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Review Article

Automation and control of water treatment plant for defluoridation

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Abstract
In recent times, water treatment plants are mainly established to ensure continuous supply of safe and good quality of water. They are mainly concerned for the conservation of water that is achieved by application of automation controls. Various industrial processes are there where water treatment is essential. To manage the productivity, productivity, improving quality of product/service, reducing downtime and operating costs in current sustainable worry requires a practical approach which can subsequently optimize efficiency of the process and available resources. Automation is one of the most effective tools to achieve this. This paper critically focuses on the technical issues of automation control system that can help in the advancement of automation industry with respect to the management level and process effectiveness.

Keywords
Automatic control system, Potable water treatment process, Process control, Present situation.

1.Introduction
Water is considered to be one of the physical environments of human being and has a direct bearing on his health. Clean drinking water is a basic human need. The average daily water consumption for a person is of 30 liters/day [1]. In total of 100% of water available on earth only 0.01% of the total water of the earth is available for consumption. India accounts for 2.45% of land area and 4% of water resources of the world but represents 16% of the world population [2]. With the present population growth-rate (1.9 per cent per year), the population is expected to cross the 1.5 billion mark by 2050 [3]. Thus need to efficiently manage the available water resources is the most important problem in front of the world. The use of automated systems is an effective way to handle the limited water resources [4]. Present economic and environment concerns require business to take a pragmatic approach to manage productivity, improving quality of product/service, reducing downtime and operating costs [5]. Automation is one of the most effective tools to achieve it [6, 7]. The developments during the last four decades in on-line instrumentation, computer technology, process understanding and subsequent model development, and control methods have been powerful driving forces for advanced control making automation even more profitable [8].

Today computational power is almost "for free". The instrumentation development shows a progress towards smarter sensors with multiple heads, possible to be placed anywhere in the processes [9]. Actuators such as variable speed drives for pumps and compressors make control more flexible. Control engineering today can offer almost any method that the water operator would need [10]. There are several important demand pull driving forces. Regulatory requirements and increased design complexity have simulated further automation control development [11].It is expected that the use of automation controls for the operation and management of wastewater systems will increase in the coming years. Other demand pull driving forces include continued population growth and urbanization leading to increased wastewater load, continued increase in the complexity in the function and capability of wastewater treatment plants, even more stringent regulations and even- stronger economic drivers[12]. The on-going climate change and the associated extreme weather conditions further add to the challenges. This paper critically reviews the development in the automation controls in water treatment plants [4].

Various Standards that are required for the safe drinking water include the following [13, 14]:

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- Water should be free from every kind of pathogens that may lead to certain kind of diseases.
- Drinking water should be free from unwanted taste and odour.
- The desirable limit of turbidity in drinking water is less than 1NTU. So, the desirable limit should be achieved.
- Drinking water should be free from residual chloride and it should be at least 0.5 ppm.

2.Role of automation in water & waste water treatment industry

Water being a critical utility in many industries (pharma, electronics, power, etc.), it is important to evaluate the benefits of automation on water and wastewater treatment plants.

To comprehend the significance of automation in waste water treatment, there are following examples [15]:

Bottled water Industry & beverage Industry: If the conductivity and pH of the treated water are not monitored and controlled, they will not meet the norms specified for packaged / bottled water specified by BIS [16].

Waste water treatment: The key design parameters for efficient wastewater treatment includes monitoring dissolved oxygen (DO) levels during various cycles of operation. In the absence of instrumentation to monitor it, the treated effluent will not be able to consistently meet the discharge norms with respect to BOD/COD/ammonical nitrogen/phosphorous levels [17]. The above examples reflect the necessity for automation of water and wastewater treatment processes, to consistently meet the standards of treatment. As with any project/process/equipment, the criticality of the process (softening for washing pipes or for boiler feed water) will determine the degree of automation.

To monitor the high purity water various kind of automated solutions have been introduced and PLC dosing system is one of the technique that is much advanced from that of the simpler timer based dosing [15].

3.Principle application of automation system in defluoridation water treatment plant

The process of water treatment plant is shown in *Figure 1*.

