



POLYELECTROLYTE TREATMENT – AN APPROACH FOR WATER QUALITY IMPROVEMENT

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ABSTRACT

Contamination of industrial water by suspended materials such as mud, dirt, turbidity, organic matter and decaying vegetation can be a serious operational problem besides reducing its aesthetic quality. The clarity of water is affected due to overloading of the clarifier and during the rainy season when turbidity is high. The operational problems encountered during alum and lime treatment programme and the improvement of clarification of raw water by using diallyl dimethyl ammonium chloride (DADMAC), a hetero-ally-cyclic organic polymer are discussed. This paper discusses the chemistry of coagulation and benefits of polyelectrolytes. Treatment recommendations and dosage of polyelectrolyte are discussed in terms of an overall system approach. The use of this organic polymer could improve the overall efficiency of raw water treatment plant with increased throughput, reduced plant maintenance and better water quality. The replacement of alum treatment is cost effective with a substantial cost savings of 25 to 30%. © 1999 IAWQ
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KEYWORDS

Alum; coagulation; colloids; polyelectrolyte; polymer; turbidity.

INTRODUCTION

Water, nature's magic elixir which supports immense and diversified forms of life can also be so corrosive that it can disintegrate the toughest metal. As a chemical it is unique and incredibly stable. The water in the form of vapour in the cloud is quite pure, but as the rain falls through the atmosphere, it gathers dust and gases. Then when it reaches the earth it picks up impurities from the ground. Hence the surface supplies contain suspended matter eroded from river banks, such as mud, dirt and turbidity. In addition they contain dissolved mineral matter, leached from earth and rocks, and organic matter and colour from sewage, trade wastes, and decaying vegetation. Thus, its physical and chemical characteristics are extremely complicated.

Water interweaves its magic into every facet of extensive use as a cooling agent, boiler feed, general services such as drinking, and flushing in chemical industries and power stations, the thermal as well as the nuclear. Although water from a particular source may be acceptable for the purpose of drinking, certain impurities, both dissolved and suspended, present in it must be removed by suitable pretreatment procedures so that it is acceptable for specific use in chemical and power industries.

The limits on the amounts of impurities (tolerances) in the water used for various industries depend on the end use. In general, the harmful effects arising due to suspended particles or water impurities may be classified as deposits or scales formed in steam generators and other heat exchanging equipment which acts

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as insulation, preventing efficient heat transfer and causing steam generator tube failure through overheating of metal. Poor quality boiler steam contains impurities that foul steam, using equipment such as turbines and decrease their efficiency. Moreover, under-deposit corrosion of boilers, heaters and other metal containers and piping cause costly plant shutdowns and make water unsuitable for drinking and other purposes because of objectionable tastes and odours or bacterial contamination. The type of treatment to be adopted depends not only on the nature of suspended particles present in the water and the end use to which it will be put to, but also on the capital and operational costs of the treatment.

Even though various methods of removing the impurities from raw water are in vogue, clarification of raw water by methods of coagulation and settling is an important step in industrial pretreatment programmes. Coagulation is induced by adding chemicals (coagulants) to the water, which agglomerate the finally divided suspended solids into masses that settle more readily.

Water treatment process used initially at NAPS

Narora Atomic Power Station (NAPS), Narora, is situated on the bank of the river "Ganga", in the district of Bulandsahar, Uttar Pradesh, and receives the raw water from upstream of the river for the cooling of various process equipments.

The raw water treatment plant at Narora Atomic Power Station (NAPS) handles 70-120 million litres per day (MLD) of raw water contaminated with suspended material resulting from colloidal clay, soil, organic matter, decaying vegetation etc. Such large quantities of water are treated by two clariflocculators. Clarification of raw water by the use of metal coagulants such as alum was in practice during the period from 1985 to 1990. The raw water of the river Ganga during the peak monsoon season used to reach a turbidity level of 1000 to 1200 NTU and silt in the range of 2000 to 5000 ppm (Fig. 1).

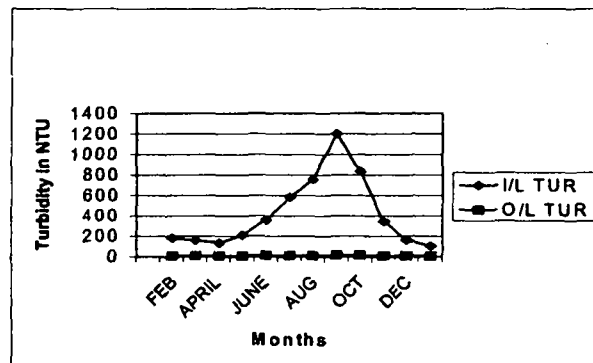


Figure 1. Variation of the turbidity in clariflocculator inlet and outlet.

