BRITISH WATER

BRITISH WATER GUIDE MONITORING PRODUCTS AND SERVICES 2019

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1 Introduction

This is the 1st edition of British Water's 'Guide to Monitoring Products and Services'. The guide has benefited from consultation and input from designers, manufacturers, practitioners and regulators of environmental and water solutions.

This first edition is intended primarily to be a live web-based publication where information can be provided within the flexibility of an electronic system. It provides detailed descriptions of components, communications systems and a list of monitored parameters, which are available from those British Water members that provide monitoring equipment. This guide aims:

- To provide brief and understandable definitions of products and services, and links to their suppliers.
- To help select the most appropriate technology needed to monitor this parameter for monitoring.
- To provide clients with a list of currently available technologies and services provided by British Water members in the area of water and environmental monitoring.

Please note that British Water, or any company or other organisation associated with this publication do not endorse nor recommend any particular product to which this Technical Guidance provides direct links. The links are provided to enable the reader to be aware of all monitoring parameters and technology available, which may be used for operation and compliance. It is the responsibility of the reader to assess each product and to determine whether it is appropriate for any particular application.

International Organization for Standardization (ISO) defines monitoring as: "the programmed process of sampling, measurement and subsequent recording or signalling, or both, of various water characteristics, often with the aim of assessing conformity to specific objectives". Effective quality monitoring is essential to the efficient operation and maintenance of Waste Water Treatment Works (WwTW). Additionally, the evidence provided by monitoring of flow and quality at WwTW is vital in demonstrating consent compliance.

This guidance publication briefly reviews monitoring and outlines many of the issues, which impact on clean, wastewater and environmental monitoring. It directs the reader to information about monitoring solutions in four principal areas: components; communication systems; services provided; monitoring parameters in water/wastewater; gases and environmental monitoring.

2 Find a Supplier

Each section under Chapter 4 Monitoring components, Chapter 5 Parameters in Water/Wastewater: and Chapter 6. Gases contains an active link to the search pages in the British Water Members Directory for that specific parameter or gas. Where no results are found, it is more likely that members are not able to list every single parameter that they provide sensors or data loggers for, rather than that no member provides sensors / loggers for the given parameter. If in doubt, use the general searches for sensors or loggers in Section 4 and enquire about your monitoring needs with the companies listed.

Still not able to find a supplier? Why not search on BWInnovate for Solutions or post your Need (British Water members only).

3 Applications

3.1 Wastewater (Sewage treatment)

Sewage treatment is the process of removing contaminants from wastewater, primarily from household sewage. Physical, chemical, and biological processes are used to remove contaminants and produce treated wastewater (or treated effluent) that is safer for the environment. A by-product of sewage treatment is usually a semi-solid waste or slurry, called sewage sludge. The sludge has to undergo further treatment before being suitable for disposal or application to land.

Sewage treatment may also be referred to as wastewater treatment. However, the latter is a broader term, which can also refer to industrial wastewater. For most cities, the sewer system will also carry a proportion of industrial effluent to the sewage treatment plant, which has usually received pre-treatment at the factories themselves to reduce the pollutant load. If the sewer system is a combined sewer then it will also carry urban runoff (stormwater) to the sewage treatment plant. Sewage water can travel towards treatment plants via piping and in a flow aided by gravity and pumps.

3.2 Drinking water

Treatment for drinking water production involves the removal of contaminants from raw water to produce water that is pure enough for human consumption without any short or long-term risk of any adverse health effect. Substances that are removed during the process of drinking water treatment include suspended solids, bacteria, algae, viruses, fungi, and minerals such as iron and manganese.

The processes involved in removing the contaminants include physical processes such as settling and filtration, chemical processes such as disinfection and coagulation and biological processes such as slow sand filtration.

Measures taken to ensure water quality not only relate to the treatment of the water, but to its conveyance and distribution after treatment. It is therefore common practice to keep residual disinfectants in the treated water to kill bacteriological contamination during distribution.

World Health Organization (WHO) guidelines are a general set of standards intended to apply where better local standards are not implemented. More rigorous standards apply across Europe, the USA and in most other developed countries.

4 Monitoring components

The main monitoring components are sensors, data collection, data communication, data storage, analytics and visualisation. This guide only includes information related to sensors and control monitoring, data collection and data communication (Fig 1).

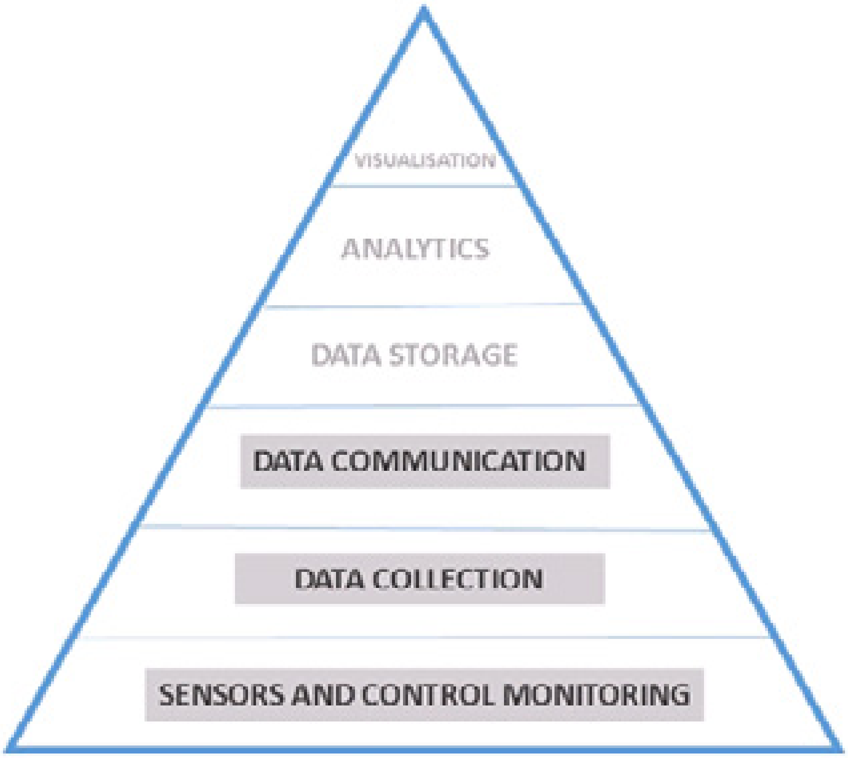

Fig 1: Monitoring components

4.1 Sensors

Sensors detect what is required to be monitored. For example, a turbidity sensor may use light scattering of infrared light to detect/sense the number of suspended particles within a water sample. Though they can sense the parameter, they are of little use without being connected to some form of controlling/configuration unit to allow configuration, log and visualise data, and often transmit that data to a central control system.

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4.2 Data Collection

Data loggers

Data loggers are devices, which record measurement data from one or more sensors. Data loggers are also known as Remote Telemetry Units (RTU). As well as supporting a range of analogue and digital measurements, data loggers can also support a number of instrumentation protocols such as SDI-12 or Modbus.

The measurement data is normally stored along with the time and date of the measurement. Data is then collected via a direct connection to the logger or automatically transmitted periodically. A direct connection will often be a cable connection such as USB or Serial, whereas transmitted data will be sent via mobile communications like GSM (Global System Mobile), 3G or even satellite. Not all data loggers have the ability to transmit their collected data.

Data loggers will vary in speed and complexity and subsequently price. They range from single-channel devices, which may have an incorporated sensor, to multi-channel devices which can acquire data from multiple sensors for extended periods. These devices will often just collect, store and transmit data, but can also be used to raise alarms and perform control functions. Configuration software provides the ability to configure what data is collected, the frequency of collection, frequency of transmission, and the data output format.

