Continuous Iron and Manganese monitoring optimizes filter performance

Problem

The performance of sand filters in drinking water treatment can be assessed by monitoring iron and manganese breakthrough. However, sampling for laboratory analysis causes unacceptable delays that prevent efficient filter management.

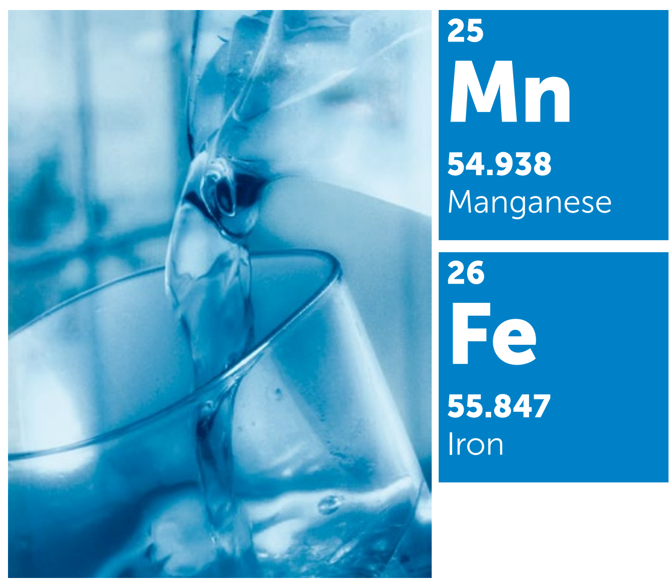
Solution

The Hach® EZ series analyzers are able to measure up to eight sample streams providing continuous data on either iron or manganese. Researchers in Denmark are exploiting this capability to radically redesign water treatment.

Benefits

Continuous monitoring provides faster and timely warning that filter backwash is necessary. Consequently, process optimization is enabled; improving flow, minimizing downtime, protecting water quality and lowering costs. Potential risk to aesthetic water quality is avoided and researchers are better able to assess new filters/ technologies.

The advantages of the colorimetric technology employed by Hach's laboratory and field use photometers are now also available in online analysers; offering users the opportunity to measure a wide variety of parameters 24/7. Two of the parameters that can now be monitored continuously are manganese and iron, and the following text will explain why monitoring these parameters is important.



Background

Both iron and manganese often exist together in source water such as groundwater, but manganese usually occurs at much lower concentrations.

Occurring naturally in soil and in most surface water and groundwater sources, manganese is an essential element for many living organisms because of its role in the function of enzymes. For humans, the largest source of manganese is usually from food. However, absorption of manganese across the gastrointestinal tract is regulated by the body to help maintain manganese homeostasis, and orally obtained manganese is generally considered to be one of the less toxic elements. Nevertheless, in the light of recent research, the guideline value for manganese in drinking water is the subject of ongoing debate.

Iron is an abundant metal in the earth's crust, existing mainly in the form of its oxides. The iron ions Fe^{2+} and Fe^{3+} readily combine with oxygen- and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides. Iron is also an essential trace element, performing vital roles in blood and enzymes.

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Iron concentration in rivers is typically low – 0.7 mg/L. In anaerobic groundwater where iron is in the form of Fe^{2+} concentrations are usually 0.5–10 mg/L, but concentrations up to 50 mg/L are possible. Levels of iron in drinking water are normally less than 0.3 mg/L but may be higher in countries where iron salts are used as coagulants in water treatment plants and where cast iron, steel, and galvanized iron pipes are used in the distribution network.

5 Reasons for monitoring

Complaints

Discoloration, bad taste and staining from tap water are the most common causes of drinking water complaints from members of the public. The handling of these complaints, and the implementation of investigation and remediation measures, can be very costly. Turbidity monitors can help to raise alarms so that action can be taken to divert cloudy water from the distribution network, but turbidity can be caused by a wide range of issues, whereas raised iron and manganese levels result from specific issues, so monitoring can help identify causes and inform appropriate mitigation measures.

Health

The health risks from iron and manganese are small, however there are risks associated with the bacteria that cause raised iron concentrations from corrosion. For humans, the lethal dose for iron is 200-250 mg/kg of body weight, which causes extensive gastrointestinal hemorrhage. However, iron toxicity is rare, and intake from drinking water is typically too low to raise health concerns. Nevertheless, iron oxides are known to be efficient scavengers of metals and semi-metals, and can be responsible for increased levels of arsenic.

