Appendix C-1:
Specifications

Microtox® LX

The Definitive Solution for Rapid Toxicity Testing

MODERN WATER
A Deepverge Company

Microtox® LX

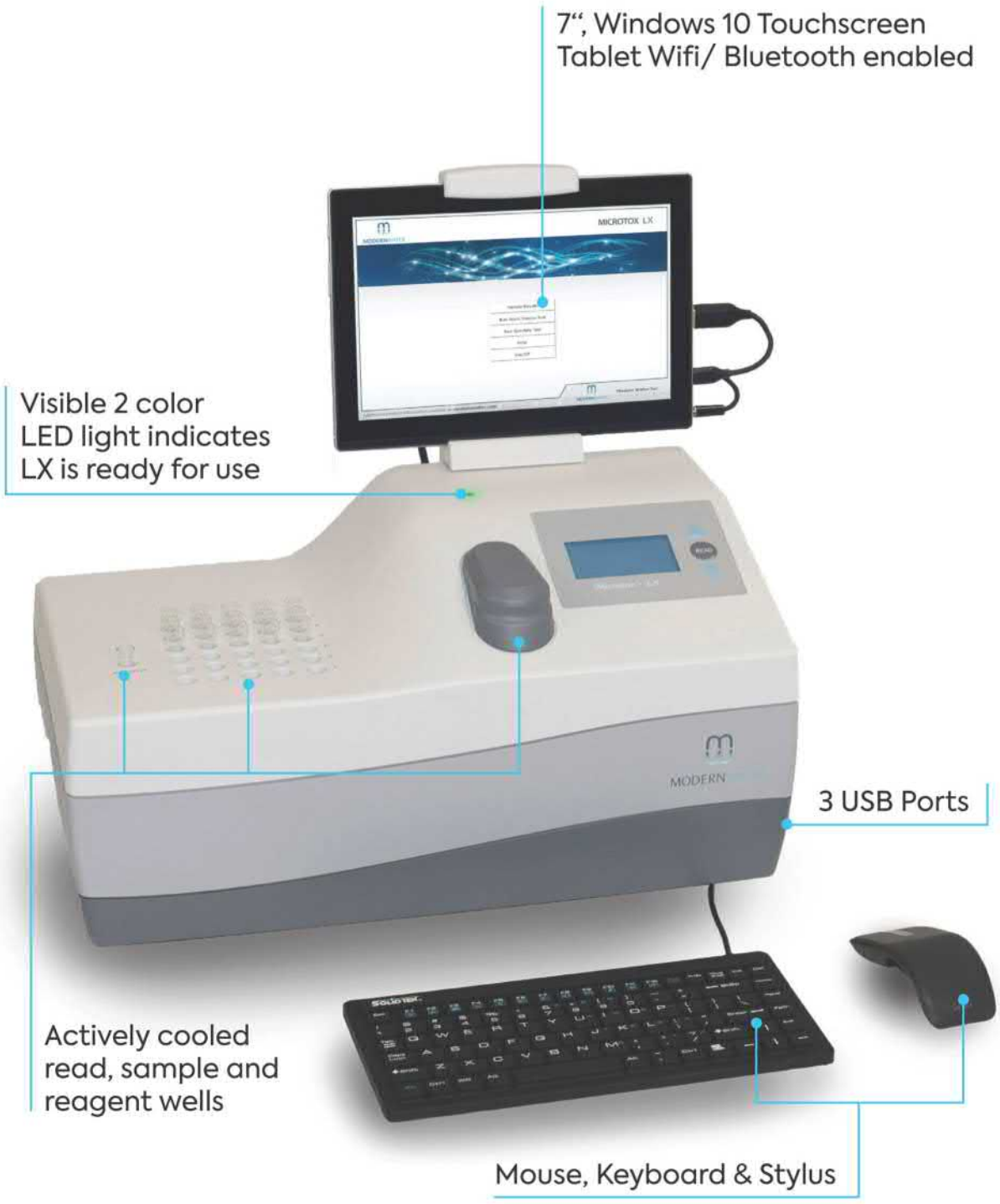
The new **Microtox LX Series** is the next generation of laboratory based acute toxicity analyzer. The new analyzer blends Modern Water's proven M500 technology with improved features to simplify testing in demanding drinking, industrial and wastewater applications.

MICROTOX® LX KEY BENEFITS

- Biological early warning system sensitive to more than 2,700 simple and complex chemicals allows the protection of drinking water supplies from accidental or deliberate contamination.
- Test results highly correlated with other widely accepted toxicity test methods helps to ensure compliance with regulatory and effluent permit standards in wastewater applications.
- Proven – Numerous independent scientific studies have documented Microtox's performance as an effective toxicity screening tool in a wide array of applications.
- Increased Sensitivity – The use of a new proprietary, fully dynamic photo multiplier increases the sensitivity of the instrument.
- Fast, Reliable and Reproducible Results – Results available in as little as 15 minutes after initial sample preparation.
- The instrument's new automatic color correction feature adjusts test results based on the sample's turbidity. This feature can be turned on or off as needed.
- Actively cooled sample and read wells enable more precise and consistent readings.
- Cost effective – A low cost toxicity test that requires small sample volumes.
- Manufactured in a certified ISO 13485 quality system with 100% lot traceability.

For over 30 years, Modern Water's Microtox technology has provided laboratories with proven, cost effective technology to protect drinking water supplies, ensure compliance with regulatory standards and conduct research. The new Microtox LX analyzer builds on the foundation that has made our toxicity product line among the most trusted in the industry.

Product Features



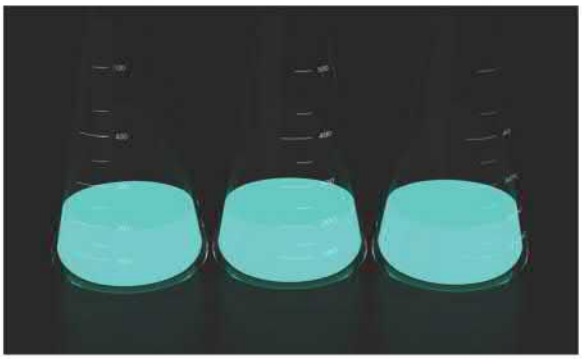
Microtox

How Microtox Technology Delivers Rapid, Highly Accurate Results

Biological monitoring techniques playing an increasingly important role in the evaluation of acute toxicity. Biosensor using bioluminescent bacteria has been in use for over 30 years. Modern Water developed Microtox technology to address limitations of conventional bioassay toxicity analysis. Due to its simplicity, speed, economics, convenience and reproducibility, Microtox has become one of the most recognized bioassays in the world today. Unlike conventional tests that can take up to 96 hours and are subject to manual counting, Microtox can provide results in less than 1 hour.

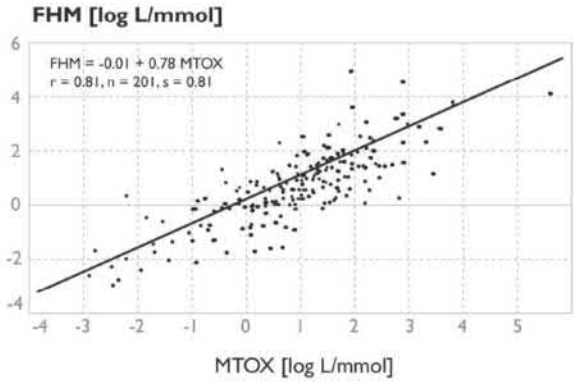
The Microtox system uses a proprietary strain of bioluminescent bacteria, *Aliivibrio fischeri*. Upon exposure to a substance or sample containing toxic materials, changes in the bacteria's light output are measured by the LX instrument's luminometer. The greater the reduction in light emitted by the bacteria, the greater the toxicity of the sample. The photometer used in the LX Series is designed specifically for use with Modern Water's bioluminescent bacteria.

Modern Water produces Microtox reagents using a proprietary manufacturing proces that ensures the *Aliivibrio fischeri* bacteria is highly sensitive. Each test sample is exposed to over 10^6 of Microtox bioluminescent bacteria. The company maintains a rigorous quality control process to ensure the bacteria is highly consistent from lot to lot.



Results Are Highly Correlated with Conventional Bioassay Toxicity Tests

Numerous independent, peer reviewed studies have demonstrated the Microtox toxicity test results have a a high degree of correlation with conventional bioassay tests such as fish, daphnia and shrimp. As a result, waste water treatment plants use Microtox acute toxicity tests to help ensure compliance with water treatment effluent permits, they measure toxicity in influent streams, determine treatment efficiency in industrial and municipal treatment plants and monitor processes from the raw influent to the final effluent.