Even though alum was used as the coagulant for the clarification of raw water it had its own limitations. Over the years, a number of operational problems were encountered with conventional treatment of alum and lime in the raw water treatment plant at NAPS, particularly during the peak monsoon season with the turbidity level of 1000 to 1200 NTU which called for the addition of high dosages of alum and lime in the range of 80-100 ppm to keep the turbidity level in the range of 10 to 20 NTU in the clarified water. As the metal coagulant is particularly sensitive towards pH and alkalinity, it was difficult to maintain the pH of treated water at an optimum level during high turbidity ingress resulting in poor clarification.

In addition to the above problems included: increase in total hardness and sulphate concentrations in the treated water, handling of around 4 to 6 tonnes of alum per day, generation of voluminous sludge which called for frequent desludging and caused increased wastage of water, frequent failures of mechanical scrapers due to the heavy load of voluminous sludge, increase in frequency of filter backwash, carry-over of aluminium (reported to cause Alzheimer disease - a form of senility) in treated water in the range of 0.2 to

0.5 ppm resulting in the fouling of ion-exchanger units, and the requirement of large storage space for chemicals.

The above mentioned problems were reduced considerably by the use of long-chained, charged synthetic polymer called polyelectrolyte.

General mechanism of coagulation and flocculation

Coagulation of suspended colloids depends on the nature of the particle, its ionic charge and concentration. The ionic charge plays a major role in agglomeration to form a larger particle. All particles carry an electrical charge on their surfaces, the sign and intensity of which depend on the nature and on the chemistry of the aqueous suspending medium. In general, aqueous suspensions at pH=4 and above carry a negative charge whereas the positively charged suspensions occur in aqueous suspensions at pH lower than 4 or particularly in stronger acids. This primary charge may result from the charged groups within the particle's surface due to discontinuity in the crystal lattice leaving an excess of +ve/-ve constituents on the surface, or may be gained by adsorption of a layer of ions from the surrounding medium. Alternatively, ions may be lost from the surface into the aqueous phase leaving an unsatisfied charge on the surface, or charged ions may be adsorbed from the aqueous phase. A solid or turbid particle as a whole cannot have a net charge, so that the charge that a given particle may possess must be counter-balanced by ions of opposite charges in the solution phase. This need for electroneutrality results in an electric double layer at the interface between solid and water consisting of both the charged particles. Thus, an equivalent excess of counter-ions of appropriate charge accumulates in the water near the surface of the particle. These counter-ions are attracted electrostatically and concentrated in the interfacial region. They are rather loosely held and may diffuse away in response to thermal agitation, and are easily replaced by other ions. These competing forces (electrical attraction and diffusion) spread the charge over a diffused layer such that the concentration of counter-ions is greatest at the interface and gradually decreases with distance from the interface. When the water contains a high concentration of ions the diffuse layer would obviously be compacted. It would thus occupy a smaller volume and would extend less far into solution.

Because of the primary charge on the particles, an electrostatic potential exists between the surface of the particle and the bulk of the solution. The charge is maximum at the particle's surface and decreases with distance from the surface. When two similar colloidal particles with similar primary positive charges approach each other, their diffuse layers begin to interact. As they come closer, the similar primary charges they possess results in repulsive forces. The closer the particles approach the stronger the repulsive force. Thus the negative charge on particles prevents their agglomeration due to the electrostatic repulsion. The way to cause agglomeration of such colloidal particles is to destabilise the suspended solids by neutralising negative charges and bringing these particles to form larger particles by the process called coagulation and flocculation.

These phenomena of coagulation and flocculation are effectively dealt with by the use of organic polymers called polyelectrolytes. The spectacular contribution of the polyelectrolyte family of compounds in raw water treatment programmes overcomes the various operational difficulties imposed by metal coagulants such as alum or aluminium sulphate.

EXPERIMENTAL SIMULATION STUDIES

As the jar test simulates the type of mixing and settling conditions found in a clarification plant, a simulation study for establishing the effectiveness of the polyelectrolyte treatment was carried out. The coagulants were measured separately into six beakers of one litre capacity each containing the 500 ml raw water with the turbidity level of 1200 NTU in such a way that the concentrations of polyelectrolyte in respective samples were 0.2, 0.4, 0.6, 0.8, 1.2 and 1.5 ppm. The samples were agitated for a period of 20 minutes by the paddle arrangement provided in the jar test apparatus. After the flocculation at very low stirring speed of 10 to 15 rotations per minute for about five minutes, the samples were examined after an established time period of 30 minutes. The supernatants of all the six samples were examined and tested for turbidity. Similarly the jar test was done in raw water of turbidity of 1200 NTU with the polyelectrolyte concentration of 1.2, 1.5, 2.0 and 2.5 ppm.