Often data loggers are battery powered, as they are deployed in areas where there is no infrastructure available. Many of these devices can be configured to automatically change their measurement of communication frequency to conserve battery power. For example, the sensor sample rate (trend frequency) may need to be increased as the river level increases, so appropriate alarms can be transmitted. When the river level returns to normal levels, the slower sample rate can be resumed.

Data loggers provide the benefit of saving the time and expense of sending someone to a remote site to take measurements, and they enable much higher data density than is achievable through manual recording and providing higher quality consistent data.

Whilst data loggers have traditionally been seen as a device that only stores historic data, they have for many years been able to respond dynamically to the data they collect and transmit data in real time when required. This can be advantageous as they can be used to filter data for alarm purposes rather than having a secondary system to process raw measurement data.

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4.3 Data communication

Transmitters are used both to configure the sensors, receive and visualise data, and to manage the transmission of data from that sensor into a central control system. Generally, transmitters are hard-wired in terms of communication links, although wireless transmitters are becoming more common. Data is transmitted from the unit using protocols such as HART, Profibus, Modbus, Ethernet, or simply using analogue 4-20mA output channels. Within the transmitter, calibration and validation sequences can be operated, data viewed graphically, along with other settings.

Communications are a vital part of any water monitoring system. Getting measurement data back to the point where it is needed can be straightforward, but can often present challenges. This is particularly the case in remote locations where there is no local communications infrastructure present. Often measurements are used for control or alarm purposes, so it is essential that the communications methodology employed is robust enough and has a bandwidth that is suitable for the application.

4.3.1 Mobile technologies: 2G, 3G, 4G and 5G

Many of the current remote applications involve the use of an RTU or data logger. These solutions will typically employ the use of a 2G or 3G modem. The main differences between 2G and 3G is how transmission of data is charged and the speed at which the data can be transmitted. 3G is faster than 2G and is charged by the amount of data transmitted, whereas 2G is normally charged by the length of time taken for data transmission.

2G was launched in 1991 and is no longer available in some countries with most of the remaining countries having announced when the 2G service will be switched off. It has been reported that both 2G and 3G will be switched off by 2020.

4G has faster data rates than both 2G and 3G (around 15 Mbits/s vs 6.1 Mbits/s provided by 3G). However, this technology has not been widely adopted for remote applications as it is more suitable for streaming large volumes of data, such as video, rather than the text-based data used in most remote monitoring applications.

5G is not yet available in the UK and the rollout is not expected until 2020. The main reported advantages of 5G are speed, reduced latency and lower power consumption. It is not expected that this technology will be used for remote monitoring applications, as the increased data rates will not be needed. It is more likely that IoT (Internet Of Things)based protocols will become the method by which measurement data is transmitted as this will achieve the lower power consumption and increase the transmission range achieved by existing technologies.

4.3.2 Radio

Radio is sometimes used as a means of transmitting measurement data from a remote location where GSM/3G is not available or too expensive. The range of radio-based systems can be a limiting factor as the range can be anything from hundreds of metres to 20 plus kilometres depending on the power of the radio and the technology used. Longer-range radios are available but these will normally need to be licensed. Systems can be employed that pass data from one monitoring point to the next (hopping) as a means of extending the range. However, this does require either monitoring stations or booster points to be deployed within range of each other.

Low Power Radio

Licence Free Radio, otherwise known as Low Power Radio, covers a wide number of industries and used within the water and wastewater industry including Wi-Fi, Bluetooth, level radar and RFID tags, both active and passive, including anti-theft devices. The UK water industry has significant history of using the licence free bands at 173.225-173.173.500MHz and 458.500-458.850MHz. More modern deployments are on 433.075-434MHz and 863-870MHz.

In essence, Low Power Radio has been free from licencing in the UK since 1993. Since December 2017 the law changed and products placed on the market since need to comply with the essential requirements of the Radio Equipment Directive 2014/53/EU. Further operation must in the UK be in line with Ofcoms's (The Office of Communications) IR 2030 - UK Interface Requirements 2030 Licence Exempt Short Range Devices. What is essential for users to appreciate is that Ofcom states that users are not exclusive and are not offered any form of protection from interference, eavesdropping or jamming.

Licenced Radio & Radio Telemetry

Licenced radio and radio telemetry has been used across the water industry for over half a century for both voice and data services. Licenced telemetry includes Private Mobile Radio including TETRA, DMR and data services, such as Scanning Telemetry and Point-to-Point links. Licencing in the UK are issued and regulated by Ofcom and are issued on either shared or an exclusive basis, plus can be national or local (geographical or technical licences). The advantage to the water industry of using licenced radio is that the service is legally protected under the powers of the Wireless Telegraphy Act 2006 Order 2010. It is a criminal offence subject to fines and custodial sentences for a non-licence holder to listen, eavesdrop, interfere or to jam any licenced service. This also includes accidental interference caused by faulty electrical apparatus. Ofcom offers a call-out and investigation service to licence holders and have a statutory right of entry to property and can confiscate illegal apparatus.

Depending upon the licence terms significantly higher power levels (longer distances) can be used when compared to Low Power Radio and as aforementioned, the service is fully protected. Once a licence is obtained, there is no limit to the number of messages that are sent and no SIM card is required. According to Ofcom, it believes there has been a recent increase in licence requests from the water industry due to interference on the Low Power Radio bands, in particular the UHF 458MHz band, from portable traffic lights.

Internet of Things

The Internet of Things (IoT) is is a broad term that encompasses everything connected to the internet, or devices that communicate with each other. An IoT device could be anything from a complex sensor to a toaster that has the ability to present or retrieve information via the internet. It allows networks or devices to provide a user information, which can then be used to analyse and potentially control that network. IoT is not a protocol as there are many protocols employed by different IoT devices. IoT is not as recent as many would believe and has been around since the late 1990s. What is important for the water industry to appreciate is that none of these services are protected and FCC certified products are not permitted in the UK as they tend to operate on the US and not UK licence free radio bands.

Wireless IoT Network Protocols

Table 1 Typical wireless communication protocols

NAME	DESCRIPTION
Bluetooth	Bluetooth works in the 2.4 GHz ISM band and uses frequency hopping. With a data rate up to 3 Mbps and maximum range of 100m. Each application type which can use Bluetooth has its own profile
EC-GSM-IoT (Extended Coverage-GSM-IoT)	Enables new capabilities of existing cellular networks for LPWA (Low Power Wide Area) IoT applications. EC-GSM-IoT can be activated through new software deployed over a very large GSM footprint, adding even more coverage to serve IoT devices

NAME	DESCRIPTION
IEEE 802 (Institute of Electrical and Electronics Engineers)	IEEE 802is a family of IEEE standards dealing withlocal area networks andmetropolitan area networks. IEEE 802.15.4 is a standard that specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs). The IEEE 802.15 working group maintains it. It is the basis for the ZigBee, ISA100.11a, WirelessHART, and MiWi specifications, each of which further extends the standard by developing the upper layers, which are not defined in IEEE 802.15.4. Alternatively, it can be used with 6LoWPAN and standard Internet protocols to build a wireless embedded Internet.
LoRaWAN (Long Range)	Network protocol intended for wireless battery operated Things in regional, national or global network
NB-IoT (Narrow-Band IoT)	Narrowband IoT also known as LTE Cat NB1, is a LPWA technology that works virtually anywhere. It connects devices more simply and efficiently on already established mobile networks and handles small amounts of 2–way data, securely and reliably. It provides: • very low power consumption • excellent extended range in buildings and underground • easy deployment into existing cellular network architecture • network security & reliability • lower component cost
Near Field Communication (NFC)	Based on the standard ISO/IEC 18092:2004, using magnetic field induction to enable communication between devices when they are touch together or a few centimetres at a centre frequency of 13.56 MHz. The data rate is up to 424 kbps and the range is with a few centimeters, short compared to the wireless sensor networks
WirelessHart	WirelessHART technology provides a robust wireless protocol for the full range of process measurement, control, and asset management applications

NAME	DESCRIPTION
ZigBee	The ZigBee protocol uses the 802.15.4 standard and operates in the 2.4 GHz frequency range with 250 kbps. The maximum number of nodes in the network is 1024 with a range up to 200 meters. ZigBee can use 128 bit AES encryption

4.3.3

4.3.4 Wi-Fi

Wi-Fi sensors are sometimes used in monitoring applications where the data is sent to a local data aggregator or access point within the proximity of the sensor. Many of these sensors occupy the 2.4Ghz frequency band as this is a licence-free band. These sensors have the advantage of being cheap as the technology used for data transmission is ubiquitous. The ease of installation is also another consideration for this type of sensor. The main drawback is the limited data transmission range.