Correlation of Microtox EC50 with Fathead Minnow LD50 (Kaiser) (r 2 = 0.81) Modern Water maintains an online library of over 700 published studies referencing Microtox technology in a wide variety of applications.

Applications

Drinking Water Plants

- monitor for accidental or deliberate contamination
- provides warning in sufficient time for action
- rapid screening and confirmatory results
- check source water
- check in process water
- check 'finished' water prior to distribution
- check water distribution system

Wastewater Plants

As part of the pre-treatment program, it allows the facility to:

- regulate the amount of pollutants coming into the facility
- maintain smooth operations
- minimize upsets
- maintain good compliance performance
- reduce and control costs and generate revenues by surcharging particularly toxic influent streams

Improve operating efficiency:

- avoid unscheduled shutdowns
- avoid damage/disruption to biological treatment systems
- avoid effluent violations
- avoid increasing chemical costs

Microtox Has Been Used In A Broad Range of Applications In A Diverse Range of Industries;

- drilling fluids and drilling muds
- mining, wastewater, soil and water
- industrial effluents
- industrial process water
- marine water
- medical/pharmaceutical products
- food packaging materials
- personal care and household chemical analysis
- sediments
- storm water runoff
- solid phase materials
- food processing water

Microtox® LX

MICROTOX® LX SPECIFICATIONS

Measurement Method	Bioluminescence
Light Source	Proprietary fully dynamic photomultiplier
Reagents	Genuine Microtox Reagents
Dimensions	18" x 10" x 17" (45.7 cm x 25.4 cm x 43.2 cm)
Bench Space Required	
Weight	20 lbs (~9 kg)
Display	17.8 mm (7 in) color touch screen tablet
Tablet Operating System	Microsoft Windows 10 with Microtox LX Software preloaded
Input	Touchscreen, Mouse, Keyboard, Stylus
Connectivity	USB, Wifi, Bluetooth
Interface	3 ports for USB flash drive, keyboard, mouse or compatible external printer
Temperature	
Room Temperature	15° C to 30° C
Active Cooling Reagent Well	5.5° C+/- 1° C
Active Cooling Incubator Block	15° C +/- 0.5° C
Active Cooling Read Well	15° C +/- 0.5° C
Reagent Operational Temperature	10° C to 28° C
Instrument Operational Humidity	5% to 95% non-condensing
Certifications	CE, IEC 610010-1:2010, IEC 61010-2-010:2014; IEC 61326-1:2103; FCC part 15, Subpart B
Water Ingress	IEC IEC 60529: IPX-O
Power Requirements	Auto-ranging universal AC input 100-240 V AC, 50/60 Hz, 200 watts
ISO Accreditation	ISO 13485 FM 583842

MICROTOX® LX SOFTWARE

Standard Protocols	Basic Toxicity Test
	Comparison Test
	Confirmation Test
	ASTM (D5660)
	DIN (Deutches Institu for Normung 38412 Teil Test)
	Screening Toxicity Test
	SOLO Screening Test
	International Standards Organization (ISO) 11348-3
	Solid Phase/Basic Solid Phase
	WET (Whole Effluent Toxicity)
Custom Protocols	Parameters of standard test protocols can be modified
Quality Control Protocols	Zinc and Phenol
Additional Analysis Capabilities	Trend Monitoring
Color Correction	Optional feature, test results adjusted for variations in water quality
Data Storage	Test results can be stored for future reference or downloaded to a USB drive

MODERN WATER
A Deepverge Company

Microtox FX

The Microtox® FX instrument has a combined detection capability that provides a very sensitive and rapid test to detect two of the most probable classes of agents, pathogens and toxic chemicals that may accidently or intentionally contaminate drinking water or wastewater. Microtox® FX's acute toxicity and ATP detection capabilities make it the ideal instrument for rapidly and accurately assessing if the quality of drinking water, from the source to the tap, has been affected by an incident.

Microtox CTM

The Microtox CTM makes fully automatic, continuous, on-line testing a reality.

It has broad range detection capabilities that provide rapid early warning of contamination by several thousand known chemicals. This enables containment measures to be actioned in time to protect against serious contamination events.

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CHAPTER 13

Microtox* Toxicity Test Systems — Where They Stand Today

Ansar A. Qureshi, Anthony A. Bulich, and Don L. Isenberg

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CONTENTS

I. BACKGROUND

One of the first microbiotests to be commercialized (Bulich 1979) was Beckman Instruments' Microtox system.** It resulted from an industry plea for an acute aquatic toxicity bioassay which would be better than the 96-h fish test as a work-a-day method for measuring and controlling general aquatic toxicity. Beckman's answer to this seemed outrageous to many, at first; what does an instrument have to do with bioassays? The world now knows. Based on bacterial luminescence as it reflects the overall health of the organisms and as measured by a photometer, the Microtox test system gave fast, cost-effective answers to the question — "How toxic is this sample?" Because of the simplicity, speed, economy, convenience, reproducibility, and other virtues of the test, the Microtox test is now one of the most thoroughly characterized and validated aquatic bioassays in

* Microtox® is a registered trademark of AZUR Environmental, Carlsbad, California.
** The rights to the Microtox patents, trademarks, and technology were purchased from Beckman in 1985 by Microbics Corporation, which in 1996 changed its name to AZUR Environmental.

0-8493-2626/5/98/$0.00+$.50

the world today, engendering more than 500 publications which testify to its place in the arena of toxicity testing.

This chapter provides an overview of the development and evolution of the Microtox test and summarizes some of the important findings from the Microtox literature as well as regulatory and standards achievements. The Microtox test, as originally presented, still flourishes and will be the focus of this chapter. However, new procedures, new tests, and new platforms are continually being developed and will also be discussed.

II. GENERAL DESCRIPTION OF THE MICROTOX TEST

The Microtox test is based on measuring changes in the light emitted by a nonpathogenic naturally luminescent marine bacterium (*Vibrio fischeri*,* NRRL B-11117) upon exposure to a toxic substance or sample containing toxic materials. The Microtox test is a short-term acute toxicity bioassay that combines the advantages of a biological test with the speed and ease of use of a laboratory instrument.

The usual expression of sample toxicity measured by the Microtox test is EC_{50}: the effective concentration of a sample that causes a 50% decrease in the light output of the test organisms under controlled experimental conditions (normally after 15 min at 15°C). According to Environment Canada's standard test method (1992), the Microtox results should be reported in terms of an inhibitory concentration (IC) which measures the quantitative reduction in light production by test bacteria relative to control. For practical purposes EC_{50} and IC_{50} are considered synonymous, but in most of the Microtox literature the investigators have used the term EC_{50}. Additionally, the Microtox test results, particularly those of screening tests, can simply be expressed qualitatively as: toxic or nontoxic, positive or negative, and presence or absence of toxicity.

In the Microtox test, like other toxicity bioassays, the relationship between the exposure time and bacterial response (in terms of light production) is dependent on the nature of the specific compound or sample being tested. For example, some samples and chemicals need a longer time to interact with the test organisms, while others react immediately to provide a response within seconds of exposure. Therefore, based on the calculated effect, the Microtox test results can be described as EC_{80}, EC_{50}, EC_{20}, and EC_{10} representing 80, 50, 20, and 10% effects, respectively. Similarly EC_5 and EC_1 could be used to represent the lowest observed effect concentration (LOEC). Furthermore, based on the exposure time, the Microtox test results may also be expressed as EC_{50} (5), EC_{50} (15), EC_{20} (5), and EC_{20} (15) to indicate 50 and 20% effects after 5 and 15 min exposure of a sample to the test organism.

The Microtox test can be extended to 30 or 60 minutes to allow the determination of effects of slightly longer exposure to a specific chemical or particular sample. In practice, however, for many chemicals and samples no significant differences have been observed between the 5 and 30 min EC_{50} values. Alternatively, Qureshi et al. (1984), while studying the toxicity of various metallic ions, observed that EC_{50} values decreased substantially up to 15 min with little change occurring between 15 and 30 min exposure. *Based on their results, Qureshi* et al. *(1984) recommended the 15 min EC_{50} as the standard for toxicity testing and assessment of all chemicals, effluents, and natural samples.* Although in the literature both the EC_{50} (5) and EC_{50} (15) data have been provided by various investigators, the use of the EC_{50} (15) endpoint has been widely accepted and now applied as a standard (norm) for expressing the results of Microtox testing. Also with respect to Microtox data interpretation, it should be noted that (similar to other toxicity bioassays) high values (e.g., EC_{50} of 70%) would indicate lower toxicity, and inversely, low values (e.g., EC_{50} of 12%) are indicative of high toxicity.

