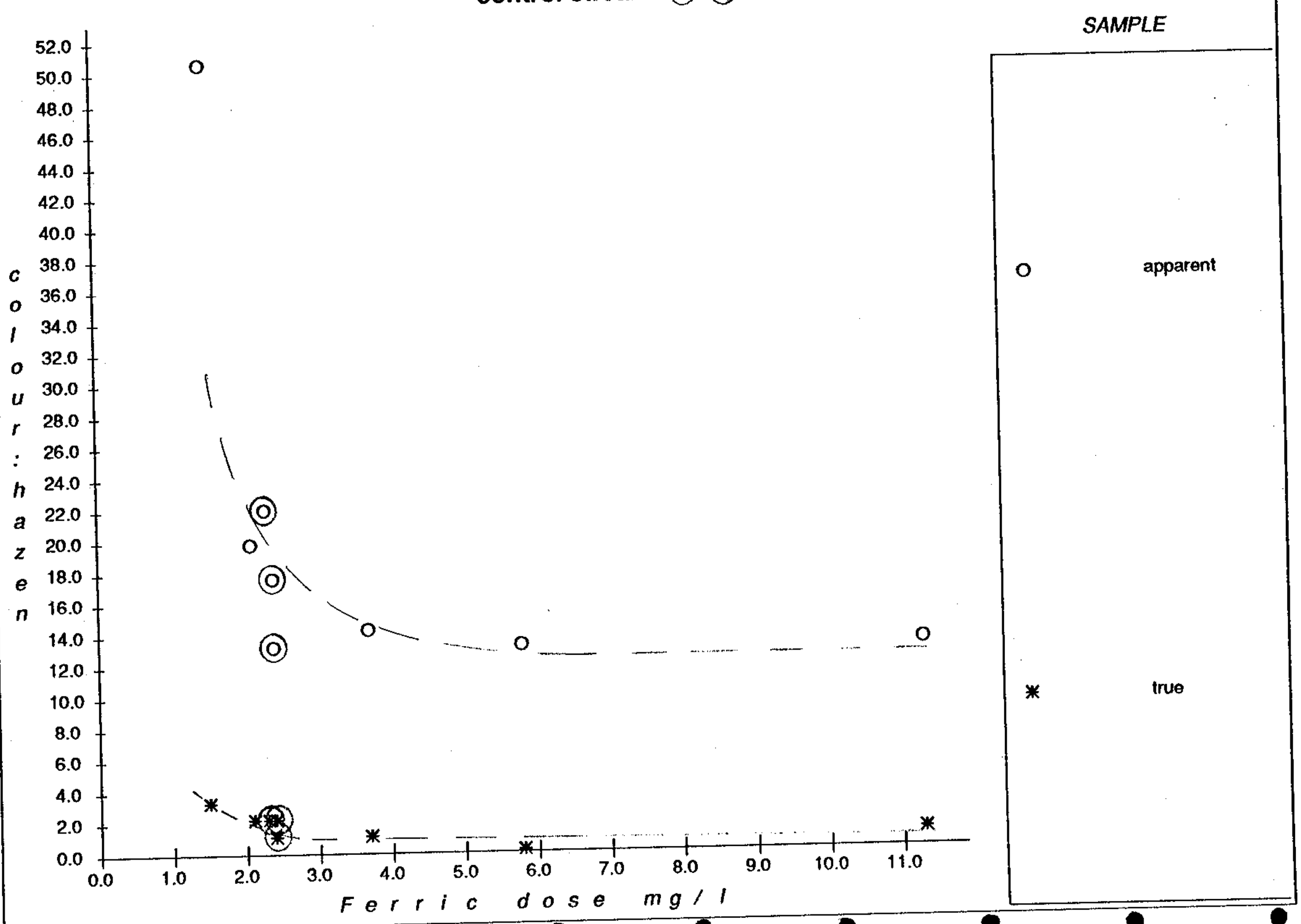


Figure 27 RGF Colour vs Ferric Dose

results from 1' and 2' rgfs

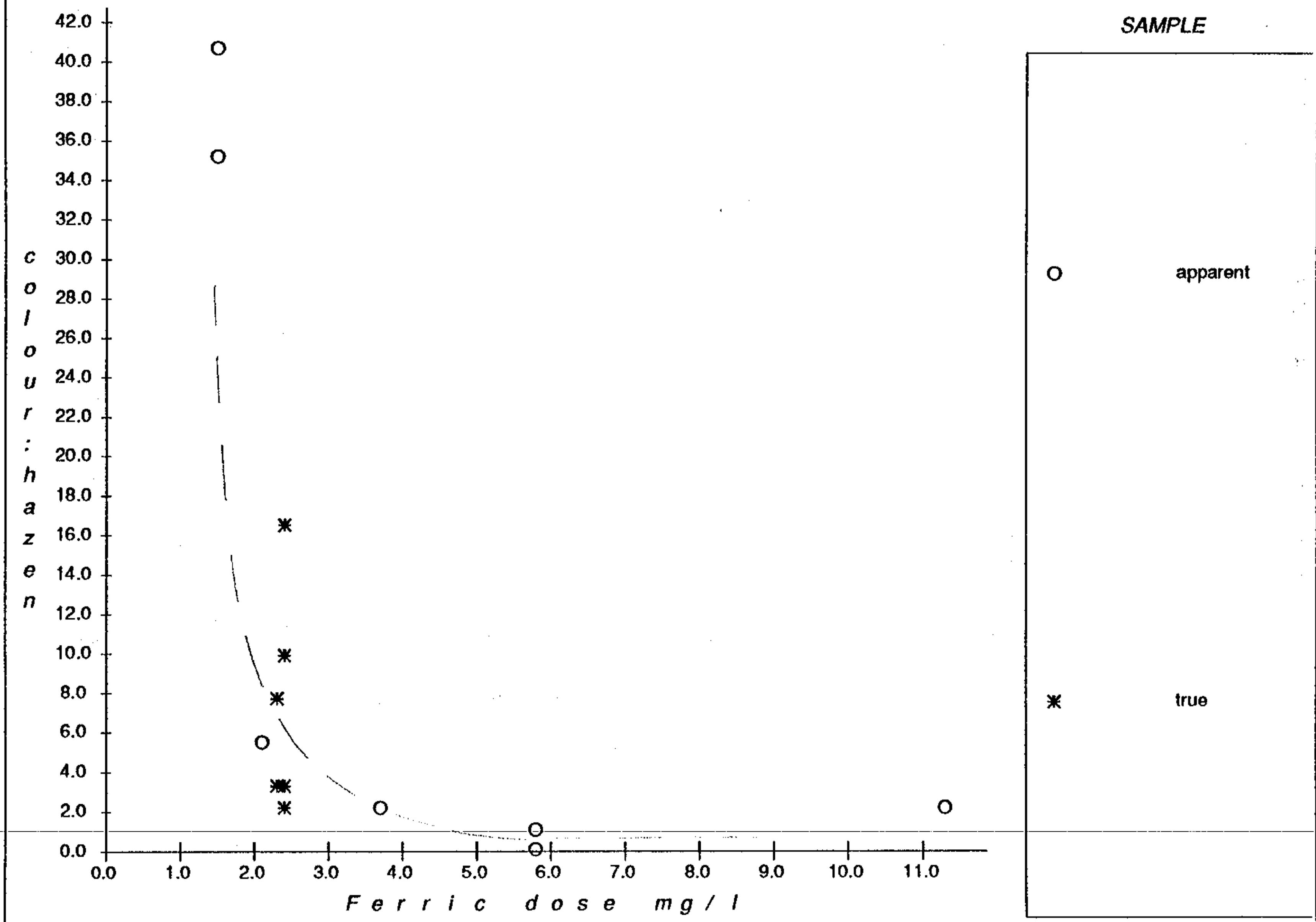


Figure 28 TOC vs Ferric Dose

results from 2' rgfs

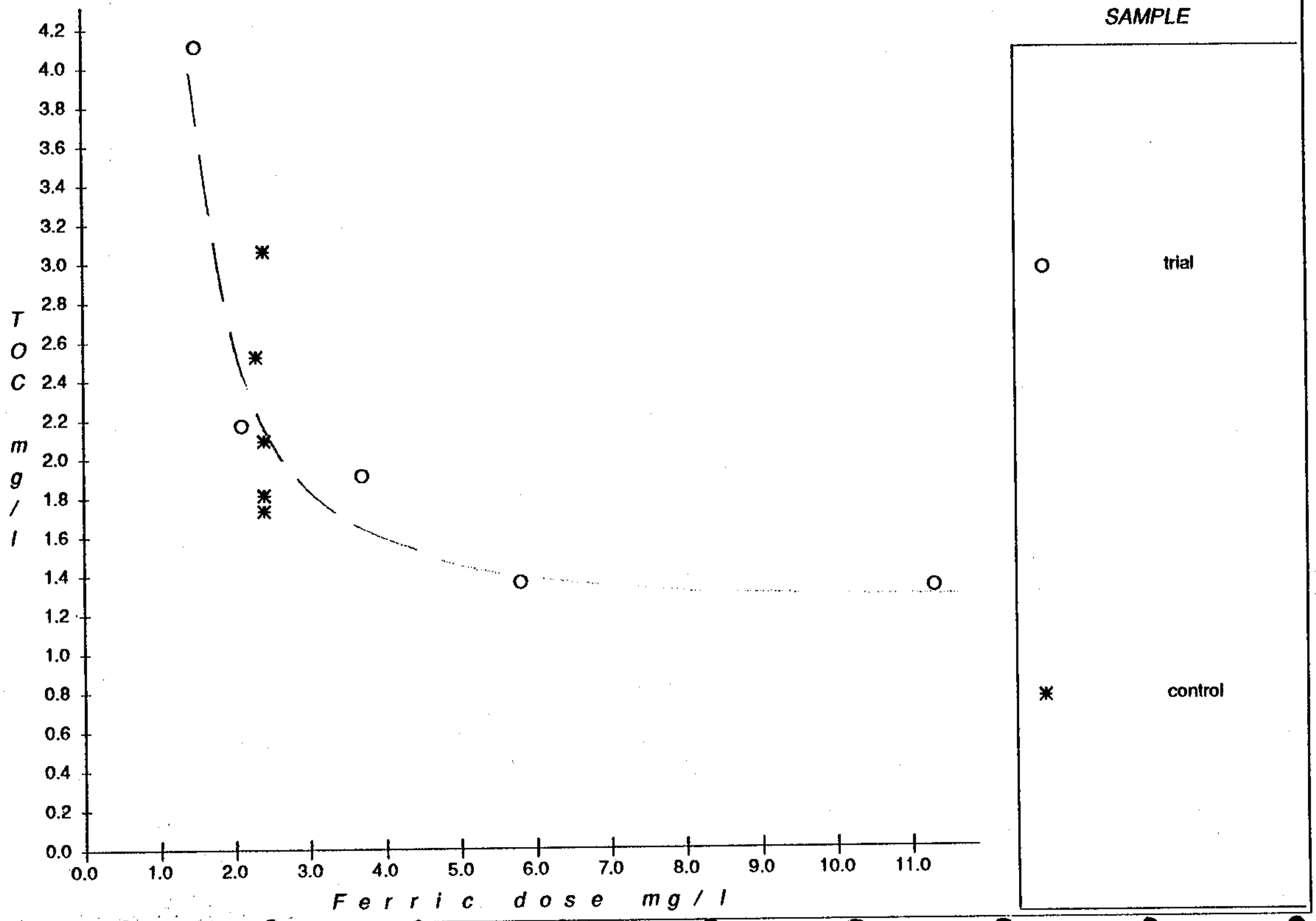


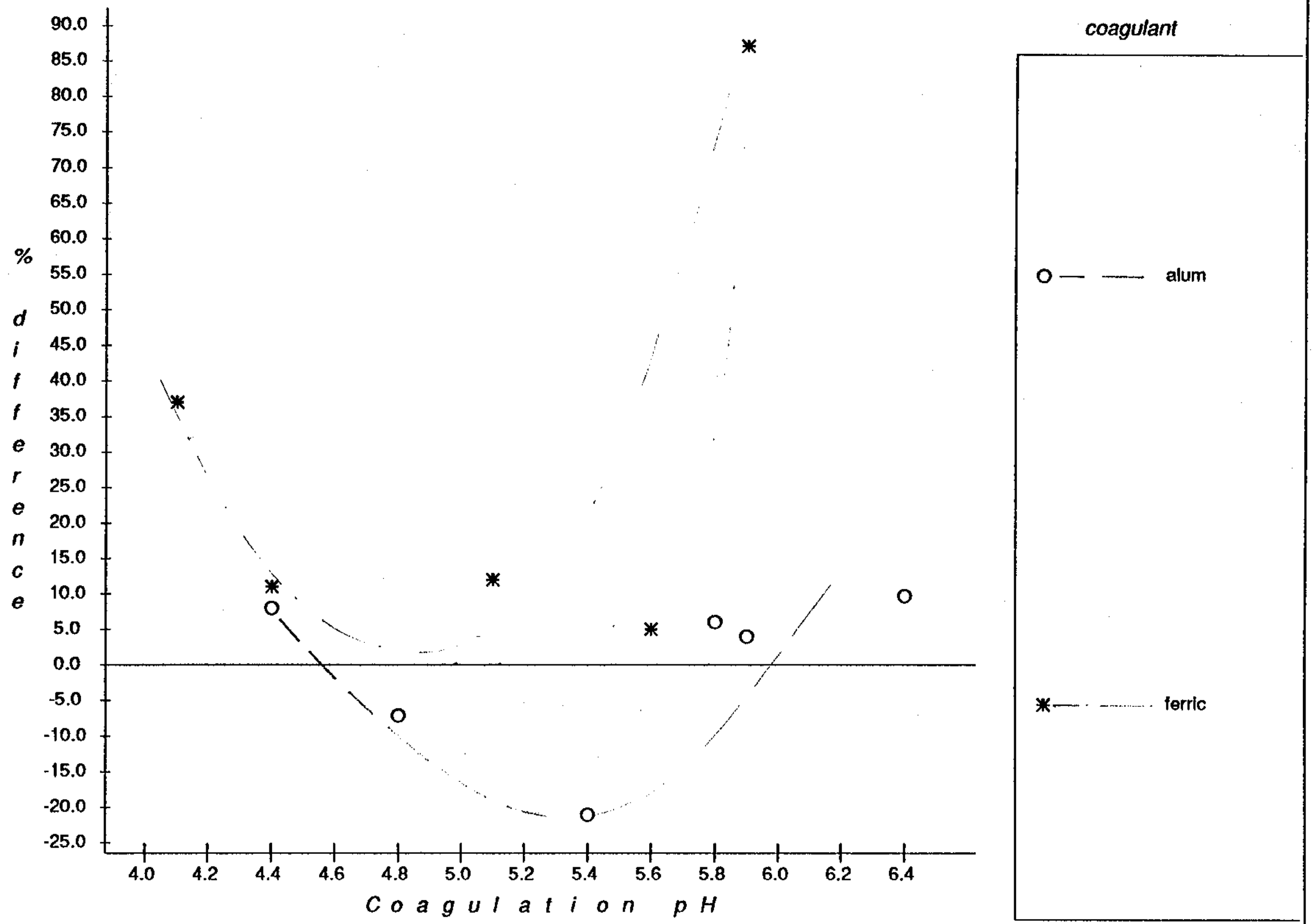
Figure 27

Trial & Control

NOT apparent – True

Fig 29 Coagulation pH vs THM Formation

((trial - control)/control) * 100



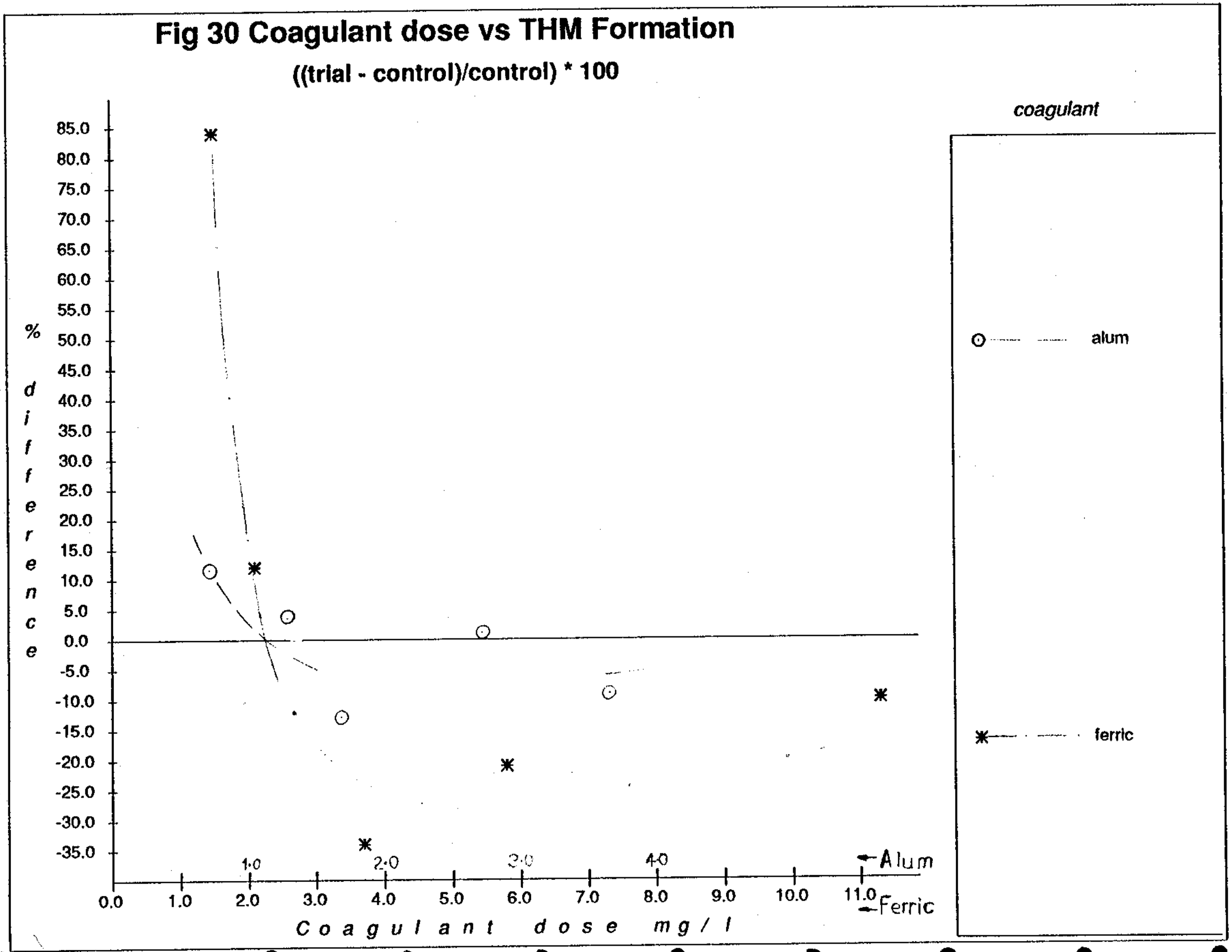


Fig 30 Coagulant dose vs THM Formation
((trial - control)/control) * 100
% difference
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
-30.0
-35.0
1.0
2.0
3.0
4.0
Alum
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
Ferric
Coagulant dose mg / l
coagulant
alum
ferric

PHASE 1, TEST (A) Part (i): EFFECT OF COAGULATION pH USING ALUM

OPERATIONAL REGIME

This test was carried out between 21 Feb and 28 March 1989. In this test, stream A was operated under constant conditions (control) whilst the coagulation pH of stream B was changed (trial). The coagulant used in both streams was aluminium sulphate. The coagulation pH has been taken as the pH of the DAF treated water or the flocculated water; at steady state these two values are identical. For both streams during the test the primary filter target pH was 6.5 and the secondary filter target pH was 9.0. The results of 6 separate runs have been considered, including 21 Feb which was a commissioning run with a slightly higher saturator pressure.

PLANT CONTROL

Coagulant dose was maintained by fixing the alum strength and the settings on the dosing pumps for the duration of the test. Measurement of the alum strength and volume used indicated that the actual doses were 1.3 mg/l for the trial and 1.2 mg/l for the control.

It was not always possible to control to the target pH values, table A1 gives the target coagulation pH and the measured pHs of the raw water, the DAF treated water, and the filtered waters. The coagulation pH was always lower than the controllers set point which may have been due to the location of the pH probe, just downstream of the caustic addition.

The control's coagulation pH was consistent; 5 of the runs were between 5.6 and 5.8 and one was at 5.4; primary filtration pH was between 6.2 and 6.6 and secondary filtration pH was between 8.6 and 9.2.

