

Ask Tom! Column

Using Zeta Potential to Optimize Water Treatment

Guest article by Ana Morfesis & Ulf Nobbmann, Malvern Instruments



Introduction

Cryptosporidium and Giardia are two of the most important microscopic pathogens that can be transmitted via drinking water. Both are present in most surface waters around the world. Infection by either organism is particularly serious for immunocompromised individuals as no effective drug treatment is available. The problem is becoming ever more significant as many of the world's highly populated areas are experiencing diminished water supplies, due to greater demand and an increasingly arid climate. Alternative water sources are therefore being sought; including for example treated municipal wastewater. Such alternatives may be more likely to contain higher concentrations of protozoan parasites such as Cryptosporidium and Giardia.

Water treatment programs are the front line in the defence against all waterborne pathogens. This article presents experimental data that demonstrate an effective technique for maximizing the efficiency of water sanitation methods, involving the measurement of zeta potential to enhance contaminant coagulation.

Invisible Threat

Cryptosporidium and Giardia are protozoan parasites commonly found in many animal species throughout the world. Cryptosporidium oocysts and Giardia cysts - highly infectious and environmentally robust - are excreted by infected animals and can enter water sources, enabling transmission to humans. Once ingested the organisms reproduce inside the intestines, causing diarrhoea, nausea, abdominal pains, fever and weight loss.

Patients with normal immune systems are able to fight off the infection in a matter of weeks. More vulnerable individuals, including those with a defective immune response due to AIDS, cancer treatment or organ transplant therapy, are at much greater risk. As there is no effective treatment, an inability to clear the pathogen from the body can result in persistent diarrhoea, eventually leading to serious dehydration and death.

A Global Issue

Outbreaks are common throughout the world, especially in less developed countries where the treatment of drinking water may be inadequate or non-existent. Although the risk is much lower, even the most sophisticated water management systems of industrialized nations sometimes allow microbial pathogens to reach concentrations that endanger health. Flooding or heavy rain, for example, can cause surface waters to mix with normally well-protected ground water supplies, rapidly introducing contaminants.

Once parasites have entered the water supply, they have the potential to affect large numbers of people. The problem is exacerbated because screening techniques are far from perfect, often only detecting a problem once contaminated water has already reached the consumer. For example, in 1993 a waterborne cryptosporidiosis outbreak occurred in Milwaukee in the United States. An estimated 400,000 residents were infected by the parasite. It is believed that over 100 immunocompromised people died prematurely as a result. Despite this, throughout the entire episode the city's treatment plants met all applicable water quality standards.

Importance of Filtration

Disinfectants are an important aspect of water treatment, however, while a common disinfectant such as chlorine can be fairly effective for removing *Giardia* from water, *Cryptosporidium* oocysts are highly resistant to it. Other disinfectant methods, such as UV treatment, have limited effect on either pathogen. Furthermore, under environmental conditions microbial pathogens can attach to colloids, reducing disinfection efficiency.

It is filtration that forms the main barrier against the spread of waterborne infections. It is much more effective against protozoan parasites than disinfection. Effective filtration relies on techniques to enhance the coagulation of microbial parasites in water, facilitating their removal or inactivation. While particles larger than one micron will settle out of water in a matter of seconds, without coagulation, smaller material – including microbial contaminants – would require a period of days or months. The addition of chemical coagulants, also called flocculants or flocculant additives, allows the process to take just hours.

Coagulation is improved through the addition of ions with the opposite charge to that of the colloidal particles. Since colloidal particles are primarily anionic or negatively charged, it is cationic (positively charged) additives that are used to neutralize charged anionic contaminants. The two main types of coagulants are aluminium salts and iron salts, with the most common example being aluminium sulphate.

A series of chemical reactions occurs when a coagulant, for example aluminium sulphate, is added to water, which result in the formation of positively charged aluminium ions. These ions join together to form large molecules. Once formed, these highly positive molecules move rapidly towards the colloidal particles, where they are adsorbed onto the negatively charged surface. This results in the formation of a coagulated precipitate that can be easily removed from water by sedimentation or filtration.



Optimizing Coagulation

Zeta potential - the degree of repulsive interaction between particles in a dispersion - is of particular importance as an indication of the stability of colloids. Colloids with high zeta potential (negative or positive) are electrically stable, while colloids with low or zero zeta potential tend to coagulate or flocculate. For water treatment applications, charged particles are stable and therefore undesirable. The efficiency of contaminant removal can be greatly enhanced by achieving a surface charge of zero, or close to zero, in the water

undergoing treatment. In these circumstances contaminants are unstable and the conditions for aggregation are maximized.

