

Interim Report

R&D Project 402

Possible replacements for the biochemical oxygen
demand (BOD₍₅₎) test and suspended solids as
measures of effluent and water quality

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POSSIBLE REPLACEMENTS FOR THE BIOCHEMICAL OXYGEN DEMAND
(BOD₍₅₎) TEST AND SUSPENDED SOLIDS AS MEASURES OF EFFLUENT AND
WATER QUALITY

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SUMMARY

Recommendation 15 of the 'Kinnorsley' Report (NRA 1990) states that the NRA should "...evaluate the suitability of TOC and turbidity as new determinands for inclusion into consents in place of BOD and suspended solids". This report gives an independent objective assessment of alternatives.

Possible replacements for BOD₍₅₎ and suspended solids as measures of water and effluent quality are reviewed. The most suitable replacements are identified and a recommendation is given to undertake comparative trials of these methods before a final decision on replacing BOD₍₅₎ and suspended solids is made.

Use of total organic carbon (TOC), chemical oxygen demand (COD), total oxygen demand (TOD) and respirometry should all be further evaluated as possible replacements for BOD₍₅₎ as broad-scale measures of effluent and water quality; and turbidity appears to be suitable for replacing suspended solids. No single parameter is likely to be best in all situations and great care must be exercised over the choice of analytical equipment.

1. INTRODUCTION

BOD₍₅₎, suspended solids and ammonia are the three determinands commonly used to set consents for sewage treatment works and other large dischargers of wastes with a high organic load. The relative importance which the NRA ascribes to these determinands can be seen by their frequency of use as consent-setting criteria, both by individual regions and nationally:

Table 1.1 Percentage use of ammonia, suspended solids and BOD₍₅₎ as consent setting criteria by NRA regions (NRA 1990)

Region	BOD ₍₅₎	Suspended solids	Ammonia
Anglian	85	97	30
Northumbrian	95	99	0
North West	95	99	1
Southern	89	91	11
Severn Trent	95	96	11
South West	98	100	15
Thames	99	96	39
Welsh	88	90	19
Wessex	99	100	95
Yorkshire	66	99	1
All consents under NRA control	89	96	20

The BOD₍₅₎ test is an empirical bioassay of air-saturated aqueous samples which, if necessary, are pre-diluted and seeded with an appropriate source of micro-organisms. Allylthiourea (ATU) is added to restrict the oxygen demand to organic oxidation only. The samples are then sealed and left in the dark at 20 °C for five days. The amount of oxygen absorbed over this period is subsequently determined by volumetric or instrumental measurements.

Clearly, BOD₍₅₎ and, even more critically, suspended solids have an extremely important role in consent setting and compliance monitoring, but in practice these methods, particularly BOD₍₅₎, have been criticised for a variety of reasons. Numerous papers have been published in the past about the shortcomings of BOD₍₅₎ as a measure of the impact of wastewaters on environmental water quality, and on its use as a measure of environmental water quality *per se*. The vast majority of these authors have concluded that a replacement for BOD₍₅₎ is required. Similarly, the NRA (1990) identified this as a cause of concern in its discharge consent and compliance policy, suggesting that TOC and turbidity should be investigated as replacements for BOD₍₅₎ and suspended solids, respectively, in the consent-setting procedure. This report gives an independent

assessment of which determinands should be further investigated as replacements for $BOD_{(5)}$, and includes the recommendations of Hatton (1992) with regard to potential alternatives for the measurement of suspended solids.

Less emphasis has been placed on the use of ammonia as a consent-setting criterion than either phosphorus or $BOD_{(5)}$, the reasons for which remain unclear.

Another determinand which is likely to become of increasing importance in consent setting and compliance is phosphorus, following its incorporation into EC legislation in the Urban Wastewater Directive (91/271/EEC). This states that the effluent produced by all sewage treatment works serving a population equivalent of 10 000 or more, or discharging into sensitive areas, will be subject to strict phosphorus limits.

2. PROS AND CONS OF BOD₍₅₎ AS A MEASURE OF OVERALL WATER QUALITY

Since its legislative introduction in the early part of this century (Royal Commission on Sewage Disposal 1912, 1913), the 5-day BOD determination has undergone a number of methodological changes. Despite major reservations, it has continued to be used in the UK (and throughout the rest of the world) because potential replacements have not been sufficiently well evaluated for consenting organisations to support such a change in policy. The arguments for and against the use of BOD₍₅₎ as a monitoring tool have been discussed by Bealing (1988), who covered the following issues:

2.1 For

1. BOD₍₅₎ is an established method. Those people involved with using the method and interpreting the results are well aware of its drawbacks, but are reluctant to change to something which is unfamiliar.
2. The method has been adapted since its inception to improve precision and make inter-sample and inter-site comparisons more valid.
3. The testing of aqueous samples is relatively unaffected by solids size.
4. The test has wide international agreement on procedures and parameters.
5. Pre-dilution of samples enables the test to be used over a wide range of values.

2.2 Against

1. The method is time-consuming. By the time results are obtained, it is too late for corrective action to be taken with regard to process control at sewage treatment works.
2. It is expensive to measure.
3. The meaning of the test is sometimes not clear. For example, a low BOD result could be indicative of a low organic content, a high organic content of which only a small fraction is readily degradable, or may possibly indicate the presence of toxins (see Point 6 below).
4. It fails to mimic natural processes since the test is carried out in the dark, so algae may artificially increase the BOD₍₅₎ value, whereas under natural conditions, they are more likely to be net exporters of oxygen (Price and Pearson 1979). This is probably not a major concern with regard to sewage treatment effluent, but may be for samples collected from surface waters.
5. The BOD plateau (the point at which biochemical oxidation is completed) may not be reached within five days due to a lack of suitable bacteria in the sample, so leading to highly variable data. Thus, abundant but slowly degradable organic

compounds, such as cellulose, are not included in the analytical results, but do have a long-term effect. Because of this, $BOD_{(5)}$ values can be considered as little more than points on a curve (Bealing 1988).

Five days was originally chosen as the incubation period for determination of BOD because biochemical oxidation of some easily degradable chemicals is completed within this time period. However, the journey time of many rivers is longer than five days and, in addition, many also feed reservoirs and lakes (either directly or by abstraction) which have much longer retention times. The five day limit is therefore of little use when assessing the likely impact of an organic pollutant load. In these cases the $BOD_{(ultimate)}$ (the biochemical oxygen demand of a sample assuming an unlimited amount of time is available for oxidation) would be of greater relevance if nitrification could be fully inhibited, though this is not always possible.

6. Dilution of samples containing high BODs (including sewage effluent) may lead to 'sliding BOD' if toxins are present in the sample, i.e. diluted samples will give higher BOD results than concentrated samples because microbial activity will be less inhibited. Thus, sewage effluent containing a high concentration of toxins as well as a high organic carbon load is likely to give a low $BOD_{(5)}$ result, but once the effluent has been discharged and diluted, the effects on the aquatic community could potentially be extremely severe.

3. APPROACH TO CHOOSING A REPLACEMENT DETERMINAND TO BOD₍₅₎ AS A MEASURE OF OVERALL WATER QUALITY

The ideal replacements for BOD₍₅₎ and suspended solids as broad-scale indicators of pollution would have an extremely wide analytical range, be equally accurate over the whole range, and not suffer from any interferences. As well as this, the determinands would be simple to measure and automate.

A number of replacement determinands to BOD₍₅₎ will be discussed in this report, some of which may produce quite different answers to those resulting from BOD₍₅₎ analysis of the same sample. These replacements, however, fall into two distinct categories: **alternatives** and **surrogates**. For the purposes of this report, any method which measures microbial activity (usually, but not always, by oxygen uptake) will be termed a surrogate, and any technique which measures a chemical parameter (e.g. chemical oxidisability, carbon content, etc.) will be considered an alternative.

The outcome of this report will be a series of recommendations outlining which methods offer the greatest potential for replacing BOD₍₅₎ in terms of practicability and usefulness. For the surrogates, close relationships with BOD₍₅₎ will probably be expected, but for the alternatives, correlation coefficients could be very much lower, especially if high concentrations of toxins are present in the samples. Thus, correlating the results of BOD₍₅₎ and another set of data may be useful in some cases but should not be viewed as the sole (or possibly even major) criterion for judging potential replacements for BOD₍₅₎. The aim of this report is to recommend the best potential replacements, so that further evaluations can be used to recommend (or otherwise) suitable replacement determinands. These may or may not be surrogates. Similar recommendations will be made for replacement parameters for suspended solids monitoring.

For the purposes of process control at sewage treatment works, on-line, continuous analysis of the parameters chosen offers enormous advantages in terms of the speed of response to changing physico-chemical parameters. Continuous monitoring is far more expensive than discrete sample analysis and water utilities are therefore reluctant to introduce on-line analysis across the board. However, since a number of sewage works, larger ones in particular, already operate using continuous monitoring for process control, and because continuous monitoring is occasionally specified in discharge consents, on-line analysis will be considered an important function of the replacement determinands chosen.

Information contained within the NRA Monitoring Equipment Database (Neville *et al* 1992) on possible replacements for BOD₍₅₎ is presented in Appendix A.

4. POSSIBLE REPLACEMENTS FOR BOD₍₅₎

4.1 Alternatives

4.1.1 Total organic carbon (TOC)

TOC is measured by chemical oxidation in the presence of ultraviolet light, or by high temperature (900 °C) catalytic oxidation. Some instruments measure TOC only after acidification and purging, whilst others also measure alternative carbon fractions: total carbon (TC), total inorganic carbon (TIC), volatile organic carbon (VOC) and/or residual organic carbon (ROC) (SCA 1979). The advantages and disadvantages of the different methods were summarised by Small *et al* (1986, Table 4.1).

Table 4.1 Merits and demerits of methods of TOC analysis (Small *et al* 1986)

Oxidation method	Advantages	Disadvantages
900 °C high-temperature combustion.	Oxidises particulates and solids. Rapid. Relatively interference-free.	Low sensitivity. Calibration blanks difficult to obtain. Low salt tolerance. Prone to lose CO ₂ in steam condensation phase. Problems with recovery of certain aromatics. High maintenance costs. Catalyst poisoning.
90 °C elevated temperature/oxidation.	High sensitivity. Good recovery. Good precision. Low maintenance costs.	Slower oxidation rate. Highly dependent on CO ₂ persulphate detector accuracy. Incomplete recovery of high concentration samples.
UV/persulphate.	High sensitivity. Good recovery. Good precision. Fast oxidation rate. Low maintenance costs.	Halides may interfere with analytical results.
UV only.	No reagents required. Low maintenance costs.	Poor oxidation efficiency. Large sample volume required. Poor precision above 5 mg l ⁻¹ TOC. Slow response.

A comparative test by the same authors found a hybrid UV/elevated temperature/persulphate method to be the preferred oxidation technique for all natural and waste water samples. Experience of TOC analysis by staff at WRc has shown high temperature systems to be better at oxidising particulate matter, though sample volumes on these instruments are very small - too small for samples to be considered representative unless they are homogenised or sonicated beforehand, and a sub-sample analysed.

Once established, the relationship between $BOD_{(5)}$ and TOC can be used to facilitate process control (Corder and Lee 1986), but this relationship is likely to vary a great deal between different effluents and water samples. For example, Chandler *et al* (1976) proposed a $BOD_{(ultimate)}:TOC$ ratio of 1.85 (assuming the measured BOD was 90% of the maximum theoretical $BOD_{(5)}$ and 77% of $BOD_{(ultimate)}$), with similar ratios being presented by other authors as being typical of domestic wastewaters. Eckenfelder (1970) presented a review of this subject in which the ratios ranged from 1.35 to 2.62, though this range was further expanded by Blier (1972) who calculated a ratio of only 0.8 ± 1 using data from the Blumental treatment plant. This latter ratio enabled the author to calculate $BOD_{(5)}$ from TOC to an accuracy of about 16% within 20 minutes of sampling.

