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ON-LINE NITRATE WATER QUALITY MONITOR FOR
DEPARTMENT OF THE ENVIRONMENT

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Photograph by ...

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ON-LINE NITRATE MONITOR

OBJECTIVES

The purpose of this project has been to establish and evaluate an on-line computer controlled monitor that reliably meets the requirements of DOE and of the water industry for the monitoring and control of nitrate levels in water intended for potable supply. The EEC guide and maximum admissible levels for nitrate nitrogen in potable waters are 5.65 and 11.3 mg/l respectively. An on-line monitor would be required to measure nitrate - N levels of between 1 and about 25 mg/l in underground and surface waters. An accuracy of 0.2 mg/l at the lower end and 1.0 mg/l at the upper end of the scale would be aimed for.

For a monitor taking discrete samples, a sampling frequency of 2 - 4 samples per hour would be adequate for most applications. A likely application for the monitor would be in controlling the blending of waters from high and low nitrate sources to produce a blended water of acceptable nitrate level. It would therefore be desirable to aim for a three stream monitor with an overall sampling frequency of approximately 10 samples per hour, similar to the existing Aztec three stream residual coagulant monitors. For control purposes, a 4 - 20 mA output corresponding to the nitrate level in the blended stream (or if required a 4 - 20mA output for each of the 3 streams) would be generated.

Oxidised nitrogen is also harmful if present in the form of nitrite. However, since nitrite is not present in significant amounts in natural waters its influence on the chosen method of monitoring has not been taken into consideration.

The evaluation work was planned to take place under the following headings:

- a) Design and laboratory evaluation of the optical system from light source to detector.
- b) Laboratory evaluation of the UV based method for nitrate, including compensation for interferences.
- c) To use the results of these evaluations to construct a reliable prototype computer controlled nitrate monitor.
- d) To adapt and extend the software from existing Aztec monitors to control all the functions of the monitor.
- e) To carry out an evaluation of the monitor's operation in the field.
- f) To provide a final report.

PRELIMINARY WORK

This project has been concerned with the evaluation of a monitor based on the UV absorption method. This method was chosen in preference to either chemical methods or a nitrate selective electrode. Chemical methods that could be used for an on-line monitor involve the reduction of nitrate to nitrite, followed by determination of the nitrite. The reduction step requires carefully controlled conditions which would be difficult to control reliably in an unattended on-line monitor. Ion selective electrodes have been used extensively in on-line monitors to date. Their performance has however been adversely affected by organic fouling of the electrode membrane when used for monitoring surface waters. The UV absorption method on the other hand, involved a simple physical measurement that should be inherently more reliable. Its disadvantage is that substances other than nitrate - in particular organic matter - can contribute to the UV absorption and must be corrected for.

A survey of the literature relating to previous work on nitrate determination by UV absorption was carried out to find the most promising method for avoiding or correcting for interferences. The most relevant work was found to be that carried out by L Brown and E G Bellinger on waters from the rivers Goyt and Etherow in the Peak District, published in Water Research, Vol 12, pp 223 - 229, 1978. Their work showed that if the UV absorption was measured not at 210nm (the peak for nitrate), but at a longer wavelength (up to 225nm) then interferences from other inorganic anions was reduced and correction for the effect of humic substances became more reliable. The correction at 225nm needed to compensate for UV absorption by humic matter was found by extrapolating back from its absorption at wavelengths above 250nm where nitrate does not absorb.

Aztec therefore decided to pursue this approach for application to the monitor starting with a laboratory investigation on the UV absorption characteristics of a number of surface waters. It would have been possible to physically remove the interfering organics by a suitable resin prior to nitrate determination by UV absorption. However, this was not considered to be feasible on a long term continuous basis.

Early consideration was also given to the form that the monitor should take so that the components of the monitor's optical system could be assembled and tested for their suitability. It was appropriate to use the same optical cell arrangement as employed in other existing Aztec on-line monitors. A vertical transparent tube contains the sample while a light beam is directed horizontally across it to pass through a monochromator and onto a detector. A piston is used to draw sample into the tube and expel it again after measurement, thus wiping clean the internal surface of the tube.

Since measurements were to be made in the 220nm to 280nm wavelength band, a deuterium lamp was chosen as the most suitable light source. The problem anticipated with such lamps is their relatively short useful life of 1000 to 1500 hours. The manufacturers suggested however that if their normal operating current of 300mA were reduced to 200mA, their useful life could probably be extended to about 4000 hours at the expense of some reduction in light intensity. It was therefore decided to operate the lamp under these conditions.

The optical tube needed to be transparent to the wavelengths being used and Vitrosil was chosen as a suitable and not too costly material. Since it was necessary to keep the number of optical components to a minimum to reduce both the light loss and the cost, it was decided to use the optical tube also as a lens to focus the light onto the detector. An internal diameter of 15mm was therefore chosen for the tube. A smaller diameter would have resulted in too short a focal wavelength for it (as a lens). A significantly greater internal diameter would have resulted in too long a path length within it (as an optical cell). This in turn would have necessitated inconveniently large sample dilutions prior to measurement to allow a measurable intensity of light to reach the detector. These constraints on the tube size were confirmed by a simple laboratory set-up. The use of any supplementary quartz lenses has thus been avoided.