4.3.5 Telecommand

Telecommand is the generic name given where commands to control or actuate are sent and received across a network. Telecommand can be performed on both Licensed and Licence Free bands. In all cases, telecommand devices must comply with the required legal essential operating requirements.

4.3.6 Typical Water Industry Protocols

PROFIBUS

PROFIBUS (Process Field Bus) is a standard for fieldbus communication technology and first appeared in the late 1980s. PROFIBUS is openly published as part of IEC 61158. There are two variants of PROFIBUS, the most commonly being PROFIBUS DP (Decentralised Peripherals), and the second being PROFIBUS PA (Process Automation). PROFIBUS DPrtu is used to control sensors and actuators via a centralised system typically used in factory automation. PROFIBUS PA is used to monitor measuring equipment via a process control system in process automation applications and is typically used in explosives environments.

Modbus

Modbus is a serial communications protocol that is a commonly available means of connecting industrial electronic devices. Modbus enables communication among many devices connected to the same network or information system, for example, an outstation measuring water level and pressure and communicates the results to a data collection server. Modbus is often used to connect a supervisory computer with a RTU in Supervisory Control And Data Acquisition (SCADA) systems. Many of the data types are named from its use in driving relays: a single-bit physical output is called a coil, and a single-bit physical input is called a discrete input or a contact.

Distributed Network Protocol (DNP3)

DNP3 is a set of communications protocols used between components in process automation systems. Its main use is in utilities such as water and gas companies. It was developed for communications between various types of data acquisition and control equipment. It plays an important role in SCADA systems, where it is used by SCADA Master Stations and RTUs. DNP3 is a reliable and efficient protocol, but it was not originally designed to be resistant to deliberate security breaches. Subsequently, secure authentication was added to the DNP3 protocol.

Water Industry Telemetry Standard (WITS)

The WITS-DNP3 protocol is entirely based on the DNP3 protocol, extending that protocol to provide functions, which are specific to the utility industry.

Device Profiles

The characteristics and capabilities of a particular WITS Field Device are defined in a 'device profile', which is in XML format. This 'device profile' is read into the WITS Master Station and used to limit what a user can do to that particular Field Device.

Device Configuration

WITS provides master stations with the ability to change incrementally the configuration of Field Devices. This is done by using DNP3 file transfer to send incremental configuration updates to a Field Device. This mechanism provides flexibility for managing the configuration of remote Field Devices from a central location. Examples of configuration changes could be analogue input scaling, a definition of alarm limits and enabling/disabling inputs.

Information exchange between a WITS Master Station and Field Device

WITS defines seven DNP3 'Data Sets' for Field Devices to report data to a Master Station and for a Master Station to control a Field Device. These are as follows:

- Reporting data
- Change of state or transgression of a limit
- Monitoring the health of a device
- Requesting a device to 'call in' and test a communications path
- Controlling programs sent to a Field Device.
- Controlling whether inputs cause events to be sent to the Master Station.

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4.4 Visualisation

Control monitor

At present, most sensors will communicate their information to a control monitor. This could be via a hardwired or remote connection but generally, sensors rely upon the control panel to interpret and display their data. The control panel acts as an interface and will typically perform several functions. This includes but are not limited to displaying sensor results, providing digital and analogue outputs, providing an input facility from other devices and performing logging of sensor data.

5 Parameters in Water/Wastewater:

5.1 Physical

5.1.1 Colour

One of the methods available for testing water to help ensure it is clean and safe is colour measurement. Water takes on many hues and colours depending on its location, the state of the natural light, and the presence of dissolved minerals and other particulate matter.

Testing the colour of any sample of water offers a way to determine the level of contamination. Most discolouration results from organic materials through inorganic substances such as various minerals can also be responsible.

The colour of water can indicate the presence of a range of chemical and organic pollutants such as copper from plumbing systems, rust from iron pipes, algae, bacteria, etc. Colour testing can be an effective way to determine the nature of water pollution.

Three of the colour scales used in colour testing are ADMI (American Dye Manufacturers Institute), APHA (American Public Health Association) and Gardner scales. Sensors used to measure these normally require a sample of water to be collected. The sample volume will then be exposed to a light source and then either the reflected light or the light that passes through the sample is measured by a detector.

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5.1.2 Flow

Flow measurements are used in both clean and wastewater applications and help assess how much water is available for clean water, how much water is being used or flowing, or to monitor the quantity of wastewater flowing into a treatment plant. The flow measurement can also be used to control (by means of pumps and valves) the rate of flow into a treatment plant. Flow is also used in the monitoring of trade effluent.

Depending on the water source that is measured there are numerous methods in which flow measurements can be made. These include, but are not limited to, contactless ultrasonic and radar, submerged or in pipe ultrasonic sensors or mechanical impeller based sensors.

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5.1.3 Level

Level sensors come in various forms and have many different applications. In the water industry, they are normally used for measuring levels of rivers, tanks reservoirs and sewers. The main sensor types are Ultrasonic, Radar, Hydrostatic (pressure) and Float Switches. All of these sensors have their advantages and disadvantages in terms of cost, power consumption, accuracy and reliability. The four most common methods are detailed below:

5.1.3.1 Ultrasonic sensors

Ultrasonic sensors are generally are a good compromise between cost, performance and power consumption. They contain piezoelectric crystals, which fire sound pulses towards the measured surface. They measure the total time of flight of the pulses to measured water and back again (reflected pulses). Being ultrasonic, they use the speed of sound and the time of flight of the pulse to calculate the distance travelled and hence the water level. One of the drawbacks is that in certain environments that contain different gases (i.e. sewers) the speed of sound can be altered by the gas content. In addition, they can be affected by reflections from objects in the area of interest and they can struggle to accurately measure fast moving or turbulent water.

5.1.3.2 Radar sensors

Radars sensors work on a similar principle to the ultrasonic sensor but use microwaves as opposed to ultrasonic pulses and, as such, they are not affected by different gases, which may have an impact on the time of flight with an ultrasonic sensor. The time of flight of a microwave pulse is dependent on the dielectric constant of the liquid being measured. Radar sensor will also normally perform better where foam is present on the surface of the liquid. The disadvantages of the radar sensor are that it typically uses more power and requires more space to install, as they are typically a bigger sensor.

5.1.3.3 Hydrostatic (pressure) sensors

Hydrostatic sensors are positioned in the medium to be measured and as such, they are exposed to whatever contaminants are present in the measured medium. This can result in degradation of the sensor or fouling of the sensor's diaphragm. Sensors, which have flush diaphragms, are less susceptible to this type of contamination. In addition, different materials are used to help ensure the longevity of the sensor in harsh environments. Materials used include stainless steel and titanium.