In theory, TOC measures all organic compounds, and is specific to organic chemicals, including some that are resistant to biochemical or chemical oxidation. TOC has been shown to correlate more closely with $BOD_{(5)}$ than COD for secondary sewage treatment effluent (Chandler *et al* 1976), a fact which may at first appear surprising, since TOC and COD are both purely chemical parameters, whilst $BOD_{(5)}$ introduces biological random bias. $BOD_{(ultimate)}$ would be expected to correlate with COD better than would $BOD_{(5)}$, since (given time) more of the organic carbon would be oxidised.

However, a close correlation between TOC and $BOD_{(5)}$ has been found by many workers, correlation coefficients from a number of studies being >0.9 (e.g. Hill and Spiegel 1980). It has therefore been assumed by a number of authors that TOC would be a good surrogate for $BOD_{(5)}$, especially since TOC can be determined on-line. However, the two determinands measure very different aspects of water quality; one is chemical, the other biological. Furthermore, when it is vital that the two readings correlate well, this is the time when results of the two determinands vary most, notably when a high organic carbon load is associated with high levels of a toxin, or contains little readily degradable carbon. Such poor correlations tend not to be reported in the literature.

This gives an insight into the main advantages of TOC: that it is more relevant to the longer-term effects of pollution incidents; and that being a purely chemical parameter, it is immune to the effects of biological toxins. The opposing disadvantages are that high levels of toxins will not be detected if TOC is the only determinand being measured, and that the results are less relevant as a measure of overall quality in fast flowing waters than in waters with a long retention time.

Nevertheless, TOC appears to be a suitable alternative to $BOD_{(5)}$ because the results are easier to envisage in terms of environmental impact. In addition, it can be measured in minutes rather than days and the close correlations often found between TOC and $BOD_{(5)}$ may make the transition period when substituting one for the other appear less radical.

than for other potential replacement determinands. TOC should be considered as one of the more likely potential alternatives for replacing BOD₍₅₎.

4.1.2 Chemical oxygen demand (COD)

BOD₍₅₎ and COD determinations may both be partly accounted for by oxidation of inorganic chemicals, and are erratic in their response to aromatic organics, since the methods only partially degrade these substances. However, whilst COD results are also affected by chlorides (Sherrard *et al* 1979), BOD₍₅₎ determinations are not. Also, while organic nitrogen is largely incorporated into BOD₍₅₎ results, this material is less well degraded by COD analysis. COD data are therefore as arbitrary as BOD₍₅₎ results, though the two can be empirically related.

The laboratory method for COD determination uses potassium dichromate as an oxidising agent, enabling results to be read within a couple of hours, but for the purposes of on-line monitoring, ozone has been adapted as the oxidising agent, enabling results to be produced within three minutes. This difference in oxidising agents probably means that the results gained by the on-line monitor (the Siepmann and Teutscher Phoenix COD Monitor) and laboratory methods are not directly comparable, but the more rapid response time for on-line analysis makes it a far better candidate for process control at sewage treatment works. For COD results to be used in this manner, a COD/BOD₍₅₎ calibration curve or linear relationship has to be established (as for TOC/BOD₍₅₎), and checks need to be made regularly to ensure that the relationship still holds (Vernimmen *et al* 1967).

At best the COD/BOD₍₅₎ relationship is a crude device for determining BOD₍₅₎ (Bealing 1988, Crockett 1988) which, together with the arbitrary nature of COD analysis, means that it cannot be recommended as strongly as TOC analysis. However, the fact that correlations do exist, suggests that the method should not immediately be written off as replacement for BOD₍₅₎. If sufficient funding is available, a more detailed investigation into COD as a replacement determinand may prove to be worthwhile in some cases, though not as a wide-scale replacement.

Whether or not COD is adopted as a replacement for BOD₍₅₎, its use as a consent-setting criterion will undoubtedly increase due to its incorporation into the Urban Wastewater Directive (91/271/EEC). Under Articles 4 and 5 of this directive, sewage effluent must contain a maximum COD level of 125 mg O₂ l⁻¹.

4.1.3 Permanganate index

The permanganate index is a measure of the oxidisability of samples by permanganate ions in acid solution. No dedicated analysers are known to be produced for this test, though one firm (CHEMetrics Inc.) is known to manufacture test kits. Analysis time using the CHEMetrics kit is two minutes, but the SCA (1983) method requires a 10-minute incubation in a boiling water bath, and while the CHEMetrics test relies on colorimetry, the SCA method relies on back-titration of excess oxalate with potassium permanganate. The SCA method is susceptible to interference by a range of chemicals

such as chloride, fluoride, phosphate, inorganic reducing agents (including ammonia and ferrous iron), and organic matter, but only under specific circumstances.

The SCA permanganate index was developed in response to an EC directive on drinking water quality (80/778/EEC) and as such is intended for analysis of potable or lightly polluted raw waters. More heavily polluted waters and effluents require dilution before analysis, though the method is not recommended for such polluted samples. Because of this, and the numerous potential causes of interference, the method (as it now stands) is not considered worthy of further investigation as a replacement for $BOD_{(5)}$, but this does not exclude development of the method for future testing of more polluted waters or effluents.

4.1.4 Total oxygen demand (TOD)

As with COD, TOD measures a number of inorganic chemicals as well as the oxygen demand of organic carbon; and of all the replacements discussed in this report it is probably the closest in concept to $BOD_{(5)}$ (Arin 1974). TOD often correlates well with COD, but tends to give higher results, the difference usually being attributed to more efficient oxidation of particulates by TOD analysis, though the two methods measure ammonia and organic nitrogen differently. TOD analysis may give misleadingly low results for some samples which release oxygen upon catalytic combustion (e.g. samples containing high levels of nitrates, peroxides or hypochlorites). Additionally, error can creep into the analytical procedure by atmospheric homogenisation - to achieve a representative aliquot, the sample should be homogenised under nitrogen (SCA 1979).

Very little information is available on comparisons between $BOD_{(5)}$ and TOD analysis, but the fundamental similarity in concept between the two determinands suggests that such investigations may prove to be worthwhile, especially when considering the long-term effects of organic pollution in slow flowing waters. A cautious recommendation is therefore made that TOD be further investigated, albeit (at this stage) as one of the less likely replacements of $BOD_{(5)}$.

4.1.5 Dissolved organic carbon (DOC)

This determinand measures the dissolved fraction of TOC, taking no account of particulate organic matter, which in some effluents may be responsible for the majority of the $BOD_{(5)}$. Methods for the determination of this carbon fraction are well established (for both on-line and laboratory use) using ultra-violet spectrophotometry or TOC analysis of filtered samples. UV spectrophotometry equipment generally has lower capital and maintenance costs than TOC analysers.

Whether DOC results correlate well with TOC data is not known, but results are likely to be effluent/water specific as with COD. DOC would not be expected to correlate well with $BOD_{(5)}$ for samples from a range of effluents and surface waters. However, in practice, one DOC monitor, the Cinque Organic Pollution (DOC) Monitor has been found to give excellent short-term predictions of $BOD_{(5)}$ (Butwell and Semple 1988), though long-term predictions were poor.

Because of the question of the long-term reliability of DOC as a measure of water quality compared to $BOD_{(5)}$, DOC may initially not be considered worthy of further investigation; but its potential as a short-term predictive determinand appears promising, providing it is calibrated against other water quality parameters (such as $BOD_{(5)}$) for specific sites and samples. Its use as a broad-scale environmental monitoring tool is therefore limited, but it could foreseeably be used as a consent setting criterion if site-specific correlations are made. Further work on this aspect of its use as a potential replacement for $BOD_{(5)}$ is therefore recommended. Also, because of the lack of data, further work on the relationship between DOC and TOC is similarly recommended, both on a site-specific and effluent-specific basis, and for a wider variety of aquatic samples.

4.1.6 Ammonia/ammonium

Ammonia is the third most frequently used criterion for consent setting and compliance monitoring because of its toxicity, notably to fish. It is also one of the easiest chemical analyses to automate since almost all instruments rely on gas-specific electrodes. The pH of the sample being analysed is raised above 11, usually by the addition of sodium hydroxide, to ensure that all ammonia is in the gaseous state (NH_3), rather than in an ionic (NH_4^+) form. EDTA is also added to prevent ammonia from complexing with any metals which may be present.

Ammonia and $BOD_{(5)}$ are fundamentally different measures of water quality: ammonia is primarily a breakdown product of organic nitrogen, while $BOD_{(5)}$ is a measure of the oxygen required for the sample to break down aerobically. The two processes are only loosely linked by the fact that both require an organic source, but ammonia monitoring can nevertheless give a useful warning of non-compliance with other parameters (Fielden 1989).

Although ammonia is known to correlate with $BOD_{(5)}$ under some circumstances, this is perhaps surprising since addition of allylthiourea to samples for $BOD_{(5)}$ analysis inhibits oxidation of ammonia to nitrite. Consequently this reaction does not contribute to the $BOD_{(5)}$ value, thus giving a reason why ammonia would not be expected to correlate particularly well with $BOD_{(5)}$. The relationship between ammonia and $BOD_{(5)}$ (or its replacement) would therefore need to be assessed for every application where it was intended to use it as an alternative measuring tool.

However, ammonia levels are extremely important in controlling nitrification in sewage works and, as such, ammonia is of greater use in process control than $BOD_{(5)}$ or suspended solids. Furthermore, ammonia may be a more sensitive indicator of the efficiency of the treatment process than either of the other parameters, at least for nitrifying plants (Hobson 1989).

Two commercially available ammonia monitors were evaluated by Hamilton (1988a,b) who found them to be reliable, but a more recent investigation by WRc showed that the same instruments failed to meet the minimum water industry standard for accuracy (WIS 7-08-00; $\pm 10\%$ of the reading or $\pm 0.02 \text{ mg l}^{-1}$, whichever is the greater). However, averaging over several samples enabled the random error to be brought down by an order

of magnitude (though it still failed to meet the WIS specification), and when outliers were ignored, random error was reduced to a large extent (from 6.1 to 2.2 mg l⁻¹). The effect of this on systematic error was not investigated.

To summarise, ammonia can be an extremely useful parameter to measure for process control at sewage treatment works, and further work in this area may produce significant benefits in terms of improved effluent quality; but its use as an environmental indicator of water quality is limited, since for aquatic fauna, ammonia is only one of many potential toxins. For aquatic flora, the situation is a little more complicated because ammonia can be taken up directly as a nutrient. Indeed, for many algae and higher plants ammonia is the preferred nitrogen source; but as ammonia usually represents only a small fraction of bioavailable nitrogen, it has little use as a measure of nutrient availability.

Ammonia is therefore worthy of further investigation for treatment process control, and despite the drawbacks listed in the above paragraph, site-specific correlations can still be found between it and BOD₍₅₎. It is therefore recommended that a detailed investigation of the relationship between ammonia and other potential replacements for BOD₍₅₎ be undertaken.

4.1.7 Direct toxicity assessment (DTA)

Discharge consents have traditionally been based on a very small number of determinands. As such, these determinands are used to assess the impact of discharges on water quality as a whole, and so have to account for biological, chemical and aesthetic aspects of water quality. One of the major criticisms aimed at BOD₍₅₎ (and other biological measures of water quality) is that the strong dependency of these results on the presence and level of toxins affects interpretation of the results as an indicator of other aspects of water chemistry.