For the detector, it was decided to evaluate both a silicon photocell and a small phototube. The response of the phototube was found to be too small to handle and the photocell was therefore chosen. The monochromator would be the single most costly item in the whole system, bearing in mind that it would be necessary to measure at at least two, and preferably three, different wavelengths in the UV to enable compensation to be made for organic interferences. The choice therefore lay between using three optical filters or a grating monochromator. The grating monochromator was chosen for the following reasons:

- a) The maximum light transmission obtainable through a filter at 220nm is 20%, whereas a grating can transmit as much as 60%.
- b) A grating monochromator controlled by a stepper motor can be used to select any desired wavelength and is hence much more versatile than fixed wavelength filters.
- c) A single grating monochromator is less expensive than three UV filters, while offering a wide range of wavelengths.

A grating monochromator is more bulky than a filter disc, but we were able to source one measuring only 90 x 50 x 40mm with a shaft drive for stepper motor control. This is sufficiently compact for easy mounting. Since the grating monochromator has a slit entrance it is ideally suited to the tubular focusing lens that produces a slit image from the point source lamp. A 1 x 6mm photocell detector has been chosen to fit flush onto the monochromator exit slit.

The components of the optical system were mounted on a test bench and a suitable amplifier was assembled to amplify the detector output to a level required by the computer input circuitry. This enabled the optimum positions for the individual components to be found and the detector and its amplifier to be adjusted to the point where an adequate output signal was obtained. At this stage, a manually operated grating monochromator was evaluated. A phototube detector was tested but rejected in favour of the silicon photocell. Apart from that, the originally chosen components were found to be satisfactory. The general arrangement of the optical components is shown in Fig.1.

LABORATORY EVALUATION OF THE METHOD

a) Inorganic Interferences:

Commonly occurring anions were first tested for their possible interference with the method by measuring their UV absorbance at 220nm in comparison with nitrate. The results were as follows:

Absorbance at 220nm in 0.5cm cell:

Nitrate	4mg/l as N	Absorbance = 0.525
Bicarbonate	300mg/l as CaCO ₃	0.008
Carbonate	100mg/l as CaCO ₃	0.024
Chloride	100mg/l	0.012
Sulphate	100mg/l	0.005

The sodium salt was used in every case.

From these results it may be seen that interference from inorganic anions is unlikely to be significant in most practical instances. Turbidity can however greatly affect results and for the investigation of natural water samples, filtration through a 0.45 micron membrane filter was always carried out prior to measuring UV absorbance.

b) Linearity:

Since the proposed measurement wavelength of 220nm is not at the absorption peak for nitrate, it was necessary to confirm a linear relationship between nitrate concentration and absorbance at this wavelength. The results (see Fig. 2) confirmed that this relationship was linear at 220nm and at other wavelengths between 210 and 225nm.

c) Evaluation of performance of the method on natural waters:

The UV absorption spectra of a selection of upland and low land surface waters were determined in the 210nm to 280nm wavelength range. The waters were sampled from: the river Avon at Rugby, the Severn at Strensham, and the rivers Goyt, Kinder and Llowyn. All showed the same characteristics as found by Brown and Bellinger for the river Etherow. These were:

- i) A gradual linear decrease in absorption with increasing wavelength above 250nm.
- ii) Below 245nm, a sharp rise in absorption with decreasing wavelength down to 210nm, the magnitude of the rise depending on the nitrate concentration.

The linear relationship between absorption and wavelength above 250nm showed that extrapolation of this line back to 220nm would be a method that could be applied generally to obtain an estimate of the organic contribution to absorption at this wavelength (see Fig. 3). Brown and Bellinger found that the extrapolation was valid down to 225nm by removing the organic matter with XAD.2 resin, thus obtaining a direct measure of its effect. Our evaluation was limited to comparing the results of chemical determinations of nitrate content with the results obtained from UV absorbance at 220, 250 and 275nm using the extrapolation method to correct for organic interference.

Twelve water samples were obtained from various locations throughout the country. Each was filtered through a 0.45 micron filter and the UV absorbance measured in a 0.5cm cell at 220, 250 and 275nm. The absorbances at 250 and 275nm were used to extrapolate back to obtain the organic contribution to the absorbance at 220nm. This figure was then subtracted from the measured absorbance at 220nm to obtain the value for nitrate only. In the case of the Thames and river Ouse samples, a two-fold dilution was made before measurement. A chemical determination of the nitrate content of each sample was then made, using either reduction by cadmium followed by determination as nitrite or by nitration of resorcinol and spectrophotometric determination of the product. These methods are taken from the following published papers:

"A Rapid Manual Method for Nitrate Determination in Small Volumes by a Modification of the Cadmium Reduction Method".
Gaugush. R., Heath.R.
Water Research. Vol 18 No. 4, pp 449-450, 1984.

"Rapid Spectrophotometric Determination of Nitrate in Mineral Waters with Resorcinol".
Velghe.N, Claeys.A.
Analyst Vol. 110, pp 313-314 1985

The results of this evaluation comparing the chemical results with those of the UV method intended for the monitor are given in Table 1. As may be seen, there was a very fair measure of agreement between the chemical and UV methods. It was of particular note that for those samples that were highly coloured but low in nitrate (e.g. Langsett) the agreement was still good even though the correction for organics (Col. A) was considerably greater than the absorbance due to nitrate alone (Col. B). It was therefore decided to apply this method to the monitor. If a different method of correcting for organics (based on UV measurements) should be found to give better results on a particular water in future, the versatility of a computer controlled monitor using a diffraction grating would enable it to be applied on the monitor. It would only require a change in the software programme to change the measurement wavelengths or alter the method of calculation.

TABLE 1 Comparison of chemical determined nitrate content with that by proposed UV method using 0.5cm cell.