The trial's coagulation pH was usually consistent with the target pH except for the run on 28 March, when the pH control unit became unstable and the coagulation pH may have varied considerably around the measured value of 5.8. The trial stream may not have been at steady state when samples were collected and the results should be treated cautiously. The primary filtration pH was between 6.4 and 6.6, with the exception of the run on 14 March, when it was 7.2. The secondary filtration pH was between 8.8 and 9.0 with the exception of the run on 28 Feb. Both of these exceptions were considered to be due to the collection of samples too close to a backwashing. Results relating to filtered waters from these runs should be treated cautiously.

RAW WATER QUALITY

True, and apparent, colour and uV absorption, and total metals (Fe, Al, Mn) changed by only 30% during the test. By contrast, filtered metals, TOC, and turbidity of the raw water changed by up to 180%. Thus depending on the parameter of interest, the effect of pH can be assessed by comparing the control with the trial, or by pooling all of the observations.

RESULTS

The results are presented in tables Ai.1 to Ai.20.

Table Ai.1 - Pilot Plant pHs

DATE	pH				
	RAW WATER	SET POINT	DAF TREATED	1' RGF	2' RGF
21 FEB	5.6	6.0 (6.0)	5.4 (5.4)	6.4 (6.4)	8.8 (9.0)
28 FEB	5.6	5.0 (6.0)	4.4 (5.8)	6.4 (6.5)*	7.2 (8.6)*
7 MAR	5.6	5.5 (6.0)	4.8 (5.8)	6.4 (6.2)	8.8 (8.8)
14 MAR	5.6	6.0 (6.0)	5.9 (5.7)	7.2 (6.6)	9.0 (8.8)
21 MAR	5.6	6.5 (6.0)	6.4 (5.8)	6.4 (6.4)	9.0 (9.0)
28 MAR	5.6	7.0 (6.0)	5.8 (5.6)	6.6 (6.2)	9.0 (9.2)

Table Ai.2 - Colour (Abs/m @400nm)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.4 (5.8)	3.0	1.6	2.7 (1.0)	0.8 (0.2)	0.4 (0.5)*	0.4 (0.6)*
4.8 (5.8)	3.0	1.5	1.1 (1.1)	0.3 (0.3)	0.3 (0.3)	0.3 (0.2)
5.4 (5.4)	3.2	1.6	1.3 (1.1)	0.2 (0.3)	0.4 (0.4)	0.3 (0.4)
5.8 (5.6)	2.5	1.3	0.8 (0.8)	0.2 (0.2)	0.2 (0.2)	0.3 (0.4)
5.9 (5.7)	2.8	1.5	1.1 (1.0)	0.4 (0.3)	0.6 (0.6)	0.6 (0.6)
6.4 (5.8)	2.6	1.4	1.6 (0.9)	0.2 (0.2)	0.4 (0.2)	0.5 (0.5)

Table Ai.3 - u.v. (Abs/m @254nm)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.4 (5.8)	18.5	15.6	17.5 (8.8)	10.9 (5.2)	5.8 (6.2)*	5.4 (6.2)*
4.8 (5.8)	17.8	14.4	8.6 (8.1)	5.1 (5.0)	5.1 (4.9)	4.5 (3.8)
5.4 (5.4)	19.1	15.9	9.2 (8.9)	5.4 (5.4)	5.9 (6.1)	4.7 (5.9)
5.8 (5.6)	16.6	13,5	6.3 (6.8)	3.9 (3.9)	3.7 (3.5)	4.1 (3.8)
5.9 (5.7)	17.7	14.9	8.6 (7.8)	5.1 (4.7)	6.4 (5.5)	5.8 (6.2)
6.4 (5.8)	17.2	14.2	11.2 (7.3)	5.0 (4.4)	5.3 (4.4)	4.6 (4.8)

Table Ai.4 - Turbdity (NTU)

pH	RAW WATER	DAF FLOATED	1' RGF	2' RGF
4.4 (5.8)	2.6	3.0 (1.1)	0.1 (0.1)*	0.1 (0.1)*
4.8 (5.8)	2.2	0.8 (0.7)	0.0 (0.1)	0.0 (0.1)
5.4 (5.4)	2.8	1.2 (1.1)	0.2 (0.2)	0.1 (0.1)
5.8 (5.6)	1.9	0.5 (0.6)	0.0 (0.1)	0.1 (0.0)
5.9 (5.7)	1.9	0.7 (0.7)	0.1 (0.1)	0.0 (0.0)
6.4 (5.8)	1.7	1.3 (0.5)	0.1 (0.1)	0.1 (0.1)

* The control stream filters were not working on this day. Data from the 1 Mar (the next day) has been used instead.