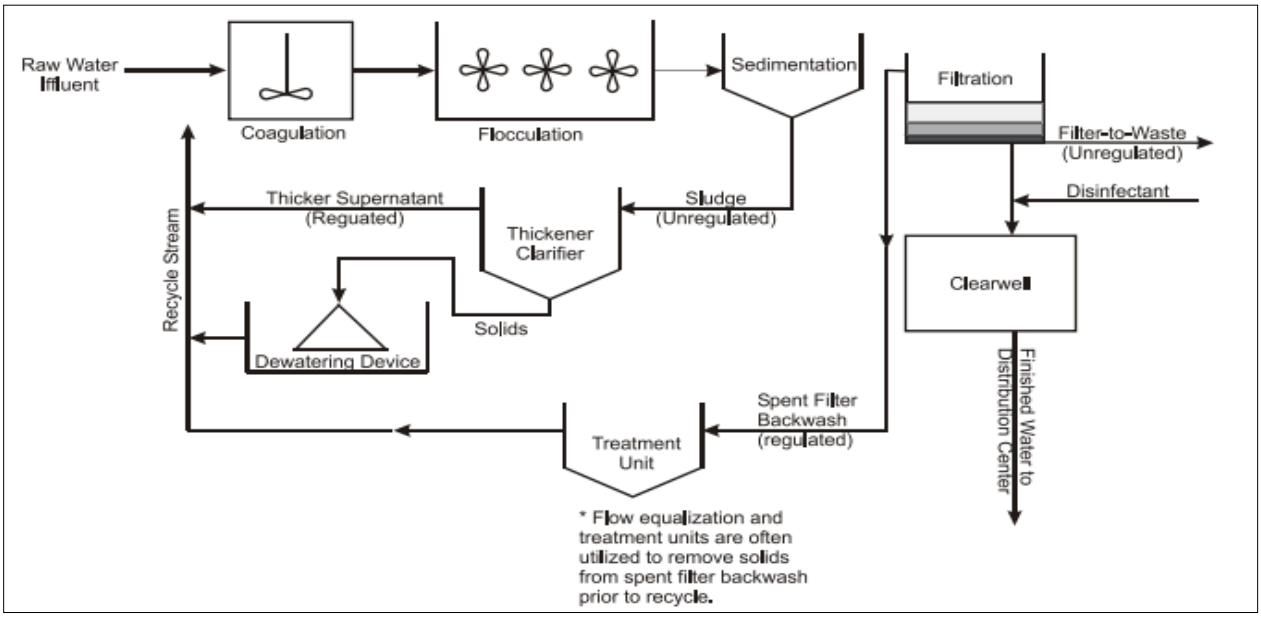

Figure 1 Schematic view of the defluoridation set-up [9]

The process consists of several stages as shown in the *Table 1* as follows: (i) Mixing (ii) Coagulation and Flocculation, (iii) Sedimentation, (iv) Filtration, and (v) Disinfection (Chlorination). Firstly, raw water comes into the coagulation tank and after that goes for flocculation where the flocks are formed. Sludge from the sedimentation tank goes into the thickener

for thickening process and the supernatant goes into the filtration tank where the suspended particles get removed.

Table 1 Process with its possible applications [18]

Process	Principle applications
Mixing	Provides uniform and rapid distribution of chemicals and gases into the water.
Coagulation	Coagulation is the addition and rapid mixing of coagulant resulting in destabilization of the colloidal particle and formation of floc
Flocculation	Flocculation of destabilized turbidity and color causing particles to form a rapid settling floc.
Sedimentation	Gravity separation of suspended solids of floc produced in treatment processes. It is used after coagulation and flocculation an chemical precipitation.
Filtration	Removal of particulate matter by percolation through granular media. Filtration media may be single, mixed or multi-layered.
Disinfection	Destroys disease causing organisms in water supply. Methods used for disinfection are ultraviolet radiation and oxidation that can be done by application of certain chemicals such as chlorine, bromine.

The process of chemical feeding and handling includes the addition of alum as per the quality of raw water. The process needs online control and monitoring so that the system can work efficiently. To purify water from the particulate matter, filtration is considered to be the most reliable technique.

The process of water treatment consists of several stages for production of pure water. Each stage consist particular equipment's, setup which has defined control functions and the process equipment and control parameters for each stage have been described in *Table 2*.

The operation of the system can be fully (in Automatic mode) controlled by the Programmable logic controller (PLC) and software. The system components are controlled with the help of the PLC, which communicates with the software. The data sent by the PLC is stored in the server in prescribed formats; this data is used by software for decision making and report generation.

Table 2 Possible control parameters in the process [19]

Process	Equipment	Control parameters
Chemical handling and feeding	Solution tank, Turbulence channel, Stirrer	pH and turbidity testing in laboratory
Coagulation and flocculation	RCC tank, bleades with gear box, Motor	Mixing of alum solution into water and formation of floc
Sedimentation	RCC tank with tube settler	Suspended particles are removed by settling
Filtration	Rapid sand filter, valve, pump	Removal of turbidity and coarse particle
Disinfection	Feed valve	Chlorine dosing to remove bacteria and residual chlorine

4.The main contents and methods of process control in potable water treatment

Dosing control system: Adding drugs is a critical aspect among the entire treatment process. The dosage of drugs directly relates to the quality of effluent water and the cost of production [10]. So, it needs to strongly improve the precision of dosing and reduce the waste of pharmaceuticals [9]. Usually, dosing control system includes coagulation control, pH control and chlorine control [20].

Coagulation control: Recent research proclaimed the streaming current detector (SCD) as an effective method for automatic coagulant dosing control [5]. The SCD selected the micro-electrical characteristics parameter which stood for the essence of coagulant dosing to control the coagulant dosage. SCD is extensively applied in China because it is socially and economically advanced, thereby trouncing the gaps present in existing techniques. The application of this technique is done in three types that are simple single-loop control, cascade control and streaming current feed-forward—single-loop control [21]. The wide research in the field of the flow control of current coagulant dosage resulted in the development of streaming current detector and that lead to the application of this technology in several water plants in Hangzhou, Daqing, Mudanjiang [2].