Column A: Absorbance correction for organics at 220nm obtained from measurements made at 250 and 275nm.

Column B: Measured absorbance at 220nm corrected for contribution from organics.

<u>SAMPLE SOURCE OR LOCATION</u>	<u>A</u>	<u>B</u>	<u>NITRATE-N UV METHOD</u>	<u>MG/L CHEMICAL METHOD</u>
4mg/l N Standard	0	0.525	4.0	4.0
Severn, Strensham	0.078	0.71	5.4	5.6
Avon, Rugby	0.115	0.69	5.25	5.4
Goyt	0.165	0.08	0.61	0.6
Kinder	0.170	0.10	0.75	0.65
Llowyn	0.170	0.05	0.37	0.2
Ouse, Clapham	0.09x2	0.63x2	9.6	9.0
Thames	0.043x2	0.47x2	7.15	7.25
Langsett	0.234	0.06	0.45	0.40
Midhope	0.148	0.07	0.53	0.45
Saltersford	0.074	0.61	4.65	4.90
Pitsford	0.070	0.43	3.30	3.04
Wing	0.085	0.305	2.30	2.30

LABORATORY TESTING OF SIMPLE PROTOTYPE

Linearity Test:

A simple prototype version of the monitor was constructed and an Aztec software programme was modified to operate it, select the wavelengths required for the absorbance measurements and calculate the optical density results from the detector output. When this had been completed, a series of nitrate solutions having concentrations ranging from 0 to 4 mg/l N were introduced for determination to find whether the optical density results were linear with respect to concentration.

It was found that the detector output at higher concentrations was greater than would have been expected from its response at the lower concentrations. A possible cause of this effect is stray light (i.e. light that has not passed through the sample) reaching the detector. To prevent this happening, the tube was shielded to permit light only to pass through the central section of it. The non-linear effect still persisted however and its cause was presumed to be due to non linearity in the response of some component such as the detector or amplifier. Since we were not equipped to fully investigate such a cause, it was decided to measure the non-linearity and to correct for it in software. The detector/amplifier response was measured at six points over the 0 to 4 mg/l N concentration range and the resulting optical density versus concentration curve plotted (see Fig. 4). A software programme was then written to linearise the curve which could be defined by entering twelve parameters (two per point on the curve) into the programme.

Further tests were then conducted with samples of known nitrate concentration which showed that the linearisation programme gave satisfactory results.

PRELIMINARY OPERATIONAL TRIALS

The software was progressed to the point where the monitor could be left to run automatically on its own and be taken out for some preliminary field trials in the form of a single stream monitor. This involved:

- i) Enabling the user to set the frequency of determination from the keyboard. Up to 10 sample determinations per hour were provided for.
- ii) Enabling the user to set one of four determination ranges from the keyboard. The monitor then automatically dilutes the sample with deionised water, according to the range chosen:

Range: 1	0-4mg/l N	No dilution
2	0-8	x 2 dilution
3	0-16	x 4 dilution
4	0-32	x 8 dilution

- iii) Implementation of a detailed printout that would give the detector/amplifier output voltages and the measured and linearised optical densities leading to the calculated final results.

Tests were carried out to determine the accuracy of dilution in the three diluting ranges and steps were taken to improve their accuracy. Range 4 initially gave the least accurate result since this range entailed taking the smallest volume of sample for dilution. Since the dilution error in a given range was consistent, the effect of this error on the results could be eliminated by calibrating the monitor on a standard solution according to the same diluting procedure (i.e. the same range) as that used for the sample determinations.

The detailed printout, of which an example is included in this report, records the following:

Line 1: Time of sampling and calculated result.
Line 2: Linearised Optical Density of sample at 220nm x 1000
Line 3: Col.1: Optical Density of sample at 220nm x 1000,
 calculated from columns 2, 3 and 4.
 Col 2: Detector/amplifier mV output when measuring
 sample.
 Col 3: Detector/amplifier mV output when measuring
 a Blank.
 Col 4: Detector/amplifier mV output with no
 illumination.

Lines 4 and 5 contain the corresponding data for the measurements made at 250 and 275nm respectively.

The final result (Line 1) in mg/l N is calculated from the linearised optical density at 220nm, after subtracting from it the correction for organics, obtained by extrapolating the optical densities at 250 and 275nm:-

$$\text{mg/l N} = \text{F.K} \left[\text{Linearised OD at 220} - 2.2(\text{OD at 250}) + 1.2(\text{OD at 275}) \right],$$

where K is the calibration constant obtained by measuring a standard nitrate solution.
and F is the dilution factor for the range chosen.

Three external sites were then chosen for carrying out field trials of a few days duration. These were:

1. South Staffordshire Water Company Laboratories,, Green Lane, Walsall.

The monitor was operated under the supervision of Dr I Fletcher partly on the laboratory tap water and partly on made up samples of known nitrate concentration. His interest in the monitor was its possible application in a multi stream version, for the control of an ion exchange nitrate removal plant. His conclusions were:

- a) The monitor was sufficiently accurate for his purpose.
- b) When a step change occurred in the sample concentration, it took two or three determinations before the monitor result had fully responded to the change. While this would not matter for a monitor following gradual raw water changes, it would not be acceptable in a plant control situation.
- c) Since the calibration constant of the monitor required changing when it was first set up on site, a procedure for automatic calibration would be desirable.