Table Ai.5 - IRON (mg Fe/l)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.4 (5.8)	0.36	0.20	0.37 (0.11)	0.05 (0.02)	0.05 -	0.02 -
4.8 (5.8)	0.35	0.16	0.13 (0.14)	0.02 (0.03)	0.02 (0.04)	0.01 (0.02)
5.4 (5.4)	0.39	0.20	0.18 (0.14)	0.04 (0.02)	0.04 (0.02)	0.02 (0.02)
5.8 (5.6)	0.40	0.16	0.10 (0.08)	0.04 (0.03)	0.01 (0.02)	0.05 (0.04)
5.9 (5.7)	0.32	0.17	0.10 (0.08)	0.01 (0.01)	0.02 (0.02)	0.01 (0.02)
6.4 (5.8)	0.31	0.14	0.17 (0.09)	0.01 (0.02)	0.01 (0.03)	0.01 (0.01)

Table Ai.6 - Manganese (mg Mn/l)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.4 (5.8)	0.12	0.12	0.12 (0.12)	0.12 (0.12)	0.33 -	0.09 -
4.8 (5.8)	0.11	0.09	0.11 (0.11)	0.10 (0.10)	0.09 (0.12)	0.01 (0.01)
5.4 (5.4)	0.13	0.13	0.13 (0.12)	0.12 (0.12)	0.09 (0.13)	0.00 (0.00)
5.8 (5.6)	0.13	0.12	0.12 (0.11)	0.12 (0.12)	0.18 (0.13)	0.00 (0.00)
5.9 (5.7)	0.12	0.12	0.12 (0.12)	0.12 (0.12)	0.01 (0.13)	0.00 (0.00)
6.4 (5.8)	0.13	0.25	0.14 (0.13)	0.25 (0.25)	0.12 (0.17)	0.01 (0.02)

Table Ai.7 - Aluminium (mg Al/l)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.4 (5.8)	0.24	0.19	1.72 (0.50)	1.59 (0.11)	0.14 -	0.22 -
4.8 (5.8)	0.25	0.21	0.97 (0.65)	0.16 (0.09)	0.05 (0.06)	0.06 (0.05)
5.4 (5.4)	0.22	0.15	0.74 (0.57)	0.37 (0.20)	0.17 (0.13)	0.06 (0.12)
5.8 (5.6)	0.23	0.22	0.51 (0.48)	0.04 (0.10)	0.05 (0.04)	0.07 (0.02)
5.9 (5.7)	0.26	0.35	0.66 (0.51)	0.29 (0.06)	0.49 (0.13)	0.05 (0.17)
6.4 (5.8)	0.23	0.18	0.85 (0.60)	0.01 (0.06)	0.02 (0.02)	0.02 (0.02)

Table Ai.8 - Bacteriological quality of 2' RGF water

pH	COLONIES		COLIFORMS	
	1 DAY	3 DAY	E-COLI	TOTAL
4.4 (5.8)	0 (-)	0 (-)	0 (-)	0 (-)
4.8 (5.8)	0 (0)	4 (0)	0 (0)	0 (0)
5.4 (5.4)	0 (0)	1 (0)	- (-)	- (-)
5.8 (5.6)	0 (0)	0(1228)	0 (0)	0 (0)
5.9 (5.7)	18 (0)	0 (5)	- (-)	- (-)
6.4 (5.8)	0 (0)	0 (0)	0 (0)	0 (0)

Table Ai.9 - Total organic carbon (mg/l)

pH	RAW WATER	2' RGF
4.4 (5.8)	4.80	1.60 (-)*
4.8 (5.8)	7.80	5.00 (5.40)
5.4 (5.4)	3.78	1.76 (1.92)*
5.8 (5.6)		
5.9 (5.7)	7.50	5.30 (5.20)
6.4 (5.8)	6.00	4.70 (4.70)

* The samples analysed for TOC on these days had no added phosphoric acid

Table Ai.10 - Trichloromethane (ug/l) $CHCl_3$

pH	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.4 (5.8)	40.2	22.7 (-)	7.6 (-)	28.4 (-)
4.8 (5.8)	44.5	18.8 (18.4)	6.1 (7.1)	12.4 (13.6)
5.4 (5.4)	23.32	9.54 (9.00)	11.15 (3.89)	8.58 (11.15)
5.8 (5.6)	32.35	14.66 (14.52)	6.68 (5.91)	14.46 (13.62)
5.9 (5.7)	43.2	14.03 (13.75)	7.0 (4.7)	14.46 (13.72)
6.4 (5.8)	38.1	19.9 (18.4)	8.3 (8.7)	16.1 (17.5)

Table Ai.11 - Brom,dichloromethane (ug/l) $CHBrCL_2$

pH	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.4 (5.8)	0.8	1.4 (-)	0.7 (-)	3.4 (-)
4.8 (5.8)	2.1	1.9 (1.9)	1.6 (1.6)	1.8 (1.8)
5.4 (5.4)	1.48	1.28 (1.20)	1.03 (0.98)	1.24 (1.89)
5.8 (5.6)	1.48	1.32 (1.38)	1.23 (1.12)	1.27 (1.26)
5.9 (5.7)	1.0	0.56 (0.57)	0.3 (0.3)	0.49 (0.51)
6.4 (5.8)	1.7	1.6 (1.6)	1.2 (1.3)	1.4 (1.4)

Table Ai.12 - Dibromo,chloromethane (ug/l) $CHClBr_2$

pH	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.4 (5.8)	<.05	<.05 (-)	<.05 (-)	0.4 (-)
4.8 (5.8)	<.05	<.05 (<.05)	<.05 (<.05)	<.05 (<.05)
5.4 (5.4)	0.16	0.17 (0.16)	<.05 (<.05)	0.17 (0.19)
5.8 (5.6)	0.19	0.18 (0.17)	0.16 (<.05)	<.05 (<.05)
5.9 (5.7)	<.05	<.05 (<.05)	<.05 (<.05)	<.05 (<.05)
6.4 (5.8)	<.05	0.1 (<.05)	<.05 (0.2)	0.2 (0.1)

Table Ai.13 - Tribromomethane (ug/l) $CHBr_3$

pH	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.4 (5.8)	<.03	0.1 (-)	<.03 (-)	<.03 (-)
4.8 (5.8)	<.03	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
5.4 (5.4)	<.03	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
5.8 (5.6)	<.03	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
5.9 (5.7)	<.03	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
6.4 (5.8)	<.03	<.03 (<.03)	2.5 (0.1)	<.03 (<.03)

Table Ai.14 - Total trihalomethanes (ug/l)

pH	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.4 (5.8)	41.1	24.3 (-)	8.4 (-)	32.4 (-)
4.8 (5.8)	46.7	20.9 (20.4)	7.9 (8.9)	14.3 (15.4)
5.4 (5.4)	24.99	11.02 (10.39)	5.95 (4.95)	10.00 (12.66)
5.8 (5.6)	34.05	16.19 (16.10)	8.10 (7.11)	15.81 (14.96)
5.9 (5.7)	44.3	14.67 (14.40)	7.4 (5.1)	14.86 (14.31)
6.4 (5.8)	40.0	21.7 (20.1)	12.2 (10.3)	17.7 (19.1)

Table Ai.15 - Chlorine demand (mg Cl/l)

pH	RAW WATER	1' RGF	2' RGF		
			FILTER DEMAND	LAB DEMAND	FREE RESIDUAL
4.4 (5.8)	1.02	0.65 (-)	- (-)	0.37?(-)	0.12 (-)
4.8 (5.8)	-	0.48 (0.44)	- (-)	0.23 (0.23)	0.08 (0.08)
5.4 (5.4)	0.90	0.48 (0.49)	- (-)	0.10 (0.25?)	0.11 (0.11)
5.8 (5.6)	0.75	0.49 (0.37)	0.25 (0.24)	0.18 (0.17)	0.07 (0.10)
5.9 (5.7)	0.85	0.42 (0.40)	0.25 (0.28)	0.17 (0.11)	0.10 (0.05)
6.4 (5.8)	0.83	0.44 (0.39)	0.24 (0.24)	0.20 (0.18)	0.11 (0.10)

Table Ai.16 - Adsorbable organic halide (ug/l)

pH	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.8	56.8	23.0	19.7	25.7
5.8	56.8	28.9	14.7	28.3
5.8	55.5	27.7	20.2	32.7
6.4	55.5	33.7	22.4	25.5

Table Ai.17 - Pesticides atrazine (ug/l)

pH	RAW WATER	2' RGF
5.4	<0.1	<0.1 (<0.1)
5.4	<0.1	<0.1 (<0.1)
5.8	<0.1	<0.1 (<0.1)
6.4	<0.1	<0.1 (<0.1)

Table Ai.18 - Pesticides simazine (ug/l)

pH	RAW WATER	2' RGF
4.8	<0.1	<0.1 (<0.1)
5.8	<0.1	<0.1 (<0.1)
5.8	<0.1	<0.1 (<0.1)
6.4	<0.1	<0.1 (<0.1)

N.B. For the Pesticides and AOX results, the first and fourth rows of data were taken from the trial stream. The second and third rows were taken from the control stream.

Table Ai.19 - Mutagenicity (Slope Value) - Chlorinated 2' RGF

	TA 98		TA 100	
pH	pH 2	pH 7	pH 2	pH 7
4.8	1.86	2.92	16.32	11.33
5.8	2.84	2.98	13.52	11.81
5.8	3.303	2.339	17.590	9.046
6.4	3.105	3.344	15.280	5.366

N.B. The first and fourth rows of data were taken from the trial stream. The second and third rows were taken from the control stream.

Table Ai.20 - Other mutagenicity assays (Slope Value)

SAMPLE	TA 98		TA 100	
	pH 2	pH 7	pH 2	pH 7
Un-chlorinated raw water	0.84	1.42	0.6	0
Un-chlorinated 2' RGF - pH 5.8	2.223	2.052	5.946	2.244

PHASE 1, TEST (A) Part (ii): EFFECT OF COAGULANT DOSE USING ALUM

OPERATIONAL REGIME

This test was carried out between 14 March and 25 April 1989. In this test, stream A was operated under constant conditions (control) whilst the coagulant dose of stream B was changed (trial). The coagulant used in both streams was aluminium sulphate. For both streams during the test the coagulation target pH was 6.0,primary filter target pH was 6.5 and the secondary filter target pH was 9.0.

The results of 5 separate runs have been considered.

PLANT CONTROL

Coagulant dose was maintained in the control stream at 1.2 to 1.3 mg/l for 3 of the runs; on 2 runs problems with the dosing valve resulted in underdosing at 0.7 and 1.0 mg/l. The trial stream dose covered a range of 0.7 to 3.7 mg/l.

Control of the coagulation pH was done manually and remained between 5.6 and 5.9 for both streams although the trial stream coagulation pH was sometimes 0.1 to 0.2 units lower.

Primary filtration pH was between 6.2 and 6.6, with the exception of 14 March when trial samples were collected too close to a backwash, and secondary filtration pH was between 8.7 and 9.1 for both streams. During this trial headloss sight tubes were fitted to the filters, this enabled headloss rates to be measured and allowed the operator to check if a 1′ filter had backwashed recently.

RAW WATER QUALITY

The raw water quality during the test was consistent in water quality parameters, with the exception of iron and higher levels during the test of 14 March. The results can be assessed by comparing the control with the trial or by pooling all of the observations.