Hunt *et al* (1989) discussed the use of direct toxicity assessment as part of the consenting procedure in the UK and concluded that in many cases it would be of great benefit. Certainly, it would indicate when BOD₍₅₎ results are influenced by toxins, and so help negate the criticism of 'sliding BOD' (Section 2.2). However, DTA gives no indication of aesthetic parameters such as suspended solids, colour, etc.; or of the likelihood of major biochemical problems such as eutrophication potential and fish kills due to low dissolved oxygen levels. While not measured for directly, these risks can often be inferred from current consent-compliance monitoring criteria.

DTA therefore represents a useful adjunct to BOD₍₅₎ and suspended solids monitoring, and will almost certainly continue to do so if they are replaced by alternative or surrogate parameters (particularly if BOD₍₅₎ is replaced by a purely chemical determinand). However, DTA alone is not a suitable broad-scale indicator of water quality, so further investigation of its potential for overall water quality monitoring purposes is not recommended as part of this study. In addition, DTA is being addressed under other areas of the NRA R&D programme.

4.1.8 Chemiluminescence

A noteworthy advance in the use of chemiluminescence has been the development of routine assays by Prof T P Whitehead and Dr G H Thorpe of Birmingham University. The presence of antioxidants in wastes and waters reduces the amount of light produced when luminol is broken down by horseradish peroxidase in the presence of peroxide and an 'enhancer' (preferably para-iodophenol, but para-hydroxy cinnamic acid or para-(imidazol-1-yl)-phenol will also suffice). Results of this assay correlate well with both TOC and BOD₍₅₎, but the method is not suitable for on-line analysis.

A list of chemicals known to affect chemiluminescent light emission includes some, such as polyphenols, substituted amines and sulphhydryl-containing compounds, which are found in sewage effluent and/or as pollutants in waters. Initially, therefore, the assay appears promising, but this is only a small list of chemical compound types that cause a response, and these will rarely be major contributors to sewage effluent or other pollution events, so an expanded list including some of the major chemicals in sewage effluent is needed before the test can be calibrated and properly assessed. Also, as with bacterial respiration, the peroxidase enzyme can be inhibited by some pollutants, so it also has one of the major drawbacks of BOD₍₅₎ as a consent-setting criterion.

Further investigations of chemiluminescent techniques appear worthwhile as a replacement for BOD₍₅₎ analysis, but the work is still in its infancy and is unlikely to produce a well-tested and trustworthy assay before this project is due to finish, so it cannot be recommended as part of this study. Nevertheless, it may be worthwhile as a longer-term development project in its own right.

4.2 Surrogates

4.2.1 Assimilable organic carbon (AOC)

Eight methods of measuring biodegradable organic matter were reviewed by Huck (1990). Six of these methods are biomass-based techniques which measure the bacterial population size (or a surrogate of it, such as ATP concentration) assuming that assimilable organic carbon (including amino acids, simple carboxylic acids, alcohols and low molecular weight carbohydrates) is the limiting nutrient. Biomass-based techniques can be divided into two groups, depending on whether a known bacterial strain (or strains) is used to inoculate the sample or whether the indigenous bacteria provide the inoculum. These bioassays take up to 30 days to complete.

Two other methods were also reviewed by Huck. Again, these methods are bioassays, but unlike the other methods, they are based on measuring a change in DOC concentration. As with, biomass-based methods, DOC-based methods require lengthy incubation periods (up to 28 days).

Neither biomass-based nor DOC-based procedures are inherently faster; both offer techniques which can achieve results within a few days and others which take considerably longer, though DOC-based methods are not suitable for samples containing

less than 0.2 mg l^{-1} biodegradable organic matter. Below this level a biomass-based approach is required to achieve sufficient sensitivity (Huck 1990).

A recent investigation into the use of AOC/DOC bioassays as an aid to process control at water treatment works (Prevost *et al* 1992) concluded that only one of three procedures which were used was simple and reliable (the Servais-Billen mortality flux method; Servais *et al* 1987, 1989). However, the method was of little use for process control because of its limited sensitivity ($\pm 0.1 \text{ mg l}^{-1}$ DOC) and the long incubation period used for the test.

The tests have only been developed only as laboratory methods and the length of incubation precludes the use of results for process control at sewage treatment works. Moreover, little information is available about the use of such tests for natural samples and no commercial monitors are available. No AOC test can therefore be recommended for further investigation as part of this study.

4.2.2 Bioprobes

A large range of bioprobes have been developed and applied as replacements for the $\text{BOD}_{(5)}$ test, though relatively few of these are commercially available. Nevertheless, all of these work on the same basic principle which is related to the AOC determination, but the probes offer the advantage of producing results much more rapidly. These probes rely on a layer of live immobilised microbial cells (bacteria or yeasts) on the outer surface of an oxygen electrode, the respiration rate of which is proportional to the concentration of readily assimilable organic matter. A higher rate of respiration means that less oxygen is able to diffuse through the microbial layer to the electrode, and so the electrical output is reduced.

Reported times for most of these electrodes to achieve a steady state current output are within the range 10-40 minutes (Kulys and Kadziauskiene 1980, Harita *et al* 1985, Karube *et al* 1977). Some authors have reported operational stabilities of up to 48 days, with an accuracy of better than $\pm 5\%$ (e.g. Riedel *et al* 1990), but other workers have obtained less accurate estimates of $\text{BOD}_{(5)}$, e.g. Karube *et al* 1977 (10%). Similarly, an operational life of 48 days appears to be exceptional; for example the sensor used by Yamane *et al* (1990) had a lifetime of about three weeks, though this particular probe was accurate to 3.8%.

Microbial probes share the drawback of 'sliding BOD' with all other methods relying on biological processes (including the $\text{BOD}_{(5)}$ test). Furthermore, if such probes are to be used for monitoring sewage effluents, sample dilution may often be required because a sample concentration of readily assimilable organic matter is eventually reached at which no oxygen can diffuse through the microbial layer to the probe. Above this concentration, the output from the electrode is zero. For the probe used by Harita *et al* (1985), this critical concentration was 82 mg l^{-1} for glucose and glutamic acid, but the electrical output/assimilable carbon relationship was shown to be linear only at concentrations below 60 mg l^{-1} .

As with all microbial assays, temperature is critical to the result, and many other factors also affect the probe's performance (e.g. thickness of the microbial layer, adhesive/method of immobilisation), so the potential for method development appears quite clear. Indeed, a large advance has already been made in this direction by Riedel *et al* (1990) who found a linear relationship between bioprobe output and $BOD_{(5)}$ for $BOD_{(5)}$ results of up to $10\,000\text{ mg l}^{-1}$.

However, despite the upbeat tone of the above paragraph, Kulys and Kadziauski (1980) presented data which cast doubt on the use of bioprobes as surrogates for $BOD_{(5)}$ monitoring. They showed that the output response of a yeast-based probe was dependent on the carbon source. At concentrations of 0.2 mM , oxygen consumption using L-lactate as a substrate was 4-5 times greater than when D,L-lactate, D-glucose and pyruvate were used; and at 0.8 mM , oxygen consumption was approximately two and three times as great using D,L-lactate and D-glucose respectively, than when using pyruvate as a carbon source. Any instrument which is so sensitive to changes in the nature of the substrate source is of little use for analysing effluents and natural waters without lengthy calibration for each particular sample beforehand. Consequently, further investigation of the use of bioprobes as a surrogate for $BOD_{(5)}$ analysis is not thought worthwhile at this stage.

4.2.3 Bioluminescence

Genetically transformed bacteria which luminesce have been used to give a 'pollution index' of waters and wastes. The technology is sufficiently well established to enable lux genes (the genes coding for luminescence) to be placed inside bacterial strains isolated from rivers and effluent samples, though few scientists working on prototype development appear to have gone this way, instead preferring to use bacterial strains with which they are familiar and present little problem to grow under laboratory conditions. One criticism often aimed at such probes is that because the microbes used in them are often not endemic, the results may not be representative of what is occurring in the natural environment.

A similar bioluminescent approach is used in the Microtox assay whereby toxicity is measured according to the suppression of luminescence in the marine bacterium *Photobacterium phosphoreum*, but in this case luminescence is a natural characteristic, not the product of genetic manipulation. The Microtox assay cannot be used on-line, but an on-line microbial sensor based on similar technology has been produced by Lee *et al* (1992).

Bioluminescence is affected by numerous chemicals/toxins, so the various methods appear to hold promise as measures of water quality. However, these methods are not suitable for on-line analysis and no water industry specification exists for their use. These factors mean that a specific type of assay/instrument must be stated, though only one is known to be commercially available, and that is primarily for toxicity testing, not for measuring water quality in a more general sense. Further investigation of bioluminescent techniques cannot, therefore, be recommended as a potential replacement of $BOD_{(5)}$ analysis.

4.2.4 Respirometry

Respirometry effectively gives a $BOD_{(5)}$ -equivalent of readily bioavailable organic carbon, and would therefore be expected to correlate well with results obtained using the assimilable organic carbon bioassay. Major advantages of respirometry over $BOD_{(5)}$ include the short analysis time (a few minutes to a few hours), the fact that on-line respirometers are commercially available, and the ability to recharge the reaction vessel with air if the sample has a high $BOD_{(5)}$ -equivalent. Thus, the need for dilution of samples may be removed. Air/oxygen recharging also allows a respiration curve to be followed, giving an idea of how readily degradable the substrate is, though this particular benefit is more of academic use than for monitoring purposes.

The principle behind respirometry is the same as that employed by bioprobes, $BOD_{(5)}$ and AOC, i.e. oxygen removal from solution as a consequence of microbial respiration. Some methods rely on the bacteria present in the sample, while others nurture a bacterial culture within the instrument.

Because of the advantages listed above, respirometry has become probably the most favoured $BOD_{(5)}$ surrogate for process control at sewage works on a world-wide basis. The interest shown by water utilities in this method has spawned the commercial production of a number of respirometers, though their use by the UK water industry has so far been limited. Indeed, the only model known to have been used in the UK is the Siepmann and Teutscher BIOX-1000 monitor which gives results in three minutes (Darmstadt 1984).

The BIOX monitor showed a high level of error (10-15%) when results from five laboratory tests were considered independently, with a far worse error when the five sets of data were considered in unison: a range of 260% was found to exist (Kohne *et al* 1986). This large amount of error has no place in a water quality monitoring regime, but the authors stressed the point that no means of absolute calibration was available. This appears to be the major argument against respirometry, yet there is no reason why standards cannot be adopted for this monitoring technique.

Other arguments against this design of monitor in particular (that particles greater than 0.5 mm in size are prevented from entering the bio-reactor) and against respirometers in general (that this approach allows little substrate to support the bacteria in the reactor, the respiration rate of which is far in excess of the bacteria in the effluent) are also strong. Furthermore, the extremely high flow-through rates of natural waters which are required because of their low biodegradable carbon content effectively excludes respirometry for this purpose.

Nevertheless, in some cases, process control made possible by respirometry results has resulted in cost savings and better control over the quality of effluent produced (Butters and Butwell 1990). If standards can be adopted for calibrating respirometers, this method may be useful for the purpose of process control (although not for monitoring natural waters) and as such further investigation of its use is recommended.