5.1.3.4 Float Switches

Float switches are a cost-effective means of measuring water level but will only indicate if the level is above or below a certain point rather than giving you a true level measurement. They also have the drawback that they can suffer from hysteresis when the trend of the level measured changes direction.

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5.1.4 Pressure

Pressure sensors are used primarily in clean water and water storage. In the clean water network, pressure sensors are used to detect leaks as well as monitoring supply and demand of water. The fast sampling of pressure sensors can be used to detect the possibility of pipe bursts while multiple pressure sensors on a length of pipe will help pinpoint the location of a leak.

In water storage (tanks and reservoirs), pressure sensors are used to calculate volumes of stored water by submerging the pressure sensor into the tank or reservoir. The resultant water pressure relates to the meters of water above the sensor.

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5.1.5 Sludge Blanket

Sludge blanket level measurement is used to determine the boundary between two material densities e.g. water and a slightly higher density sludge. Water quality may be maintained by determining the sludge blanket level, which can affect effluent or drinking water quality. As well as manual observation, there are techniques to measure automatically the density of the formed blanket. The main techniques used for automatic observation use light (infrared or near infrared) or sonar. Infrared sensors will typically detect attenuation of the emitted light which will be completely blocked in the region of the sludge blanket, whereas ultrasonic sensors determine the sludge blanket level from analysing the received signal and verifying that the measurement profile matches that of a sludge blanket. The higher the density of the measured liquid, the greater the change of the received profile of the signal.

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5.1.6 Suspended Solids and Turbidity

Suspended solids refer to small solid particles, which remain in suspension in water, and it is used as one indicator of water quality. Traditionally, suspended solids were measured by filtering and drying samples of water to give an accurate concentration in mg/l. This would necessitate regular collection of water samples for laboratory analysis.

Turbidity is caused by particles suspended or dissolved in water that scatter light making the water look cloudy or dirty. Particulate matter can include sediments such as clay and silt, fine organic and inorganic matter, soluble coloured organic compounds, algae, and other microscopic organisms. Turbidity is generally measured by passing a light beam through the water and either the resultant scattering of light is measured or the level of light attenuation depending on the technology employed. The measured value (intensity of scattered light or level of light attenuation) corresponds to the turbidity of the sampled water, which is expressed in NTU (Nephelometric Turbidity Units). Turbidity sensors have the advantage that they are placed directly in the water to be sampled and give instant and continuous readings without the need for manual intervention or collection of water samples for laboratory analysis.

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5.1.7 Temperature

Accurate temperature measurement is used in many water treatment applications. Water temperature has an effect on many water treatment processes, both physical and chemical. Areas where the temperature has an effect may include, but is not limited to, disinfection, sedimentation, filtration and corrosion control. The main methods of temperature measurement is a Thermistor (also known as an RTD, resistance temperature detector) or a Thermocouple. Temperature is then determined either by a voltage or resistance measurement across the device. Temperature probes can often also be found with digital interfaces such as SDI-12 or RS232, to make it easier to connect to remote monitoring equipment.

Many of the parameters measured in water treatment are temperature dependent. It is important that the temperature sensors are mounted in the same area of interest as these sensors. To that end, many sensors that are temperature dependent have built-in temperature sensors.

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5.2 Chemical

Determining both particulate and solute chemistry is critical for water, power, and industrial process operators. In order to maintain water quality compliance, operators must prove concentrations of certain solutes and particulates are within legislative limits prior to either distribution to consumer taps (potable water) or prior to release into a sewer system or the environment (wastewater). To prove compliance, certain parameters must be continuously monitored to provide a complete record.

Parameters that require monitoring can be naturally occurring or synthetically introduced components of a source water, by-products of a manufacturing or distribution process or disinfectants added synthetically during the treatment of water or a certain process.

5.2.1 Aluminium

Aluminium is an insoluble metal, readily precipitating when oxygen and pH conditions are favourable. It is often used as a coagulant for removing dissolved organics from potable water. Overdosing is costly and a significant risk to water quality downstream of the dosing point and therefore, its concentration is monitored and controlled in potable and waste waters.

Aluminium salts are a common coagulant used in the removal of dissolved organics and other unwanted solutes during the treatment process. Aluminium monitoring is therefore, employed before and after the coagulant stage during potable water treatment. It is also often monitored in the final treated water prior to entry into the distribution system to ensure consent limits are being met.

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5.2.2 Ammonia

Ammonia is used in fertilizer and animal feed production and in the manufacture of fibres, plastics, explosives, paper, and rubber. It is used as a coolant, in metal processing, and as a starting product for many nitrogen-containing compounds.

Ammonia monitoring tends to be employed towards the end of wastewater treatment processes to ensure water entering watercourses contains ammonia concentrations below consent limits. Ammonia monitoring can often also be employed in intake water prior to potable water treatment.

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5.2.3 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand is a measurement of the oxygen required to oxidise soluble and particulate organic matter in water. Chemical Oxygen Demand is an important water quality parameter because it provides an index to assess the effect discharged wastewater will have on the receiving environment. Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce DO levels. A reduction in DO can lead to anaerobic conditions, which is detrimental to aquatic life forms. The COD test can be used as an alternative to Biological Oxygen Demand (BOD) due to a shorter length of testing time.

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5.2.4 Chlorine

Chlorine is the most widely used disinfectant in the home. It is also the disinfectant used by the water industry to maintain hygienic conditions within the public water supply network of pipes. At the very low levels used in drinking water it is perfectly safe.

Chlorine in drinking water

Although several methods eliminate disease-causing microorganisms in water, chlorination is the most commonly used. Chlorination is effective against many pathogenic bacteria, but at normal dosage rates it does not kill all viruses, cysts, or worms. When combined with filtration, chlorination is an excellent way to disinfect drinking water supplies.

Chlorine in wastewater

The amount of chlorine allowed in the final plant effluent before being discharged into lakes, rivers or the ocean is regulated. This requires de-chlorination, which removes the free and combined chlorine residuals to reduce the toxicity after chlorination and before discharge.

5.2.5 Conductivity

Conductivity is a broad measurement that indicates the level of dissolved minerals in the water, for process waters it is an indicator that the water purifier system is not working. In some cases, it can be used to prevent problems with scaling due to the hardness of tap water, especially in boiler feed water. In many applications, conductivity can be used as a measurement of Total Dissolved Solids (TDS) and is a useful general indicator of water quality.

C***onductivity in drinking wate***r

Conductivity, in particular, specific conductance is one of the most useful and commonly measured water quality parameters. In addition to being the basis of most salinity and TDS calculations, conductivity is an early indicator of change in a water system. Most bodies of water maintain a constant conductivity that can be used as a baseline of comparison to future measurements.

Conductivity in wastewater

In the same manner as conductivity in drinking water, it is usually used to measure TDS in wastewater treatment plants. Reducing TDS can be achieved by reverse osmosis or distillation.

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5.2.6 Dissolved Oxygen

Dissolved oxygen (DO) is a key ingredient in the treatment of organic waste in water. DO measurement is mainly employed during the secondary stage of the wastewater treatment process.

The secondary treatment stage is the point at which organic waste is oxidised to form carbon dioxide, water and nitrogen compounds. To achieve this, most modern plants use an activated sludge system, which uses a culture of bacteria and other organisms to feed on the organic materials in the sewage.

When added in combination with the right temperature, these bacteria and organisms use DO to burn or break down organic carbons into carbon dioxide, water and energy, clearing the water of harmful substances.

DO measurement is also critical for boiler feed waters within the power sector. Corrosion risk is heavily controlled through the elimination of oxygen from waters. Low concentration measurement of DO is; therefore, critical for maintaining a healthy boiler and plant.

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5.2.7 Fluoride

Fluoride is a naturally occurring mineral found in water in varying amounts, depending on the source of water.