Table Aii.1 - Coagulant doses and sample pHs

DATE	DOSE (mg Al/l)	pH			
		RAW WATER	DAF TREATED	1' RGF	2' RGF
14 MAR	1.3 (1.2)	5.6	5.9 (5.7)	7.2 (6.6)	9.0 (8.8)
4 APR	0.7 (1.2)	5.6	5.6 (5.6)	6.2 (6.2)	9.0 (9.0)
11 APR	3.7 (1.0)	5.6	5.8 (5.6)	6.5 (6.3)	9.1 (9.0)
18 APR	1.7 (0.7)	5.6	5.6 (5.6)	6.2 (6.2)	8.8 (8.7)
25 APR	2.7 (1.3)	5.6	5.8 (5.7)	6.4 (6.4)	8.9 (8.9)

Table Aii.2 - Colour (Abs/m @400nm)

DOSE	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
0.7 (1.2)	2.2	1.1	1.0 (0.6)	0.1 (0.0)	0.2 (0.0)	0.3 (0.2)
1.3 (1.2)	2.8	1.5	1.1 (1.0)	0.4 (0.3)	0.6 (0.6)	0.6 (0.6)
1.7 (0.7)	2.3	1.2	0.7 (1.1)	0.1 (0.2)	0.1 (0.2)	0.2 (0.4)
2.7 (1.3)	2.1	1.1	0.4 (0.6)	0.0 (0.1)	0.1 (0.1)	0.1 (0.2)
3.7 (1.0)	2.3	1.2	0.6 (0.8)	0.1 (0.2)	0.1 (0.1)	0.0 (0.2)

Table Aii.3 - u.v. (Abs/m @254nm)

DOSE	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
0.7 (1.2)	15.7	12.9	8.4 (6.3)	4.8 (3.5)	4.5 (3.1)	4.5 (3.3)
1.3 (1.2)	17.7	14.9	8.6 (7.8)	5.1 (4.7)	6.4 (5.5)	5.8 (6.2)
1.7 (0.7)	15.7	13.1	6.2 (9.2)	3.5 (5.3)	3.2 (4.9)	3.3 (5.1)
2.7 (1.3)	15.5	12.9	5.8 (6.6)	3.5 (4.1)	3.4 (3.7)	3.5 (3.9)
3.7 (1.0)	15.7	12.6	5.0 (7.2)	2.9 (4.1)	2.8 (3.5)	2.8 (3.5)

Table Aii.4 - Turbdity (NTU)

DOSE	RAW WATER	DAF FLOATED	1' RGF	2' RGF
0.7 (1.2)	1.5	0.8 (0.5)	0.0 (0.0)	0.1 (0.0)
1.3 (1.2)	1.9	0.7 (0.7)	0.1 (0.1)	0.0 (0.0)
1.7 (0.7)	1.4	0.4 (0.8)	0.0 (0.1)	0.0 (0.1)
2.7 (1.3)	1.4	0.5 (0.7)	0.0 (0.1)	0.1 (0.1)
3.7 (1.0)	1.4	0.4 (0.6)	0.0 (0.1)	0.0 (0.1)

Table Aii.5 - Total Organic carbon (mg/l)

pH	RAW WATER	2' RGF
0.7 (1.2)	3.51	2.21 1.86
1.3 (1.2)	7.50	5.30 (5.20)
1.7 (0.7)	3.47	1.75 2.21
2.7 (1.3)	3.85	1.59 1.75
3.7 (1.0)	3.64	1.35 1.99

Table Aii.6 - Iron (mg Fe/l)

DOSE	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
0.7 (1.2)	0.29	0.15	0.13 (0.08)	0.06 (0.02)	0.05 (0.02)	0.34 (0.01)
1.3 (1.2)	0.32	0.17	0.10 (0.08)	0.01 (0.01)	0.02 (0.02)	0.01 (0.02)
1.7 (0.7)	0.24	0.12	0.05 (0.09)	0.00 (0.01)	0.00 (0.01)	0.01 (0.00)
2.7 (1.3)	0.18	0.10	0.03 (0.04)	0.00 (0.01)	0.01 (0.01)	0.01 (0.01)
3.7 (1.0)	0.21	0.11	0.06 (0.06)	0.01 (0.02)	0.01 (0.01)	0.01 (0.02)

Table Aii.7 - Manganese (mg Mn/l)

DOSE	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
0.7 (1.2)	0.12	0.13	0.12 (0.12)	0.12 (0.20)	0.13 (0.12)	0.01 (0.00)
1.3 (1.2)	0.12	0.12	0.12 (0.12)	0.12 (0.12)	0.01 (0.13)	0.00 (0.00)
1.7 (0.7)	0.13	0.13	0.13 (0.13)	0.13 (0.13)	0.14 (0.13)	0.00 (0.00)
2.7 (1.3)	0.12	0.12	0.12 (0.12)	0.11 (0.11)	0.12 (0.14)	0.00 (0.01)
3.7 (1.0)	0.13	0.13	0.13 (0.13)	0.11 (0.12)	0.12 (0.14)	0.01 (0.00)

Table Aii.8 - Aluminium (mg Al/l)

DOSE	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
0.7 (1.2)	0.21	0.18	0.65 (0.54)	0.13 (0.07)	0.04 (0.02)	0.12 (0.04)
1.3 (1.2)	0.26	0.35	0.66 (0.51)	0.29 (0.06)	0.49 (0.13)	0.05 (0.17)
1.7 (0.7)	0.26	0.21	1.34 (0.56)	0.13 (0.15)	0.05 (0.11)	0.05 (0.08)
2.7 (1.3)	0.21	0.14	0.38 (0.34)	0.02 (0.06)	0.01 (0.04)	0.01 (0.02)
3.7 (1.0)	0.22	0.16	0.74 (0.36)	0.01 (0.07)	0.01 (0.01)	0.07 (0.04)

Table Aii.9 - Bacteriological quality of 2' RGF water

DOSE	COLONIES/ml		COLIFORMS/100 ml	
	1 DAY	3 DAY	E-COLI	TOTAL
0.7 (1.2)	0 (0)	0 (0)	0 (0)	0 (0)
1.3 (1.2)	18 (0)	0 (5)	- (-)	- (-)
1.7 (0.7)	0 (0)	1 (0)	0 (0)	0 (0)
2.7 (1.3)	0 (0)	3 (7)	0 (0)	0 (0)
3.7 (1.0)	0 (0)	0 (0)	0 (0)	0 (0)

Table Aii.10 - Headloss development rate (mm/hr) in 1' RGFs

pH	1'RGF
0.7 (1.2)	- (-)
1.3 (1.2)	- (-)
1.7 (0.7)	56 (54)
2.7 (1.3)	65 (61)
3.7 (1.0)	- (-)

Table Aii.11 - Trichloromethane (ug/l) $CHCl_3$

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Al/1)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
0.7 (1.2)	26.36	12.86 (10.84)	5.06 (4.92)	12.49 (10.93)
1.3 (1.2)	43.2	14.03 (13.75)	7.0 (4.7)	14.46 (13.72)
1.7 (0.7)	29.64	11.54 (14.37)	6.51 (7.00)	13.70 (16.07)
2.7 (1.3)	30.04	9.80 (11.50)	5.28 (5.84)	11.54 (11.49)
3.7 (1.0)	34.41	15.27 (15.18)	8.28 (7.52)	13.50 (14.72)

Table Aii.12 - Bromo, dichloromethane (ug/l) $CHCl_2Br$

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Fe/1)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
0.7 (1.2)	1.25	1.14 (1.13)	0.82 (0.87)	1.05 (1.04)
1.3 (1.2)	1.0	0.56 (0.57)	0.3 (0.3)	0.49 (0.51)
1.7 (0.7)	1.12	0.92 (1.01)	0.68 (0.68)	0.92 (0.98)
2.7 (1.3)	0.92	0.74 (0.79)	0.54 (0.55)	0.76 (0.68)
3.7 (1.0)	1.30	1.09 (1.05)	0.67 (0.65)	0.81 (0.90)

Table Aii.13 - Chloro, dibromomethane (ug/l) $CHClBr_2$

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Al/1)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
0.7 (1.2)	0.11	0.09 (<0.05)	<0.05 (0.10)	0.07 (0.07)
1.3 (1.2)	<0.05	<0.05 (<0.05)	<0.05 (<0.05)	<0.05 (<0.05)
1.7 (0.7)	0.13	0.09 (0.10)	0.08 (0.08)	0.16 (0.10)
2.7 (1.3)	<0.05	<0.05 (<0.05)	<0.05 (<0.05)	<0.05 (<0.05)
3.7 (1.0)	<0.05	<0.05 (<0.05)	<0.05 (<0.05)	<0.05 (0.23)

Table Aii.14 - Tribromomethane (ug/l) $CHBr_3$

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Al/l)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
0.7 (1.2)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)
1.3 (1.2)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)
1.7 (0.7)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)
2.7 (1.3)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)
3.7 (1.0)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)

Table Aii.15 - Total trihalomethanes (ug/l)

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Al/l)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
0.7 (1.2)	27.75	14.12 (12.05)	5.96 (5.92)	13.64 (12.07)
1.3 (1.2)	44.3	14.67 (14.40)	7.4 (5.1)	14.86 (14.31)
1.7 (0.7)	30.92	12.58 (15.51)	7.30 (7.79)	14.81 (17.18)
2.7 (1.3)	31.04	10.62 (12.37)	5.90 (6.47)	12.38 (12.25)
3.7 (1.0)	35.79	16.44 (16.31)	9.03 (8.25)	14.39 (15.88)

Table Aii.16 - Chlorine demand (mg Cl/l)

DOSE	RAW WATER	1' RGF	2' RGF		
			FILTER DEMAND	LAB DEMAND	FREE RESIDUAL
0.7 (1.2)	0.90	0.47 (0.39)	0.26 (0.29)	0.18 (0.14)	0.07 (0.07)
1.3 (1.2)	0.85	0.42 (0.40)	0.25 (0.28)	0.17 (0.11)	0.10 (0.05)
1.7 (0.7)	0.82	0.35 (0.45)	0.30 (0.29)	0.12 (0.16)	0.08 (0.07)
2.7 (1.3)	0.76	0.29 (0.37)	0.29 (0.20)	0.09 (0.12)	0.08 (0.13)
3.7 (1.0)	0.85	0.38 (0.39)	0.29 (0.26)	0.11 (0.12)	0.09 (0.05)

Table Aii.17 - Adsorbable organic halide (ug/l)

DOSE	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
0.7	65.7	33.1	27.0	39.2
0.7	69.1	35.1	18.4	33.2
1.2	69.1	20.4	16.5	29.3
1.7	65.7	22.3	20.0	29.2

N.B. Rows 1 and three are results of the control stream (row 1 was obtained when the control stream coagulant dosing system was faulty). Rows 2 and 4 are results of the trial stream.

PHASE 1, TEST (B) Part (i): EFFECT OF COAGULATION pH USING FERRIC

OPERATIONAL REGIME

This test was carried out between 2 May and 30 May 1989. In this test, stream A was operated under constant conditions (control) whilst the coagulation pH of stream B was changed (trial). The coagulant used in both streams was ferric sulphate. The coagulation pH has been taken as the pH of the DAF treated water or the flocculated water; at steady state these two values are identical. For both streams during the test the primary filter target pH was 6.5 and the secondary filter target pH was 9.0.

The results of 5 separate runs have been considered.

PLANT CONTROL

Coagulant dose was maintained by fixing the ferric strength and the settings on the dosing pumps for the duration of the test. Measurement of the ferric strength and volume used indicated that the actual doses were 2.0 mg/l for the trial (with the exception of 2 May, 1.4) and 2.3 mg/l for the control.

It was not always possible to control to the target pH values. Table B1 gives the measured pHs of the raw water , the DAF treated water, and the filtered waters.

The control's coagulation pH varied between 4.7 and 5.5; primary filtration pH was between 6.5 and 6.6 and secondary filtration pH was between 8.8 and 9.0.

The trial's coagulation pH was usually consistent with the target pH. Primary filtration pH was between 6.2 and 6.7; secondary filtration pH was between 8.8 and 9.3. (the high pH value was the result of a reduction in the flow to the secondary filter and levels of chlorination by-products may have been affected by this).

There were some minor mechanical faults which led to poor float removal on 2 May and 16 May. On 9 May a backwash probe on the primary filter of the control stream stuck which resulted in continuous backwashing, the plant was allowed to stabilise before taking samples.

RAW WATER QUALITY

There was only a slight change in the raw water quality during the test; the effect of pH can be assessed by comparing the control with the trial or by pooling all of the observations.

RESULTS

The results are presented in tables Bi.1 to Bi.20.