5. POSSIBLE REPLACEMENTS FOR SUSPENDED SOLIDS (SS)

5.1 Light scattering and absorption

Hatton (1992) recently reviewed turbidity as an alternative to suspended sediment as a consent-setting criterion and concluded that this could be a suitable replacement. However, Hatton was cautious about a blanket replacement of suspended solids with turbidity, since results are influenced by methodology and sample characteristics.

Turbidity can be measured by light scattering (nephelometry), light attenuation/absorbance (spectrophotometry) or a combination of both (ratiometric analysis). Those methods relying on light attenuation tend to be used for measuring water with a high solids content (generally >100 FTU), whilst nephelometric methods are used primarily for samples with a low content of suspended and colloidal material. Ratiometric analysers offer advantages of both light scattering and absorbance, as well as enabling colour to be compensated for; but these analysers cannot be used on-line.

Hatton's review includes a comparison by Crowther and Al-Ani (1981) of suspended solids and turbidity. They found very different relationships to occur for raw sewage and primary tank effluent (which had correlation coefficients of 0.74 and 0.85, respectively), and treated effluent, where the suspended solids/turbidity correlation coefficient was less than 0.02. Results from this survey suggest that turbidity cannot be used for consent setting or compliance monitoring, but this may have been due (partly at least) to the choice of instrumentation for the turbidity analysis (light attenuation). Certainly, the experience of laboratory staff at WRc has been that over the short term at least, quite close relationships can be demonstrated between suspended solids and turbidity, but whether this relationship holds over the long term, and how important the sample source is to maintaining a close relationship, needs further investigation. Major changes in particle size distribution as well as suspended solids in sewage effluent and natural waters may occur depending on climatic and hydrological conditions. Particle size exerts an important influence on turbidity results, but to what extent this affects the turbidity/suspended solids relationship is not known.

5.2 Biosassays

A 'phage luminescence test' which relies on luminescent bacteria is marketed by Amersham International. This test has not yet been adapted for on-line analysis but the present system generates results within an hour and appears to be particularly good for detecting low levels of solids. This is advantageous for environmental monitoring in relatively unpolluted environments, though improved accuracy and precision at the middle to high end of scale is more important for analysis of sewage effluent.

The test doesn't measure solids *per se*, but rather the size of the luminescent bacterial population which grows. This is subsequently related to suspended solids concentration. The procedure requires a catalyst which, once made up, has a very limited shelf life, so

the level of maintenance required for this technique is high and, as such, the method is not considered worthy of further evaluation as part of this project.

6. STANDARDS AND SPECIFICATIONS

Water industry instrument specifications (WISs) have been written for a number of the determinands discussed in this report. These are (WAA/FWR/WRc 1991):

- Suspended solids: WIS 7-07-00
- Ammonia: WIS 7-08-00
- Turbidity: WIS 7-09-00
- TOC analysers: WIS 7-10-01

Whichever determinand is chosen as an alternative to $BOD_{(5)}$, the instrument used for obtaining such a sample must have a sample chamber which is large enough to collect a representative sample. This is especially so for on-line monitoring where the additional expense and bother of manual homogenisation and sub-sampling is not an option. On-line TOC and COD analysers must therefore have the ability to homogenise and sub-sample automatically, since it appears that much of the oxygen demand and carbon content of sewage effluent is associated with suspended sediment, which in some samples may form large, unevenly distributed aggregates. The opposite is true for turbidity analysis, however, since sample homogenisation can greatly affect the results.

At present, some $BOD_{(5)}$ sewage effluent consent limits in England and Wales are set in excess of 150 mg l^{-1} , though the vast majority are set below 50 mg l^{-1} (NRA 1990). Any replacement for $BOD_{(5)}$ for measuring the quality of sewage treatment effluent will therefore need to be able to measure $BOD_{(5)}$ -equivalents of at least $5\text{-}200 \text{ mg l}^{-1}$. For use as a measure of environmental quality in surface waters, a replacement would need to measure lower $BOD_{(5)}$ -equivalents.

7. DISCUSSION

Bealing (1988) was careful to emphasise that no single criterion would be suitable to replace all uses of $BOD_{(5)}$ as a water quality monitoring tool, though his conclusion appears to have been based largely on the assumption that a surrogate, rather an alternative determinand was required. Nevertheless, this statement still holds a good deal of truth, albeit tempered since the publication of his report.

Whilst those familiar with the use and interpretation of $BOD_{(5)}$ results may feel more comfortable using a surrogate, all the available biologically-based options suffer the drawbacks of 'sliding BOD' if toxins are present in sufficiently large concentrations, and results are only of relevance for short-term impacts on water quality. Surrogate methods are also highly temperature-dependent, so the use of portable bioprobes, whilst initially appealing, will need developmental work to determine suitable temperature-response curves so that results can be automatically compensated. It may be that such probes can only be used within a limited temperature range.

An analogous problem to sliding BOD, 'catalyst poisoning', may occur in high temperature catalysed reactions. Thus, for samples containing high levels of heavy metals or some sulphur compounds, artificially low TOC or TOD may result. So chemical replacements are not without their problems, but do not suffer from a lack of precision caused by ageing of microbial populations or random biological error, though random error for chemical determinands does affect the reproducibility of these results.

8. CONCLUSIONS

BOD₍₅₎ and suspended solids determinations have a number of disadvantages for use as broad-scale indicators of water quality; the former, in particular, offering little use for process control at sewage treatment works.

A number of other parameters may be suitable as replacements for BOD₍₅₎, notably TOC, COD, TOD and respirometry. Sufficient data have not been collated to draw any conclusions about the use of ammonia as a broad-scale water quality indicator. While this determinand has a number of theoretical disadvantages, the correlations which some workers have found between it and BOD₍₅₎ cannot be ignored. As with all of the other determinands mentioned above, these drawbacks make ammonia less useful as a measure of water quality in some situations (and for some purposes) than others. No single replacement is ideal for all uses.

Turbidity is likely to be a suitable replacement for suspended solids, but not for all applications. Ratiometric analysers offer advantages for measuring turbidity as a surrogate of solids content, but only for laboratory analysis. Ratiometric analysers cannot be used on-line, so for the purposes of process control, simpler instruments which rely only on nephelometry or light attenuation have to be used.

9. RECOMMENDATIONS

Use of total organic carbon (TOC), chemical oxygen demand (COD), total oxygen demand (TOD) and respirometry should all be further investigated as possible replacements for $BOD_{(5)}$ as broad-scale measures of effluent and water quality. A detailed investigation of the relationship between ammonia and these determinands should also be undertaken.

The effect of the angle of light scattering/detection on results should be further investigated if turbidity is to replace suspended solids as a measure of effluent and water quality.

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APPENDIX A - POTENTIAL BOD₍₅₎ REPLACEMENT MONITORING EQUIPMENT

Record No. 387

SINGLE DETERMINAND

BOD

Manufacturer: YSI INCORPORATED 0101 513 767 7241

Supplier: YSI-CLANDON 0252 514711

Model: YSI Model 5300

Usage : FIXED

Method: ELECTROCHEMICAL (general)

Range:

600 ul - 50 ml at

Output: VISUAL

Notes :

Measures oxygen uptake or evolution over a wide range of samples

Completion time: 2 to 15 minutes

BOD

600 ul - 50 ml

Record No. 782

SINGLE DETERMINAND

BOD

Manufacturer: CARDIFF LAB FOR ENERGY & RESC. 0222 481877

Supplier: as above

Model: BOD-M3

Usage : TRANSPORTABLE

Method: ELECTROCHEMICAL (general)

Range:

2 - 10,000mg/l at

Output: VISUAL

Notes :

Continuous short-time BOD measurement

Time for analysis: 3 mins

Calibration: once a week

Application: rivers or any continuous waste stream

BOD

2 - 10,000mg/l

Record No. 915

SINGLE DETERMINAND

BOD

Manufacturer: ENVITECH LTD 0222-229982-

Supplier: as above

Model: BOD-M3

Usage : FIXED

Method: BIOLOGICAL - CELLULAR

Range:

2-10,000mg/l at

Output: VISUAL/ANALOGUE

Notes :

Continuous short-time BOD measurement unit.

Analysis time: 3 minutes.

BOD

2-10,000mg/l

Record No. 916

SINGLE DETERMINAND

BOD

Manufacturer: ENVITECH LTD 0222 229982

Supplier: as above

Model: BIOX-N

Usage : FIXED

Method: BIOLOGICAL - CELLULAR

Range:

2-500 mg/l at

Output: VISUAL/ANALOGUE

Notes :

Analysis time: 3 minutes.

Autocalibration of O2 probe.

Alarm limits for high and low slope.

BOD

2-500 mg/l

Record No. 662

SINGLE DETERMINAND

BOD

Manufacturer: WTW 01049 0881 1830

Supplier: BURMAC LTD 0428 724477

Model: BSB (BOD) 620T

Usage : FIXED

Method: BIOLOGICAL - CELLULAR
Range:
0-4000 mg/l at Output: VISUAL
Notes :
6 measuring points: 0-40, 0-80, 0-400, 0-800, 0-2000, 0-4000 mg/l
Necessary sample quantities: 432, 365, 250, 164, 97, 43.5, 22.7 ml
Temperature constant: 20C +/- 0.5C
Measuring scales: division 0-40
BOD 0-4000 mg/l

Record No. 663
SINGLE DETERMINAND BOD
Manufacturer: WTW 01049 0881 1830
Supplier: BURMAC LTD 0428 724477
Model: BSB (BOD) 1020T Usage : FIXED
Method: BIOLOGICAL - CELLULAR
Range:
0-4000 mg/l at Output: VISUAL
Notes :
10 measuring ranges
Sample quantities: 432, 365, 250, 164, 97, 43.5, 22.7 ml
Temperature constant: 20C +/- 0.5C
BOD 0-4000 mg/l

Record No. 1128
SINGLE DETERMINAND BOD
Manufacturer: STROHLEIN GmbH & Co 01049 02101 6060
Supplier: J AND R SCIENTIFIC 0371 850507
Model: BSB5 Usage : FIXED
Method: GAS SENSING (general)
Range:
0-60 mg/l at ± 0.1 mg/l Output: VISUAL/ANALOGUE
Notes :
Parallel measurement of 3 samples in 3 dilution stages.
BOD 0-60 mg/l at ± 0.1 mg/l

Record No. 974

SINGLE DETERMINAND

COD

Manufacturer: HORIBA INSTRUMENTS LTD 0604 65171

Supplier: as above

Model: CODA-111/112

Usage : FIXED

Method: OPTICAL - COLOURIMETRY

Range:

0-500 mgO/l at

Output: VISUAL/ANALOGUE

Notes :

Uses acid-based and alkali-based, potassium permanganate method.

COD

0-500 mgO/l

Record No. 88

SINGLE DETERMINAND

COD

Manufacturer: IONICS INCORPORATED 0101 617 926 2500

Supplier: IONICS (UK) 061 776 4550

Model: 304 COD Analyser

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-5000 ppm at

Output: VISUAL/ANALOGUE

Notes :

Chloride correction (automatic)

Measures additionally: organics, nitrites, ferrous compounds

sulphides, sulphites and chlorides

COD

0-5000 ppm

Record No. 1247

SINGLE DETERMINAND

COD

Manufacturer: HACH EUROPE 010 32 81 445381

Supplier:

Model: DR/2000

Usage : PORTABLE (hand-held)

Method: OPTICAL - UV/IR SPECTROPHOTOME

Range:

0-15,000 mg/l at

Output: VISUAL/ANALOGUE/SERIAL

Notes :

Permanently stored 120 programmed calibrations. Customised to suit requirements.