One way of achieving a low zeta potential is by optimizing the amount of cationic additives. The experimental data that follow shows how periodic measurement of zeta potential can be used to adjust coagulant dosage levels to reach optimum coagulation efficiency.

Instrumentation

The Zetasizer Nano was used to monitor and optimize flocculant usage in: a) a water sample containing bentonite, and b) a water treatment facility. All zeta potential measurements were carried out using reusable/disposable capillary cells, together with an MPT-2 autotitrator (Malvern Instruments). See box for more information on the Zetasizer Nano and the MPT-2 autotitrator.

Results and Discussion

Analysis of bentonite in water

Bentonite, an aluminium-silicate clay material, was added to water to simulate pre-filtration conditions at a water purification plant. It provides a good model for monitoring the effect of flocculant dosage on zeta potential because, analogous to most environmental contaminants including *Cryptosporidium* oocysts and *Giardia* cysts, when dispersed into water it becomes negatively charged. Zeta potential and turbidity were recorded as incremental amounts of a typical alum flocculant were introduced.

Figure 1 shows that at low dosages of the flocculating agent, turbidity is high and the zeta potential is approximately -16mV. The addition of flocculating agent causes an increase in zeta potential and a decrease of turbidity. Turbidity decreases as suspended bentonite is removed from the water through coagulation and sedimentation. Figure 1 shows that at a zeta potential of +2mV, turbidity has reached an absolute minimum. From the graph it can be ascertained that a flocculant concentration of 10 ppm was required to achieve this point. Further addition of flocculating agent causes an increase in zeta potential and turbidity – corresponding to a re-stabilization of bentonite in the water

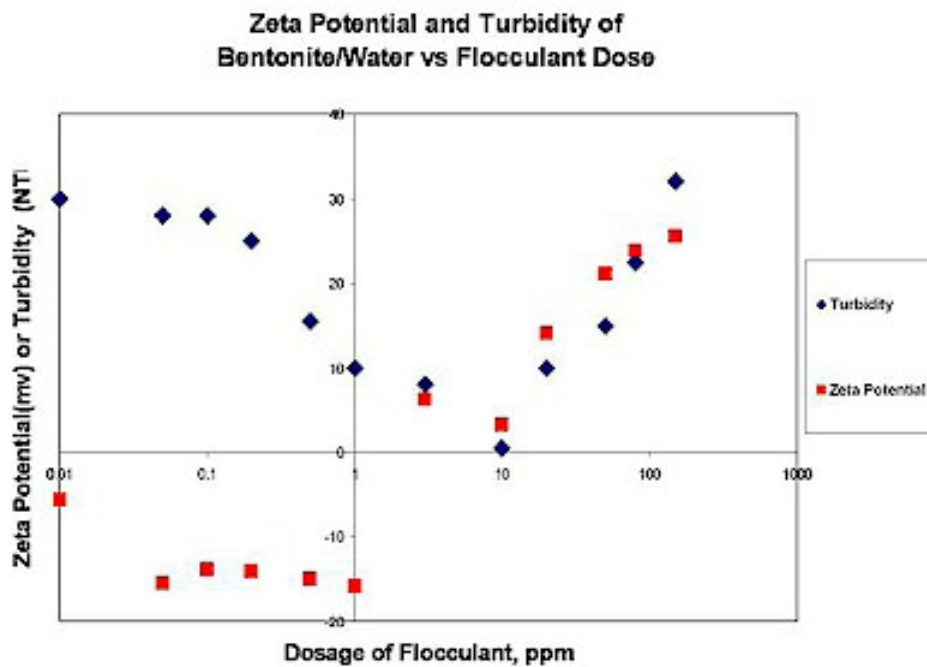


Figure 1: Zeta Potential and Turbidity vs. Alum (Flocculant) Concentration of Bentonite Particles in Water

This investigation shows that the measurement of zeta potential is a critical factor for the determination of optimum flocculant dosage for maximum coagulation efficiency.

Analysis at a water treatment facility

Measurements were conducted at a city's water treatment facility in the United States. Concentration of alum flocculating agent, zeta potential and turbidity were monitored and adjusted during a period of one year. Figures 2 and 3 show the facility's control charts: figure 2 shows zeta potential against alum concentration in four settling tanks; and figure 3 indicates zeta potential and settling turbidity of the water produced in one tank (or train).