Table Bi.1 - Coagulant doses and pHs

DATE	DOSE (mg Fe/l)	pH			
		RAW WATER	DAF TREATED	1' RGF	2' RGF
2 MAY 89	1.4 (2.2)	5.6	5.9 (5.5)	6.6 (6.6)	9.3 (9.0)
9 MAY 89	2.0 (2.3)	5.6	4.4 (5.1)	6.2 (6.5)	8.8 (8.9)
16 MAY 89	2.0 (2.3)	5.6	4.1 (4.7)	6.5 (6.6)	8.9 (8.8)
23 MAY 89	2.0 (2.3)	5.8	5.6 (5.0)	6.7 (6.5)	9.0 (8.9)
30 MAY 88	2.1 (2.4)	5.8	5.1 (4.8)	6.5 (6.5)	9.1 (8.9)

Table Bi.2 - Colour (Abs/m @400nm)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.1 (4.7)	2.1	1.0	2.5 (1.4)	0.5 (0.1)	0.3 (0.0)	0.3 (0.1)
4.4 (5.1)	2.2	1.1	2.2 (1.4)	0.4 (0.2)	0.2 (0.2)	0.2 (0.3)
5.1 (4.8)	2.2	1.1	1.8 (1.2)	0.2 (0.1)	0.5 (0.2)	0.5 (0.3)
5.6 (5.0)	2.0	0.9	2.1 (1.1)	0.2 (0.1)	0.8 (0.2)	0.6 (0.2)
5.9 (5.5)	2.3	1.2	3.7 (1.6)	0.4 (0.2)	3.3 (0.3)	3.2 (0.3)

Table Bi.3 - u.v. (Abs/m @254nm)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.1 (4.7)	13.9	10.8	13.2 (9.3)	6.0 (3.1)	5.5 (3.0)	5.2 (2.9)
4.4 (5.1)	14.7	11.7	10.8 (9.8)	4.4 (3.5)	3.3 (3.9)	3.1 (3.9)
5.1 (4.8)	13.4	10.5	11.6 (8.8)	3.9 (3.6)	4.7 (3.8)	4.7 (3.8)
5.6 (5.0)	13.0	10.4	13.6 (8.1)	3.8 (3.0)	6.5 (3.5)	5.9 (3.3)
5.9 (5.5)	15.1	12.3	24.1(11.0)	6.0 (3.9)	22.2 (4.2)	21.7 (4.2)

Table Bi.4 - Turbdity (NTU)

pH	RAW WATER	DAF FLOATED	1' RGF	2' RGF
4.1 (4.7)	1.4	2.4 (0.8)	0.1 (0.1)	0.2 (0.1)
4.4 (5.1)	1.4	1.8 (0.8)	0.1 (0.1)	0.1 (0.1)
5.1 (4.8)	1.2	1.0 (0.6)	0.2 (0.1)	0.1 (0.1)
5.6 (5.0)	1.3	1.0 (0.7)	0.3 (0.1)	0.2 (0.1)
5.9 (5.5)	1.4	2.0 (1.0)	1.4 (0.1)	1.1 (0.1)

Table Bi.5 - Total Organic carbon (mg/l)

	RAW WATER	2' RGF
4.1 (4.7)	4.68	4.68 (2.51)
4.4 (5.1)	3.74	1.53 (1.70)
5.1 (4.8)	3.96	2.17 (2.09)
5.6 (5.0)	4.14	2.89 (4.02)
5.9 (5.5)	3.38	3.04 (1.73)

Table Bi.6 - Iron (mg Fe/l)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.1 (4.7)	0.20	0.08	1.23 (0.61)	0.64 (0.06)	0.09 (0.03)	0.06 (0.02)
4.4 (5.1)	0.23	0.09	1.05 (0.83)	0.38 (0.05)	0.03 (0.02)	0.01 (0.02)
5.1 (4.8)	0.25	0.08	0.90 (0.69)	0.06 (0.07)	0.11 (0.05)	0.10 (0.04)
5.6 (5.0)	0.24	0.09	1.08 (0.65)	0.05 (0.06)	0.26 (0.03)	0.19 (0.03)
5.9 (5.5)	0.24	0.11	1.56 (0.87)	0.07 (0.06)	1.33 (0.05)	1.24 (0.04)

Table Bi.7 - Manganese (mg Mn/l)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.1 (4.7)	0.11	0.11	0.12 (0.12)	0.12 (0.11)	0.11 (0.15)	0.00 (0.00)
4.4 (5.1)	0.11	0.11	0.12 (0.12)	0.12 (0.12)	0.12 (0.13)	0.00 (0.00)
5.1 (4.8)	0.10	0.10	0.10 (0.10)	0.10 (0.10)	0.17 (0.15)	0.01 (0.00)
5.6 (5.0)	0.11	0.11	0.13 (0.13)	0.11 (0.11)	0.14 (0.12)	0.01 (0.00)
5.9 (5.5)	0.12	0.11	0.12 (0.11)	0.12 (0.12)	0.14 (0.19)	0.02 (0.00)

Table Bi.8 - Aluminium (mg Al/l)

pH	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
4.1 (4.7)	0.19	0.10	0.13 (0.09)	0.06 (0.05)	0.01 (0.01)	0.01 (0.01)
4.4 (5.1)	0.22	0.17	0.14 (0.10)	0.12 (0.07)	0.02 (0.01)	0.04 (0.04)
5.1 (4.8)	0.12	0.02	0.04 (0.03)	0.00 (0.00)	0.02 (0.02)	0.02 (0.02)
5.6 (5.0)	0.15	0.06	0.06 (0.06)	<.01 (0.02)	<.01 (<.01)	<.01 (<.01)
5.9 (5.5)	0.20	0.16	0.20 (0.12)	0.01 (0.07)	0.15 (0.01)	0.15 (0.02)

Table Bi.9 - Bacteriological quality of 2' RGF water

pH	COLONIES		COLIFORMS	
	1 DAY	3 DAY	E-COLI	TOTAL
4.1 (4 7)	0 (0)	0 (0)	0 (0)	0 (0)
4.4 (5.1)	1 (0)	1 (1)	0 (0)	0 (0)
5.1 (4.8)	0 (0)	15 (23)	0 (0)	0 (0)
5.6 (5.0)	30 (1)	112 (9)	0 (0)	0 (0)
5.9 (5.5)	0 (4)	95 (95)	0 (0)	0 (0)

Table Bi.10 - Headloss development rate (mm /hr) in 1' RGFs

pH	1'RGF
4.1 (5.7)	42 (53)
4.4 (5.1)	81 (60)
5.1 (4.8)	46 (46)
5.6 (5.0)	51 (38)
5.9 (5.5)	34 (59)

Table Bi.11 - Trichloromethane (ug/l)

pH	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.1 (4.7)	36.14	21.24 (9.72)	8.42 (6.24)	24.42 (17.53)
4.4 (5.1)	41.04	14.67 (16.70)	8.65 (8.49)	17.31 (15.56)
5.1 (4.8)	45.96	25.75 (26.54)	18.68 (16.99)	33.27 (29.24)
5.6 (5.0)	22.42	12.62 (10.53)	5.95 (6.23)	11.68 (10.62)
5.9 (5.5)	32.32	30.87 (10.86)	9.32 (5.92)	29.24 (14.71)

Table Bi.12 - Bromodichloromethane (ug/l)

pH	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.1 (4.7)	1.00	1.14 (1.11)	0.60 (0.68)	1.23 (1.16)
4.4 (5.1)	1.21	1.55 (1.61)	1.26 (1.26)	1.85 (1.59)
5.1 (4.8)	2.34	2.40 (2.50)	1.91 (1.87)	2.40 (2.44)
5.6 (5.0)	0.53	0.78 (0.49)	0.20 (0.26)	0.44 (0.67)
5.9 (5.5)	1.07	1.27 (1.07)	0.75 (0.74)	1.10 (1.24)

Table Bi.13 - Dibromochloromethane (ug/l)

pH	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.1 (4.7)	<.05	2.70 (0.09)	<.05 (<.05)	<.05 (<.05)
4.4 (5.1)	0.17	0.16 (0.17)	<.05 (<.05)	0.22 (0.16)
5.1 (4.8)	0.32	0.33 (0.35)	<.05 (<.05)	0.33 (0.36)
5.6 (5.0)	0.08	0.07 (<.05)	<.05 (0.06)	<.05 (0.06)
5.9 (5.5)	0.12	0.10 (0.09)	0.12 (<.05)	0.07 (0.16)

Table Bi.14 - Tribromomethane (ug/l)

pH	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.1 (4.7)	<.03	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
4.4 (5.1)	<.03	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
5.1 (4.8)	<.03	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
5.6 (5.0)	0.21	<.03 (<.03)	<.03 (<.03)	<.03 (0.38)
5.9 (5.5)	0.19	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)

Table Bi.15 - Total trihalomethanes (ug/l)

pH	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.1 (4.7)	37.22	25.11 (10.95)	9.10 (6.98)	25.72 (18.77)
4.4 (5.1)	42.45	16.41 (18.51)	9.99 (9.83)	19.41 (17.34)
5.1 (4.8)	48.65	28.51 (29.42)	20.67 (18.94)	36.03 (32.07)
5.6 (5.0)	23.24	13.50 (11.10)	6.23 (6.58)	12.20 (11.73)
5.9 (5.5)	33.70	32.27 (12.05)	10.22 (6.74)	30.44 (16.14)

Table Bi.16 - Chlorine demand (mg Cl/l)

pH	RAW WATER	1' RGF	2' RGF		
			FILTER DEMAND	LAB DEMAND	FREE RESIDUAL
4.1 (4.7)	0.61	0.36 (0.26)	0.35 (0.31)	0.16 (0.10)	0.08 (0.09)
4.4 (5.1)	0.77	0.24 (0.35)	0.29 (0.27)	0.15 (0.17)	0.11 (0.10)
5.1 (4.8)	0.71	0.39 (0.37)	0.41 (0.40)	0.18 (0.16)	0.12 (0.09)
5.6 (5.0)	0.65	0.33 (0.25)	0.39 (0.33)	0.19 (0.13)	0.08 (0.09)
5.9 (5.5)	0.80	0.72 (0.36)	0.34 (0.23)	0.46 (0.14)	0.04 (0.10)

Table Bi.17 - Adsorbable organic halide (ug/l)

pH	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
4.4 (5.1)	62.9	24.4 (33.1)	15.6 (19.1)	16.4 (31.6)
5.6 (5.0)	35.2	30.3 (23.1)	14.0 (17.7)	34.5 (47.0)

Table Bi.18 - Atrazine (ug/l)

pH	RAW WATER	2' RGF
4.4	<0.1	<0.1
5.1	<0.1	<0.1
5.6	<0.1	<0.1

Table Bi.19 - Simazine (ug/l)

	RAW WATER	2' RGF
4.4	<0.1	<0.1
5.1	<0.1	<0.1
5.6	<0.1	<0.1

Table Bi.20 - Mutagenicity (slope value)

	CHLORINATED 2' RGF				CHLORINATED 1' RGF			
pH	T A 9 8		T A 1 0 0		T A 9 8		T A 1 0 0	
	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7
4.4	3.69	3.55	30.12	17.38	3.09	4.57	24.21	25.78
5.0	2.27	4.52	22.04	14.67	------	------	------	------
5.1	4.52	3.79	29.13	19.25	------	------	------	------
5.6	3.16	6.69	24.61	13.02	3.64	3.68	16.12	10.48

NOTE: In the above tables of pesticides, AOX and mutagenicity, data from the control and trial streams has been combined. The values obtained at pH 4.4 and 5.6 are from the trial (B) stream, and those at 5.0 and 5.1 are from the control (A) stream.

PHASE 1, TEST (B) Part (ii): EFFECT OF COAGULANT DOSE USING FERRIC

OPERATIONAL REGIME

This test was carried out between 30 May and 11 July 1989. In this test stream A was operated under constant conditions (control) whilst the coagulant dose of stream B was changed (trial). The coagulant used in both streams was ferric sulphate. For both streams during the test the primary filter target pH was 6.5 and the secondary filter target pH was 9.0.

The results of 5 separate runs have been considered.

PLANT CONTROL

Coagulant dose was maintained in the control stream at 2.4 mg/l. The trial stream dose covered a range of 1.5 to 11.3 mg/l.

Control of the coagulation pH was done manually and remained between 4.6 and 4.8 for both streams with the exception of one run when the trial stream coagulation pH was 5.1.

Primary filtration pH was between 6.3 and 6.7 and secondary filtration pH was between 8.8 and 9.1 for both streams. During this test the secondary filters were set to backwash during the night.

RAW WATER QUALITY

There was a sudden change in the raw water quality during the test due to a 48 hour period of heavy rain. Because of the sudden increase in colour and because the control stream dose was close to the minimum required, the treated water quality deteriorated on the control stream. The effect of dose can be best assessed by comparing the control with the trial. But by pooling all of the observations, the sensitivity of dose to changes in raw water quality can be seen.