Regulatory

For many organizations, (including drinking water providers and the beverage industry) there is a regulatory requirement to ensure that iron and manganese levels do not exceed specified maximum concentrations.

The EU Drinking Water Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption says: For the purposes of the minimum requirements of this Directive, water intended for human consumption shall be wholesome and clean if it: (a) is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health, and (b) meets the minimum requirements set out in Annex I, Parts A and B. In Annex 1, Part C 'Indicator Parameters' the Directive includes a standard for manganese of 0.05 mg/L and of 0.2 mg/L for iron. However, most of the former indicator parameters have since been moved to annex IV, which concerns information to consumers. The rationale for this is that indicator parameters do not provide health-related information, but rather, information of interest to consumers (such as taste, color and hardness).

Discharge consents at wastewater treatment plants often also include limits for iron (often as total iron) where iron salts are employed as coagulants in phosphate removal.

In the United States, the US EPA has established Secondary Maximum Contaminant Levels (SMCLs) for contaminants that affect the aesthetics of drinking water but do not pose a risk to human health. SMCLs are not federally enforceable, so public water treatment facilities are not necessarily required to monitor them unless required to do so at a State level.

The SMCL for iron is 0.3 mg/L, with potential aesthetic problems listed as rusty color; sediment; metallic taste; and reddish or orange staining. The SMCL for manganese is 0.05 mg/L, with potential aesthetic problems listed as black to brown color; black staining and a bitter metallic taste.

The US EPA believes that if these contaminants are present in water at levels above the standards, the contaminants may cause people to stop using water from the public water supply system even though the water is actually safe to drink. Secondary standards are therefore set to give public water systems some guidance on removing these chemicals to levels that are below what most people will find to be noticeable.

It is also important to note that the aesthetic problems listed above may cause livestock and other animals to refrain from drinking.

Scaling and Corrosion

Cast iron pipes and equipment used in industrial plant handling steam or cooling water, are susceptible to multiple corrosion mechanisms. Mechanical and chemical corrosion can strip and dissolve iron from steel surfaces, and this unbound iron can deposit on surfaces at other points in the water handling system where it induces further corrosion.

Chemical cost reduction

For water treatments plants employing iron salts as coagulants, such chemicals can represent a significant cost. So, whilst it is important to deploy sufficient coagulant to successfully remove solids, it is also necessary not to overdose, because this could overload filters and leave residual iron salts in the water; which would be a waste of money.

Continuous monitoring – how it works

The EZ Series of analyzers employ online colorimetric technologies to measure key water quality parameters accurately and reliably. Smart, automated features contribute to enhanced analytical performance, minimized downtime and negligible operator intervention. Cleaning is automatic and both calibration and validation frequency can be set by the user. The EZ1000 series has the ability to measure multiple streams simultaneously, up to a maximum of eight. This reduces the cost per sampling point, but must be specified at the time of ordering.

The EZ1000 Iron Analyzer utilizes the TPTZ reagent to form a deep blue-purple color in a reaction which measures dissolved iron Fe(II), Fe(III) and total dissolved iron Fe(II+III), with a cycle time of 15 minutes, and a measuring range of 0-1 mg/L.

The EZ1000 Manganese Analyzer measures dissolved Manganese Mn(II), by the formaldoxime method at 450 nm, with a measuring range of 0-1 mg/L Mn and a cycle time of 10 minutes. However, customers wishing to also measure total manganese would choose the EZ2000 Manganese Analyzer which has an internal sample digestion unit that provides an additional step prior to analysis for measuring non-soluble or complexed metal species.

The advantages of continuous monitoring

In general, laboratory analysis of process parameters helps to detect trends and identify potential problems. However, there is a time delay between sampling and the delivery of a result, and occasional sampling risks missing a spike in the concentration. Continuous monitoring therefore provides a more timely warning of raised levels and helps to identify the causes.

The EZ1000 Series analyzer can provide a standard 4-20 mA signal output with alarm processing, so that any increases in measured concentrations are detected almost immediately. This means that alarms can be raised and appropriate and timely action can be implemented.

Case Study: VIA University College

In a research and development project funded by the Danish Environmental Protection Agency and managed by VIA University College, researchers are completely redesigning water treatment by radically rethinking the drinking water production process. The project partners include Aarhus Water, VandcenterSyd, Vand & Teknik, Amphi-Bac, Dansk Kvartsindustri and NIRAS. The aim of the project is to create compact waterworks with:

- greater treatment capacity
- more efficient production
- shorter start-up periods
- energy savings
- improved water quality

In Denmark, drinking water supply is based on groundwater and the government's position is that drinking water should be derived from pure groundwater which only needs simple treatment with aeration, possible pH adjustment and then filtration before distribution. Sand filtration has been utilized in Denmark for over 100 years, and the results of the filter development project will be communicated at the IWA Water Congress (in Denmark) in 2020.