* Originally identified as *Photobacterium phosphoreum*, it has recently been classified as a strain of *Vibrio fischeri*. Deposit with the Northern Regional Research Laboratory (NRRL), Peoria, IL, makes the strain freely available, making classification somewhat academic.

The Microtox test is a simple, rapid, reproducible, sensitive, practical, and cost-effective bioassay. It has been extensively used worldwide for over 18 years for toxicity screening of chemicals and effluents, water quality and sediment contamination surveys, and environmental risk assessment. More specifically the Microtox test has been effectively used in the toxicity monitoring and assessment of complex industrial effluents, domestic wastewaters, sewage and sludges, lake and river waters, agricultural and storm water runoffs, leachates, and aqueous extracts of contaminated soils and sediments, groundwater, drilling muds and sump fluids, diverse industrial inorganic and organic chemicals, herbicides, pesticides, mycotoxins, landfill leachates and mixtures of contaminants and chemicals (Bulich 1979, 1982; Bulich et al., 1981; Curtis et al., 1982; Qureshi et al., 1982; Yates and Porter, 1982; Plotkin and Ram, 1984; Liu and Dutka, 1984; Strosher, 1984; Bitton and Dutka, 1986; Ribo and Kaiser, 1987; Blaise et al., 1988; Kaiser and Ribo, 1988; Kaiser et al., 1988; E.V.S. Consultant, 1989; Mazidji et al., 1990; Blaise, 1991; Hankenson and Schaeffer, 1991; Kaiser and Palabrica, 1991; Richardson, 1993; Bengtsson and Triet, 1994; Galli et al., 1994; Gaggi et al., 1995; Cook and Wells, 1996; Gosh et al., 1996; Newman and McClosky, 1996; McClosky et al., 1996).

The Microtox test has also been used extensively to produce toxicity data for the prediction assessment, and relationships of chemicals (through computer modeling) based on quantitative structure–activity relationships (QSAR) (Kaiser and Ribo, 1985; Kaiser et al., 1984, 1987; Kaiser, 1993; Zhao et al., 1993; Shultz and Cronin, 1997). Also, it is a useful predictor of the outcomes of other bioassays, chemical testing, and process changes. The study of potential interactions of combinations of toxic substances generally present in industrial effluents would not be feasible with the fish acute lethality test, but could be conducted using the Microtox assay (Michaud et al., 1990). In fact, Qureshi et al. (1984) examined toxicity patterns of binary metal mixtures and found that various combinations of metallic ions exhibited a variety of synergistic, additive, and antagonistic responses with the Microtox test.

III. STANDARDIZATION OF MICROTOX METHODS

The Microtox test is performed by reconstituting freeze-dried reagent (containing about 10^8 bacteria/vial) and determining the initial light emission (before the addition of test sample) of homogenized and stabilized luminescent bacterial suspensions. Appropriate aliquots of osmotically adjusted sample dilutions are then added to bacterial suspensions, and light output measurements are made at specific intervals (mostly 5 and 15 min, or perhaps after 30 min for slow-acting toxicants). The light readings are corrected according to change in the dilution control (blank) to allow for natural time-dependent drifts in light output and small dilution effects. The EC_{50} and other desirable endpoints are calculated by log-linear plotting of sample concentration (dose) versus percent light decrease (response) or more precisely by log-log plotting of gamma versus concentration (Johnson et al., 1974). In practice, the gamma (which is the corrected ratio of the amount of light lost to the amount remaining) and corresponding EC_{50} values are calculated using various computer programs and data reduction systems.

The Microtox test procedures were described by Bulich and co-workers (1979, 1980, 1981, 1982) and were detailed in the original Operating Manual (#015-55879). Numerous investigators used these test procedures for toxicity assessment of diverse chemicals, complex effluents, and a wide variety of environmental samples. As a result, within a short period of time, extensive Microtox data became available in the published literature, and some in unpublished work. Unfortunately, considerable variation and discrepancy were observed in the EC_{50} values of various toxicants reported by different investigators. Qureshi et al. (1984) and Greene et al. (1985) initially defined the assessment of factors which could introduce variability in the early Microtox data. These factors include: (1) use of different compounds/formulations of specific toxicants; (2) different endpoints and exposure time (i.e., 5, 10, 15, 20, or 30 min); (3) methods used in measuring/determining

Table 13.1 Major Sources of Standardized Methods for the Microtox Bioassay

1. Microtox Assay Procedure, Part 3, Section 2. *Microbiological Methods Manual.* AECV90-M2. A.A. Qureshi (Ed.) 1990. Alberta Environmental Centre, Vegreville, AB.
2. Luminescent Bacteria — Microtox DIN38412-L34, 1991. Deutsche Institute für Normung (DIN) — German Institute for Standardization (Hansen, 1993).
3. Microtox Manual, Vol. 1 to 5. 1992. Microbics Corporation, Carlsbad, CA.
4. Environment Canada (EC) 1992. *Biological Test Method: Toxicity Test Using Luminescent Bacteria (Photobacterium phosphoreum),* EPS1/RM/24.
5. Western Canada Microtox User Committee (WCMUC) *Standard Procedure for Microtox Analysis.* AECV 94-G1. I.D. Gaudet (Ed.) 1994. Alberta Environmental Centre, Vegreville, AB.
6. APHA, AWWA, WEF 1995 *Standard Methods for the Examination of Water and Wastewater,* Part 8050 Bacterial Luminescence.
7. ASTM 1995 *Standard Test Method for Assessing the Microbial Detoxification of Chemically Contaminated Water and Soil Using a Toxicity Test with a Luminescent Marine Bacterium.* D-5660-95.
8. Microtox Bioassay, Test Requirements and Specifications, Appendix 4. Guide 50 Drilling Waste Management. 1996. Alberta Energy and Utilities Board (AEUB), Calgary, AB.

toxicant concentrations; (4) operator inaccuracies in diluting and pipetting samples; (5) sample pH and solubility; (6) age of bacterial reagent; (7) salt concentration in osmotic adjustment; (8) test temperature; (9) improper storage and handling of bacterial and other reagents; and (10) dissimilar data reduction and analysis procedures.

Subsequently, various investigators (Qureshi et al., 1984; Vasseur et al., 1984a; Yates and Porter, 1984; Greene et al., 1985; Ribo and Kaiser, 1987; Ghosh and Doctor, 1992; Carlson-Ekvall and Morrison, 1995) critically studied and evaluated the test methods, procedures, conditions, and various physical and chemical factors influencing the Microtox data and results. Based on the findings and recommendations of these investigators, several initiatives were undertaken by various agencies and groups to develop standardized Microtox test methods and procedures. After extensive literature reviews, evaluation of various test procedures and variables, and several interlaboratory comparisons, the Microtox test methods have been standardized in both the U.S. and Canada, as well as internationally. As a result, the Microtox test has been accepted and adopted for toxicity testing in many countries. The standard Microtox procedures are available in the open literature and also from organizations that have developed the standardized methodologies. Some of the major sources of standardized methods for conducting Microtox toxicity testing are summarized in Table 13.1.

It should be emphasized that, while the standardized Microtox methods from various sources have many common elements and procedures, they differ somewhat from each other in scope, content, experimental setup, protocol types, and test results applications. Nevertheless, the use of standardized Microtox methods and procedures has improved test precision.

As a positive outcome of the test methods standardization, there is now a general agreement on the types of Microtox protocols that can be used for toxicity assessment of chemicals, wastes, and environmental samples. The selection of the appropriate procedure depends, among other factors, on the type and physical characteristics of the sample, relative toxicity of the sample, information needed according to testing objectives, and intended application of the results. Some of the standardized Microtox protocols are: 1) screening test (2, 32, and 90% concentrations); 2) basic test (45% concentration); 3) basic test (82% concentration); 4) 100% test (90% concentration); 5) inhibition test (90% concentration); and 6) comparison test (82% concentration).

Specific details for all of these Microtox protocols may be found in the Microtox Manual (Vols. 2 and 3 of AZUR Environmental) as well as the listed sources and documents of standardized methods summarized in Table 13.1.

The precision, sensitivity and general robustness of the Microtox system has led to the incorporation of variations of the basic Microtox test into several written standards and governmental regulations. The initial work of Casseri et al. (1983) was the basis for the first request for a consensus standard for the Microtox test, which eventually resulted in ASTM Standard D-5660 (ASTM, 1995). Over the years, many standards and regulations have been finalized or are now in process, which are based upon the Microtox acute test method. These are summarized in Table 13.2.