2. Cosford Treatment Works, STWA, near Shifnal.

The monitor was left unattended for two days at the head of a borehole supply adjacent to the River Worf. The initial result of 3.70 mg/l N agreed with the value determined in the laboratory. At the end of the period, the result had risen to 3.95 mg/l N whereas the laboratory determination still gave 3.70 mg/l N.

The reason for the 7% upward drift in the result is not clear, but shows that an automatic recalibration with a standard solution every 12 or 24 hours would be desirable to prevent it.

3. Clapham Treatment Works, AWA near Bedford.

The monitor was left with minimal attention for six days, sampling untreated water from the River Ouse. A continuous membrane filtration unit was used to remove all turbidity from the water before it was sampled by the monitor. The results obtained in Range 3 are as follows:-

Date:(1988)	10/5	11/5	12/5	13/5	14/5	15/5	16/5
Monitor Result	8.2	8.7	8.6	8.0	9.5	10.1	9.2
Clapham Result	8.6	8.6	8.2	7.6	8.5	8.8	8.6
Our Lab Result	8.2	-	-	-	-	-	8.45

Our laboratory results were obtained by the same UV method as that used by the monitor, while the Clapham laboratory results were obtained by a slightly different UV method.

A comparison of these results shows that the monitor did respond to the drop in nitrate concentration on May 13th, but that there was an upward drift in the monitor results of perhaps as much as 12% over 6 days. This again indicates a need for periodic automatic recalibration.

During the course of the field trials and again subsequently as the monitor continued to operate, a further problem became evident. The detector/amplifier output voltage, when measuring a blank, dropped off with time at a rate that was unacceptable for the long term operation of the monitor. Fig. 5 indicates the magnitude of this effect which was estimated at a decrease of 0.6% per hour at the start, falling to 0.25% per hour after several days of operation. At first this was ascribed to ageing of the deuterium lamp, but was later found to be due to solarisation of the Vitrosil sample tube causing it to become less transparent to UV light. Rotating the tube to present a new section to the light restored the detector response to its original value for a time. The solution to this problem was to replace the Vitrosil tube with Spectrosil which, although more expensive, is a purer grade of silica that does not contain the impurities responsible for the solarisation.

As a result of the findings to date, the next stage in the development of the monitor included the following changes or additions:

- a) Replacement of the Vitrosil tube with Spectrosil.
- b) Automatic recalibration at regular intervals.
- c) A change in operating procedure to speed up response to concentration changes.
- d) Hardware and software modifications needed to convert the monitor to a 3 stream version.

SECOND STAGE OF DEVELOPMENT

- a) Replacement of Vitrosil Tube with Spectrosil:

This was implemented and the detector response no longer fell off perceptibly with time. However, after some days of operation problems were experienced with the piston seal that operates within the tube. This is due to the rougher surface finish that is obtained with Spectrosil. Despite extensive experimentation with different types of piston seal this problem has not been solved satisfactorily to date. However a specialist glass firm is looking at extruding satisfactory Spectrosil for us.

At present the answer has been sought in another direction. The Vitrosil tube has been reinstated and a solenoid operated shutter, controlled by the computer, has been introduced between the lamp and the Vitrosil sample tube. Instead of being constantly exposed to the UV lamp, the tube is now only exposed for a few seconds per sampling when the shutter opens to enable measurements to be made. This is expected to make the Vitrosil tube usable for at least as long as the deuterium lamp (around 4000 hours).

- b) Automatic Recalibration:

The software has been modified to enable the user to set the frequency of autocalibration from the keyboard. Autocalibration will now take place at least once every 24 hours, as is the case with some other Aztec monitors. This should eliminate the problem of long term drift in the results, though a further period of field testing will be needed to confirm this.

The monitor will need to be provided with a 4 mg/l Nitrate standard solution for calibration. It has been found that acidification of the standard with up to 10mls per litre of 5N hydrochloric acid does not affect its absorbance and may assist in prolonging the life of the standard and preventing the formation of scale in the sample tube when monitoring hard waters.

TABLE: 2 Response tests using step concentration changes.

<u>Results mg/l N</u>				
Range	1	2	3	4
Sample Dilution	-	x2	x4	x8
2(a)				
Low concentration	0.09	0.34	0.85	0.59
↓	0.10	0.34	0.80	0.55
Change to high conc n	3.70	7.43	13.4	12.6
↓	3.76	7.56	14.1	19.9
↓	3.79	7.53	14.2	19.8
↓	3.74	7.55	14.1	19.9
Change to low conc n	0.12	0.42	1.22	8.0
	0.07	0.44	0.58	0.95
	0.08		0.55	0.66
2(b)				
Low concentration			0.36	0.39
↓			0.34	0.39
Change to high conc n			11.81	20.2
↓			11.90	20.3
↓			11.86	20.3
Change to low conc n			0.36	0.64
			0.27	0.37
			0.26	0.37

c) Improving response times:

The monitor should be capable of giving a true result for the sample it has just taken, regardless of how much higher or lower the nitrate concentration was in the previous sample. A more vigorous line-priming and mixing pot rinsing procedure was therefore introduced by making further software changes. This resulted in an increase in the time required for a determination so that 10 samples results per hour would no longer be obtainable. To reduce the determination time again it was therefore decided not to carry out a Blank determination with every sample as had been done previously, but to do one per hour at most. Past results for Blank determinations indicate that they do not change significantly over a period of a few hours.

Table 2(a) shows the results obtained using the new rinsing procedure. The vertical columns show the succession of results obtained when the monitor was presented with a sample of low nitrate concentration, followed by a sudden change to high concentration and back to low concentration again. It was anticipated that rapidity of response would vary according to the Range (i.e. dilution) used for sample determination and the test was therefore carried out in each range, choosing the high sample concentration to be towards the top of the range in each case.