Table Bii.1 - Coagulant doses, and sample pHs

DATE	DOSE (mg Fe/l)	pH			
		RAW WATER	DAF TREATED	1' RGF	2' RGF
30 May 89	2.1 (2.4)	5.8	5.1 (4.8)	6.5 (6.5)	9.1 (8.9)
7 June 89	11.3 (2.4)	5.7	4.6 (4.7)	6.5 (6.4)	8.9 (8.9)
27 June 89	5.8 (2.4)	5.8	4.7 (4.7)	6.5 (6.5)	8.9 (9.0)
4 July 89	1.5 (2.3)	5.6	4.6 (4.6)	6.3 (6.4)	8.8 (8.9)
11 July 89	3.7 (2.4)	5.6	4.7 (4.8)	6.7 (6.7)	9.1 (8.9)

Table Bii.2 - Colour (abs/m @400nm)

DOSE (mg Fe/l)	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
1.5 (2.3)	3.8	1.3	4.6 (2.0)	0.3 (0.2)	3.7 (0.3)	3.2 (0.7)
2.1 (2.4)	2.2	1.1	1.8 (1.2)	0.2 (0.1)	0.5 (0.2)	0.5 (0.3)
3.7 (2.4)	2.6	1.6	1.3 (1.6)	0.1 (0.2)	0.2 (0.9)	0.2 (1.5)
5.8 (2.4)	1.8	1.0	1.2 (1.2)	0.0 (0.1)	0.1 (0.2)	0.0 (0.2)
11.3 (2.4)	1.9	0.9	1.2 (1.2)	0.1 (0.2)	0.2 (0.2)	0.2 (0.2)

Table Bii.3 - u.v. (Asm @254nm)

DOSE (mg Fe/l)	RAW WATER		DAF FLOATED		1' RGF	2 ' RGF
	APPARENT	TRUE	APPARENT	TRUE		
1.5 (2.3)	19.5	14.5	23.1 (11.1)	6.0 (4.3)	22.2 (4.8)	21.3 (7.3)
2.1 (2.4)	13.4	10.5	11.6 (8.8)	3.9 (3.6)	4.7 (3.8)	4.7 (3.8)
3.7 (2.4)	17.7	15.2	8.9 (11.2)	3.4 (4.3)	3.4 (8.9)	3.4 (12.6)
5.8 (2.4)	13.3	10.9	7.7 (8.3)	2.4 (3.1)	2.4 (3.3)	2.3 (4.0)
11.3 (2.4)	12.7	10.0	8.3 (8.2)	2.5 (3.1)	2.3 (3.2)	2.3 (3.2)

Table Bii.4 - Turbidity (NTU)

DOSE	RAW WATER	DAF FLOATED	1' RGF	2' RGF
1.5 (2.3)	4.7	4.5 (1.6)	3.0 (0.2)	2.0 (0.3)
2.1 (2.4)	1.2	1.0 (0.6)	0.2 (0.1)	0.1 (0.1)
3.7 (2.4)	1.9	0.9 (1.1)	0.1 (0.5)	0.1 (0.5)
5.8 (2.4)	0.9	0.4 (0.6)	0.0 (0.0)	0.0 (0.1)
11.3 (2.4)	1.4	0.6 (1.1)	0.1 (0.1)	0.1 (0.1)

Table Bii.5 - Total Organic carbon (mg/l)

DOSE	RAW WATER	2' RGF
1.5 (2.3)	4.46	4.11 (2.52)
2.1 (2.4)	3.96	2.17 (2.09)
3.7 (2.4)	4.08	1.91 (3.06)
5.8 (2.4)	3.22	1.36 (1.81)
11.3 (2.4)	3.53	1.33 (1.73)

Table Bii.6 - Iron (mg Fe/l)

DOSE	RAW WATER		DAF FLOATED		1' RGF	2' RGF
(mg Fe/l)	APPARENT	TRUE	APPARENT	TRUE		
1.5 (2.3)	0.52	0.19	1.64 (0.98)	0.23 (0.23)	1.27 (0.08)	1.17 (0.23)
2.1 (2.4)	0.25	0.08	0.90 (0.69)	0.06 (0.07)	0.11 (0.05)	0.10 (0.04)
3.7 (2.4)	0.20	0.19	0.50 (0.42)	0.19 (0.19)	0.10 (0.48)	0.11 (0.77)
5.8 (2.4)	0.31	0.12	0.90 (0.66)	0.09 (0.07)	0.02 (0.03)	0.01 (0.07)
11.3 (2.4)	0.24	0.07	1.20 (0.76)	0.17 (0.09)	0.04 (0.02)	0.00 (0.01)

Table Bii.7 - Manganese (ug Mn/l)

DOSE	RAW WATER		DAF FLOATED		1' RGF	2' RGF
(mg Fe/l)	APPARENT	TRUE	APPARENT	TRUE		
1.5 (2.3)	0.18	0.18	0.18 (0.18)	0.18 (0.18)	0.31 (0.24)	0.02 (0.00)
2.1 (2.4)	0.10	0.10	0.10 (0.10)	0.10 (0.10)	0.17 (0.15)	0.01 (0.00)
3.7 (2.4)	0.21	0.20	0.22 (0.21)	0.22 (0.21)	0.26 (0.22)	0.01 (0.02)
5.8 (2.4)	0.14	0.13	0.14 (0.14)	0.14 (0.14)	0.13 (0.14)	0.00 (0.00)
11.3 (2.4)	0.11	0.10	0.11 (0.11)	0.12 (0.10	0.12 (0.17)	0.00 (0.00)

Table Bii.8 - Aluminium (ug Al/l)

DOSE (mg Fe/l)	RAW WATER APPARENT	RAW WATER TRUE	DAF FLOATED APPARENT	DAF FLOATED TRUE	1' RGF	2' RGF
1.5 (2.3)	0.16	0.09	0.15 (0.11)	0.07 (0.07)	0.12 (0.01)	0.09 (0.02)
2.1 (2.4)	0.12	0.02	0.04 (0.03)	0.00 (0.00)	0.02 (0.02)	0.02 (0.02)
3.7 (2.4)	0.14	0.09	0.07 (0.08)	0.05 (0.05)	0.00 (0.02)	0.00 (0.03)
5.8 (2.4)	0.12	0.07	0.06 (0.06)	0.04 (0.05)	0.02 (0.02)	0.02 (0.02)
11.3 (2.4)	0.10	0.04	0.03 (0.03)	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)

Table Bii.9 - Bacteriological quality of 2' RGF water

DOSE (mg Fe/l)	COLONIES 1 DAY	COLONIES 3 DAY	COLIFORMS E-COLI	COLIFORMS TOTAL
1.5 (2.3)	2, 2 (1, 0)	67, 1 (1, 0)	1,0 (0,0)	2,0 (0,0)
2.1 (2.4)	0, - (0, -)	15, - (23, -)	0,- (0,-)	0,- (0,-)
3.7 (2.4)	0, 0 (0, 0)	1, 0 (2, 0)	0,0 (0,0)	0,0 (0,0)
5.8 (2.4)	0, - (0, -)	5, - (72, -)	0,- (0,-)	0,- (0,-)
11.3 (2.4)	0, 0 (0, 0)	0, 6 (0, 1)	0,0 (0,0)	0,0 (0,0)

N.B. There are two numbers for each sample, seperated by a comma. The first number is tha analysis of the un hand chlorinated sample, the second is for the hand chlorinated sample.

Table Bii.10 - Headloss development rate (mm /hr) in 1' RGFs

DOSE	1'RGF
1.5 (2.3)	23 (61)
2.1 (2.4)	46 (46)
3.7 (2.4)	86 (59)
5.8 (2.4)	63 (47)
11.3 (2.4)	67 (79)

Table Bii.11 - Trichloromethane (ug/l)

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Fe/l)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
1.5 (2.3)	20.68	50.57 (33.90)	42.61 (8.77)	45.24 (24.24)
2.1 (2.4)	45.96	25.75 (26.54)	18.68 (16.99)	33.27 (29.24)
3.7 (2.4)	68.52	22.26 (31.03)	3.42 (10.03)	29.33 (45.84)
5.8 (2.4)	31.40	11.33 (15.91)	6.50 (7.32)	LOST (14.57)
11.3 (2.4)	33.00	9.13 (11.64)	5.27 (5.05)	11.99 (13.42)

Table Bii.12 - Bromodichloromethane (ug/l)

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Fe/l)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
1.5 (2.3)	1.37	7.85 (1.58)	1.47 (1.05)	2.45 (1.63)
2.1 (2.4)	2.34	2.40 (2.50)	1.91 (1.87)	2.40 (2.44)
3.7 (2.4)	2.03	1.12 (1.58)	1.17 (0.90)	2.02 (2.07)
5.8 (2.4)	1.66	1.29 (1.65)	0.94 (0.94)	LOST (1.45)
11.3 (2.4)	1.07	0.74 (0.88)	0.44 (0.42)	0.80 (0.82)

Table Bii.13 - Dibromo,chloromethane (ug/l)

DOSE	RAW WATER	1' RGF	2' R G F	
(mg Fe/l)	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
1.5 (2.3)	0.07	1.67 (0.07)	<0.05 (0.06)	0.15 (0.12)
2.1 (2.4)	0.32	0.33 (0.35)	<0.05 (<0.05)	0.33 (0.36)
3.7 (2.4)	0.07	<0.05 (0.07)	0.10 (<0.05)	0.13 (0.09)
5.8 (2.4)	<0.05	<0.05 (0.12)	<0.05 (0.09)	LOST (<0.05)
11.3 (2.4)	<0.05	0.08 (0.08)	<0.05 (<0.05)	0.10 (0.08)

Table Bii.14 - Tribromomethane (ug/l)

DOSE (mg Fe/l)	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
1.5 (2.3)	<0.03	0.34 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)
2.1 (2.4)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)
3.7 (2.4)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	0.15 (<0.03)
5.8 (2.4)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	LOST (<0.03)
11.3 (2.4)	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)

Table Bii.15 - Total trihalomethanes (ug/l)

DOSE (mg Fe/l)	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
1.5 (2.3)	22.15	60.43 (35.58)	44.16 (9.91)	47.87 (26.02)
2.1 (2.4)	48.65	28.51 (29.42)	20.67 (18.94)	36.03 (32.07)
3.7 (2.4)	70.65	23.46 (32.71)	4.72 (11.01)	31.63 (48.03)
5.8 (2.4)	33.14	12.70 (17.71)	7.52 (8.38)	LOST (16.10)
11.3 (2.4)	34.15	9.98 (12.63)	5.79 (5.55)	12.92 (14.35)

Table Bii.16 - Chlorine demand (mg Cl/l)

DOSE (mg Fe/l)	RAW WATER	1' RGF	2' RGF		
			FILTER DEMAND	LAB DEMAND	FREE RESIDUAL
1.5 (2.3)	1.21	0.66 (0.48)	0.55 (0.52)	0.45 (0.20)	0.09 (0.06)
2.1 (2.4)	0.71	0.39 (0.37)	0.41 (0.40)	0.18 (0.16)	0.12 (0.09)
3.7 (2.4)	1.31	0.66 (0.78)	0.69 (0.71)	0.26 (0.43)	0.07 (0.08)
5.8 (2.4)	0.81	0.33 (0.42)	0.52 (0.39)	0.13 (0.15)	0.11 (0.13)
11.3 (2.4)	0.76	0.20 (0.24)	0.20 (0.41)	0.06 (0.12)	0.17 (0.11)

Table Bii.17 - Adsorbable organic halide (ug/l)

DOSE mg/l	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
3.7 (2.4)	60.0	64.6 (33.8)	22.7 (26.6)	29.1 (43.6)
5.8 (2.4)	45.7	23.8 (25.7)	LOST (19.4)	18.1 (26.9)

Table Bii.18 - Atrazine (ug/l)

DOSE	RAW WATER	2' RGF
2.4	>0.05	>0.05 (>0.05)
2.4	>0.05	>0.05 (>0.05)
3.7	>0.05	>0.05 (>0.05)
5.8	>0.05	>0.05 (>0.05)

Table Bii.19 - Simazine (ug/l)

DOSE	RAW WATER	2' RGF
2.4	>0.05	>0.05 (>0.05)
2.4	>0.05	>0.05 (>0.05)
3.7	>0.05	>0.05 (>0.05)
5.8	>0.05	>0.05 (>0.05)

Table Bii.20 - Mutagenicity (slope value)

pH	CHLORINATED 2' RGF				CHLORINATED 1' RGF			
	TA 98		TA 100		TA 98		TA 100	
	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7
2.4	4.1	5.1	24.9	4.7	----	----	----	----
3.7	3.1	7.3	21.1	9.4	2.1	2.8	14.5	11.2

NOTE: In the above tables of pesticides, AOX and mutagenicity, data from the control and trial streams has been combined. The values obtained at ferric dose 3.7 and 5.8 are from the trial stream, those at 2.4 from the control stream.