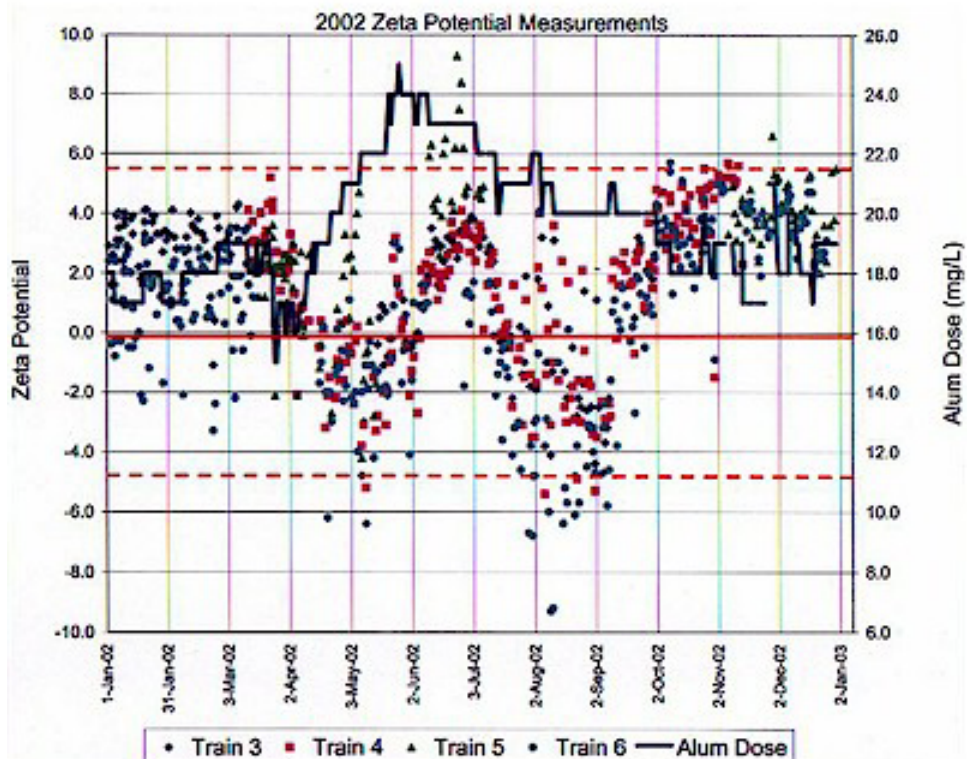


Figure 2: Water treatment production control chart in 2002 monitoring zeta potential results and Alum concentration across four trains or settling tanks in a US water treatment facility