The results show a satisfactory response in Ranges 1 and 2, and rather less satisfactory in Range 3. An unsatisfactory result was obtained in Range 4 where the first result after a concentration change differed very markedly from subsequent results. A further modification to the sample handling procedure was therefore undertaken and the results of it are given for Ranges 3 and 4 in Table 2(b). As may be seen, the initial response to a sudden concentration change is now much improved and is acceptable.

d) Conversion of Monitor to three stream version:

This has involved modifications and additions to both the hardware and software to handle and coordinate the determination procedure for the two additional streams.

Hardware modifications included the provision of two extra mixing pots for diluting the samples (in Ranges 2, 3 and 4). Although only one sample is handled at a time, it was decided to dedicate a separate mixing pot to each stream to prevent any carry-over occurring between streams. This in turn necessitated a valve block with four extra valves and liquid intake ports, to accommodate the extra two sample lines and mixing pots.

The additional software included providing the user with the facility to set from the keyboard the sequence in which the streams are sampled. This enables one stream to be sampled either less or more frequently than the others. It was also decided to enable the user to set the determination Range independently for each sample stream from the keyboard. Thus a sample stream of low nitrate concentration can be determined in Range 1 (with no dilution), while another sample stream of high concentration can be set for determination in Range 3 (x 4 dilution) for example.

The format of the printout of the results obtainable from a printer was configured to give the results in three columns, one for each stream, for easy reference. The user printout also included the result for the Calibration Constant whenever an auto or manually initiated calibration is carried out. Lastly, whenever a Blank determination is done (at a frequency set by the user) the detector/amplifier output voltage is printed. This is to give early warning of any fall off in detector output that could eventually affect the reliability of the results. Causes of such a fall-off could include: ageing of the lamp, smearing or deposit formation on the optical tube, contamination of the deionised water used for the Blank, degradation of the detector. A UV system is more likely to be affected by such problems than one operating in the visible range, so that a reasonably frequent indication of the state of the optical system was thought to be advisable. An example of the user printout is included in this report.

Example of detailed printout for performance evaluation :

Corrected OD at 220nm = 588
OD220 = 651 357 1575 8
OD250 = 62 1405 1621
OD275 = 50 999 1121

15:00 Nitrate/N : 07.98
Corrected OD at 220nm = 589
OD220 = 643 365 1581 8
OD250 = 61 1409 1623
OD275 = 49 1001 1121

15:10 Nitrate/N : 08.13
Corrected OD at 220nm = 701
OD220 = 653 357 1581 8
OD250 = 61 1409 1622
OD275 = 49 1001 1121

15:20 Nitrate/N : 08.11
Corrected OD at 220nm = 598
OD220 = 651 358 1582 7
OD250 = 61 1409 1622
OD275 = 50 1001 1121

15:30 Nitrate/N : 08.07
Corrected OD at 220nm = 596
OD220 = 649 359 1578 7
OD250 = 62 1405 1623
OD275 = 51 998 1121

15:40 Nitrate/N : 08.06
Corrected OD at 220nm = 598
OD220 = 651 359 1583 8
OD250 = 64 1401 1624
OD275 = 52 996 1122

15:50 Nitrate/N : 08.02
Corrected OD at 220nm = 593
OD220 = 647 363 1586 8
OD250 = 62 1404 1621
OD275 = 50 998 1120

17:00 Nitrate/N : 08.12
Corrected OD at 220nm = 701
OD220 = 653 356 1582 7
OD250 = 62 1405 1621
OD275 = 50 999 1120

17:10 Nitrate/N : 08.21
Corrected OD at 220nm = 709
OD220 = 660 352 1588 7
OD250 = 64 1396 1620
OD275 = 53 991 1119

17:20 Nitrate/N : 08.07
Corrected OD at 220nm = 697
OD220 = 650 357 1573 7
OD250 = 63 1399 1619
OD275 = 52 994 1119

17:30 Nitrate/N : 07.98
Corrected OD at 220nm = 700
OD220 = 652 355 1578 6
OD250 = 71 1374 1619

Example of users printout giving results for three streams :

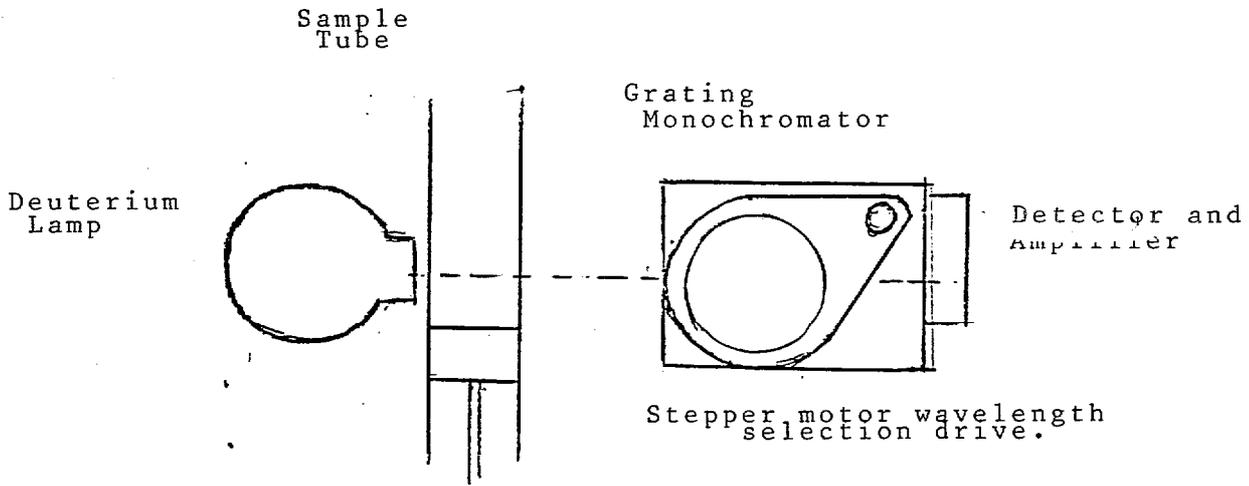
00:00	2		04.34	
00:10	3			03.85
00:20	1	04.48		
00:30	2		04.21	
00:40	3			03.58
00:50	1	04.48		
Blank volts 1.75				
Calibration Constant 1 2.88				
01:00	2		04.45	
Blank volts 1.71				
01:10	3			03.90