It can help prevent tooth decay, which is why it is added to many brands of toothpaste and in some areas to the water at the request of the local authority through a process called fluoridation.

Fluoride in drinking water

Most water supplies contain some fluoride and in the early 20th century, levels of tooth decay were found to be associated with fluoride levels in drinking water. This led to the introduction of water fluoridation schemes to add fluoride to water supplies to improve dental health.

Community water fluoridation schemes have operated for over 70 years; the first fluoridation scheme was introduced in the US in 1945. The first substantive UK scheme was established in Birmingham in 1964.

Fluoride in wastewater

Fluoride wastewater treatment is increasingly important to the discharge authorities and discharge limits and consent levels are common.

In a typical application, fluorides are removed from wastewater via Calcium Fluoride (CaF_2) precipitation and subsequent pH neutralization. The fluorides, once properly treated, are handled as a completely inert, non-hazardous, dry sludge cake with resale / recycle value.

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5.2.8 Heavy metals

Heavy metals include elements such as arsenic, mercury, lead, cadmium, copper and zinc. Most are toxic to humans and the environment, although the degree of toxicity varies with the element.

Heavy metals in drinking water

Heavy metals) in drinking water sources have a variety of origins: some, like arsenic, are present in the geology of many areas and will be a natural part of the groundwater. Others are a historic legacy from old industrial and mining use and have made their way into groundwater or surface water. Finally, others originate from accidental or deliberate contamination of rivers and watercourses by industrial spills, illegal dumping or malicious acts.

Water treatment works whose raw water source regularly contains metals should have means to remove these if present at the expected concentrations. The levels of metals in the incoming raw water often need careful monitoring to allow the works to operate most efficiently.

If heavy metals enter the waterworks at higher than expected levels, the treatment system may not be capable of removing all the metals, and there is a risk that the final water will be contaminated.

For waterworks located in areas at risk of metals contamination, for example, downstream of an industrial plant or in a naturally metal rich area, monitoring of the incoming raw water can, therefore, be of highest importance.

Heavy metals in wastewater

All industries working with or producing metal products will have cooling or process water containing metals. Power stations and waste incinerators produce scrubber water containing metals originating from the material burned or incinerated. Municipal wastewater treatment works may receive industrial waste containing metals, which if not removed fully by the waterworks, may be discharged into the watercourse.

The plant's individual wastewater discharge permit, as issued by the local Environment Agency, dictates the amount of metals it is allowed to discharge into the watercourse or sewer.

The plant often has a metal removals system that treats the process water before discharge. Its discharge permit dictates the minimum frequency of laboratory testing of the effluent stream to comply with the law. Breaches of the permitted limits may incur fines.

Issues:

- Metal levels in the process water vary and may spike at certain times
- Overdosing of treatment chemicals is common to ensure that spike levels are covered
- Spikes may not be fully removed and may be discharged at levels above the permitted, risking fines and damage to the environment
- Laboratory analysis often takes days or weeks to return results
- Changes and improvements to the treatment process are difficult to manage if the lab results take days or weeks to arrive

Real-time metals monitoring of both process water and the effluent from metals removal plants is, therefore a great help to ensure that permits are not breached, to help manage the plant and to save on treatment chemicals.

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5.2.9 Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) is a germicidal agent composed only of water and oxygen. Like ozone, it kills disease organisms by oxidation. For this reason, Hydrogen peroxide is considered a safe natural effective sanitizer.

Hydrogen Peroxide in drinking water

Hydrogen peroxide has been used for years as a chemical treatment in municipal water systems. It has several benefits, including iron and hydrogen sulphide removal and the neutralization of tastes and odours.

Hydrogen peroxide kills microorganisms by oxidising them, which can be best described as a controlled burning process. When hydrogen peroxide reacts with organic material it breaks down into oxygen and water, meaning it is non-toxic for general use.

Hydrogen Peroxide in wastewater

Hydrogen peroxide is most commonly used to remove pollutants from wastewater and from air. It contests bacterial growth (for example biofouling in water systems) and it can enhance bacterial growth (for example bioremediation of polluted soils and groundwater) through oxygen addition. It can also be used to treat pollution that can be easily oxidised (for example iron and sulphides) and pollutions that are difficult to oxidise (for example dissolved solids, gasoline and pesticides).

Find a supplier

5.2.10 Hydrogen Sulphide

Hydrogen sulphide (H_2S) is a dissolved gas that gives stagnant water a characteristic "rotten egg" taste and odour. It corrodes piping, creates odours in the house and turns water black. Homeowners will notice that it can change sterling silver to black almost instantly. H_2S can cause odour problems at a concentration level as low as 0.05 mg/L in well water.

Hydrogen Sulphide in drinking water

The odour of water with as little as 0.5 ppm (parts per million) of hydrogen sulphide concentration is detectable by most people. Concentrations less than 1 ppm give the water a "musty" or "swampy" odour. A 1-2 ppm hydrogen sulphide concentration gives water a "rotten egg" odour and makes the water very corrosive to plumbing.

Hydrogen Sulphide in wastewater

Hydrogen sulphide results from septic conditions during the collection and treatment of wastewater. Hydrogen sulphide has long been recognised as a major problem for municipal wastewater systems. This colourless gas, known for its rotten egg smell, is produced by the biological reduction of sulphates and the decomposition of organic material. It forms at virtually every point in a treatment system and can be a major contributor to corrosion of pipes, fixtures and fittings.

Hydrogen sulphide gas is acutely toxic to workers in sewer systems. Although disagreeably pungent at first, it quickly deadens the sense of smell and a worker may not be aware that it is there. Even at low concentrations in air, exposure to hydrogen sulphide has been linked to fatigue, headaches, eye irritation, sore throats and other health problems.

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5.2.11 Iron

Iron is the fourth most abundant element in the earth's crust and; therefore, is naturally occurring in varying concentrations. Although not a health risk in itself to humans, its tendency to precipitate out of solution and form hydroxides giving water a brown colouration, means that its concentration is controlled in treated and distributed potable waters.

Iron salts are a common coagulant used in the removal of unwanted solutes in potable waters. Iron is often monitored before and after the coagulant stage during potable water treatment. It is also often monitored in final waters prior to entry into the distribution system or prior to release into the environment.

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5.2.12 Manganese

Manganese is an insoluble metal, readily precipitating when oxygen and pH conditions are favourable. It is an undesirable metal in the distribution system due to its accumulation and role in discolouration of water supply.

It is; therefore, often monitored on final treated water but also can be a measure on intake water coming from boreholes for example and prior to treatment. Manganese monitoring, depending on the process, can also be employed prior to effluent discharge into the environment, to ensure consent limits are being met.

Find a supplier

5.2.13 Nitrate

As a major by-product of agricultural processes, in particular, nitrate needs to be closely monitored and controlled. When present in watercourses, nitrate is a major contributor to eutrophication, where an environment becomes enriched with nutrients. In humans, nitrate is reduced to nitrite and reacts with haemoglobin. This prevents oxygen transport in the body, potentially causing Blue Baby Syndrome (Methaemoglobinaemia) in bottle-fed babies. It is, therefore, a key control measure.

Nitrate monitoring tends to be employed towards the end of wastewater treatment processes to ensure water entering watercourses contains nitrate concentrations below consent limits. Nitrate monitoring can also often be employed in intake water prior to potable water treatment.

Find a supplier

5.2.14 Oil and Hydrocarbons

Hydrocarbons are fuels, oils, greases, and tar-type compounds, originating from petroleum products, industrial activities such as coking works, and sustainably sourced fuels.

Hydrocarbon products, to a greater or lesser extent, contain compounds toxic to humans and the environment. These include for example polyaromatic hydrocarbons (PAHs), benzene, and other BTEX compounds, both of which are carcinogenic.