Implementation of polyelectrolyte treatment in the plant

The alum treatment programme was discontinued. The polyelectrolyte treatment programme was implemented. The average quantity of raw water handled was 96 MLD. During the entire period of the treatment programme, the turbidity level in the raw water was in the range of 50 NTU to 1200 NTU. After establishing the optimum polyelectrolyte dose with respect to the various raw water turbidity levels, polyelectrolyte dosing was done accordingly by the metering pump arrangement at the suction of raw water pumps. The polyelectrolyte concentration with respect to the above raw water turbidity level was of the order of 0.2 to 1.5 ppm.

RESULTS AND DISCUSSION

Clarification results are sensitive to chemical dosage, mixing energy and length of mixing. The addition of coagulant with high energy mixing to disperse it in the water could help to promote increased frequency of collisions. The jar test experiments indicated that in the slow mix period, floc building proceeds until the floc becomes bigger in size. After a slow mixing period of five minutes, the turbidity in the supernatant liquid was found to be in the acceptable range of 5 to 10 NTU and the polyelectrolyte dose was established to be 0.2, 0.4, 0.6, 0.8, 1.2 and 1.5 ppm with respect to the turbidity range of 20-50, 50-150, 150-300, 300-500, 500-800 and 800-1200 NTU (Fig. 2).

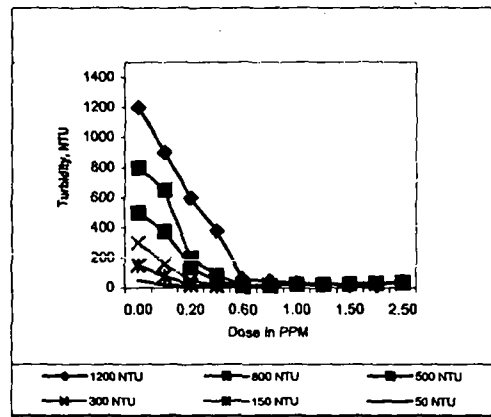


Figure 2. Optimization of polyelectrolyte dose.

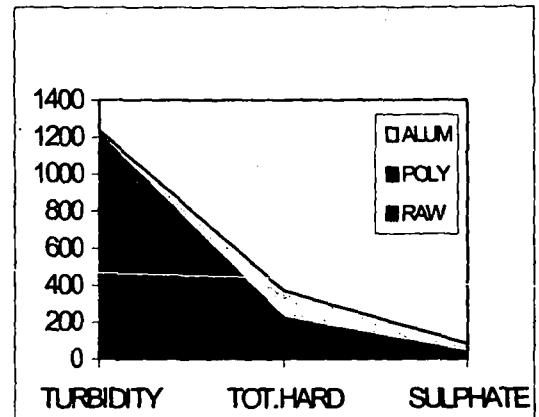


Figure 3. Variation in ionic load.

Polyelectrolyte concentration in the range of 0.2 to 1.5 ppm for raw water turbidity between 50 to 1200 NTU gave an average turbidity of 16.0 NTU in clarified water, which is well within the acceptable limits prescribed by NAPS. Floc formation was excellent in the clarifier within 10 to 15 minutes of polyelectrolyte addition. The flocs formed were dense and compact. With the maximum turbidity level of 1200 NTU, the alum dose requirement was 75 ppm against the polyelectrolyte dose of 1.5 ppm. Hence the handling of such a large amount of alum is eliminated. As compared to alum, the sludge generated during the polyelectrolyte treatment was 40 to 60% less in volume, hence problems related to frequent maintenance of mechanical scrapers and sludge disposal system were significantly reduced. During the peak monsoon season, the reduction of pH and alkalinity in the treated water, which resulted due to the addition of higher amounts of alum and lime was overcome by the use of polyelectrolyte.

As alum and lime addition increases the ionic load, viz. sulphate, aluminium and total hardness (Fig. 3), in treated water, the use of polyelectrolyte eliminated the additional ionic load and fouling of ion exchangers and improved the service hours between two successive regenerations. Moreover, the concentration of aluminium in recirculating condenser cooling water and the discharged plant water could be controlled well within the stipulated limits.

As the polyelectrolyte is a liquid product and completely miscible in water, preparation of the solution was easy and there was no need of a separate chemical preparation tank. The polyelectrolyte solution could be fed directly into the inlet channel of pump suction by the metering pump arrangement. Hence the sophisticated dosing of alum and lime addition system and its costly maintenance could also be avoided. The merits and effectiveness could eliminate the alum and lime treatment.

CONCLUSION

The replacement of alum treatment with polyelectrolyte treatment is cost-effective. The use of this organic polymer not only improved the overall efficiency of the clariflocculators in the raw water treatment plant with increased throughput and better quality of water, but also eliminated the handling of solid chemicals such as alum and lime with a substantial cost savings of 25% to 30%. The maintenance of equipment was also substantially reduced.

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