Table 13.2 Microtox Status — Regulations and Standards

Organization	Application	Status
Deutsches Institut für Normung — Germany	Effluent testing	Standard 9/91
Sverige Natur Verkar — Sweden	Effluent testing	Issued 4/90
Netherlands Normalization Institut — Netherlands	Effluent testing	Final 6/93
Inter-governmental Aquatic Toxicity Group — Canada	Effluent testing	Final 1/92
Energy Resources Conservation Board — Canada*	Drilling waste testing	Guide 6/93
International Standards Organization-International	Effluent testing	In Process TC 147/SC
Environment Agency — UK	Effluent testing	In Process
L'Association Francaise de Normalisation — France	Effluent testing	Standard 8/91
National Government Laboratory and Research Institute — Italy	Effluent testing	In Process
Environmental Protection Agency — Spain	Soil leachates	Standard 1991
Environmental Protection Agency — Mexico	Wastewater	Standard 10/96 Sedesol
United States Public Health Service	Wastewater	Issued 10/95 Standard Methods #8050
American Society for Testing and Materials — US	Wastewater	Issued 2/96 D-5660
American Society for Testing and Materials — US	Sediments	In Process E47.01
American Society for Testing and Materials — US	Sediments	In Process E47.03
United States Environmental Protection Agency	Effluent testing	In Process

* Guide 50 Drilling Waste Management (10/96), Alberta Energy and Utilities Board — Canada.

IV. ADVANTAGES OF THE MICROTOX TEST

Of the many different microbiotests, the Microtox test has been most widely used worldwide for toxicity screening and assessment of chemicals, wastes, leachates, effluents, and diverse environmental samples. Many researchers and investigators favor the use of the Microtox test as an effective alternative to fish and other aquatic bioassays for a variety of reasons. Indeed there are many attractive features of the Microtox test which have contributed to its present widespread utility. Major advantages of the Microtox test are listed in Table 13.3.

V. PRECISION OF THE MICROTOX TEST

The precision of the Microtox test has been addressed in many studies. Results of such studies, involving both the inter- and intralaboratory trials, demonstrated excellent reproducibility (between-lab precision) and repeatability (within-lab precision) of the Microtox test. There seems to be a broad consensus from numerous studies reporting the Microtox test coefficients of variation (CV) between 10 and 20%.

The precision of the Microtox assay was evaluated in an exhaustive study conducted by the Canadian Petroleum Association (Strosher 1984) which involved the testing of 29 waste drilling fluids by three laboratories. The average CV for EC_{50} (5) and EC_{50} (15) values were 11 and 13%, respectively, with a maximum of 31% for both endpoints. As a comparison, in the same study, the results of fish bioassays from the three laboratories showed a maximum CV of 98% with a mean of 30%.

Another study by Casseri et al. (1983) found the Microtox data to be very reproducible (with CVs between 5 and 10%) not only for duplicated tests, but also for testing conducted at different times on split samples of effluents. Also, Vasseur et al. (1984a) reported CVs ranging from 3 to 20% (with an average of 12%) based on the Microtox testing of 39 effluents. Curtis et al. (1982) examined 68 chemicals for toxicity assessment using the Microtox test. Based on duplicate tests of seven of these chemicals, they found that overall replicates deviated from the EC_{50} (5) values by only 10%. In a similar study involving pure compounds, De Zwart and Slooff (1983) reported a CV of 10% for their Microtox reproducibility data. Vasseur et al. (1984b) reported the average CV of 27.6% for all EC_{50} values obtained from triplicate testing of 55 different water samples.

Table 13.3 Major Advantages of the Microtox Test

- Easy to use and convenient
- Simple, fast, and practical
- Highly sensitive, reliable, and reproducible
- Precise and accurate data/information
- High degree of standardization
- Excellent quality control
- Suitable for interlab round robins
- Economical (low cost/test, labor saving)
- Time/Cost-effective
- Fast turn-around time; results in two hours or less
- Instant test capability (lab testing or field studies)
- Ease of test reagent availability and storage
- Bacterial reagent availability, consistency, and stability (long term use)
- Excellent correlation with common acute toxicity tests
- Applicable to testing of solid and liquid samples
- Applicable to testing of highly turbid and colored samples
- Statistical advantage in using large number (10^5) of test organisms
- Allows screening of large number of samples in relatively short time
- Requires small sample volumes (2.0 mL)
- Requires little lab space (<10 sq. ft.)
- Does not require elaborate lab facilities
- Specialized expertise/skilled manpower not essential
- Suitable for compliance monitoring/new product testing
- Ecologically and environmentally relevant
- Applicable and practical for regulatory testing
- Suitable for toxicity identification evaluation (TIE) and toxicity reduction evaluation (TRE) studies
- One test for many applications

Walker (1988) reviewed the Microtox data for phenol from eight different laboratories and found that the $EC_{50}(5)$ values ranged from 22.0 to 40.2 mg/L with a mean of 26.2 ± 6.3 mg/L. The CV of 21.8% was highly acceptable considering the large number of tests and diversity of laboratories involved.

One of the most comprehensive Microtox interlaboratory studies was conducted by Qureshi et al. (1987, 1990) to evaluate data reproducibility and variability. The study involved 18 laboratories in four round robins, during which five blind samples of the same toxicants were tested using the same bacterial reagent belonging to two different lots. Based on the pooled data of four round robins, 87 (96.7%) of the 90 test EC_{50} (15) values (18 labs × 5 samples) were within X ± 2 S.D. limits, indicating excellent data reproducibility between laboratories. The CV for the pooled data set ranged from 14.29 to 18.57, while the overall CV (regardless of sample) was 17.8%. These results further demonstrated excellent precision of the Microtox data produced by a very large number (18) of diverse laboratories.

With respect to the Microtox test repeatability (within-laboratory precision), many of the laboratories involved in Microtox testing now use zinc sulfate (as the reference toxicant) to produce internal quality control (QC) data and also to evaluate variability among different batches of the bacterial reagent. The EC_{50} (15) data, obtained from replicate analyses, are then used to develop and establish QC charts for monitoring laboratory precision and performance of the Microtox test. Such charts include upper and lower warning limits (UWL, LWL) and upper and lower control limits (UCL, LCL) based respectively on 2± and 3± standard deviations of long-term means.

VI. COMPARISON OF THE MICROTOX TEST SYSTEMS WITH OTHER BIOASSAYS

The Microtox test has been used and compared with other toxicity bioassays in numerous studies during the last several years. In fact, most of the available data on correlations between

Table 13.4 Summary of Microtox Correlation Coefficients with Three Common Acute Toxicity Bioassays

Bioassays	Correlation Coefficient (r)	References
Fathead minnows	0.41, 0.80, 0.80, 0.85, 0.85, 0.85, 0.86, 0.90, 0.91, 1.00	Chang et al., 1981; Lebsack et al., 1981; Curtis et al., 1982; Indorato et al., 1984; Kaiser and Esterby, 1991; Isenberg, 1993.
Rainbow trout	0.74, 0.81, 0.84, 0.85, 0.89	Lebsack et al., 1981; Ribo and Kaiser, 1983; Strosher et al., 1984; Kaiser and Esterby, 1991; Isenberg, 1993.
Daphnids	0.80, 0.85, 0.85, 0.85, 0.85 0.85, 0.86, 0.87	Ribo and Kaiser, 1983; Kaiser and Esterby, 1991; Isenberg, 1993.

microbiotests and other aquatic toxicity bioassays deal with the Microtox test. Most of these comparative investigations, from laboratories around the world, have evaluated and quantitated the relative sensitivity and correlations of the Microtox test toward pure chemicals (both organic and inorganic), industrial and municipal effluents, and diverse and complex environmental samples.

The Microtox comparative studies have involved the use of over 50 different test organisms, species, and systems, but have focused mainly on the three most common acute lethality bioassays, i.e., rainbow trout, fathead minnow, and daphnids. To date, the sensitivity of the Microtox test has been quantified for over 1300 individual compounds (Kaiser and Palabrica, 1991).

While conducting comparative studies, most of the investigators elected to compare results of various bioassays (involving diverse test organisms) using correlation coefficients (r). In some cases they reported results in terms of percent agreement using various assessment and classification systems (e.g., the log units ranking system used by Bulich, 1982). Various other authors summarized LC_{50} and EC_{50} data but did not quantitate the correlations and instead made general comments about data comparability.