Hydrocarbons in drinking water

Hydrocarbons end up in drinking water sources by illegal dumping or accidental spillage of fuels into rivers, as well as street run-offs and industrial activities.

Water treatment works whose water source occasionally is contaminated with hydrocarbons can benefit greatly from real-time hydrocarbon monitoring of the incoming water, allowing them to temporarily stop the intake and prevent the hydrocarbons from entering the works.

Hydrocarbons in wastewater

Refineries, petro-chemical industries, airports and railway maintenance stations can all produce hydrocarbon-containing effluents that are discharged into rivers or sewers. Their effluent permits, issued by the Environment Agency, regulate how much hydrocarbons they are allowed to discharge, and how often they need to monitor the effluent to comply with the law.

GACs are often installed to remove the hydrocarbons before discharge.

Issues:

-GACs are expensive to change

-If the GAC becomes saturated with oil, it will no longer remove the hydrocarbons, risking breaches of permits and damage to the environment

-Laboratory analysis often takes days or weeks to return results, making it difficult to manage the change-out of the GACs

Real time hydrocarbon monitoring of the effluent from the hydrocarbon removal system and between the GAC beds helps to manage the change-out of the beds. This results in large cost savings, protects the environment and minimises the risk of permit breaches.

Find a supplier

5.2.15 Ozone

Ozone (O_3) is an unstable, pale-blue gas, with a penetrating odour. It is an allotropic form of oxygen usually formed by a silent electrical discharge in air. Ozone can be created by imposing a high voltage alternating current (6 to 20 kilovolts) across a dielectric discharge gap that contains an oxygen-bearing gas. Ozone is generated on-site because it is unstable and decomposes to elemental oxygen in a short amount of time after generation.

Ozone in drinking water

Because of its excellent disinfection and oxidation qualities, ozone can be used for drinking water treatment. Ozone can be added at several points throughout the treatment system, such as during pre-oxidation, intermediate oxidation or final disinfection. Usually, it is recommended to use ozone for pre-oxidation, before a sand filter or an active carbon filter (GAC).

Ozone in wastewater

In a similar manner to drinking water treatment, wastewater plants can generate and use ozone as a disinfectant. It can be used as an oxidizing, deodorizing, bleaching agent in the treatment of wastewater.

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5.2.16 pH

pH indicates the sample's acidity but is actually a measurement of the potential activity of hydrogen ions (H+) in the sample. pH measurements run on a scale from 0 to 14, with 7.0 considered neutral. Solutions with a pH below 7.0 are considered acids. Solutions with a pH above 7.0, up to 14.0 are considered bases. The pH scale is logarithmic, so every one-unit change in pH actually represents a ten-fold change in acidity.

pH in drinking water

The pH value of drinking water may need to be adjusted during treatment and before distribution. Many raw surface waters are slightly acidic and coagulation processes further increase acidity.

An increase in pH can be achieved by dosing with sodium hydroxide, calcium hydroxide or sodium carbonate. Other methods such as passing the water through a bed of alkaline medium or aeration to remove excess carbon dioxide are also used.

Reduction of pH can be achieved by dosing with a suitable acid such as sulphuric acid, hydrochloric acid, sodium hydrogen sulphate or carbon dioxide.

pH in wastewater

Wastewater effluent should be neither too acidic nor too basic (ideally completely neutral at pH 7), as this will help to prevent undesirable chemical reactions when the wastewater mixes with another effluent. pH neutralisation is even more important if the wastewater outlets directly into a lake or river, as changing the localised pH can harm wildlife and cause knock-on issues for the local ecosystem.

pH adjustment (usually from acidic to basic) can be used in post-process water treatment as a way of precipitating out dissolved contaminants, such as heavy metals and toxic metals, which then need to be neutralised before final discharge. Addition of small, carefully controlled doses of a strongly acidic or, more commonly, basic compounds (such as sodium hydroxide (NaOH)) during wastewater processing is a simple way of ensuring that the pH of the effluent outflow remains within stated guidelines.

Find a supplier

5.2.17 Phosphate (ortho and total)

As a major by-product of wastewater treatment and agricultural processes. in particular, phosphate needs to be closely monitored and controlled.

When present in watercourses, phosphate is a major contributor to eutrophication. In such environments, algae can flourish, consuming dissolved oxygen in the water, which is further depleted as other aquatic plants compete for the remaining oxygen. Known as aquatic hypoxia, this process can quickly result in the death of aquatic life.

Phosphate monitoring tends to be employed towards the end of wastewater treatment processes to ensure water entering watercourses contains phosphate concentrations below consent limits. Phosphate monitoring can also be employed as a control measure on plumbosolvency schemes, to determine the correct concentration of phosphate is being delivered into the distribution system to prevent dissolution of lead from pipes into consumer supplies.

5.2.18 Redox

The terms oxidation and reduction refers to the gain or loss of oxygen or hydrogen or electrons. There is always a transfer of electrons in reactions involving oxidation and reduction, that is, the oxidation state of one or more of the elements is always changed.

The term Redox or Oxidation-Reduction Potential (ORP) describes a chemical reaction involving oxidation and reduction. The two processes always occur together because an oxidising agent is always reduced during oxidation and a reducing agent is always oxidised during reduction.

Redox Potential is a measure of the power of a substance to gain electrons in solution. A strong reducing agent which readily loses electrons (which it can give to another substance), will have a high negative redox potential. A strong oxidising agent will have a high positive redox potential (Redox potential is the same as electrode potential).

Redox in drinking water

Chlorine is normally added to drinking water because it has a high positive ORP and will, therefore, oxidise and destroy the bacteria that are harmful to humans.

Optimal drinking water is one with a negative ORP. Drinking water with a positive ORP is reduced to a reductive ORP by consuming the electrical energy from cell membranes.

Redox in wastewater

As Redox is a measurement of levels of reduction and oxidation processes within a solution or liquor its use to determine the efficiency of the biological removal of ammonia and nitrate in the activated sludge plants would appear obvious. Monitoring Redox allows an operator to determine whether biological reactions are occurring and whether any processes changes are required to improve the efficiency of those reactions.

Discharge limits mean that nitrification and denitrification processes are required to remove ammonia, nitrate and to break down pollutants in the wastewater. The nitrification process is performed by nitrifying bacteria when he Redox value is in the region of +100 to +350 mV. In this condition, the process is turning ammonia (NH_3) into nitrate (NO_3^-).

The de-nitrification process reduces the nitrate (NO_3^-) to nitrogen (N_2), the denitrifying bacteria require the wastewater to have a redox potential in the range -50 to +50 mV.

Find a supplier

5.2.19 Total Organic Carbon

Total Organic Carbon (TOC) is a term used to describe the measurement of organic (carbon-based) contaminants in a water system. Organic contamination can come from a variety of sources, since "organics" are compounds such as sugar, sucrose, alcohol, petroleum, PVC cement, plastic-based derivatives, etc. The test is non-specific which means TOC will not determine which compounds are present. Instead, TOC will inform the user of the sum of all organic carbon within those compounds.

Issues:

- Organics may exist in the feed water.
- Organics may result from the leaching or shedding of various components within the purification or water distribution system.
- Organics may result from the formation of biofilms (bacteria) in the water system.

TOC in drinking water

The production of high-quality drinking water depends on a number of closely monitored parameters. The TOC of drinking water is as such an important parameter to measure. Drinking water is often produced and distributed in a matter of hours. Therefore, fast screening of the allowed TOC load of the product needs to be accurate and fast.

Typical TOC values in drinking water may range up to 25 ppm (depending on regulatory compliance and region).

The produced TOC number indicates organic materials (natural), disinfectants, and disinfection by-products.

TOC in wastewater

Monitoring organic carbon of influent facilitates process controls for maximizing plant efficiency, while monitoring effluent is often a requirement for discharging into surface waters.