(MULTIPLE)

ALUMINIUM	0-0.8 mg/l
BARIUM	0-100 mg/l
CADMIUM	0-80 ug/l
CHLORIDE	0-20 mg/l
CHLORINE	0-2 mg/l
CHROMIUM	0-20 g/l
COPPER	0-5 mg/l
CYANIDE	0-0.2 mg/l
FLUORIDE	0-2 mg/l
HYDRAZINE	0-5 ug/l
IRON	0-3 mg/l
LEAD	0-160 ug/l
MANGANESE	0-20 mg/l
MOLYBDATE	0-20 mg/l
NICKEL	0-8 g/l
NITRATE	0-4.5 mg/l
NITRITE	0-150 mg/l
OIL-IN-WATER	0-85 ppm
DISSOLVED OXYGEN	0-13 mg/l
COD	0-15,000 mg/l
PHENOLS	0-0.2 mg/l
SILICA	0-100 mg/l

TURBIDITY

0-450 FTU

Record No. 1755

SINGLE DETERMINAND

COD

Manufacturer: HACH EUROPE 010 32 81 445381

Supplier: CAMLAB LTD 0223 424222

Model: HH/41100-*

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

0-1500 mg/l at

Output: VISUAL

Notes :

Portable kits incorporating a variety of colourimetric methods.

(MULTIPLE)

ALUMINIUM	0-0.25 mg/l
CHROMIUM	0-0.5 mg/l
HYDRAZINE	0-0.3 mg/l
IRON	0-5 mg/l
DISSOLVED OXYGEN	0-10 mg/l
AMMONIA	0-3 mg/l
NITRATE	0-150 mg/l
FLUORIDE	0-8 mg/l
CYANIDE	0-0.2 mg/l
COD	0-1500 mg/l
CHLORINE	0-3.5 mg/l
LEAD	0-150 mg/l
COPPER	0-3 mg/l
SILVER	0-0.7 mg/l
NITRITE	0-150 mg/l
MANGANESE	0-10 mg/l
MOLYBDATE	0-5 mg/l
NICKEL	0-0.6 mg/l
SULPHATE	0-80 mg/l

Record No. 1020

SINGLE DETERMINAND

COD

Manufacturer: DR LANGE 01049 211 500970

Supplier: ROBIN INSTRUMENTS LTD 0276 26987/8

Model: LP 2 W

Usage : FIXED

Method: OPTICAL - COLOURIMETRY

Range:

Output: VISUAL

Notes :

Rapid and simple colourimetric analysis using wide range of pre-mixed cuvettes. Programmable for special requirements. Example determinands entered, many more available.

(MULTIPLE)

AMMONIUM
ALUMINIUM
CHROMIUM
COD
CYANIDE
FORMALDEHYDE
NITRATE
PHOSPHATE

Record No. 1272

SINGLE DETERMINAND

COD

Manufacturer: DR LANGE 01049 211 500970

Supplier: as above

Model: LASA Aqua

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

2-10,000 mg/l at

Output: VISUAL

Notes :

(MULTIPLE)

ALUMINIUM	0.02-0.5 mg/l
AMMONIUM	0.01-47 mg/l
CADMIUM	0.02-0.3 mg/l
CALCIUM	0.5-10 mg/l
CHLORIDE	1-70 mg/l
CHLORINE	0.05-2 mg/l
CHROMIUM	0.01-1 mg/l
COD	2-10,000 mg/l
COPPER	0.01-8 mg/l
CYANIDE	0.01-0.5 mg/l
FLUORIDE	0.1-1.5 mg/l
IRON	0.1-10 mg/l
LEAD	0.1-2 mg/l
NICKEL	0.01-6 mg/l
NITRATE	0.2-60 mg/l
NITRITE	0.01-2 mg/l
PHENOLS	5-200 mg/l
PHOSPHATE	0.003-30 mg/l
POTASSIUM	8-50 mg/l
SILVER	5-3000 mg/l
SULPHATE	10-150 mg/l
MANGANESE	0.02-5 mg/l

Record No. 1127

SINGLE DETERMINAND

COD

Manufacturer: STROHLEIN GmbH & Co 01049 02101 6060

Supplier: J AND R SCIENTIFIC 0371 850507

Model: CBS

Usage : FIXED

Method: VOLTAMMETRY/POLAROGRAPHY

Range:

Output: VISUAL

Notes :

Titration and back titration included in method.

COD

Record No. 1314

SINGLE DETERMINAND

COD

Manufacturer: SIEPMANN UND TECTSCHER GMBH 01049 0607 87860

Supplier: ENVITECH LTD 0222 229982

Model: Phoenix:On-Line COD

Usage : FIXED

Method: GAS SENSING (general)

Range:

5-1,000 mg/l at

Output: VISUAL/SERIAL

Notes :

Analysis of wastewater using Ozone - Peter Kalte

COD

5-1,000 mg/l

Record No. 87

SINGLE DETERMINAND TOC

Manufacturer: IONICS INCORPORATED 0101 617 926 2500

Supplier: IONICS (UK) 061 776 4550

Model: M-85

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-40,000 ppm C at

Output: VISUAL/ANALOGUE

Notes :

Sample oxidation in reaction chamber at 900°C

No interference from inorganic carbon or CO₂

TOC 0-40,000 ppm C

Record No. 89

SINGLE DETERMINAND TOC

Manufacturer: IONICS INCORPORATED 0101 617 926 2500

Supplier: IONICS (UK) 061 776 4550

Model: 6800 Series

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-30,000 ppm C at

Output: VISUAL/ANALOGUE

Notes :

TC/TOC Analyser for on-line monitoring

TOC 0-30,000 ppm C

Record No. 90

SINGLE DETERMINAND TOC

Manufacturer: IONICS INCORPORATED 0101 617 926 2500

Supplier: IONICS (UK) 061 776 4550

Model: 1200 Series

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-1000 ppm at >50ppm 5%

Output: VISUAL/ANALOGUE

Notes :

TOC/TC/TOD Analyser

Cycle time TOC/TC 5min, TC/TOD 3min, TOC 5min

TOC 0-1000 ppm at >50ppm 5%

Record No. 894

SINGLE DETERMINAND TOC

Manufacturer: IONICS INCORPORATED 0101 617 926 2500

Supplier: IONICS (UK) 061 776 4550

Model: Model 1555

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-2000ppm C . at

Output: VISUAL/ANALOGUE

Notes :

Syringe injection 20-200 microlitre sample size.

Analysis time: 90 seconds.

Carrier gas: prepurified nitrogen or oxygen.

TOC 0-2000ppm C .

Record No. 1145

SINGLE DETERMINAND TOC

Manufacturer: ROSEMOUNT LTD 0243 863121

Supplier: as above

Model: 1100

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-1000 ppb at \pm 3%

Output: VISUAL/ANALOGUE

Notes :

Principle: ultraviolet oxidation/Conductivity detection.

The sample must be free of particles larger than 50 microns.

Flow rate: 50-2000 ml/min.

TOC

0-1000 ppb at $\pm 3\%$

Record No. 1146

SINGLE DETERMINAND

TOC

Manufacturer: ROSEMOUNT LTD 0243 863121

Supplier: as above

Model: 2100

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-5000 ppm at $\pm 3\%$

Output: VISUAL/ANALOGUE

Notes :

Principle: ultraviolet-promoted persulphate oxidation/single beam, non-dispersive infrared detection.

Response time: < 5 minutes to 90% FSD.

TOC

0-5000 ppm at $\pm 3\%$

Record No. 230

SINGLE DETERMINAND

TOC

Manufacturer: WESTINGHOUSE ELECTRIC S.A 0462 422222

Supplier: as above

Model: TOCOR 2

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-1000mg/l C at

Output: VISUAL/ANALOGUE/SERIAL

Notes :

TOC/TIC/TC/VOC Analyser

Measurement: infra-red analyser

2 measuring ranges

TOC

0-1000mg/l C

Record No. 231

SINGLE DETERMINAND

TOC

Manufacturer: WESTINGHOUSE ELECTRIC S.A 0462 422222

Supplier: as above

Model: TOCOR 4

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-30mg/l C at

Output: VISUAL/ANALOGUE/SERIAL

Notes :

DOC/TOC/DC/TC Analyser

Continuous measuring principal

2 measuring ranges

TOC

0-30mg/l C

Record No. 1424

SINGLE DETERMINAND

TOC

Manufacturer: ASTRO-MED Inc 0628 668836

Supplier: as above

Model: 1800

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-10,000 ppm at $\pm 2\%$

Output: VISUAL/ANALOGUE/SERIAL

Notes :

provides rapid detection of organic contamination in water

continuous flow configuration provides minimal drift

designed for multi-stream monitoring applications.

TOC

0-10,000 ppm at $\pm 2\%$

Record No. 1425

SINGLE DETERMINAND

TOC

Manufacturer: ASTRO-MED Inc 0628 668836

Supplier: as above

Model: 1900

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-10,000 ppm C at $\pm 2\%$

Output: VISUAL/ANALOGUE/SERIAL

Notes :

housed in a dual component rugged enclosure

insures less than 2% drift between normal 60 day maintenance inte

isolates electronics from wetted parts, wall or rack mountable

TOC

0-10,000 ppm C at $\pm 2\%$

Record No. 1005

SINGLE DETERMINAND

TOC

Manufacturer: EDEN SCIENTIFIC 081 546 8386

Supplier: as above

Model: 700

Usage : TRANSPORTABLE

Method: OPTICAL - UV/IR PHOTOMETRY

Range:

4-10,000 ppm at $\pm 2\%$

Output: VISUAL

Notes :

Total organic carbon analyser.

IR analysis

Automatic after injection of sample.

Time of analysis: 7 mins.

Sample size: 1ul to 10ml.

Single point calibration via standard or CO2 injection.

TOC

4-10,000 ppm at $\pm 2\%$

Record No. 101

SINGLE DETERMINAND

TOC

Manufacturer: OPTEK-DANULAT GmbH & Co KG 01049 201 634090

Supplier: KC CONTROLS LTD 0737 222931

Model: OPTEK 110/AF10

Usage : FIXED

Method: OPTICAL - UV/IR PHOTOMETRY

Range:

0-5 CU at $< 1\%$

Output: VISUAL/ANALOGUE

Notes :

Single beam absorption measuring system

Spectral range VIS and NIR

Application - Carbon in water up to 2%

Solids concentration monitor

6 measuring ranges

TOC

0-5 CU at $< 1\%$

Record No. 877

SINGLE DETERMINAND

TOC

Manufacturer: SHIMADZU CORPORATION 01081 3 2195641

Supplier: DYSON INSTRUMENTS LTD 091 526 0452

Model: TOC-5000

Usage : FIXED

Method: PROCESS ANALYSER

Range:

4ppb to 4000ppm at $\pm 2\%$

Output: VISUAL/ANALOGUE/SERIAL

Notes :

Flow rate of sample: 100-200ml/min

TOC

4ppb to 4000ppm at $\pm 2\%$

Record No. 1066

SINGLE DETERMINAND

TOC

Manufacturer: SHIMADZU CORPORATION 01081 3 2195641

Supplier: DYSON INSTRUMENTS LTD 091 526 0452
Model: 5050 Usage : FIXED
Method: PROCESS ANALYSER
Range: 50ppb-4000ppm at
Notes : Output: VISUAL/SERIAL
Combustion followed by non-dispersive IR gas analysis.
TOC 50ppb-4000ppm

