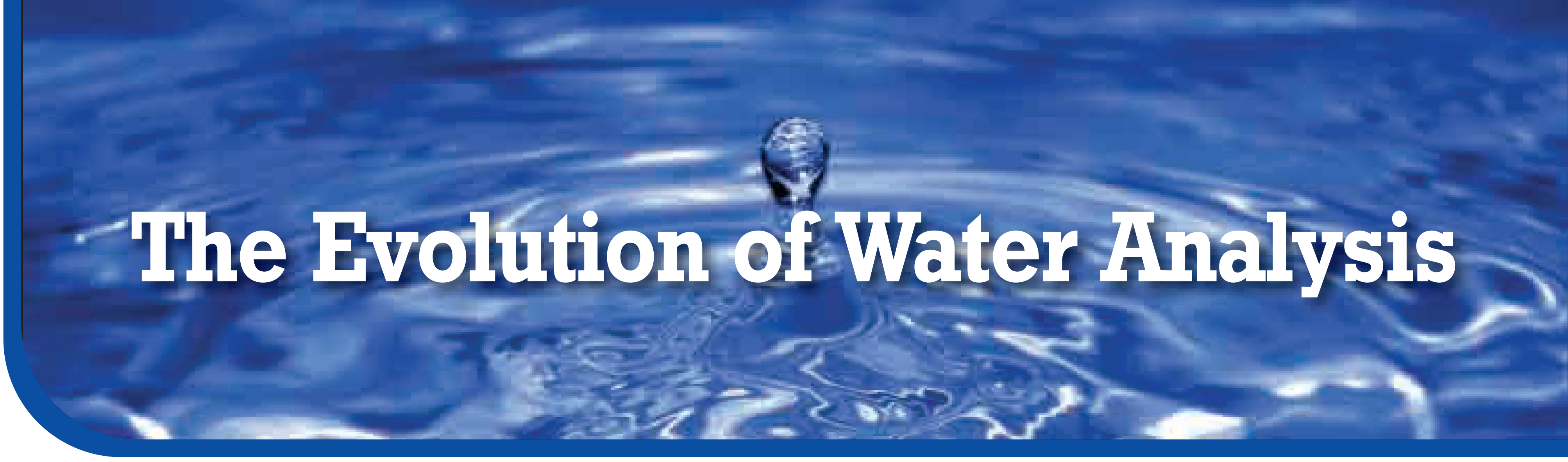

The Evolution of Water Analysis

Nowadays, water analysis is something we take for granted. One click of the mouse, and the internet provides us with up-to-date information on the water quality of the great rivers. Water analysis has caught on significantly in our part of the world, be this in the monitoring of surface water such as lakes and rivers, in controlling the quality of water treatment or in managing processes in purification plants. Nowadays, an abundance of wide-ranging analytical procedures are used in the area of water analysis. To examine how water analysis has evolved over time is also to question what the driving forces behind the development of these procedures has been. In other words, why do we need to analyse water? To answer this question, let us take a look at the history of water and wastewater treatment and examine when and why human beings started to take an interest in water quality.

The preoccupation with water quality is closely intertwined with concern about its availability; water is a precious commodity which is in sparse supply and must be transported over long distances. If we take a look at the living conditions in past millennia, we find that population density was low in the countryside and high in the cities and towns. How was the issue of water quality dealt with back then?

This question takes us back to ancient Greece. There are public latrines; wastewater and sometimes also rainwater are directed via a canal to a catchment basin outside the city. From here, the wastewater mixture is distributed back to the fields or used to fertilise vegetables. Water quality was determined by the quality of the fresh water.

In Roman times, there was an awareness of the correlation between wastewater and fresh water. Viaducts were built to make externally situated sources of fresh water available to the city. However, the "Cloaca Maxima" was also built. This was a canal in the center of Rome which was used initially to drain the marshes and, at a later stage, to meet the complete drainage needs of the Forum Romanum. Wastewater was directed into the Tiber. Measurement technology as we know it today was not yet required.