One of the other promising technologies includes Flocculation pulse detection technology that measures the relative change of size in the flocculation process of impurities in water. The main advantage of this technology is that the detection process is not affected by presence of any kind of impurity in water which consequently overcomes the shortcoming of SCD technology. The first application of this technology was done by China to control the high turbidity in Yellow river water in 1992 but because of the high complexion in water, it was not successful and further research needs to be carry out[22, 23].

pH Control: Many researchers have considered the clarification stage as the central process of whole water treatment process.

It is here that pH control strategies will be focused, since pH is a fundamental factor controlling the performance of the clarification process[24].On the coagulation processes, it may be necessary to use an acid and/or a base for pH correction purposes to reach the best removal of pollutants[25].However, pH control with an acid and a base is more complex due to the multi-actuator set-up and also the bi-linear effects caused by differing solution strengths. The control strategy for pH control is shown in *Figure 2*.

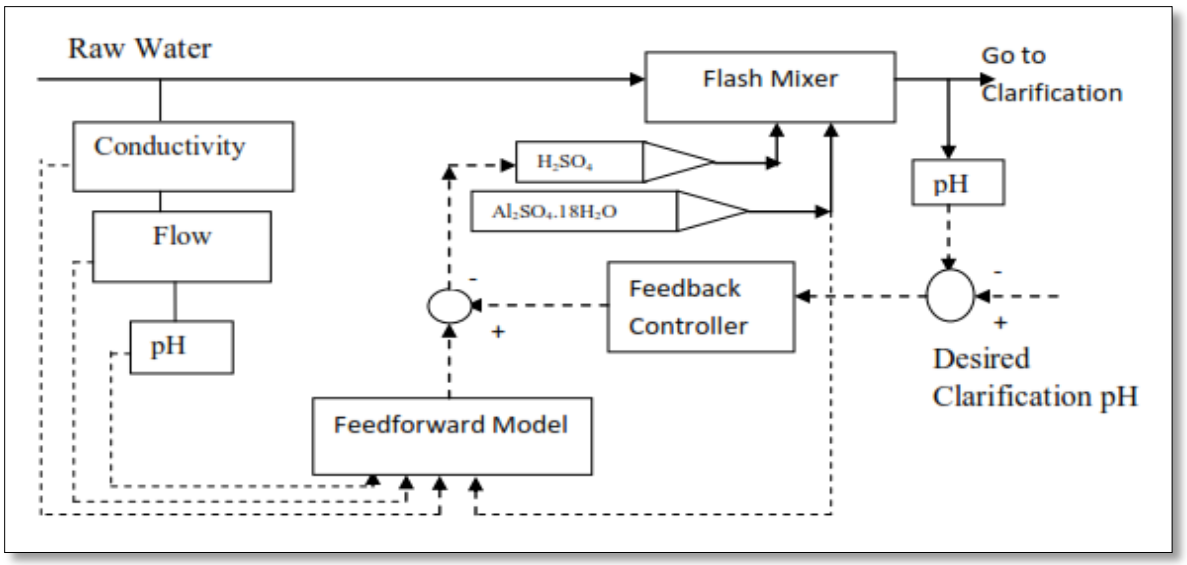

Figure 2 pH control strategy [25]

In the above system, raw water and other chemicals get mixed in the flash mixer and the pH is measured by the feedback controller and the desired clarification is adjusted accordingly. Conductivity, flow rate and pH of raw water are controlled by the feed-forward model.

Sedimentation control system: Sedimentation includes deposition of settle floc loaded with fluoride, turbidity, pathogens and other impurities under the effect of gravity [26]. To increase the efficiency of the process, chemical coagulation and flocculation is done before which ultimately results in formation of bigger flocs that enhances the settling process [27]. In the process of sedimentation control, sludge is controlled in sedimentation tank by controlling the sludge volume, sludge cycle and sludge process through the application of mud drainage equipment [25]. Utilization of this equipment is very much beneficial in terms of reducing water consumption and energy consumption in water plant operation and also results in high water quality. Nowadays, PLC which is based on the principle of law of deposition, sludge level is used to attain the control sludge in sedimentation tank. PLC control system is composed of host computer, PLC, Suction Pump Control, Fault Alarm and so on [28].

5.Conclusion

Successful process control requires maintenance and knowledge personnel. With automation, routine operator decisions are less critical but effective routine maintenance and the availability of competent personnel for operating emergencies are needed. To ensure such competency at small plants, the implementation of the micro-processor control

projects would be achieved through the use of private consulting firms which have an interest in operating treatment plants as an offered service. The development had led to the automation system developing of intelligent, decentralized, network, and further promoted the information system to be established in integrated enterprise of control and management.

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Conflicts of interest
The authors have no conflicts of interest to declare.

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