Record No. 1067
SINGLE DETERMINAND TOC
Manufacturer: SHIMADZU CORPORATION 01081 3 2195641
Supplier: DYSON INSTRUMENTS LTD 091 526 0452
Model: TOC-500 Usage : FIXED
Method: PROCESS ANALYSER
Range: 2-3000ppm at
Notes : Output: VISUAL/SERIAL
Combustion followed by non-dispersive IR gas analysis.
TOC 2-3000ppm

Record No. 1315
SINGLE DETERMINAND TOC
Manufacturer: MAIHAK AG 01049 40 27160
Supplier: FLUID DATA LTD 0322 528125
Model: TOCOR2 Usage : FIXED
Method: PROCESS ANALYSER
Range: 0-10 g/l C at $\pm 1\%$
Notes : Output: VISUAL/ANALOGUE/SERIAL
Suited for on-line measurement of pre-filtered water.
Used in the monitoring of surface water.
TOC 0-10 g/l C at $\pm 1\%$

Record No. 1542
SINGLE DETERMINAND TOC
Manufacturer: MAIHAK AG 01049 40 27160
Supplier: FLUID DATA LTD 0322 528125
Model: TOCOR 4.2 Usage : FIXED
Method: OPTICAL - UV/IR PHOTOMETRY
Range: 0-3 mg/l C at
Notes : Output: VISUAL/ANALOGUE
TOC 0-3 mg/l C

Record No. 1543
SINGLE DETERMINAND TOC
Manufacturer: MAIHAK AG 01049 40 27160
Supplier: FLUID DATA LTD 0322 528125
Model: TOCOR 4-DOC Usage : FIXED
Method: OPTICAL - UV/IR PHOTOMETRY
Range: 0-3 mg/l C at
Notes : Output: VISUAL/ANALOGUE/SERIAL
TOC 0-3 mg/l C

Record No. 1079
SINGLE DETERMINAND TOC
Manufacturer: HERAEUS SENSOR GMBH 01049 061 81351
Supplier: FOSS ELECTRIC LTD 0904 707944
Model: LIQUITOC Usage : FIXED
Method: PROCESS ANALYSER

Range:
4-10,000 PPM at $\pm 2\%$ Output: VISUAL/ANALOGUE/SERIAL

Notes :
Carousel for 120 liquid samples with an analysis time of 3-6 minutes.

TOC 4-10,000 PPM at $\pm 2\%$

Record No. 1051

SINGLE DETERMINAND TOC

Manufacturer: SERES 0734 328880

Supplier: as above

Model: COT 712

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-10,000 mg/lc at $\pm 2\%$

Output: VISUAL/ANALOGUE

Notes :

Potassium persulphate/UV oxidation followed by IR detection of CO₂. Auto zero adjustment and calibration.

TOC 0-10,000 mg/lc at $\pm 2\%$

Record No. 1063

SINGLE DETERMINAND TOC

Manufacturer: POLLUTION & PROCESS MONITORING 0732 882044

Supplier: as above

Model: Organics Analyser

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-10,000 ppm at

Output: VISUAL

Notes :

Analyser uses an ultra violet promoted persulphate oxidation with IR detection. Auto-calibration. Alarms.

TOC 0-10,000 ppm

Record No. 1126

SINGLE DETERMINAND TOC

Manufacturer: STROHLEIN GmbH & Co 01049 02101 6060

Supplier: J AND R SCIENTIFIC 0371 850507

Model: C-MAT 500 LI

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-6% C at

Output: VISUAL/ANALOGUE

Notes :

Consists of a combustion and measuring system with IR analysis.

TOC 0-6% C

Record No. 1129

SINGLE DETERMINAND TOC

Manufacturer: STROHLEIN GmbH & Co 01049 02101 6060

Supplier: J AND R SCIENTIFIC 0371 850507

Model: Coulomat 702 GA/L1

Usage : FIXED

Method: PROCESS ANALYSER

Range:

0-100 % at

Output: VISUAL/ANALOGUE

Notes :

Evaluates TOC by calculating the difference between total and inorganic carbon (TC-TIC).

TOC 0-100 %

Record No. 1485

SINGLE DETERMINAND TOC

Manufacturer: ASTRO INTERNATIONAL CORP. 0101 713 332 2484

Supplier: APPLIKON ANALYSERS LTD 0252 372303

Model: 1800/1900

Usage : FIXED

Method: OPTICAL - UV/IR PHOTOMETRY

Range:

0-5 to 0-10,000 at 2%

Output: VISUAL/ANALOGUE

Notes :

On-line detection of organic contamination. Oxidation of organics
to carbon dioxide. This is measured by IR analyzer.

TOC

0-5 to 0-10,000 at 2%

Record No. 305

SINGLE DETERMINAND

AMMONIA

Manufacturer: EDT ANALYTICAL 0304 213555

Supplier: as above

Model: 321

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

Output: ANALOGUE

Notes :

ISE with gas membrane

AMMONIA

Record No. 5

SINGLE DETERMINAND

AMMONIA

Manufacturer: ABB KENT PLC 0582 31255

Supplier: as above

Model: 8002 800

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

0.001-1.0g/l at

Output: ANALOGUE

Notes :

Temperature range: 5-40C

Interferences: volatile amines

pH range: 12

AMMONIA

0.001-1.0g/l

Record No. 1032

SINGLE DETERMINAND

AMMONIA

Manufacturer: ABB KENT PLC 0582 31255

Supplier: as above

Model: 8080

Usage : FIXED

Method: ION-SELECTIVE

Range:

Output: VISUAL/ANALOGUE/SERIAL

Notes :

Water Quality Analyser

(MULTIPLE)

AMMONIA

FLUORIDE

NITRATE

CYANIDE

Record No. 1518

SINGLE DETERMINAND

AMMONIA

Manufacturer: ABB KENT PLC 0582 31255

Supplier: as above

Model: 8082

Usage : FIXED

Method: GAS SENSING (general)

Range:

0-20mg/l at

Output: VISUAL/ANALOGUE/SERIAL

Notes :

PISEG/WRC FR0048, 1990 and 333E, 1988

AMMONIA

0-20mg/l

Record No. 1

SINGLE DETERMINAND

AMMONIA

Manufacturer: RUSSELL pH LTD 0337 28871

Supplier: as above

Model: ISE95-5129

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

0.05-50mg/l at

Output: ANALOGUE

Notes :

Concentration range 0.02ppm to 1M

Temperature range 0-50C

Interferences: volatile amines

AMMONIA

0.05-50mg/l

Record No. 2

SINGLE DETERMINAND

AMMONIA

Manufacturer: PHILIPS SCIENTIFIC 0223 358880

Supplier: as above

Model: R9436 094 75503

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

0.017-17000ppm at

Output: ANALOGUE

Notes :

Gas sensing ISE

AMMONIA

0.017-17000ppm

Record No. 4

SINGLE DETERMINAND

AMMONIA

Manufacturer: CORNING MEDICAL AND SCIENTIFIC 0787 472461

Supplier: as above

Model: 476130

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

0.02-1700ppm at

Output: ANALOGUE

Notes :

No reference electrode

AMMONIA

0.02-1700ppm

Record No. 1497

SINGLE DETERMINAND

AMMONIA

Manufacturer: YSI-CLANDON 0252 514711

Supplier: GRANT INSTRUMENTS LTD 0763 260811

Model: 3800

Usage : PORTABLE (hand-held)

Method: ELECTROCHEMICAL (general)

Range:

0 to 100 at $\pm 15\%$

Output: VISUAL/ANALOGUE/SERIAL

Notes :

System consists of data logger/control unit with a sonde.

Measures temp, pH, DO and Salinity optional depth and turbidity

Can operate as real time meter or data logger or both at the

same time. Powered by internal batteries or for longer term

external 9 to 12 volt battery.

(MULTIPLE)

TEMPERATURE

-5 to 50 deg C at 0.1 deg C

SALINITY

0 to 50 ppt at 2.5 ppt

pH

0 to 14 pH at ± 0.04 pH

DISSOLVED OXYGEN

0 to 200 % at ± 3 %

CONDUCTIVITY

0 to 100 mS/cm at ± 4 %

AMMONIUM

0 to 100 mg/l at ± 10 %

AMMONIA

0 to 100 at $\pm 15\%$

TURBIDITY

0 to 1000 NTU at $\pm 10\%$

Record No. 319

SINGLE DETERMINAND

AMMONIA

Manufacturer: PHOX SYSTEMS LTD 0462 817070

Supplier: as above

Model: Ammonia monitor

Usage : FIXED

Method: GAS SENSING (general)

Range:

Output: VISUAL/ANALOGUE

Notes :

Prefiltration; autocleaning; auto-calibration.

AMMONIA

Record No. 1026

SINGLE DETERMINAND

AMMONIA

Manufacturer: PHOX SYSTEMS LTD 0462 817070

Supplier: as above

Model: 1800 Mk 2 Series

Usage : FIXED

Method: ION-SELECTIVE

Range:

0.5-100 mg/l at

Output: VISUAL/ANALOGUE

Notes :

Auto-calibrating; status alarms and digital outputs provided.

(MULTIPLE)

AMMONIA 0.5-100 mg/l

FLUORIDE 0.02-1000 mg/l

NITRATE 0.01-100 mg/l

Record No. 1423

SINGLE DETERMINAND

AMMONIA

Manufacturer: PHOX SYSTEMS LTD 0462 817070

Supplier: as above

Model: 1801

Usage : FIXED

Method: ION-SELECTIVE

Range:

0-20 mg/l at

Output: VISUAL/ANALOGUE

Notes :

industrially based monitor to operate in unattended sites

generally used on a continuous mode, intermittent operation offer

used in both fixed site and mobile installations

PISEG/WRC FR 0049, 1990

AMMONIA 0-20 mg/l

Record No. 979

SINGLE DETERMINAND

AMMONIA

Manufacturer: HORIBA INSTRUMENTS LTD 0604 65171

Supplier: as above

Model: AMNA-100 series

Usage : FIXED

Method: OPTICAL - COLOURIMETRY

Range:

0.01-1,000 ppm at

Output: VISUAL/ANALOGUE

Notes :

Repeatability: $\pm 3\%$ of full scale.

AMMONIA 0.01-1,000 ppm

Record No. 309

SINGLE DETERMINAND

AMMONIA

Manufacturer: ORION RESEARCH UK 0342 824033

Supplier: as above

Model: 951201

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

Output: ANALOGUE

Notes :

Epoxy body electrode

AMMONIA

Record No. 1167

SINGLE DETERMINAND

AMMONIA

Manufacturer: PALINTEST LTD 091 491 0808

Supplier: as above

Model: PT 220

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

0-1.0 mg/l at

Output: VISUAL

Notes :

Palintest comparator with interchangeable colour discs.
(MULTIPLE)

AMMONIA	0-1.0 mg/l
ALUMINIUM	0-0.5 mg/l
CHLORINE	0-250 mg/l
COPPER	0-5.0 mg/l
FLUORIDE	0-1.5 mg/l
IRON	0-10 mg/l
MANGANESE	0-0.03 mg/l
MOLYBDATE	0-100 mg/l
NITRATE	0-15 mg/l
NITRITE	0-0.4 mg/l
PHOSPHATE	0-100 mg/l
SILICA	0-4 mg/l
SULPHIDE	0-0.5 mg/l

Record No. 1181

SINGLE DETERMINAND

AMMONIA

Manufacturer: PALINTEST LTD 091 491 0808

Supplier: as above

Model: PT 260

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

0-1 mg/l at

Output: VISUAL

Notes :

Comprises of the Photometer 5000.