Historical wastewater treatment plant in Frankfurt/Main, Germany

Let us move on to to the Middle Ages in Europe, which marked a rather bleak period from the point of view of sanitation. Disease and plagues are rampant. Waste is disposed of in the street. The first "garbage collectors" are to be found in Paris in the 14th century. Cesspools become commonplace, and the renaissance of wastewater canals begins. In terms of water quality assessment, there is little to be learnt from this period. However, there is much to be learnt about the risks attached to blocked and overflowing cesspools and the associated repercussions for the lives of people at the time.

From 1750, at the start of the industrial revolution, the European cities experienced an explosion in population density. In London, water and wastewater facilities including water closets were commonplace at this time. However, it was precisely the intensive use of toilets, which were discharged directly into the Thames, coupled with a hot summer and low water levels in the river that led to the "Great Stink" of 1858 which smothered London. This event triggered the start of the London wastewater canal system. Around this time, extensive work also began on canal systems in Hamburg, Frankfurt and other cities. While wastewater was initially used to fertilise fields close to the edge of

Historical wastewater treatment plant in Frankfurt/Main, Germany

the city or to irrigate allotments, it was the cities' increasing need for land and the ever increasing amounts of wastewater which brought about the necessary pressure for further developments in wastewater technology. The chemical treatment of wastewater with lime became popular as a means of removing particles or contamination. This meant that water could again be discharged into rivers. In addition, it gave rise to saleable fertilisers.

However, the purification levels which could be achieved using these chemical methods were limited. Subsequently, it became clear that the previous approach of "dilution is the solution" was no longer sufficient for the amount of wastewater being generated. Mechanical purification methods were developed, which we are familiar with today as the primary stage of water purification. An example still exists today in the historical sewage treatment plant in Frankfurt am Main. However, even then, water analysis did not yet play a proper role.

One system from this period, which is still in use today, is the Imhoff tank which was designed by Karl Imhoff in 1906. Here, water is segregated from the deposit-forming sludge in an upper basin with horizontal flow, and the sludge is collected in a lower basin where it is left to decompose anaerobically (i.e. without the addition of oxygen), before being disposed of or distributed in the fields. Knowledge of the anaerobic processing of sludge was documented in France in the second half of the 19th century and forms the basis of the multi-chamber cesspits which are still in common use today.

What about water analysis during this period? The driving force is the issue of drinking water quality and the elimination of epidemics from the fast-growing urban centers. Ultimately, there was also a realisation that the repercussions of wastewater discharge, which sometimes included contamination of drinking water, had a direct effect on the health of the population. In London, it was found that the consumption of drinking water in an area with high levels of wastewater was

Aeration basin of an industrial water treatment plant today

Aeration basin of a municipal water treatment plant today

contributing to the spread of cholera. Institutes concerned themselves with the chemical analysis of water and also, to an increasing extent, with bacteriological issues. There are not yet any limit values for water as we know them today.

One event with far-reaching implications took place in 1912. The "Royal Commission on Sewage Disposal", which was appointed by the British government, produced the first known standard for the discharge of wastewater into rivers: 20 mg/l BOD5 and 30 mg/l of suspended matter are regarded as acceptable. This standard is adopted in many other countries. The value is roughly equivalent to the incoming wastewater being diluted eight times. The discharge values are calculated in a laboratory. None of the methods used are comparable with today's online measurement technology.

However, where did the term BOD5 come from? This variable denotes the oxygen demand of a water or wastewater sample based on the activity of microorganisms over a five-day period. The necessary measurement methodology was developed around 1890 by the chemist L. Winkler. The data on oxygen solubility in water, which are in common use today, are based on his work. To be exact, he developed a method for examining the production of oxygen by organisms living in water, which involves comparing the oxygen content of a water sample in a clear bottle with a sample in a dark bottle. This method proves that oxygen is produced as a result of photosynthesis and can be applied in an adapted form to verify biological oxygen demand. Nowadays, we use online measurement technology to do this in a modified way.