PHASE 1, TEST (C) EFFECT OF COAGULANT TYPE

OPERATIONAL REGIME

This test was carried out between 18 July and 22 August 1989. In this test stream A was operated under constant conditions using ferric (control) whilst the coagulant used for stream B was changed (trial). For both streams during the test the primary filter target pH was 6.5 and the secondary filter target pH was 9.0.

The results of 6 separate runs have been considered.

PLANT CONTROL

Coagulant dose was maintained in the control stream at 3.8 to 4.0 mg/l. The control coagulation pH remained between 4.6 and 4.8. The alum dose was set to be equimolar to the ferric dose and was maintained at 1.9 mg/l, the corresponding coagulation pH was 5.4.

The chlorinated copperas dose was set to be equal (as iron) to the control and was maintained at 3.9 to 4.0 mg/l. The chlorine dose was set to be as close to the stoichiometric requirements (2.5 mgCl/l) as possible whilst giving a measurable residual, the dose was increased slightly for the second run but the free residual was highest in the first run.

The LT31 dose was selected from jar tests, at 5.1 mg/l it is approximately half the maximum dose allowed to be applied during water treatment. The coagulation pH was set at 4.7 for one run (equal to the control) and 6.7 for the second run (equal to the 1′ RGF pH).

Primary filtration pH was between 6.3 and 6.7 and secondary filtration pH was between 8.8 and 9.2 for both streams.

RAW WATER QUALITY

The raw water quality during the test was consistent for filtered parameters, but turbidity and apparent parameters varied. The effect of coagulant type can be best assessed by comparing the control with the trial.

RESULTS

The results are presented in Tables C.1 to C.18.

Table C.1 - Coagulant types and doses, and sample pHs

DATE	TRIAL STREAM COAGULANT	DOSE (mg/l)	Cl DOSE mg/l	pH			
				RAW	DAF TREATED	1' RGF	2' RGF
18 July 89	Alum	1.9 (3.8)	-	5.5	5.4 (4.6)	6.5 (6.4)	8.9 (8.8)
25 July 89	Coperas	3.8 (4.0)	3.3	5.4	4.7 (4.7)	6.7 (6.6)	9.2 (9.2)
1 Aug 89	Coperas	3.9 (3.9)	3.8	5.5	4.6 (4.7)	6.7 (6.7)	9.0 (9.1)
8 Aug 89	LT31	5.1 (4.0)	-	5.8	4.7 (4.6)	6.3 (6.4)	8.9 (9.0)
15 Aug 89	LT31	5.1 (4.0)	-	6.1	6.7 (4.7)	6.7 (6.8)	8.9 (8.9)
22 Aug 89	Alum	1.9 (4.0)	-	6.0	5.4 (4.8)	6.5 (6.5)	9.1 (9.0)

Table C.1A - Free & total chlorine residuals with chlorinated coperas

DATE	DOSED WATER		1ST FLOC TANK		DAF OVERFLOW	
	FREE	TOTAL	FREE	TOTAL	FREE	TOTAL
25 JULY	0.39	0.58	0.07	0.25	0.00	0.15
1 AUG	0.08	0.31	0.02	0.18	0.01	0.14

Table C.2 - Colour (Abs/m @400nm)

COAGULANT	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
Alum	2.9	1.6	0.7 (1.6)	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)
Coperas	4.0	1.7	1.5 (1.5)	0.1 (0.2)	0.3 (0.2)	0.3 (0.2)
Coperas	3.0	1.8	1.2 (1.2)	0.0 (0.1)	0.1 (0.1)	0.1 (0.1)
LT31	3.2	1.8	1.3 (1.6)	0.4 (0.2)	0.5 (0.3)	0.4 (0.3)
LT31	3.0	1.8	1.4 (1.2)	0.5 (0.3)	0.5 (0.3)	0.5 (0.3)
Alum	3.5	1.6	0.7 (1.2)	0.3 (0.2)	0.2 (0.2)	0.3 (0.2)

Table C.3 - u.v. (Abs/m @254nm)

COAGULANT	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
Alum	19.5	15.6	6.8 (9.7)	4.4 (3.2)	4.0 (2.9)	4.0 (3.2)
Coperas	23.9	16.3	9.6 (9.2)	3.7 (3.8)	4.9 (3.5)	4.9 (3.6)
Coperas	20.6	16.7	8.4 (8.5)	3.3 (3.6)	3.6 (3.4)	3.9 (3.7)
LT31	20.5	16.1	10.6 (9.3)	6.6 (3.2)	6.7 (3.2)	6.2 (3.5)
LT31	18.9	15.3	11.0 (8.1)	6.7 (3.3)	6.5 (3.6)	6.2 (3.6)
Alum	21.2	15.5	7.0 (8.3)	4.8 (3.5)	3.8 (3.6)	4.3 (3.8)

Table C.4 - Turbidity (NTU)

COAGULANT	RAW WATER	DAF FLOATED	1' RGF	2' RGF
Alum	1.9	0.5 (0.9)	0.1 (0.1)	0.1 (0.0)
Coperas	2.3	0.7 (0.8)	0.1 (0.1)	0.1 (0.1)
Coperas	1.5	0.6 (0.6)	0.1 (0.1)	0.1 (0.1)
LT31	1.4	0.7 (0.8)	0.1 (0.1)	0.1 (0.1)
LT31	1.6	1.0 (0.6)	0.1 (0.1)	0.1 (0.1)
Alum	2.0	0.5 (0.6)	0.0 (0.0)	0.0 (0.0)

Table C.5 - Total Organic carbon (mg/l)

COAGULANT	RAW WATER	2' RGF
Alum	5.50	3.51 (2.88)
Coperas	5.53	3.60 (3.06)
Coperas	5.37	3.20 (3.10)
LT31	4.79	3.51 (2.47)
LT31	5.09	3.64 (2.83)
Alum	5.57	3.05 (2.92)

Table C.6 - Iron (mg Fe/l)

COAGULANT	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
Alum	0.63	0.32	0.10 (1.06)	0.01 (0.17)	0.01 (0.02)	0.00 (0.01)
Coperas	1.11	0.34	0.85 (0.88)	0.11 (0.19)	0.10 (0.02)	0.07 (0.01)
Coperas	0.71	0.37	0.94 (0.82)	0.25 (0.11)	0.03 (0.28)	0.02 (0.02)
LT31	0.75	0.34	0.24 (0.97)	0.01 (0.14)	0.01 (0.04)	0.02 (0.01)
LT31	0.63	0.31	0.23 (0.79)	0.01 (0.12)	0.02 (0.03)	0.01 (0.01)
Alum	0.81	0.30	0.12 (0.93)	0.01 (0.10)	0.02 (0.020	0.01 (0.01)

Table C.7 - Manganese (ug Mn/l)

COAGULANT	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
Alum	0.22	0.23	0.22 (0.22)	0.22 (0.22)	0.20 (0.24)	0.00 (0.01)
Coperas	0.29	0.26	0.15 (0.20)	0.15 (0.22)	0.15 (0.21)	0.01 (0.00)
Coperas	0.23	0.23	0.19 (0.23)	0.19 (0.23)	0.20 (0.29)	0.01 (0.00)
LT31	0.19	0.20	0.19 (0.22)	0.20 (0.19)	0.20 (0.28)	0.01 (0.01)
LT31	0.15	0.13	0.14 (0.14)	0.12 (0.13)	0.14 (0.19)	0.00 (0.00)
Alum	0.19	0.19	0.18 (0.18)	0.18 (0.17)	0.18 (0.20)	0.00 (0.00)

Table C.8 - Aluminium (ug Al/l)

COAGULANT	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
Alum	0.13	0.08	0.50 (0.07)	0.14 (0.04)	0.00 (0.00)	0.00 (0.00)
Coperas	0.51	0.07	0.04 (0.04)	0.03 (0.07)	0.00 (0.00)	0.00 (0.00)
Coperas	0.14	0.10	0.04 (0.06)	0.02 (0.04)	0.02 (0.42)	0.01 (0.02)
LT31	0.11	0.04	0.03 (0.03)	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)
LT31	0.11	0.06	0.04 (0.04)	0.02 (0.03)	0.00 (0.00)	0.03 (0.04)
Alum	0.09	0.02	0.37 (0.01)	0.18 (0.00)	0.00 (0.00)	0.00 (0.00)

Table C.9 - Bacteriological quality of 2' RGF water

COAGULANT	COLONIES		COLIFORMS	
	1 DAY	3 DAY	E-COLI	TOTAL
Alum	0, 0 (0, 0)	0, 1 (6, 2)	0, 0 (0, 0)	0, 0 (0, 0)
Coperas	0, 0 (0, 0)	0, 0 (10, 0)	0, 0 (0, 0)	0, 0 (0, 0)
Coperas	0, 0 (0, 0)	0, 0 (0, 1)	0, 0 (0, 0)	0, 0 (0, 0)
LT31	2, 0 (0, 0)	0, 3 (12, 9)	0, 0 (0, 0)	0, 0 (0, 0)
LT31	0, 0 (0, 0)	42, 4 (6, 0)	0, 0 (0, 0)	0, 0 (0, 0)
Alum	0, 0 (0, 0)	0, 3 (0, 2)	0, 0 (0, 0)	0, 0 (0, 0)

The first number is for non hand chlorinated water, the second number is for hand chlorinated water.

Table C.10 - Headloss development rate (mm/hr) in 1' RGFs

COAGULANT	1'RGF
Alum	59 (56)
Coperas	40 (78)
Coperas	54 (55)
LT31	33 (56)
LT31	37 (58)
Alum	59 (58)

Table C.11 - Trichloromethane (ug/l)

COAGULANT	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
Alum	L	O	S	T
Coperas	L	O	S	T
Coperas	76.49	54.13 (31.41)	21 96 (7.28)	56.18 (34.46)
LT31	16.30	11.54 (1.48)	0.02 (0.12)	36.63 (2.36)
LT31	36.54	23.43 (11.54)	15.73 (6.15)	26.21 (11.67)
Alum	24.92	11.16 (9.92)	6.97 (5.14)	13.57 (8.13)

Table C.12 - Bromodichloromethane (ug/l)

COAGULANT	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
Alum	L	O	S	T
Coperas	L	O	S	T
Coperas	2.17	4.52 (1.90)	2.45 (0.79)	5.85 (3.15)
LT31	1.79	1.81 (1.72)	1.18 (1.02)	3.22 (1.97)
LT31	1.59	1.17 (1.17)	1.89 (1.21)	1.64 (1.19)
Alum	0.88	0.74 (0.74)	0.55 (0.58)	0.93 (0.44)

Table C.13 - Dibromochloromethane (ug/l)

COAGULANT	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
Alum	L	O	S	T
Coperas	L	O	S	T
Coperas	0.08	0.42 (0.07)	0.22 (0.03)	0.60 (0.52)
LT31	6.21	0.23 (0.24)	0.23 (0.24)	0.32 (0.27)
LT31	<0.05	<0.05 (<0.05)	0.30 (0.20)	<0.05 (0.07)
Alum	0.25	0.27 (8.93)	0.11 (0.13)	0.11 (0.15)

Table C.14 - Tribromomethane (ug/l)

COAGULANT	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
Alum	L	O	S	T
Coperas	L	O	S	T
Coperas	<.03	<.03 (<.03)	<.03 (0.10)	<.03 (0.17)
LT31	0.05	<.03 (<.03)	<.03 (<.03)	<.03 (<.03)
LT31	<0.05	<.05 (<.05)	0.12 (<.05)	<.05 (<.05)
Alum	<0.05	<.05 (<.05)	<.05 (<.05)	<.05 (<.05)

Table C.15 - Total trihalomethanes (ug/l)

COAGULANT	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
Alum	L	O	S	T
Coperas	L	O	S	T
Coperas	78.77	59.10 (33.41)	24.66 (8.20)	62.66 (38.30)
LT31	24.35	13.61 (3.47)	1.46 (1.41)	40.20 (4.63)
LT31	38.21	24.68 (12.79)	18.04 (7.95)	27.93 (12.96)
Alum	26.08	12.20 (19.63)	7.65 (5.88)	14.64 (9.25)

Table C.16 - Chlorine demand (mg Cl/l)