A description of all studies which have compared the Microtox test with at least one other acute toxicity bioassay is exhaustive and certainly outside the scope of this chapter. For additional detailed information and to appreciate the quality and breadth of Microtox comparative data, interested readers are directed to consult many excellent reviews and articles available in the literature. Several relevant publications and specific papers include: Bulich et al., 1981; Chang et al., 1981; Dutka and Kwan, 1981, 1982, 1984; Lebsack et al., 1981; Curtis et al., 1982; Qureshi et al., 1982; Casseri et al., 1983; DeZwart and Sloof, 1983; Dutka et al., 1983; McFeters et al., 1983; Ribo and Kaiser, 1983; Sloof et al., 1983; Liu and Dutka, 1984; Strosher et al., 1984; Vasseur et al., 1984a; Coleman and Qureshi, 1985; Greene et al., 1985; Blaise et al., 1988; Elnabarawy et al., 1988; E.V.S. Consultant, 1989; Blaise, 1991; Kaiser and Esterby, 1991; Kaiser and Palabrica, 1991; Munkittrick et al., 1991; Fort, 1992; Richardson, 1993; Kwan and Dutka, 1995; Toussaint et al., 1995; and Vismara et al., 1996.

Results of comparative studies and correlations between various toxicity tests must be interpreted carefully because a perfect correlation is neither desirable nor necessarily the optimum case. Instead, a clear evidence of colinearity, short of complete equivalency, is important. Such a result would demonstrate that any given two tests have certain general similarities (i.e., they both measure and indicate toxicity), but that each also has its own particular characteristics (i.e., high sensitivity to certain groups of compounds and low sensitivity to other types of samples). In the context of correlations, Table 13.4 summarizes the correlation coefficients (r) of Microtox results with three other common acute toxicity bioassays as obtained in two dozen independent investigations (Isenberg, 1993). The r values ranged from 0.41 to 1.00, 0.80 to 0.87, and 0.74 to 0.89 for fathead

minnows, daphnids, and rainbow trout bioassays, respectively. The average correlation of 85% (r = 0.85) appears to be as good as for any interspecies correlation and demonstrates the same or increased sensitivity range for the Microtox test as obtained with other traditional toxicity bioassays.

While correlation coefficients give an indication of the degree of similarity of two parallel sets of results, they provide no information on relative sensitivity of two toxicity tests. The Microtox test has been found to be too sensitive by some investigators, not sensitive enough by others, but sufficiently sensitive by most investigators. The level of sensitivity can become a legitimate concern in a threshold detection test (e.g., rainbow trout), where a simple yes or no answer is often sufficient. Microtox, however, is a quantitative test in which each use determines baseline toxicity limits to serve the needs and objectives of specific applications. Regarding the sensitivity issue, as pointed out by Isenberg (1993), "too sensitive" had less to do with the Microtox technology than with politics.

In general, the data sets of bioassay comparative studies invariably show Microtox as being more sensitive to certain groups of chemicals and less or equally sensitive to others. It appears that the Microtox reagent demonstrates increased sensitivity to some organic chemicals because they can cross cell walls of bacteria easily and rapidly, while with other compounds (like metals) somewhat decreased sensitivity is observed because of the presence of salt in the test medium (Hinwood and McCormick, 1987). Irrespective of the type of toxicant, however, the results of most of the comparative studies indicated that the relative (average) sensitivity of the Microtox test is well within the same order of magnitude as the sensitivity of other toxicity bioassays. In this regard, it should be emphasized that Microtox EC_{50} values were used in most of these sensitivity comparisons. The degree of Microtox sensitivity can easily be increased by selecting another endpoint. For example, if chosen, the EC_{20} values will be 2.5 times more sensitive than the EC_{50} data. Also, such a selection of more sensitive endpoints is possible with the Microtox assay, because it is a quantitative and functional test which involves measuring the integrated response of approximately one million individual bacterial cells during each experimental unit exposure (Ross, 1993).

In an excellent review, Munkittrick et al. (1991) compared the relative sensitivity of Microtox to daphnids, rainbow trout, and fathead minnow acute lethality bioassays for the toxicity assessment of various chemical compounds, complex effluents, sediments, and other environmental samples. The study results suggested that despite considerable differences and variability in the relative sensitivity of the Microtox assay and the other three acute lethality bioassays, the Microtox test appears to be the best available choice for rapid screening and assessment (presence or absence) of toxicity of diverse environmental samples, pure compounds, and complex effluents.

VII. USES AND APPLICATIONS OF THE MICROTOX TEST SYSTEM

Since the development of the Microtox test in 1979 (Bulich, 1979), microbiologists, ecologists, biologists, ecotoxicologists, regulators, and other investigators worldwide have used it extensively for toxicity assessment of chemicals, wastewaters, industrial effluents, and a wide variety of environmental samples. The Microtox test system has also been used in water quality monitoring, soil extract testing, contaminated sediment, or site surveys and environmental impact and risk assessment studies (Matthews et al., 1987; Symons et al., 1988; U.S. EPA, 1989; Loehr, 1989; Giesy et al., 1989; Dombroski et al., 1996).

In industrial applications, the Microtox test has been proved to be a useful predictor of the outcome of other bioassays, chemical testing, and process changes. Microtox could also be used effectively as a screening test for the monitoring and testing of large numbers of samples in a very cost-effective manner, or as an early warning system (EWS) to detect the presence of toxic materials in the aquatic environment before they can cause adverse effects (Coleman and Qureshi, 1985). The EWS applications may include the detection of abruptly increased concentrations of toxicants in effluents, process change impacts, waste spills, and for the monitoring of wastewater and

Table 13.5 Applications and Uses of the Microtox Test

- Rapid toxicity screening of complex effluents and receiving waters
- Influent monitoring and biomass protection in water and wastewater treatment plants
- Toxicity testing of sewage, sludges, and contaminated soils and sediments
- Toxicity monitoring and evaluation of agricultural, storm water, and combined sewer runoffs
- Toxicity assessment of groundwater, surface waters, and drinking waters
- Toxicity screening of inorganics and organic chemicals individually and based on quantitative structure-activity relationships (QSAR)
- Prediction of other bioassay results and process changes
- Determining the toxicity of potentially hazardous wastes
- Screening and testing of diverse environmental samples
- Toxicity screening of septage and landfill leachates
- Monitoring efficiency and effectiveness of drinking water treatment operations and systems
- Detection and prediction of ocular irritancy in substances and products designed for industrial, pharmaceutical, and cosmetic uses
- Environmental effects monitoring (EEM)
- Regulatory decision-making and compliance monitoring
- Toxicity screening of drilling muds and additives and sump waste fluids
- Detection and control of toxic trade effluents and spillages
- Identification and prioritization of effluents and discharges for toxicity-based control
- Comparison and correlations with other traditional and nontraditional toxicity bioassays
- Ecotoxicological monitoring and testing
- Toxicity identification evaluation (TIE) and toxicity reduction evaluation (TRE) studies and investigations
- Toxicity assessment of fossil fuel process waters and phenolic constituents
- Toxicity testing of biocides, pesticides, herbicides, and bactericides
- Industrial waste streams and process control monitoring
- Quality control monitoring of raw materials and new chemicals and formulations
- Determining toxicity of plasticizers, stabilizers, antioxidants, and surfactants
- Toxicity screening of mycotoxins and biological toxins
- Provision of marine toxicity data for offshore chemical control schemes
- Toxicity testing of wastewater and effluents from plastics, resins, wood, pulp and paper, textile, and leather industrial sectors
- Determining and assessing synergistic, additive, and antagonistic effects of metal mixtures and other toxicants present in aquatic environments
- Toxicity detection of wastewaters associated with oil refinery and petroleum industry
- Biological effects monitoring of air and pollutants in livestock operations
- Bioreactivity and safety evaluation and assessment of biomaterials
- Research and developmental studies in diverse areas
- Evaluation and assessment of genotoxicity and chronic toxicity

industrial plant influents and source waters for drinking water supplies. The Microtox technology has also been applied to nonenvironmental uses such as an *in vitro* alternative to animal testing (Bulich et al., 1989).

The multiplicity of uses and applications have resulted in the production of voluminous literature on the Microtox test comprising over 500 publications. For details and specific information on particular applications, readers are directed to many of the references cited in Section II. Some of the major uses and applications of the Microtox test are listed in Table 13.5. The variety of samples that have been analyzed by the Microtox systems is not only unique, but cannot be matched by any other toxicity bioassay.

VIII. NEW DEVELOPMENTS BASED ON LUMINESCENT BACTERIA

The use of light as a biological endpoint offers many advantages, as demonstrated by the success of the Microtox acute bioassay. Over the years many additional Microtox bioassays and specialized systems have been developed to take advantage of this unique attribute of luminescent bacteria. This section will briefly describe some of these new and exciting developments.