(MULTIPLE)

AMMONIA	0-1 mg/l
ALUMINIUM	0-0.5 mg/l
CHLORINE	0-250 mg/l
COPPER	0-5 mg/l
FLUORIDE	0-1.5 mg/l
IRON	0-10 mg/l
MANGANESE	0-0.03 mg/l
MOLYBDATE	0-100 mg/l
NITRATE	0-20 mg/l
NITRITE	0-0.5 mg/l
pH	6.8-8.4
PHOSPHATE	0-100 mg/l
POTASSIUM	0-12 mg/l
SILICA	0-4 mg/l
SULPHATE	0-200 mg/l
SULPHIDE	0-0.5 mg/l

Record No. 235

SINGLE DETERMINAND

AMMONIA

Manufacturer: WPA 0223 892688

Supplier: as above

Model: ISE 321

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

10(-1)=5(10-6)M at

Output: ANALOGUE

Notes :

Interferences: hydrazine and aliphatic amines

AMMONIA 10(-1)=5(10-6)M

Record No. 265

SINGLE DETERMINAND

AMMONIA

Manufacturer: FLOWLINE SYSTEMS LTD 081 207 6565

Supplier: as above
 Model: AM-1 / AM-2 Usage : PORTABLE (hand-held)
 Method: GAS SENSING (general)
 Range: 0.01-10000 ppm at Output: VISUAL/ANALOGUE/SERIAL
 Notes :
 Built in 1000 reading datalogger, can download to Lotus 123 etc
 Water proof case
 AMMONIA 0.01-10000 ppm

Record No. 944
 SINGLE DETERMINAND AMMONIA
 Manufacturer: JENWAY LTD 0371 820122
 Supplier: as above
 Model: 924118 Usage : COMPONENT
 Method: GAS SENSING (general)
 Range: 1M - 10(-6)M at Output: ANALOGUE
 Notes :
 pH range: 11-13.
 Temperature range: 0-50C.
 Lower limit: 0.02 ppm.
 Interferences: hydrazine = $5 \times 10(-2)$ M, aliphatic amines 0.1 - 0.5.
 AMMONIA 1M - 10(-6)M

Record No. 1680
 SINGLE DETERMINAND AMMONIA
 Manufacturer: JENWAY LTD 0371 820122
 Supplier: as above
 Model: 3045 Usage : FIXED
 Method: ION-SELECTIVE
 Range: 1M-10(-6)M at Output: VISUAL
 Notes :
 Measures pH and temperature together with 3 selective ions.
 ION SELECTIVE
 AMMONIA 1M-10(-6)M
 BARIUM 1M- $5 \times 10(-5)$ M
 BROMIDE 1M- $5 \times 10(-6)$ M
 CADMIUM 10(-1)-10(-6)M
 CALCIUM 1M- $5 \times 10(-7)$ M
 CHLORIDE 1M- $5 \times 10(-5)$ M
 COPPER 1M- $5 \times 10(-6)$ M
 CYANIDE 10(-2)-10(-6)M
 FLUORIDE 1M- $5 \times 10(-7)$ M
 IODIDE 1M-10(-7)M
 LEAD 10(-1)- $5 \times 10(-6)$ M
 NITRATE 1M- $5 \times 10(-6)$ M
 POTASSIUM 1M-10(-6)M
 SILVER 1M-10(-7)M
 SODIUM 10(-1)-10(-3)M
 SULPHIDE 1M-10(-7)M
 THIOCYANATE 1M- $5 \times 10(-6)$ M

Record No. 677
 SINGLE DETERMINAND AMMONIA
 Manufacturer: CP INSTRUMENT COMPANY LTD 0279 757711
 Supplier: as above
 Model: RU5722-16A Usage : COMPONENT
 Method: GAS SENSING (general)
 Range: 0.02-17000 ppm at Output: ANALOGUE

Notes :

Temp/pH range: 0-50C and 11-13pH

Interferences: volatile amines

AMMONIA 0.02-17000 ppm

Record No. 961

SINGLE DETERMINAND AMMONIA

Manufacturer: APPLIKON ANALYSERS LTD 0252 372303

Supplier: as above

Model: TDS C3

Usage : FIXED

Method: OPTICAL - COLOURIMETRY

Range:

0-10mg/l NH3 at

Output: VISUAL/ANALOGUE/SERIAL

Notes :

Sample size: 2 mls.

Sample temperature: 15-35C.

Sampling: on time basis, automatic, or remote selection.

AMMONIA 0-10mg/l NH3

Record No. 962

SINGLE DETERMINAND AMMONIA

Manufacturer: APPLIKON ANALYSERS LTD 0252 372303

Supplier: as above

Model: TDS C2

Usage : FIXED

Method: OPTICAL - COLOURIMETRY

Range:

0-1000 ug/l NH3 at

Output: VISUAL/ANALOGUE/SERIAL

Notes :

Detection limit: 1,5 ug/l.

Sample size: 20ml.

Sample temperature: 15-35C.

Interferences: amino compounds, chlorine.

AMMONIA 0-1000 ug/l NH3

Record No. 1751

SINGLE DETERMINAND AMMONIA

Manufacturer: HACH EUROPE 010 32 81 445381

Supplier: CAMLAB LTD 0223 424222

Model: HH/41100-*

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

0-3 mg/l at

Output: VISUAL

Notes :

Portable kits incorporating a variety of colourimetric methods.

(MULTIPLE)

ALUMINIUM 0-0.25 mg/l

CHROMIUM 0-0.5 mg/l

HYDRAZINE 0-0.3 mg/l

IRON 0-5 mg/l

DISSOLVED OXYGEN 0-10 mg/l

AMMONIA 0-3 mg/l

NITRATE 0-150 mg/l

FLUORIDE 0-8 mg/l

CYANIDE 0-0.2 mg/l

COD 0-1500 mg/l

CHLORINE 0-3.5 mg/l

LEAD 0-150 mg/l

COPPER 0-3 mg/l

SILVER 0-0.7 mg/l

NITRITE 0-150 mg/l

MANGANESE 0-10 mg/l

MOLYBDATE 0-5 mg/l

NICKEL 0-0.6 mg/l
SULPHATE 0-80 mg/l

Record No. 308

SINGLE DETERMINAND

AMMONIA

Manufacturer: METROHM LTD 01041 071 521114

Supplier: V.A HOWE AND CO LTD 0295 252600

Model: 6.0506.010

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

1x10(-6) - 1 at

Output: ANALOGUE

Notes :

Glass membrane, plastic foil with fixed cable

Includes reference electrode

Interferences: volatile amines, Hg2+

AMMONIA

1x10(-6) - 1

Record No. 176

SINGLE DETERMINAND

AMMONIA

Manufacturer: WTW 01049 0881 1830

Supplier: BURMAC LTD 0428 724477

Model: NH 500/2

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

0.1-1000ppm at

Output: ANALOGUE

Notes :

Specific ion electrode for ammonia also ammonium

AMMONIA

0.1-1000ppm

Record No. 556

SINGLE DETERMINAND

AMMONIA

Manufacturer: CIBA CORNING ANALYTICAL 0787 475155

Supplier: PATTERSON SCIENTIFIC 0582 475575

Model: 476130

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

1700-0.02 ppm at

Output: ANALOGUE

Notes :

pH range: 11-13

No reference electrode

AMMONIA

1700-0.02 ppm

Record No. 1778

SINGLE DETERMINAND

AMMONIA

Manufacturer: SKALAR B.V 01031 76 225477

Supplier: VW SCIENTIFIC 0904 414956

Model: SA9000

Usage : FIXED

Method: CHROMATOGRAPHY (Ion)

Range:

Output: VISUAL/ANALOGUE/SERIAL

Notes :

Capable of measuring 1 or 2 determinands. Multi-stream sampling.

(MULTIPLE)

ALUMINIUM

AMMONIA

CHLORIDE

CHLORINE

CHROMIUM

COPPER

CYANIDE

IRON

MANGANESE

NICKEL

NITRATE
NITRITE
pH
PHENOLS
PHOSPHATE
SULPHATE
SULPHIDE
ZINC

Record No. 1038

SINGLE DETERMINAND

AMMONIA

Manufacturer: SERES 0734 328880

Supplier: as above

Model: SERES 2000

Usage : FIXED

Method: OPTICAL - COLOURIMETRY

Range:

Output: VISUAL/ANALOGUE

Notes :

Monitor capable of modification to make use of other analytical methods: photometry, titrimetry, nephelometry & electrochemical. Capable of sampling from up to 6 sources. Auto-calibration.

(MULTIPLE)

ALUMINIUM
AMMONIA
BROMIDE
CHLORIDE
CHROMIUM
COPPER
HYDRAZINE
IRON
MANGANESE
NITRITE
PHENOLS
PHOSPHATE
SILICA
SULPHATE

Record No. 1138

SINGLE DETERMINAND

AMMONIA

Manufacturer: TINTOMETER LTD 0722 27242

Supplier: as above

Model: LOVIBOND CHECKIT

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

0-0.75 mg/l at 37

Output: VISUAL

Notes :

Ultra low power enabling 2000 tests to be carried out per battery

(MULTIPLE)

ALUMINIUM	0-0.5 mg/l
AMMONIA	0-0.75 mg/l at 37
CHLORINE	0-6 mg/l at 37
COPPER	0-1.0 mg/l at 37
IRON	0-1.0 mg/l at 37
NITRATE	0-10 mg/l at 37
PHOSPHATE	0-4.0 mg/l at 37
pH	6.5-8.4 pH at 37

Record No. 1110

SINGLE DETERMINAND

AMMONIA

Manufacturer: BRAN & LUEBBE LTD 0256 842062

Supplier: as above

Model: Ionometer AC 200

Usage : FIXED

Method: PROCESS ANALYSER

Range: 0-10 ppm at $\pm 5\%$ Output: VISUAL/ANALOGUE
Notes :
On-line analyser with up to 6 sample streams. Service interval normally 2 weeks.
(MULTIPLE)
SODIUM 0-20 ppb at $\pm 5\%$
CHLORIDE 0-100 ppb at $\pm 5\%$
AMMONIA 0-10 ppm at $\pm 5\%$
ALUMINIUM 0-10 ppm at $\pm 5\%$
FLUORIDE 0-10 ppm at $\pm 5\%$
SULPHIDE 0-30 ppm at $\pm 5\%$

Record No. 1567
SINGLE DETERMINAND AMMONIA
Manufacturer: CHEMetrics Inc. 0101 800 356 3072
Supplier: GALGO (UK) LTD 0727 50267/837872
Model: K-1500 series Usage : TEST KIT
Method: OPTICAL - COLOURIMETRY
Range: 0-10,000 ppm at Output: VISUAL
Notes :
Analysis time 2 - 3 minutes.
7 different ranges.
AMMONIA 0-10,000 ppm

Record No. 1845
SINGLE DETERMINAND AMMONIA
Manufacturer: PROCESS-STYRNING AB 08-7120425
Supplier: PERSTORP ANALYTICAL LTD 0454 417798
Model: Ammonia Monitor Usage : FIXED
Method: ION-SELECTIVE
Range: 0.3-1000 mg/l at Output: VISUAL/ANALOGUE
Notes :
Measuring principle: ammonium is converted to ammonium hydrate.
Automatic temperature compensation.
AMMONIA 0.3-1000 mg/l

Re
SI
Ma
Su
Mo
Me
Ra
No
/
At

Re
SI
Ma
SI
Ma
Ma
R:
O
N:

A

R
S
M
S
M
F
C
N

Record No. 306

SINGLE DETERMINAND

AMMONIUM

Manufacturer: ABB KENT PLC 0582 31255

Supplier: as above

Model: 1057-200

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

Output: ANALOGUE

Notes :

Ammonium/Potassium electrode

AMMONIUM

Record No. 3

SINGLE DETERMINAND

AMMONIUM

Manufacturer: PHILIPS SCIENTIFIC 0223 358880

Supplier: as above

Model: R9436 094 75253

Usage : COMPONENT

Method: GAS SENSING (general)

Range:

0.02 - 1800 ppm at -

Output: ANALOGUE

Notes :

Plastic membrane

AMMONIUM

0.02 - 1800 ppm at -

Record No. 1496

SINGLE DETERMINAND

AMMONIUM

Manufacturer: YSI-CLANDON 0252 514711

Supplier: GRANT INSTRUMENTS LTD 0763 260811

Model: 3800

Usage : PORTABLE (hand-held)

Method: ELECTROCHEMICAL (general)

Range:

0 to 100-mg/l at $\pm 10\%$

Output: VISUAL/ANALOGUE/SERIAL

Notes :

System consists of data logger/control unit with a sonde.