COAGULANT	RAW WATER	1' RGF	2' RGF		
			FILTER DEMAND	LAB DEMAND	FREE RESIDUAL
Alum	1.35	0.77 (0.79)	0.88 (0.66)	0.25 (0.30)	0.09 (0.07)
Coperas	1.25	0.62 (0.73)	0.68 (0.67)	0.16 (0.13)	0.30 (0.12)
Coperas	1.49	0.63 (0.85)	0.48 (0.50)	0.30 (0.20)	0.06 (0.06)
LT31	1.39	1.07 (0.78)	1.10 (0.64)	0.29 (0.21)	0.37 (0.09)
LT31	1.20	0.89 (0.52)	0.75 (0.43)	0.35 (0.19)	0.06 (0.08)
Alum	1.07	0.58 (0.52)	0.75 (0.42)	0.17 (0.14)	0.18 (0.13)

Table C.17 - Adsorbable organic halide (ug/l)

COAGULANT	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
Alum	50.9	32.2 (29.7)	22.9 (13.4)	26.9 (20.1)
Coperas	61.3	24.7 (31.0)	26.8 (-)	41.3 (32.4)
LT31	61.3	58.0 (26.4)	28.8 (18.1)	42.4 (25.2)

Table C.18 - Mutagenicity (slope value)

COAGULANT	CHLORINATED 2' RGF				CHLORINATED 1' RGF			
	TA 98		TA 100		TA 98		TA 100	
	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7
Ferric	3.96	5.87	14.77	8.36	-	-	-	-
Alum	5.09	7.27	19.33	9.21	5.73	4.87	17.58	5.75
Ferric	2.44	5.03	11.39	6.00	-	-	-	-
Coperas	3.77	4.48	19.57	7.99	3.88	3.86	13.83	5.36
Ferric	2.38	4.09	18.65	8.38	-	-	-	-
LT31	2.94	4.76	26.56	13.63	3.36	3.79	26.75	13.63

In table 18, the control stream mutagenicity is given in the line above the trial stream.

PHASE 1, TEST (D) EFFECT OF FLOCCULANT AIDS

OPERATIONAL REGIME

This test was carried out between 29 August and 26 September 1989. In this test streams A and B were operated under constant conditions using ferric but stream B had either Magnafloc LT22 (cationic) or Magnafloc LT25 (anionic) added to the flocculation tank. Two different doses of each floc-aid were examined. For both streams during the test the primary filter target pH was 6.5 and the secondary filter target pH was 9.0.

The results of 4 separate runs have been considered.

PLANT CONTROL

Coagulant dose was maintained in both streams at 2.3 to 3.8 mg/l. The variation was due to decreasing raw water flow because of the reduced head caused by falling reservoir levels. The raw water flow available dropped from 3.5 to 2.5 m^3/hr thus these tests were carried out at longer flocculation times and slower rise rates than previous tests (42 mins instead of 30 mins and 5.7 m/hr instead of 8 m/hr). Previous tests have indicated that this should not have a significant impact on organics removal.

The coagulation pH was maintained at 4.6 to 4.8 in both streams;primary filtration pH was between 6.4 and 7.0 and secondary filtration pH was between 8.7 and 9.3. The variation was due to the problems associated with maintaining raw water flows.

The polymer dose was either 0.12 mg/l or 0.5-0.6 mg/l. The LT25 produced a slightly thicker float but the LT22 produced a much thicker float, such that the float removal drain became blocked on occasions.

RAW WATER QUALITY

The raw water quality during the test was consistent for filtered parameters, but turbidity and apparent parameters varied. The effect of floc aid can be best assessed by comparing the control with the trial.

RESULTS

The results are presented in Tables D.1 to D.18.

Table D.1 - Ferric, floc aid doses and sample pHs

DAT	TRIAL STREAM FLOC AID	FERRIC DOSE (mg/l)	POLY DOSE mg/l	pH			
				RAW	DAF TREATED	1' RGF	2' RGF
29 Aug 89	LT25	3.4 (3.7)	0.12	6.1	4.7 (4.6)	6.4 (6.6)	9.1 (9.1)
5 Sep 89	LT25	3.6 (3.8)	0.5	6.1	4.6 (4.8)	6.6 (6.7)	8.9 (8.9)
20 Sep 89	LT22	2.3 (2.7)	0.12	6.3	4.7 (4.7)	6.6 (7.0)	8.7 (9.0)
26 Sep 89	LT22	3.5 (3.7)	0.6	6.2	4.7 (4.7)	6.7 (6.6)	8.9 (9.3)

Table D.2 - Colour (Abs/m @400nm)

POLY	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
LT25	3.9	1.8	1.5 (1.5)	0.3 (0.4)	0.3 (0.3)	0.4 (0.4)
LT25	3.5	2.0	2.0 (1.4)	0.2 (0.2)	0.3 (0.3)	0.3 (0.3)
LT22	3.8	1.9	1.5 (1.6)	0.3 (0.3)	0.4 (0.5)	0.4 (0.5)
LT22	3.2	2.1	1.6 (1.3)	0.3 (0.3)	0.3 (0.3)	0.3 (0.3)

Table D.3 - u.v. (Abs/m @254nm)

POLY	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
LT25	23.0	15.9	9.4 (9.3)	3.7 (3.7)	3.5 (3.6)	3.7 (3.7)
LT25	21.8	17.1	10.7 (8.8)	3.3 (3.1)	3.4 (3.3)	3.5 (3.7)
LT22	22.5	16.9	9.4 (10.0)	3.9 (4.0)	4.8 (5.5)	4.8 (5.3)
LT22	20.7	17.8	9.2 (8.5)	3.4 (3.4)	3.3 (3.8)	3.5 (3.8)

Table D.4 - Turbidity (NTU)

POLY	RAW WATER	DAF FLOATED	1' RGF	2' RGF
LT25	2.2	0.8 (0.8)	0.1 (0.1)	0.0 (0.1)
LT25	1.8	1.2 (0.8)	0.1 (0.0)	0.1 (0.1)
LT22	2.2	0.9 (1.0)	0.1 (0.1)	0.0 (0.1)
LT22	1.8	1.0 (0.8)	0.1 (0.1)	0.0 (0.1)

Table D.5 - Total Organic carbon (mg/l)

POLY	RAW WATER	2' RGF
LT25	6.11	3.26 (3.07)
LT25	4.35	1.94 (2.01)
LT22	4.95	2.15 (2.33)
LT22	4.78	2.04 (2.02)

Table D.6 - Iron (mg Fe/l)

POLY	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
LT25	0.99	0.36	0.83 (0.98)	0.17 (0.11)	0.02 (0.02)	0.00 (0.01)
LT25	0.98	0.41	1.25 (1.01)	0.18 (0.15)	0.01 (0.01)	0.01 (0.01)
LT22	1.07	0.38	0.76 (0.85)	0.13 (0.10)	0.04 (0.09)	0.03 (0.05)
LT22	0.85	0.47	0.89 (0.85)	0.13 (0.11)	0.03 (0.04)	0.01 (0.03)

Table D.7 - Manganese (mg Mn/l)

POLY	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
LT25	0.19	0.20	0.20 (0.19)	0.20 (0.19)	0.26 (0.34)	0.01 (0.01)
LT25	0.22	0.19	0.22 (0.22)	0.21 (0.21)	0.25 (0.25)	0.01 (0.00)
LT22	0.21	0.19	0.20 (0.20)	0.20 (0.20)	0.20 (0.22)	0.01 (0.01)
LT22	0.19	0.18	0.19 (0.19)	0.18 (0.19)	0.24 (0.20)	0.00 (0.00)

Table D.8 - Aluminium (ug Al/l)

POLY	RAW WATER		DAF FLOATED		1' RGF	2' RGF
	APPARENT	TRUE	APPARENT	TRUE		
LT25	0.10	0.02	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
LT25	0.10	0.02	0.02 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
LT22	0.10	0.03	0.02 (0.03)	0.01 (0.01)	0.00 (0.01)	0.00 (0.01)
LT22	0.10	0.06	0.04 (0.04)	0.03 (0.02)	0.02 (0.03)	0.02 (0.03)

Table D.9 - Bacteriological quality of 2' RGF water

POLY	COLONIES		COLIFORMS	
	1 DAY	3 DAY	E-COLI	TOTAL
LT25	0, 0 (0, 0)	5, 1 (1, 0)	0, 0 (0, 0)	0, 0 (0, 0)
LT25	0, 0 (0, 0)	<100,50 (17, 0)	0, 0 (0, 0)	0, 0 (0, 0)
LT22	0, 0 (0, 0)	12, 0 (2, 0)	0, 0 (0, 0)	0, 0 (0, 0)
LT22	0, 0 (0, 0)	2, 0 (5, 1)	0, 0 (0, 0)	0, 0 (0, 0)

The first number is for non hand chlorinated water, the second number is for hand chlorinated water.

Table D.10 - Headloss development rate (mm/hr) in 1' RGFs

FLOC AID	1'RGF
LT25	58 (49)
LT25	98 (56)
LT22	40 (60)
LT22	109 (58)

Table D.11 - Trichloromethane (ug/l)

POLY	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
LT25	L	O	S	T
LT25	35.30	12.91 (17.15)	9.57 (8.50)	17.76 (17.38)
LT22	16.18	12.46 (11.87)	3.44 (2.91)	13.45 (12.31)
LT22	24.57	10.37 (10.26)	8.32 (6.66)	12.35 (12.94)

Table D.12 - Bromodichloromethane (ug/l)

POLY	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
Alum	L	O	S	T
LT31	1.55	1.19 (1.34)	1.04 (1.15)	1.44 (1.39)
LT31	0.68	0.39 (0.41)	0.05 (0.06)	0.76 (0.52)
Alum	1.24	0.97 (1.07)	0.74 (0.74)	1.25 (1.10)

Table D.13 - Dibromochloromethane (ug/l)

POLY	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
LT25	L	O	S	T
LT25	<0.05	0.08 (0.09)	0.09 (<0.05)	0.11 (0.09)
LT22	0.18	0.18 (<0.05)	<0.05 (<0.05)	0.18 (0.18)
LT22	0.10	0.10 (0.11)	0.10 (0.10)	0.13 (0.89)

Table D.14 - Tribromomethane (ug/l)

POLY	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
LT25	L	O	S	T
LT25	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)
LT22	<0.03	<0.03 (<0.03)	0.06 (<0.03)	<0.03 (<0.03)
LT22	<0.03	<0.03 (<0.03)	<0.03 (<0.03)	<0.03 (<0.03)

Table D.15 - Total trihalomethanes (ug/l)

POLY	RAW WATER	1' RGF	2' R G F	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
LT25	L	O	S	T
LT25	36.93	14.21 (18.96)	10.73 (9.73)	19.34 (18.89)
LT22	17.07	13.06 (12.36)	3.60 (3.05)	14.42 (13.04)
LT22	25.94	11.47 (11.47)	9.19 (7.53)	13.76 (14.96)

Table D.16 - Chlorine demand (mg Cl/l)

POLY	RAW WATER	1' RGF	2' RGF		
			FILTER DEMAND	LAB DEMAND	FREE RESIDUAL
LT25	1.19	0.59 (0.56)	0.65 (0.49)	0.17 (0.16)	0.05 (0.08)
LT25	1.15	0.58 (0.54)	0.58 (0.57)	0.19 (0.19)	0.06 (0.04)
LT22	1.13	0.61 (0.63)	0.57 (0.53)	0.19 (0.21)	0.03 (0.08)
LT22	1.11	0.54 (0.56)	0.61 (0.54)	0.16 (0.17)	0.11 (0.15)

Table D.17 - Adsorbable organic halide (ug/l)

POLY	RAW WATER	1' RGF	2' RGF	
	CHLORINATED	CHLORINATED	UN-CHLORINATED	CHLORINATED
LT25	58.2	17.8 (24.3)	14.2 (15.3)	24.8 (27.7)
LT22	39.5	21.5 (22.1)	16.7 (20.8)	21.8 (25.8)

Table D.18 - Mutagenicity (slope value)

POLY	CHLORINATED 2' RGF				CHLORINATED 1' RGF			
	TA 98		TA 100		TA 98		TA 100	
	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7	pH 2	pH 7
FERRIC	3.298	4.55	12.98	5.97	-	-	-	-
LT25	2.71	3.15	13.97	9.65	2.38	3.14	12.06	9.00
FERRIC	NA	NA	NA	NA	-	-	-	-
LT22	NA	NA	NA	NA	NA	NA	NA	NA

In table 18, the control stream mutagenicity is given in the line above the trial stream.