Methods have been provided for adapting the Microtox system to direct contact measurement of toxicity of soils, sediments, and sludges. The procedures avoid the necessity of using solvent extraction or the use of pore water, although these practices are not incompatible with the Microtox test and are still used for specific situations and applications. The Microtox Solid-Phase Tests (SPT) provide direct contact between test organisms and sample particles, increasing the probability for the measurement of the responses to particle bound and marginally soluble toxicants. Although care must be taken in interpreting results of the Microtox Solid-Phase test because of possible nonspecific interferences, a procedure is provided for correcting results to minimize these potential nonspecific factors. This procedure uses a presumed nontoxic sample of soil or sediment, with characteristics similar to the unknown sample, for the correction. In fact such a correction is only necessary for samples having marginal toxicity. Additionally the Microtox SPT has been found to be useful for toxicity assessment of contaminated sediments (Kwan and Dutka, 1995; Day et al., 1995; Cook and Wells, 1996).

Another major development was the Mutatox®* genotoxicity test system. This bioassay is designed to detect the effect of DNA-damaging agents by measuring the light output of a specially selected dark variant of *Photobacterium leiognathi* (Ulitzur, 1986). When these organisms are grown in appropriate sample concentrations, they begin to produce light in proportion to the presence of genotoxicity after an incubation period of 16 to 24 hours. The test may be performed with and without S-9 activation. The Mutatox test has been used and compared with other assays for genotoxicity screening (Kwan et al., 1990; Legault et al., 1994; Jarvis et al., 1996).

With currently increasing concern over chronic toxicity, the Microtox Chronic Toxicity Test (Bulich et al., 1996) offers sensitivity comparable to the popular *Ceriodaphnia* chronic test over a wide range of toxicants, with better precision and faster results. The Microtox chronic test is a 22-h growth inhibition/light induction assay, with light output once again being the endpoint. Software is provided for calculating the lowest observed effect concentration (LOEC) and the highest no observed effect concentration (NOEC).

In addition to these new tests the Microtox family of instrumental platforms is increasing. The original photometer included in the Microtox system introduced in 1979, the Model 2055, was a benchtop, research-oriented instrument. In 1988, the Microtox Model 500 was introduced as a more dedicated and simpler-to-operate instrument with more throughput capacity. The methods and protocols mentioned above were designed to be compatible and work with both instruments.

The first departure from benchtop-oriented systems resulted from a joint development between the Microbics Corporation and Compagnie Générale des Eaux (a major French water company). The system has been in use since 1990 for continuous, on-line, unattended monitoring of surface waters for the purpose of protecting drinking water sources. The systems are monitored and controlled by remote access. More recently a joint development between AZUR Environmental, Seimens Environmental plc, and Yorkshire Water plc (a major U.K. water company) was announced that would extend the same on-line capability to monitoring influents and effluents to and from water and sewage treatment plants, as well as in-plant process control. This system, the Microtox®-OS On-line System, is currently undergoing beta site testing and is expected to be commercially available in late 1997. The Microtox-OS is designed to sample and test at 15-min intervals and will operate unattended for 14 days.

Finally, a major new capability is the development and introduction of the DeltaTox™** PS1 Test System. It combines a new, field-portable instrument, having an unusually wide photometric dynamic range, with a specially selected strain of *Photobacterium leiognathi*. The focus of this system is onsite toxicity screening and nonregulatory applications for monitoring the quality of influents and wastewaters. It can be easily and conveniently used in remote field environments at ambient (sample) temperatures (10 to 35°C). Its dynamic range and dual function capability make

* Mutatox is a registered trademark of AZUR Environmental.
** DeltaTox is a trademark of AZUR Environmental.

it suitable, not only for toxicity screening, but also for biomass estimation with conventional ATP reagents and methods.

IX. CONCLUSIONS

The Microtox system for acute, aquatic toxicity testing, first introduced in 1979, pioneered commercial availability of microbiotests, and thereby created a new, exciting, and viable market. Its virtues of simplicity, fast results, economy, precision, and flexibility of adapting to specific applications have established a new testing standard. Most of all, the Microtox acute test is generally standardized worldwide and has the largest pure compound database of any aquatic toxicity bioassay. The embodied technology has spawned additional capabilities which extend the utility to other important test systems for measuring the responses of bioreactive substances which routinely invade our precarious ecosystems. It is also evident that the Microtox and other bioluminescence-based assays will continue to be important as an integral component of multispecies and multitrophic level toxicity tests for environmental monitoring, regulations, and ecotoxicological investigations.

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New Product

TD-550/560 OIL IN WATER ANALYZER

Turner Designs Hydrocarbon Instruments is proud to introduce the new standard in grab sample oil in water analysis—the TD-550 and TD-560. The TD-550, which features a greatly enhanced detection range (low ppb to 5000 ppm), is well-suited for crude and other heavy oils. The TD-560 includes the same optical channel found in the TD-550 along with a second channel for detecting lighter hydrocarbons, such as BTEX, gas condensates, gasoline, jet fuel, kerosene, transformer oils, styrene and phenol.

Based on our experience with the highly successful TD-500D and TD-3100, the new TD-550 and TD-560 add many features never before offered on oil in water analyzers, while providing a low-cost and simple solution.

Simple
Accurate
Flexible

FEATURES

- Low cost per sample analysis
- Large full-color touch screen interface
- Advanced data logging and graphing capabilities
- Compatible with all popular extraction solvents and TDHI's No-Solvent Method
- Results can be correlated to official lab methods such as USEPA 1664A and ISO 9377-1

TURNER DESIGNS
Hydrocarbon Instruments

TD-550/560

OIL IN WATER ANALYZER

#1 Worldwide
for process and environmental
oil in water monitors

APPLICATIONS

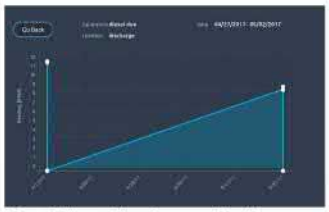
- produced water
- waste water
- steam condensate
- cooling water
- intake protection
- discharge compliance
- oil in soil analysis
- storm water
- treatment verification

ADVANCED INTERFACE

Analyze samples quickly with saved calibration.

Filter data by calibration, location or date.

Select channel, cuvette and extraction ratio.



Graph filtered data from reading history.

SPECIFICATIONS

Common Target Oils	TD-550: crude oil, diesel, lubrication oils and fuel oils TD-560: all oils listed for the TD-550 plus gas condensates, BTEX, gasoline, styrene, phenol, jet fuel, kerosene, heat transfer fluids and hydraulic oils
Detection Range	5 ppb to 5000 ppm (dependent on target oil)
Power	External power supply: 90–240 VAC and 6–8 hours on battery
Data Output	USB and Micro SD card
Calibration	Direct and raw
Display Units	ppm, ppb, mg/l, ug/l, raw
Approvals	CE
Data Logging and Graphing	Stores multiple calibrations and site locations Records each sample analyzed with time stamp, location and results for fast lookup Sort by date, location or calibration

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Hydrocarbon Instruments

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DNV REGISTERED

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Smart Sensor

TD-120

OIL IN WATER MONITOR

Turner Designs Hydrocarbon Instruments has been the world leader in oil in water monitoring for more than 20 years. The TD-120 Oil in Water Monitor was developed based on our extensive real-world experience and offers UV fluorescence technology with industry leading features. The TD-120 is available with either a standard care package or custom care package to match the needs of your site conditions and application. The customer care packages include calibration to known standards or calibration to your target hydrocarbon, using sample analysis—making your installation and start-up process trouble free. The TD-120 is ideal for detection of oil leaks and spills for heat exchangers, boilers, and membrane systems as well as optimization of water treatment systems.

With low detection limits and greatly extended detection range, the TD-120 provides the necessary tools and ease of use to meet today's complex oil in water needs.