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		STR 1	STR 2	STR 3
00:00	1	04.81		
00:10	2		04.57	
00:20	3			03.84
00:30	1	04.83		
00:40	2		04.52	
00:50	3			03.75
01:00	1	04.87		
01:10	2		04.53	
01:20	3			03.65
Blank volts 1.74				
01:30	1	04.91		
01:40	2		04.72	
01:50	3			04.15
02:00	1	04.90		
02:10	2		04.65	
02:20	3			04.28
02:30	1	04.87		
02:40	2		04.68	
02:50	3			04.12
03:00	1	04.82		
03:10	2		04.70	
03:20	3			04.32
Blank volts 1.72				
03:30	1	04.78		
03:40	2		04.23	
03:50	3			03.38
04:00	1	04.73		
04:10	2		04.37	
04:20	3			03.42
04:30	1	04.75		
04:40	2		04.38	
04:50	3			03.48
05:00	1	04.75		
05:10	2		04.38	
05:20	3			03.38
05:30	1	04.75		
05:40	2		04.38	
05:50	3			03.38
Blank volts 1.71				
06:00	1	04.85		
06:10	2		04.51	
06:20	3			03.88
06:30	1	04.85		
06:40	2		04.57	
06:50	3			03.91
07:00	1	04.90		
07:10	2		04.62	
07:20	3			03.95
07:30	1	04.93		

Fig: 1. Schematic Diagram of Optical System.

Side View:



Top View:

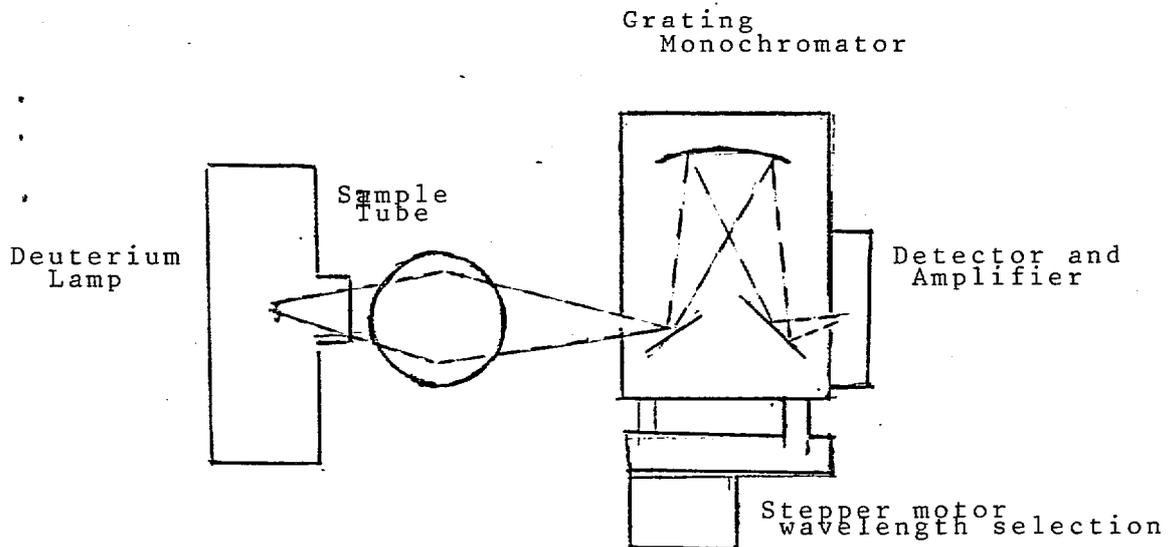


Fig: 2

2) in 0.5cm cell

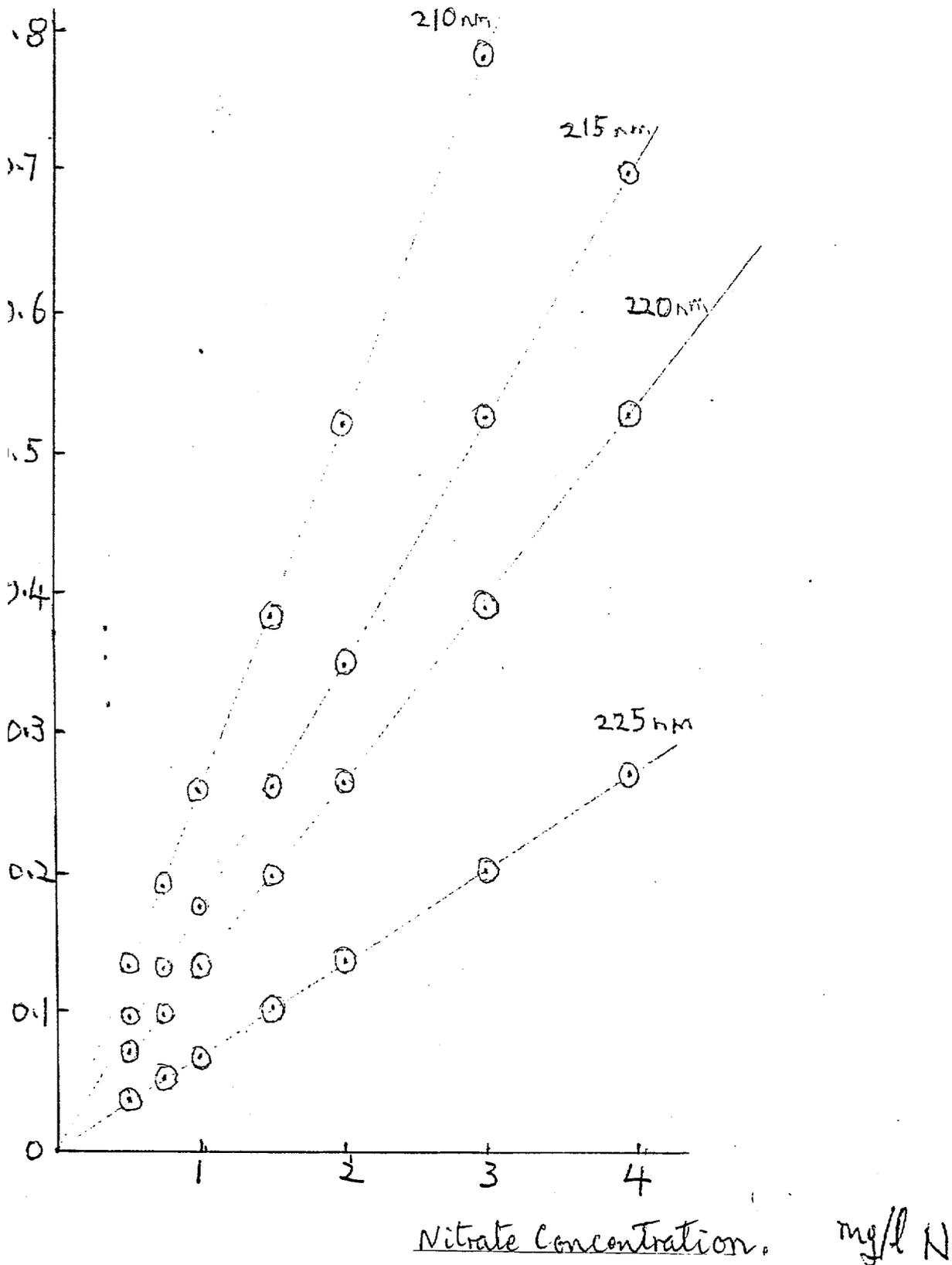


Fig. 2. UV absorption of natural water.

Optical Density.