The scientific work was conducted on Lundeværket, a part of Vandcenter Syd, in Denmark, which is a typical Danish waterworks.

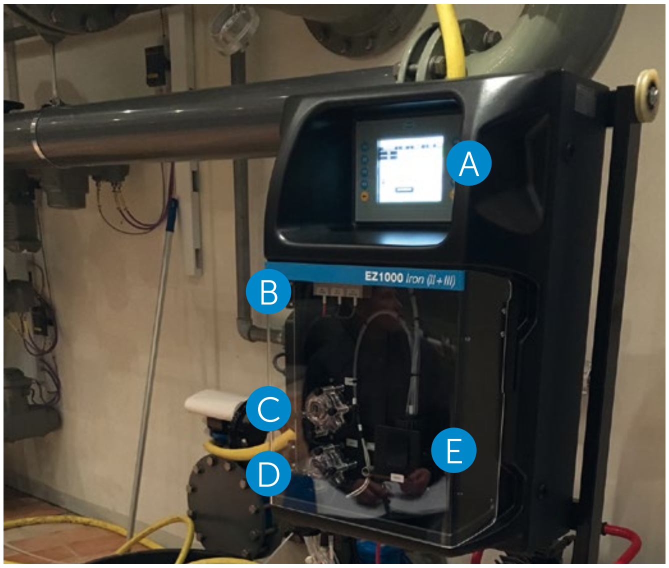
Sand filters are commonly employed at water treatment works around the world, helping to remove suspended solids and pathogens, and improve taste and color, without additional chemicals. The optimum performance of these filters is maintained by regular backwashing to remove accumulated particles and improve flow rates. However, the process of backwashing interrupts the treatment process. Monitoring is therefore necessary to optimize filtration performance. Turbidity and flow rate can be monitored continuously to give an indicator of filter performance, but chemical analysis provides greater insight into process conditions.

In 2018 a new drinking water regulation was implemented in Denmark to align with EU regulation relating to parameters, sampling frequency and sampling sites. Previously it was necessary to monitor at both the waterworks outlet (lower limit) and at the consumer's tap. Following the EU alignment, monitoring is required at the consumer tap with the following limits: Iron 0.2 mg/L, Manganese: 0.05 mg/L.

Traditional practice has been to take occasional grab samples for the laboratory analysis of a range of parameters including iron and manganese. Failure to remove contaminants by backwashing necessitates replacement of the filter, which is time-consuming and represents costly downtime. The performance of the filter and the need for backwash can therefore be assessed by monitoring breakthrough of iron and manganese in the filter, and in the different layers within the filter.

The project is undertaking continuous online measurements both before and after the filter with a Hach EZ1024 for total dissolved iron (Fe(II) and Fe(III)), and a Hach EZ1025 for manganese. These instruments were installed in November 2018, taking samples four times per hour. Initially, each instrument was set to take two samples from the filter inlet and two from the outlet each hour, 24/7. Initial results show good correlation with comparable laboratory results.

Project manager Senior Associate Professor Loren Ramsay from VIA University College says: "Monitoring is an essential component of research in drinking water treatment. For monitoring to be proper, it must be composed of frequent measurements in multiple locations within the treatment process. The use of online iron and manganese autoanalyzers with multi-channel capabilities suits our needs nicely. We are confident that the results of our project will be very useful throughout the drinking water treatment industry."



EZ1024 Iron (II+III) Analyzer on site
Components: ***A*** *industrial panel PC,* ***B*** *high precision micropumps,* ***C*** *sample pump,* ***D*** *drain pump,* ***E*** *photometer*

Summary

As sensor technologies advance, continuous monitoring and real-time control systems are helping to optimize a wide range of treatment processes within the water sector. This is helping to improve performance whilst lowering costs. Following the development of Hach's EZ series continuous analyzers, it is now possible to optimize the performance of sand filters in drinking water treatment, to prevent the breakthrough or iron and manganese and to manage the timing of backwash operations more efficiently. Furthermore, as is the case in Denmark, continuous monitoring of manganese and iron enables the development of new improved filtration systems.

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