Simple Accurate Reliable

FEATURES

- Internal tablet interface for quick setup and calibration
- New auto-valve capabilities: temperature protection, fresh water flush, and process isolation
- Minimal maintenance
- Low cost of ownership—no reagents or instrument air needed for operation
- OEM opportunities

TURNER DESIGNS
Hydrocarbon Instruments

TD-120

OIL IN WATER MONITOR

SPECIFICATIONS

Applications	Steam condensate, boiler feed water, cooling water, intake protection, dam sumps, process optimization
Hydrocarbons	Diesel, fuel oil, crude oil, gasoline, jet fuel, lubricating oils, phenol, heat transfer fluids, aromatic chemicals
Detection Range	Low PPB–6000 PPM (range is dependent on oil solubility in water and background)
Dimensions (Wall Mount)	16" H x 20" W x 5.5" D (406 mm x 508 mm x 140 mm)
Weight	24 lbs (10.9 kg)
Local Color Display	PPM, PPB, or raw signal
Controls	External touch pad for events, history log, and maintenance, with internal tablet for configuration and calibration
Power Requirement	100–240 VAC 50/60 Hz, 1.3 A max 1 phase, neutral or hot (inrush current not to exceed 40 A max)
Communications	4–20 mA isolated, selectable loop or instrument powered Optional: HART
Alarms	4x dry contact user configurable alarms: Early, High, System, Cell Condition, High Temperature
Plumbing Requirements	Feed 1/4" tube, Return 1/4" tube, Flush 1/4" tube
Sample Inlet	10–100 psig (69-690 kPag)—for higher pressures consult factory
Sample Temperature	32–122 °F (0–50 °C)—for higher temperatures consult factory
Ambient Operating Temperature	32–131 °F (0–55 °C)
Flow Rate	Limits: 0.03–0.79 US gallons/min (0.1–3L/min) Recommended: 0.26–0.52 gallons/min (1–2L/min) optional sample pump available
Operational Principle	UV Fluorescence
Response Time	3 seconds default (user adjustable, down to 0.5 seconds), continuous reading
Calibration Stability	+/- 10% over 12 months or better
Certification	EN 61010-1:2010 and EN 61326-1:2013 CAN/CSA-C22.2 No. 61010-1:2012 + UPD No. 1:2015-07

#1 Worldwide

for process and environmental oil in water monitors

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OPTIMIZE YOUR RESULTS. PROTECT OUR ENVIRONMENT.

ONLINE PECOD® ANALYZER
REAL TIME COD, BOD, AND TOC

REAL USER BENEFITS

Green chemistry with no hazardous reagents protects operators and the environment

Save time and money through process optimization

Full autonomous control, operators simply set sampling frequency and press START

INNOVATIVE TECHNIQUE

The patented PeCOD® technology provides a unique nanotechnology-based photoelectochemical technique for determining bulk oxidizability of a sample stream

The strong oxidation power of the Titanium Dioxide photosensor facilitates rapid oxidation of all reactive organic matter, providing results in just 10 minutes!

Online PeCOD Specifications

COD Method	Photocatalytic TiO_2 Oxidation
Measuring Range	0.7 – 15,000 mg/L
Auto-Dilution Capability	Extends range >200,000 mg/L
Time of Analysis	10 – 15 minutes
User Control	Fully Automated via Software
Calibration and QC	Automatic Timed Intervals
Method Precision	≤ ± 5%
Compatible Matrices	Water, Wastewater, Process
Waste Disposal	Non-Hazardous, Drain/Carboy
Organizer Options	Cabinet or Rolling Cart
System Dimensions (Cabinet)	20 x 42 x 60 in 50 x 107 x 153 cm
Enclosure Material	Corrosion-Resistant Steel
Operating Temperature	5 to 40°C
Power Requirements	Standard 100 – 240V AC Outlet
Parameter Add-Ons	pH, EC, Alkalinity and more
Additional Capabilities	Manual/Portable Operation
	4-20mA for SCADA Control
	Multi-Stream Analysis
	Real-Time Alerts

For more information and pricing, contact us at:
519-763-4245
info@mantech-inc.com

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OPTIMIZE YOUR RESULTS. PROTECT OUR ENVIRONMENT.

PeCOD® ANALYZER 10-MINUTE CHEMICAL/BIOCHEMICAL OXYGEN DEMAND (COD/BOD) ANALYSIS

THE WATER QUALITY MONITORING SYSTEM THAT IS MERCURY AND DICHROMATE FREE

MANTECH

The revolutionary PeCOD® Analyzer technology provides Chemical/Biochemical Oxygen Demand results in under 10 minutes in a Simple-Safe-Effective manner.

With our mercury and dichromate free chemistry installed in over 20 countries, the PeCOD® Analyzer has delivered successful test monitoring of COD in a variety of environments with our approved and published MOECC method (E3515).

Through our proprietary testing methods our customers are saving millions of dollars utilizing both process and efficiency improvements in their facilities.

The PeCOD® technology is supporting the health and safety of their operators while also protecting the environment.

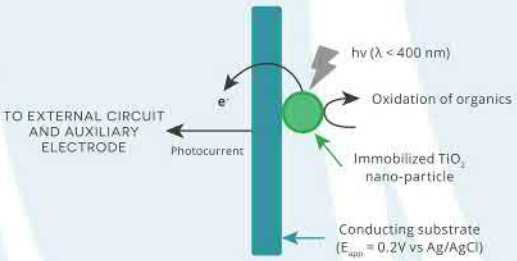

Figure 1: peCOD Nanotechnology
Roughly 2 times the oxidizing power vs. dichromate i.e. Benzene, 1.8 by CODCr and 2.6 by peCOD

PeCOD® ANALYZER SENSOR

The PeCOD® Analyzer offers a unique nanotechnology-based approach to Chemical Oxygen Demand (COD) analysis which overcomes many of the problems encountered by traditional methods.

The PeCOD® Analyzer offers a safe, green chemistry method that can be used by anyone. This eliminates the need for trained analytical chemists on staff or an external lab facility.

MANTECH's portable, online and laboratory PeCOD® Analyzers test thousands of samples every day for a wide variety of applications, including:

- Pulp and paper mills
- Food and beverage producers
- University and college laboratories
- Industrial and municipal wastewater treatment

PeCOD® ANALYZER BENEFITS

Laboratory, portable and online configurations use identical technology and method

Eliminates the use of hazardous chemicals such as Mercury and Dichromate

10 minute test enables faster treatment decisions

Proven strong correlation to BOD5 test

PeCOD® ANALYZER BENEFITS

MANTECH's PeCOD® Analyzer can be configured to accommodate laboratory operations, automated sampling or continuous process monitoring.

LABORATORY MODELS

- Benchtop L50 has a small footprint *(280 x 210 mm, 11.00 x 8.25 in)* and is lightweight *(7 kg, 15 lb)*
- Bottle-top Dispenser provided for fast, simple sample preparation
- Can be upgraded to Automated or Online systems

ONLINE MODELS

- The only online COD analyzer on the market which offers a direct measure of COD
- Save time and money through process optimization with real time COD results
- Additional parameters can be added on, including pH, conductivity, alkalinity, and ammonia

* Delivered model may not be exactly as shown.

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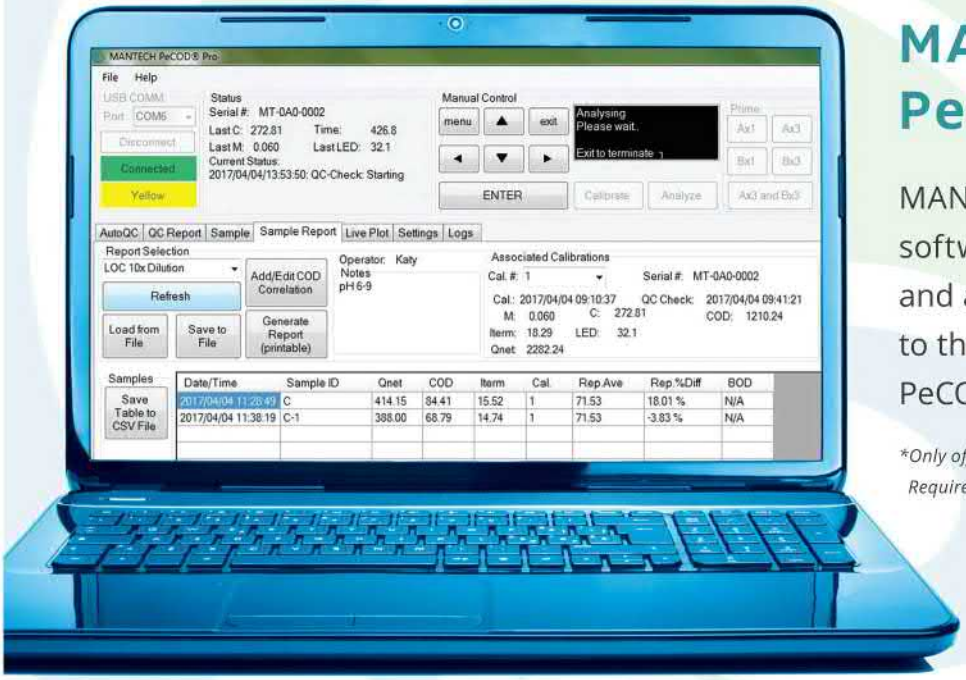
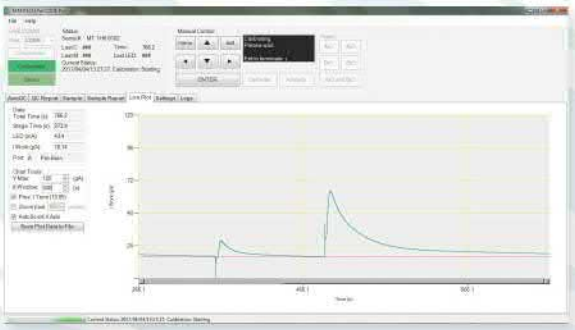


MANTECH PeCOD® PRO

MANTECH's PeCOD® Pro software adds automation and a sleek user interface to the Benchtop L50 PeCOD® Analyzer.