The effluent stream in an industrial or municipal wastewater treatment process can contain numerous organic and inorganic contaminants. Because the effluent stream is typically released into the environment, the quality of the effluent must comply with regulations to avoid costly fines and a potentially hazardous environmental situation.

Find a supplier

5.3 Biological

5.3.1 Toxicity

Toxicity tests measure the effect of a compound or mixed effluent on a living organism. They do not measure absolute concentrations, nor do they identify what causes the toxicity.

While chemical analyses identify and quantify individual compounds, they only detect what they have been asked to detect. Toxicity tests detect everything that is toxic to the test organism, i.e. unknowns, as well as the effects of mixtures.

Toxicity is measured as a particular effect, for example, the death of the organism or a change in behaviour. LD_{50} (half-lethal dose) means the concentration of a compound or a sample that causes death to 50% of the test population. EC_{50} (half-maximum effective dose) means the concentration of sample or compound that causes a particular effect in 50% of the test population. For example the concentration of cadmium, or of a particular effluent, that causes 50% of the fish in the tank to stop swimming.

Toxicity is often assessed using a battery of test organisms relevant to the environment where the water is discharged. Often a tiered assessment system is used, where a quick toxicity-screening test is used as a first tier, moving on to higher organisms for more specific assessment.

Toxicity in drinking water

Drinking water sources such as rivers, groundwater or storage tanks and reservoirs, can be contaminated either by naturally occurring compounds, accidental chemical release or by malicious acts. Toxicity screening tests can be used to detect gross contamination of a water source by an unknown compound.

Toxicity in wastewater

Wastewater treatment works usually have biological treatment tanks containing bacteria that break down the organic waste. If toxic waste from an industrial source enters the works, this can kill the bacterial population in the biological tanks, which becomes very expensive to replace and can render the works unable to treat organic waste.

Works that regularly accept mixed industrial waste can, therefore, benefit from online toxicity testing of the incoming wastewater to protect the biological treatment tanks. It is critical that the toxicity test can warn and/or divert the intake in a timeframe short enough to stop water entering the tank.

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5.3.2 Bacteria

Bacterial monitoring (e.g E.coli, Cryptosporidium, total coliforms) tends to be undertaken through manual sampling and subsequent laboratory analysis on a fairly low frequency. Whilst continuous methods for components of this manual analysis are in development, deployment and extended use of this type of analyser are still in their infancy.

Find a supplier

5.3.3 Biological Oxygen Demand

Biological Oxygen Demand (BOD) is a measurement of the amount of dissolved oxygen used by aerobic microorganisms when decomposing organic matter in water.

BOD is an important water quality parameter because it provides an index to assess the effect discharged wastewater will have on the receiving environment. The higher the BOD value, the greater the amount of organic matter available for oxygen-consuming bacteria.

BOD in drinking water

BOD is used in drinking water applications as a measure of the amount of organic waste present. Generally, the lower level of BOD the better, a BOD level of 1-2 ppm is considered very good.

A water supply with a BOD level of 3-5 ppm is considered moderately clean. Above these values, the water supply is considered polluted as organic matter is present and bacteria are decomposing this waste matter.

BOD in wastewater

One of the main aims of wastewater treatment plants is to reduce the BOD in the effluent discharged to natural waters. Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The excess bacteria grown in the system are removed as sludge, and this "solid" waste is then disposed of on land. If effluent with high BOD levels is discharged into a stream or river, it will accelerate bacterial growth in the river and consume the oxygen levels in the river. The oxygen may diminish to levels that are lethal for most fish and many aquatic insects.

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5.3.4 Algae

The measurement of algae has become increasingly important in water treatment processes as climate changes have directly impacted on algae populations, rate of growth and variability. Impacts of invasive species have also impacted on the range of algae groups found within natural water systems.

Water utilities need to know algae concentrations within abstracted waters as they can disrupt water-processing systems with increased maintenance on filter systems, impacting on coagulation and raising potential of trihalomethanes. Algae in high concentrations can also create taste and odour issues.

The prescribed method for monitoring for algae are laboratory techniques, which can provide detailed information on algae type and concentration. Many water companies also use real time monitors for algae, the majority of these being fluorometers targeted to detect the dominant algae pigment Chlorophyll-a. The fluorometry method uses light of a specific wavelength to illuminate a sample and detect the light emitted back (which is of a higher wavelength). The fluorometry method provides benefits of being both very sensitive and specific to the fluorescing compound. There are also multi-spectral fluorometers available that can provide information on algae type targeting cyanobacteria (blue green) pigments phycocyanin and phycoerythrin (phycoerythrin more common in marine waters). Use of multi-spectral fluorometers helps inform on the specific algae groups.

Some water utilities are now looking at other techniques for determination of algae taxa with the use of flow cytometers. These instruments can analyse algae down to individual cells/particles by using a combination of laser light scatter and detecting the fluorescence emitted by intracellular pigments.

Other new technologies that have been applied to the measurement of algae include Fast Repetition Rate Fluorometry (FRRF) and Pulsed Amplitude Modulation techniques, which measure the rate of algae growth, with the FRRF technique more suited for use in flowing waters.

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6 Gases

Within the water industry, and during the production of potable water and treatment of wastewater, many toxic and flammable gases can be produced. Often both permanently positioned and mobile gas-monitoring devices are important components of an appropriate monitoring programme to keep processes optimum and more importantly to keep personnel safe.

As a general rule, initial potable water treatment processes involve physical or biological processes. Therefore, gas monitoring is not a required consideration until the disinfection stage; the point at which chemicals, often in gaseous form, are introduced. Key gases to be monitored within the clean water industry are chlorine, chlorine dioxide, sulphur dioxide, ozone, and ammonia, originating from locations such as gas storage areas and dosing plant.

Within the wastewater side of the industry, there are many gas hazards, including methane, oxygen, hydrogen sulphide, chlorine, carbon monoxide and carbon dioxide. These gases originate from many sources, such as sewers, pumping stations, aeration tanks, sludge digester tanks, deodorising plant and treatment plants.

Beyond the water industry, monitoring gas emissions is also an important consideration for industrial operators. This is mainly because the emission of specific gases is stringently regulated. For example, there is a legal requirement in many countries to continually monitor the emission of SO_2, NO_x, CO, CO_2, and dust/airborne particulate matter within stack emissions and to report this data to regulators. Largely this regulation has been driven by a need to reduce acid rain incidence and to reduce the rate of climate change to which these gases, at elevated levels, are implicated as part of the cause.

However, in addition to ensuring compliance within stack emissions, operators are also interested in measuring other gases. These include O_2, CO, and CO_2 for determining combustion efficiency and many other gases such as Cl_2, H_2S, CH_4, and NH_3 for minimising health and safety risk and for optimising industrial processes involving these gases.

Below is more detail on monitoring certain gases within both the water and wider industry.

6.3.1 Ammonia

Ammonia is a colourless gas. It is a weak alkali, which is very soluble in water and has a choking and distinctive smell. Ammonia is used to make fertilisers, explosives, dyes, household cleaners and nylon. Within the water industry, it can be used during chloramination schemes, wherein ammonia is mixed with chlorine to generate monochloramine, a disinfectant with a longer lifespan than free chlorine within the distribution system. The mixing ratio to generate monochloramine is 3-5 parts free chlorine to 1 part ammonia. Feeding ammonia into water for complexation with free chlorine to generate monochloramine can be in gaseous or liquid form. When the former is preferred, a gas leakage programme is an important consideration. Ammonia is also a by-product of wastewater treatment processes during the decomposition of organic matter present in the water. Therefore, monitoring its presence on wastewater treatment plants is important.