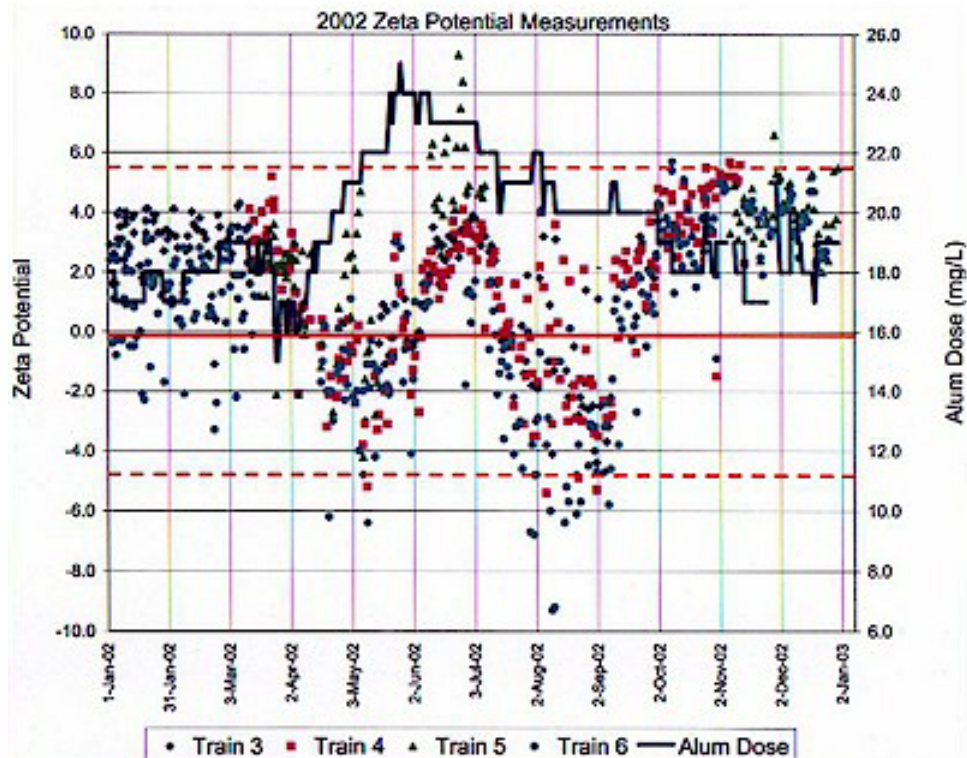


Figure 3: Water treatment control chart during 2002. Monitoring the zeta potential and turbidity results in a single train (settling tank)

The aim of the facility is to maintain a zeta potential around zero, specifically between the values of +5 and -5mV. The graphs show that this is achieved for the vast majority of time, providing an indication of the relationship between alum dosage and zeta potential.

Alum or coagulant dose has historically been selected by a number of factors including zeta potential, jar test (sedimentation) results, streaming current, Total Organic Carbon (TOC), color, turbidity and various other indicators. However, based on natural weather conditions during specific times of the year, rapid decisions about coagulant dosages must be made in water treatment facilities.

Specifically, tests like 2hr jar tests are often not representative of the water requirements during the day. Therefore, in this US water treatment facility, it is the frequent use of zeta potential measurements that provide optimal monitoring results for monitoring coagulant dosage, particularly during times of rapidly changing water conditions.

Figure 2, shows data for zeta potential and alum concentration during a one year time period across four settling tanks producing 20million gallons of water per day. In this specific example, seasonal changes occurred in April and May that affected the process control of this manufacturing facility. These seasonal changes occurred naturally and were due to the raw incoming water supply at this location.

The figure 2 results indicate that during this April to May time, frame water production did operate more on the negative side of the zeta potential control range, however the zeta potential specifications (-5 to +5mV) were maintained and this produced the best floc and best water quality during this time period.

Using the Zetasizer Nano, the facility can monitor the zeta potential of water to optimize alum dosage. Consequently, the plant achieves the long-term maintenance of the most effective filtration conditions, while also minimizing treatment costs by avoiding excessive additive use.



Conclusion

Purification is an essential process for the removal of a wide range of contaminants from water, including suspended organic material, toxic metals and minerals, and disease causing organisms. Cryptosporidium and Giardia are two waterborne parasites that have gained particular notoriety as a threat to public health. They are highly persistent, resistant to many disinfectants and very small, thus presenting a challenge for even the most advanced water treatment systems.

Filtration is the most effective method for the removal of contaminants such as Cryptosporidium and Giardia from drinking water. The highest removal rates are achieved when coagulants (flocculants) are applied to the water before filtration, increasing the rate of sedimentation.

Controlling the effective charge of suspended particles, which changes with the addition of flocculating agents, can optimize the coagulation process and rates of sedimentation. The measurement of zeta potential provides an accurate and precise method of quantifying the effective charge. At close-to-neutral charge, particles flocculate and sediment more easily.

The Malvern Zetasizer Nano, together with the MPT-2 autotitrator, was used to monitor zeta potential and optimize flocculant usage. The data showed that measurement of zeta potential is a precise and accurate method for the enhancement of water filtration, providing an invaluable tool for water treatment facilities.



About the Zetasizer Nano

The Zetasizer Nano system from Malvern Instruments was the first commercial instrument to include hardware and software for combined dynamic, static and electrophoretic light scattering (zeta potential) measurements. Its unique, disposable cell design consists of electrodes and a folded capillary, which are moulded into a single precision measurement chamber. The Zetasizer Nano enables the measurement of both particle size and zeta potential.

For water treatment applications, zeta potential is often studied as a function of additive (flocculant) concentration or pH. The MPT-2 autotitrator can be used with the Zetasizer Nano to facilitate such comparative measurements.

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Welcome to Ask Tom!, a monthly column by our resident water treatment guru, Tom Keenan of National Environmental Services Agency (NESA). Tom addresses the issues that bug you the most. And Tom knows!! With 35 years experience in providing environmental support services to public and private sector clients on a wide range of environmental issues.

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