**Only offered with Manual L50. Requires laptop.*



BENEFITS

1. Easy to use interface
2. Unit is ready to analyze samples when the work day begins. Automated calibration and control check can be scheduled ahead of time.
3. Customized sample names and batches
4. Operates two Benchtop L50 units from a single computer

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PeCOD®
Analyzer

✓COD

✓Estimated BOD

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WHO IS MANTECH?

Manufacturer of laboratory, online and portable analyzers for water, wastewater, soil, food and beverage analysis.

*Mission to generate the **highest quality results** in the **shortest amount of time** with the goal of enabling our customers to have significant **positive economic and sustainable impacts** on their businesses and communities.*


TRUSTED & PROVEN GLOBALLY
bp
SGS
eurofins
UNIVERSITY of GUELPH
Environment Canada
PETRONA
Petroliam National Be
>3,000 ANALYZERS
>50 COUNTRIES
>670,000 SAMPLES/DAY
Ontario
Ministry of the Environment
ARAUCO
Growing the Future
sochem
TestAmerica
SOLVAY
asking more from chemistry
Rhodia
kemira
Environmental Protection
Heineken
MANTECH
SLEEMAN
WD Western Digital
BUREAU VERITAS

Chemical/Biochemical Oxygen Demand

- The amount of oxygen required to fully oxidize organic matter
  - A valuable measurement for the determination of water quality in natural waterways and waste streams
- COD By Dichromate Method
  - Uses **hazardous chemicals** (e.g., dichromate, mercury and acid)
  - Analysis time is **3 hours** per batch
- BOD5
  - Involves ***5-day incubation period*** to allow for biological oxidation of organic matter
  - Time consuming and complex

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PeCOD® BOD/COD Analyzer

Safe & Green

- No hazardous chemicals (e.g., mercury, dichromate, etc.)
  - Only salt & sugar
- No PPE required
- Zero risk of cross-contamination

Rapid Results

- Results in **10 minutes or less** vs. 3 hours or 5 days
- Make informed & impactful decisions for process optimization

Reliable & Trusted

- Conforms to MECP method E3515 & ASTM International Method D8084
- Hundreds of analyzers in the market

Accurate

- Detection limit of 0.7mg/L and upper range 15,000mg/L
- Sample dilution allows measurement >200,000mg/L

Easy-to-Use

- Designed for staff unfamiliar with water quality analysis (e.g., operators and engineers)

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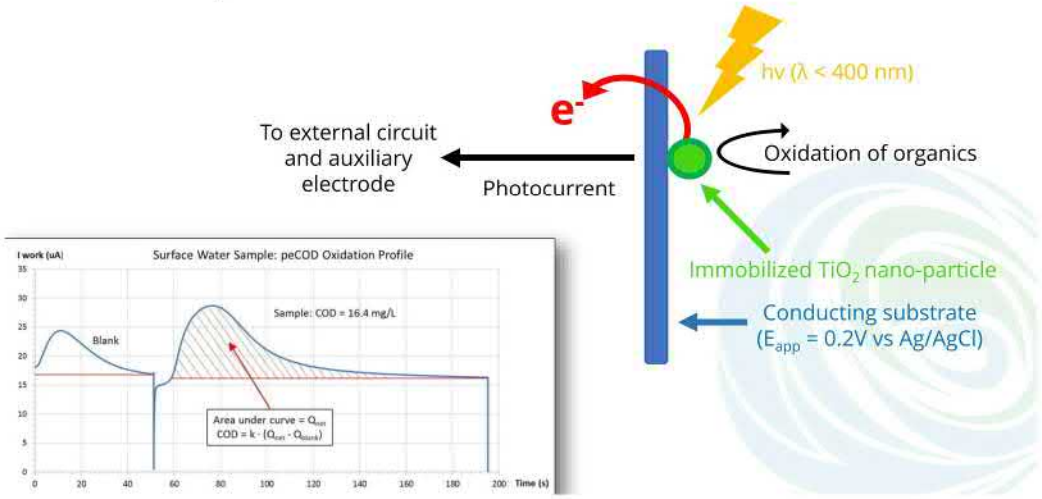
PeCOD® | A Nanotechnology Based Approach



PATENTED TECHNOLOGY

Core technology is the PeCOD® sensor consists of:

- UV-activated nanoparticle TiO2 (titanium dioxide) photocatalyst
- Coupled to an external circuit

Powerful oxidization potential ensures:

- Rapid results – **ONLY 10-minutes!**
- Complete oxidization of virtually all species
- A true measure of COD/BOD

Manufactured at MANTECH-sponsored Lab at University of Waterloo's Institute of Nanotechnology

MANTECH x

PeCOD® Components

1. Port A – for sample and calibration solution
2. Port B – for blank control solution
3. Port W – for waste
4. Analyzer Lid
5. Electrode Block
6. Sensor

Consumable Items:

- Calibrant Solution - COD Standard
- Electrolyte
- Sensors

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OPTIMIZE YOUR RESULTS. PROTECT OUR ENVIRONMENT

Believe it or not...

The most hazardous component being introduced is the sample itself! As PeCOD is treating the sample with an advanced oxidation process (AOP), the sample waste exits cleaner than when it was introduced. Meaning the sample waste can be disposed of down the drain.

Sample Preparation

1. Pour sample in test tube
2. Homogenize sample for 1-2 minutes ***OR*** pre-filter
3. Pre-dilute sample with deionized water (DI), if necessary
4. Use bottle-top dispenser to add electrolyte (salt solution)
5. Stir ***OR*** homogenize to mix sample
6. Press "START"

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OPTIMIZE YOUR RESULTS. PROTECT OUR ENVIRONMENT

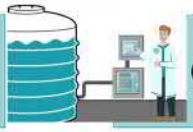
Would you rather add a 1- to 2-minute step to a **safe, simple, and rapid method** or use an **unsafe, hazardous** method and wait **3+ hours** for results?

One Technology, Multiple Configurations

Benchtop

Automated

Portable



Online

Coming 2022

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OPTIMIZE YOUR RESULTS. PROTECT OUR ENVIRONMENT

PeCOD® Applications

Municipal

- Incoming COD monitoring
- Weather events
- Discharge compliance
- Potable water analysis
- Water reuse applications

Industrial

- In-plant COD monitoring
- Process optimization
- Upset prevention
- Discharge compliance
- Fine avoidance

Laboratory

- Rapid COD analysis
- Automated with multi-parameter
- Improved accuracy and detection
- Safety of employees
- Reduction of hazardous waste

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PeCOD® Customer: Industrial Wastewater

Case Study: PeCOD® Optimizes Treatment Operations

Without PeCOD®	With PeCOD®
Results in • 3-6 hours COD incoming • 30 days BOD discharge (monthly billing)	Results in 10-minutes
Uninformed operational decision-making	Operational feedback for optimization
Unknown BOD discharge	Continuous BOD monitoring of discharge

Reduced consumption of raw materials, energy, transportation & sewer discharge costs =

Saved >$500,000 since PeCOD®

THE *ANCHOR* OF THE PLANT!

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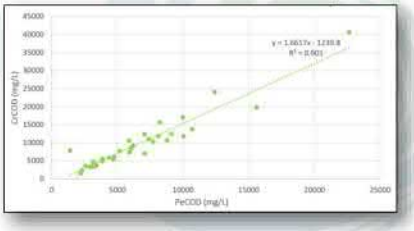
OPTIMIZE YOUR RESULTS. PROTECT OUR ENVIRONMENT

CleanHarbors ENVIRONMENTAL SERVICES®

PeCOD® strong correlation to BOD5 (sometimes stronger than CODCr)



PeCOD® Customer: Municipal Wastewater

Sewer Discharge Compliance

Industrial Account

- Monitor own discharge into sewer
- Avoid fines and/or surcharges

Benchtop & online models are ideal.

City of El Paso, TX

- Monitor industrial discharge into sewer
- Enforce fines and/or surcharges

Benchtop and portable models are ideal.

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