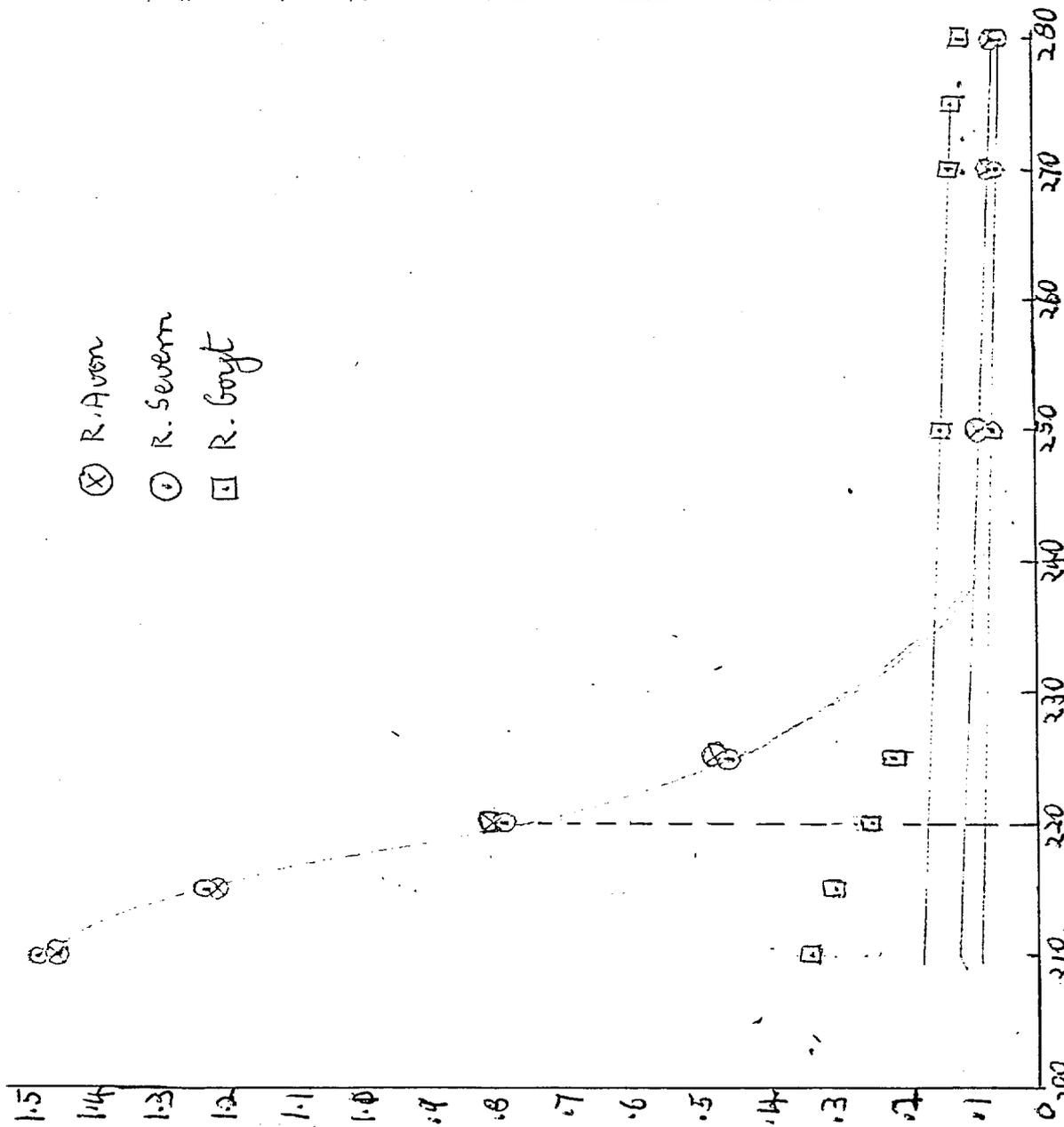


Fig-4 Linearity Test.

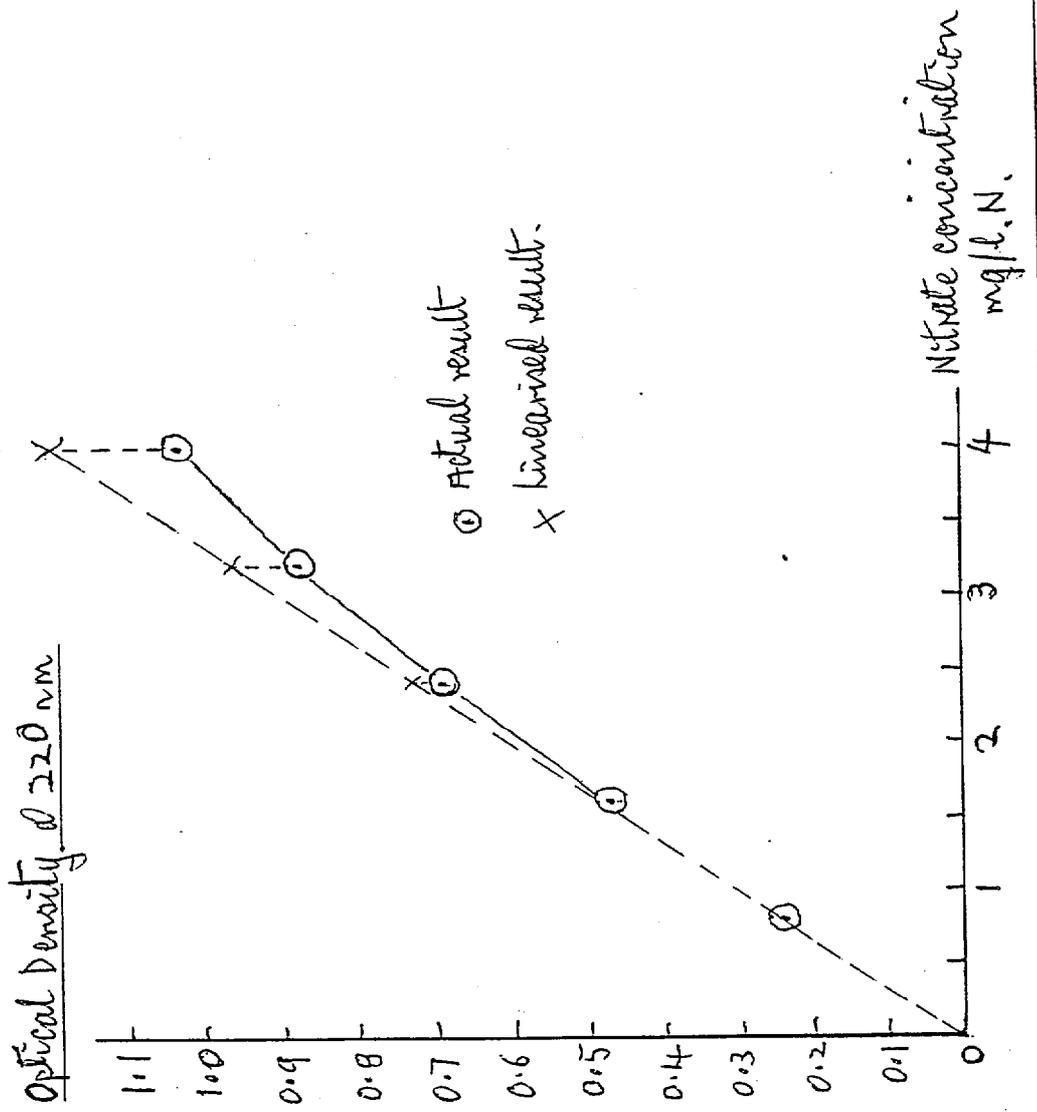


Fig. 1. 1.000- μ W in receptor response