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6.3.2 Carbon Dioxide

Carbon dioxide (CO_2) has been implicated as a major contributor towards the enhancement of global warming. In the wastewater industry, it is generated during aerobic treatment (activated sludge or biological filtration) processes. Contributing approximately 1% of total UK carbon dioxide emissions, monitoring of its presence on wastewater plants is obviously an important component of total carbon emission calculations. Because high concentrations are associated with depletion of oxygen in the air and potential asphyxiation, it is also an important gas to be monitored for the safety of personnel.

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6.3.3 Carbon Monoxide

Carbon monoxide is toxic due to its affinity to bind to haemoglobin molecules. For this reason, elevated levels of carbon monoxide can lead to the haemoglobin in red blood cells carrying insufficient oxygen; exposure to high levels (0.1% volume) can lead to asphyxiation. Carbon monoxide can be generated during wastewater treatment and, therefore, monitoring of this gas is important.

Find a supplier

6.3.4 Chlorine gas

Today Chlorine gas remains the most common form of disinfection in both potable and waste waters across the world. Chlorine gas is a highly effective disinfectant which has a green/yellow colour when it approaches room temperature. However, it is also highly toxic due to it reacting within the human body to form hydrochloric acid. Because of this, extreme care must be taken when storing and dosing Chlorine gas. Monitoring programmes should be carefully planned to account for all eventualities.

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6.3.5 Chlorine dioxide

Chlorine dioxide is also a common disinfectant used within the water industry and other industries such as food and beverage. In water treatment, it is often used prior to traditional chlorination as a step to eliminate the formation of trihalomethanes. However, Chlorine dioxide is prone to an explosion; careful and rigorous monitoring within treatment plants is essential in any health and safety programme revolving around Chlorine dioxide.

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6.3.6 Hydrogen sulphide

Hydrogen Sulphide (H_2S) is a highly toxic gas. Within the wastewater industry, it is produced as a by-product of the initial stages of decomposition, wherever large holding tanks or settling basins are located.

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6.3.7 Methane

Also known as, natural gas, methane is an explosive gas (Lower Explosive Limit 5% volume) produced primarily during the initial stages of decomposition. Because of its low density, methane will accumulate in pockets near the ceiling of enclosed areas such as holding tanks and settling basins. Monitoring of methane on wastewater treatment plants is obviously an important consideration.

Find a supplier

6.3.8 Sulphur Dioxide

Sulphur dioxide (SO_2) is a pungent, corrosive gas, which is colourless at room temperature. Within the water industry, it is often used to dechlorinate wastewater prior to the release of that water into the environment. If inhaled by humans, it is associated with respiratory problems and; therefore, monitoring and control of this gas within the water industry is an important consideration.

In terms of atmospheric emissions, SO_2 released into the atmosphere is a precursor to acid rain. Acid rain is rain that is unusually acidic and can affect the manufactured environment such as steel structures, increasing the rate of corrosion and the natural environment, damaging both terrestrial and aquatic ecosystems and also human health. Since the 1970s, there has been a drive from certain governments to reduce the flux of SO_2 into the atmosphere. SO_2 is, therefore, a common and often regularly monitored gas in stack emissions.

Find a supplier

6.3.9 Oxygen

Because of the high number of chemical and organic processes occurring in any wastewater treatment plant, adequate levels of oxygen must be maintained to ensure worker safety. Oxygen sensors should be located in enclosed areas, wherever oxygen levels may be in question.

Find a supplier

6.3.10 Ozone

Ozone (O_3) is an effective disinfectant used in potable water treatment and with growing popularity. In addition to directly disinfecting, it also assists in the oxidation of iron, manganese and in protection against giardia and cryptosporidium. In the latter case, it has benefit over Chlorine, which cannot pass through and inactivate cryptosporidium cells. O_3 is highly oxidising and, therefore, where it is used for disinfection, monitoring for gas leakage is essential. It is known to cause respiratory problems in animals and humans at concentrations above 100 ppb.

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7 Environmental monitoring

This guide is focused on water and wastewater quality and therefore is not an exhaustive guide of environmental monitoring parameters. Water quality is normally one of the major areas of environmental monitoring together with:

- Soil quality: soil moisture, electrical conductivity, pH.
- Hydrology: water level, flow and velocity, sediment transport and deposition, groundwater, runoff, tides.
- Weather and atmosphere: temperature, solar radiation, wind speed and direction, barometric pressure, humidity, precipitation.
- Air quality: carbon monoxide, sulphur dioxide, ozone, volatile organic compounds

There are many reasons to monitor the environment as it has a direct impact on the availability, quality and management of water. Climate change is further driving the need to monitor. Some of the potential impacts are listed below, but it is still unknown what the impact of these will be for the water industry:

- higher average and peak temperatures
- changes in seasonal rainfall patterns
- rising sea levels
- increase in extreme weather events
- more frequent and severe droughts and flooding

Increasing temperatures and changes in rainfall patterns coupled with increasing population can place an extreme demand on water resources. Environmental monitoring gives useful information to help manage water resources in terms of availability and flooding.

Find a supplier

8 Standards and Regulations

Water companies: water treatment works discharge limits for environmental permits

Monitoring emissions to air, land and water (MCERTS)

Discharges to surface water and groundwater: environmental permits

WMO weather monitoring standards and guidelines

Council Directive 91/271/EEC concerning urban waste-water treatment

Drinking Water Inspectorate

Environmental protection act 1990

Water Resources act 1991

The Environment Act 1995

IEEE Standard for Sensor Performance Parameter Definitions

Low pressure compliance for drinking water distribution DG2

9 Glossary of ABBREVIATIONS AND definitions

2G, 3G, 4G, 5G	Generation of wireless mobile telecommunications technology
AES	Advanced Encryption Standard
Bluetooth	Wireless technology standard for exchanging data over short distances
BOD	Biological Oxygen Demand
BTEX	Refers to the chemicals benzene, toluene, ethylbenzene and xylene
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
DMR	Digital Mobile Radio
DO	Dissolved oxygen
EC_{50}	Half Maximum Effective Dose
Ethernet	Way of connecting computers together in a local area network
FCC	Federal Communications Commision
FRRF	Fast Repetition Rate Fluorometry
GACs	Granular Activated Carbon filters
GSM	Global System for Mobile
HART	Highway Addressable Remote Transducer
Hz	Hertz
IEEE	Institute of Electrical and Electronics Engineers
IoT	The Internet of Things
ISM	Industrial Scientific and Medical
ISO	International Organization for Standardization
ISO/IEC	International Organization for Standardization/International Electrotechnical Commission
LD_{50}	Half Lethal Dose

LPWA	Low Power Wide Area
LR-WPAN	Low-Rate Wireless Personal Area Networks
m	metre
mA	Miliamperes
Mbps	Megabits per second
Modbus	Serial communications protocol
NB	Narrow Band
Near Field Communication	NFC
NO_x	Nitrogen oxides
NTU	Nephelometric Turbidity Units
ORP	Oxidation-Reduction Potential
PAHs	Polyaromatic Hydrocarbons
PAM	Pulsed Amplitude Modulation
ppm	parts per million
PROFIBUS	Process Field Bus
RFID tags	Radio Frequency Identification: type of tracking system that uses smart barcodes in order to identify items
RTU	Remote Telemetry Units
SCADA	Supervisory Control And Data Acquisition
SDI-12	Serial Digital Interface at 1200 baud
SIM	Subscriber Identity Module
SO_2	Sulphur dioxide
TDS	Total Dissolved Solids
TETRA	Terrestrial Trunked Radio
TOC	Total Organic Carbon
USB	Universal Serial Bus
WHO	World Health Organization
Wi-Fi	Wireless fidelity: Wireless networking technology that uses radio waves to provide wireless high-speed Internet and network connections

BRITISH WATER