Measures temp, pH, DO and Salinity optional depth and turbidity

Can operate as real time meter or data logger or both at the same time. Powered by internal batteries or for longer term external 9 to 12 volt battery.

(MULTIPLE)

TEMPERATURE

-5 to 50 deg C at 0.1 deg C

SALINITY

0 to 50 ppt at 2.5 ppt

pH

0 to 14 pH at ± 0.04 pH

DISSOLVED OXYGEN

0 to 200 % at $\pm 3\%$

CONDUCTIVITY

0 to 100 mS/cm at $\pm 4\%$

AMMONIUM

0 to 100 mg/l at $\pm 10\%$

AMMONIA

0 to 100 at $\pm 15\%$

TURBIDITY

0 to 1000 NTU at $\pm 10\%$

Record No. 1553

SINGLE DETERMINAND

AMMONIUM

Manufacturer: SIEMENS LTD 0932 785691

Supplier: as above

Model: MERLIN

Usage : TRANSPORTABLE

Method: ELECTROCHEMICAL (general)

Range:

0.1 - 100mg/l at 1%

Output: ANALOGUE/SERIAL

Notes :

Floating system providing continuous monitoring.

Telemetry system: internal datalogger connected to Cellnet modem.

pH

0-14 pH at 0.05 pH

TURBIDITY

0-14 pH at 5%

AMMONIUM 0.1 - 100mg/l at 1%
DISSOLVED OXYGEN 0-100% at $\pm 1\%$
TEMPERATURE -5 to 60C at $\pm 0.1\%$
CONDUCTIVITY 0-100mS at $\pm 1\text{mS}$

Record No. 1562

SINGLE DETERMINAND

AMMONIUM

Manufacturer: SIEMENS LTD 0932 785691

Supplier: as above

Model: SHERLOCK

Usage : TRANSPORTABLE

Method: ELECTROCHEMICAL (general)

Range:

0.1 - 100 mg/l at $\pm 1\%$

Output: ANALOGUE/SERIAL

Notes :

Transportable system located on river banks or docksides.

Radio telemetry system consisting of internal data logger and modem. Expandable system and robust in construction.

pH 0-14 pH at ± 0.05 pHDISSOLVED OXYGEN 0-100 % at $\pm 1\%$ TEMPERATURE -5 to 60C at $\pm 0.1\text{C}$ TURBIDITY -5 to 60C at $\pm 5\%$ AMMONIUM 0.1 - 100 mg/l at $\pm 1\%$ CONDUCTIVITY 0-100mS at $\pm 1\text{mS}$

Record No. 771

SINGLE DETERMINAND

AMMONIUM

Manufacturer: DMP ELECTRONICS LTD 0840 213838

Supplier: PHOX SYSTEMS LTD 0462 817070

Model: Probe Type 1824

Usage : COMPONENT

Method: ION-SELECTIVE

Range:

1 - 150 mg/l at 1 %

Output: ANALOGUE

Notes :

Ammonium probe (combination of a ref and specific ion electrode)

Current consumption: 30 mA for 10 secs/reading

Signal type: EMF generated by cell

Constructed from black delrin and grey PVC

Probe is fully sealed and capable of 2m immersion

Fitted with 3m length cable

Designed to fit standard probe cluster and self cleaning unit

A Kevlar strand in the cable gives a very high breaking strain

AMMONIUM 1 - 150 mg/l at 1 %

Record No. 930

SINGLE DETERMINAND

AMMONIUM

Manufacturer: RADIOMETER LTD 0293 517599

Supplier: as above

Model: F2322NH4

Usage : COMPONENT

Method: ION-SELECTIVE

Range:

10 - 10(-5)M at

Output: ANALOGUE

Notes :

Detection limit: 1.8 ppm.

Activity range: 10 - 10(-5)M.

Temperature range: 0-60C.

PVC membrane sensor type.

AMMONIUM 10 - 10(-5)M

Record No. 1017

SINGLE DETERMINAND

AMMONIUM

Manufacturer: DR LANGE 01049 211 500970

Supplier: ROBIN INSTRUMENTS LTD 0276 26987/8

Model: LP 2 W Usage : FIXED
 Method: OPTICAL - COLOURIMETRY
 Range: - - - - - Output: - VISUAL
 Notes :

Rapid and simple colourimetric analysis using wide range of pre-mixed cuvettes. Programmable for special requirements. Example determinands entered, many more available.

(MULTIPLE)

AMMONIUM
 ALUMINIUM
 CHROMIUM
 COD
 CYANIDE
 FORMALDEHYDE
 NITRATE
 PHOSPHATE

Record No. 1266

SINGLE DETERMINAND AMMONIUM

Manufacturer: DR LANGE 01049 211 500970

Supplier: as above

Model: LASA Aqua

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

0.01-47 mg/l at

Output: VISUAL

Notes :

(MULTIPLE)

ALUMINIUM	0.02-0.5 mg/l
AMMONIUM	0.01-47 mg/l
CADMIUM	0.02-0.3 mg/l
CALCIUM	0.5-10 mg/l
CHLORIDE	1-70 mg/l
CHLORINE	0.05-2 mg/l
CHROMIUM	0.01-1 mg/l
COD	2-10,000 mg/l
COPPER	0.01-8 mg/l
CYANIDE	0.01-0.5 mg/l
FLUORIDE	0.1-1.5 mg/l
IRON	0.1-10 mg/l
LEAD	0.1-2 mg/l
NICKEL	0.01-6 mg/l
NITRATE	0.2-60 mg/l
NITRITE	0.01-2 mg/l
PHENOLS	5-200 mg/l
PHOSPHATE	0.003-30 mg/l
POTASSIUM	8-50 mg/l
SILVER	5-3000 mg/l
SULPHATE	10-150 mg/l
MANGANESE	0.02-5 mg/l

Record No. 1115

SINGLE DETERMINAND AMMONIUM

Manufacturer: BRAN & LUEBBE LTD 0256 842062

Supplier: as above

Model: 90

Usage : FIXED

Method: GAS SENSING (general)

Range:

0-10 mg/l at $\pm 5\%$

Output: VISUAL/ANALOGUE/SERIAL

Notes :

(MULTIPLE)

AMMONIUM	0-10 mg/l at $\pm 5\%$
NITRATE	0-10 mg/l at $\pm 5\%$

PHOSPHATE

0-10 mg/l at $\pm 2\%$

Record No. 1299

SINGLE DETERMINAND

AMMONIUM

Manufacturer: SIEMENS PLESSEY CONTROLS LTD 0202 782000

Supplier: SIEMENS LTD 0932 785691

Model: Sherlock

Usage : TRANSPORTABLE

Method: ELECTROCHEMICAL (general)

Range:

Output: ANALOGUE/SERIAL

Notes :

Bankside version of NRA (Wessex) integrated monitoring system.
Standard parameters plus ammonium. Communications for alarms
and remote interrogation. Autosampling possible at several
points on the river by radio control.

EXTENDED PARAMETERS

AMMONIUM

DISSOLVED OXYGEN

TEMPERATURE

pH

CONDUCTIVITY

TURBIDITY

Record No. 1730

SINGLE DETERMINAND

AMMONIUM

Manufacturer: SIEMENS PLESSEY CONTROLS LTD 0202 782000

Supplier: SIEMENS LTD 0932 785691

Model: Merlin

Usage : TRANSPORTABLE

Method: ELECTROCHEMICAL (general)

Range:

0.1 - 100 mg/l at $\pm 1\%$

Output: ANALOGUE/SERIAL

Notes :

'In-river' version of NRA (Wessex) integrated monitoring system.
Measures standard parameters + ammonium and has communications
for alarms and remote interrogation and autosampling
capabilities at several distant points by radio triggering.

EXTENDED PARAMETERS

pH

0-14 pH at ± 0.05 pH

TURBIDITY

0-14 pH at $\pm 5\%$

DISSOLVED OXYGEN

0-200% at $\pm 1\%$

AMMONIUM

0.1 - 100 mg/l at $\pm 1\%$

TEMPERATURE

-5 to 60C at $\pm 0.1\%$

CONDUCTIVITY

0-100mS at ± 1 mS

Record No. 1255

SINGLE DETERMINAND

AMMONIUM

Manufacturer: CAMLAB LTD 0223 424222

Supplier: as above

Model: Quantofix

Usage : PORTABLE (hand-held)

Method: OPTICAL - COLOURIMETRY

Range:

0-400 mg/l at 6

Output: VISUAL

Notes :

Test sticks for semi-quantitative determinations. Shelf life of
2.5 years. Dip and read method.

(MULTIPLE)

ALUMINIUM

0-500 mg/l at 6

AMMONIUM

0-400 mg/l at 6

COPPER

0-1000 mg/l at 6

IRON

0-1000 mg/l at 6

NICKEL

0-1000 mg/l at 6

NITRATE

0-500 mg/l at 6

NITRITE

0-50 mg/l at 6

uct

POTASSIUM	0-1500 mg/l at 6
SILVER	0-10 g/l at 6
pH	4-8 pH at 6

Record No. 1842

SINGLE DETERMINAND

AMMONIUM

Manufacturer: GRANT/YSI ENVIR. SYSTEMS LTD 0763 260811

Supplier: as above

Model: 3800

Usage : PORTABLE (hand-held)

Method: ELECTROCHEMICAL (general)

Range:

0-100 mg/l at $\pm 15\%$

Output: VISUAL/ANALOGUE/SERIAL

Notes :

NRA 63/9/ST, NRA 63/10/ST.

Key application: water quality assesment. Uses 3815 Sonde.

Robust, flexible data analysis.

EXTENDED PARAMETERS

CONDUCTIVITY	0-100 mS/cm at $\pm 4\%$
DISSOLVED OXYGEN	0-20 mg/l at $\pm 30 \text{ ug/l}$
pH	0-14 pH at ± 0.04
SALINITY	0-50 % at $\pm 2.5\%$
TEMPERATURE	-5 to 50C at $\pm 0.4C$
AMMONIUM	0-100 mg/l at $\pm 15\%$
TURBIDITY	0-1000 NTU at $\pm 1 \text{ NTU}$

Record No. 1580

SINGLE DETERMINAND

PERMANGANATE

Manufacturer: CHEMetrics Inc. 0101 800 356 3072

Supplier: GALGO (UK) LTD 0727 50267/837872

Model: K-7600 series

Usage : TEST KIT

Method: OPTICAL - COLOURIMETRY

Range:

0-60% at

Output: VISUAL

Notes :

3 ranges. Analysis time of 2 minutes.

PERMANGANATE

0-60%