The development of a measurement methodology is always preceded by a motive. Why should a value such as this be used as a variable for evaluation purposes? The reason is that filtering the increasing amounts of wastewater (using clay-based filters) was seen as a way of removing and disposing of suspended matter on a sustained basis, while also achieving high-quality purified water. Some of these filters had long life spans and also output water of high quality. Around 1880, it was discovered that organisms in the water ensured these favorable properties. Soon it became clear that the availability of oxygen was a significant requirement for these processes. This led quickly to the use of flow filters, which were initially implemented in the form of simple contact beds and which can still be found today in a wide range of water treatment facilities. Measurements were now being conducted in the ever increasing number of laboratories where the issues of concern were the efficiency of the purification stages and the quality of the water being discharged.

Final sedimentation basin of a municipal wastewater treatment plant today.

At this time, laboratory technology was based on chemical analysis; weighing, dosing, boiling, titrating, weighing, comparing and calculating were the order of the day. Photometry and spectroscopy were in the early stages of development. The next big breakthrough came in 1914 with the development of the activated sludge process. Up until then, the wastewater was being passed through the biological purification process only once. However, now the medium is also being aerated and the sludge phase returned. High-quality water purification is achieved, and the medium is oxidised. This work formed the basis of what we know today as biological water treatment, which has become a virtual standard in the secondary stage of wastewater purification.

From around 1950, there is a growing interest in the performance of these plants, and optimisation is carried out. With regard to wastewater technology, there is an increasing focus on the reduction of nutrients in the effluent. Denitrification is developed. With regard to drinking water supply, there is a growing awareness of contamination by trace elements, and later pesticides. From the point of view of water analysis, which is still performed in a laboratory, there are many new components to be measured. In terms of measurement technology, photometrical and spectroscopic methods are gaining ground in the laboratories. More information is being analysed in shorter periods of time.

By the 1970s at the latest, environmental issues have increased in importance. Guidelines are developed, such as the Clean Water Act in the USA or the surface water guidelines, and are followed by EU guidelines for drinking water. Within the EU, the Water Framework Directive is nowadays regarded as a legal guideline. It calls for wide-ranging protection of existing drinking water supplies. Existing reservoirs must be named and, depending on the situation, their quality must be improved on a sustained basis. The discharge values of wastewater purification plants must comply with this directive and can be determined on a case-by-case basis. Limit values are based to an increasing extent on environmental aspects which must be respected in the technological design of processes.

Water treatment plant

Water analysis is undergoing a dramatic transformation. There is a move away from laboratory-based practices to online measurement technology for water treatment and for the monitoring of watercourses. What was once a methodology used exclusively in a laboratory is now an independently functioning field measurement device which takes samples and collects data. A clearer distinction is made between process control measurements for the optimisation of individual stages and plant performance measurements. This is key to the issue of quality across the entire process. With rising energy costs, optimising the energy consumption of plants is a topic of increasing importance. While process control measurements are being conducted to an increasing extent in situ, i.e. directly in the process without any further sampling, we are dependent on laboratory methods for many of the more specialised areas, such as the detection of metal. Process control measurements deal with the stability and accuracy of the measured values while keeping the maintenance cost of the installed base low. However, when it comes to determining the presence of trace substances, it is the verifiability, the detection limit and the clarity of the results which are of prime importance.

What is the outlook for the future? As already shown, there are various driving forces behind the evolution of water analysis. On the one hand, there is the protection of drinking water as a precious commodity which has given rise to monitoring. The necessary information is supplied by autarkic measuring nets used for water analysis. On the other hand, there is the optimisation of processes, with signals being received into the control room via intelligent in-situ sensors. In addition, laboratory analysis techniques provide us with information on components which are difficult to access. What all of these have in common is their mutual development and enhancement; what may be inconceivable today will be in a laboratory the next day and in a plant or in the field the day after.

New developments, which are often cost-driven, are already on the horizon. One example is sewer management. This involves, on the one hand, the maintenance of canals and of the distribution network and the use of these canals for the intermediary storage of water surpluses. In addition, incoming organic content can be measured, and downstream systems can be maintained at an almost constant level of operation by mixing the different wastewater fractions from different parts of the distribution network. Here too, there will be a need for suitable water analysis.

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