CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Literature survey about the water treatment process was carried out in two perspectives. One is the coagulant dosage predictor implementation and the other one is automatic dosing control. Many of the dosage predictors use different soft computing techniques to find the optimal coagulant dosage. Automatic dosage control is suggested based on the predictor output.

2.2 REVIEW OF PREVIOUS RESEARCH ON WATER TREATMENT

Different methods of ANFIS were analysed for predicting coagulant dosage by Salim et al. (2012). From this study it was understood by the author that the relationship between coagulant dosage and the water quality parameters were nonlinear. It was very difficult to control the coagulant dosage using conventional control techniques. Jar tests were used for determining the coagulant dosage. This technique was time consuming and it responded very slowly with the changes in the raw water quality parameters. In this study, two types of ANFIS were used for coagulant dosage prediction model. Six process variables were used to develop the models. These variables include turbidity, conductivity, temperature, dissolved oxygen, ultraviolet absorbance, and the pH of water to build the coagulant dosage model. The two models were grid partition-based fuzzy inference system, called ANFIS-GRID, and subtractive clustering based fuzzy inference system, called ANFIS-SUB. Based on the analysis using root mean square error and correlation coefficient dosage, the model using ANFIS-SUB performed better than the dosage model using ANFIS-GRID.

Malgorzata and Malgorzata. (2011) proposed an ANN based model to predict water quality after coagulation and ultrafiltration processes using an immersed membrane, various structures of multilayer perceptron with one hidden
layer were created. Feed water turbidity, turbidity in a tank, pH and temperature in the tank as well as trans membrane pressure and permeate flux were treated as input signals. Based on the best network chosen, prediction of water quality was done.

Shahin et al. (2010) presented a study about the performance of the coagulants poly-aluminum chloride and aluminum sulphate in leachate treatment. The coagulation study was analysed by the author. The coagulation test was carried out to remove chemical oxygen demand, colour, total suspended solids and turbidity. Optimum coagulant dose was found as 1.9 g/L for Poly aluminium chloride, and 9.4 g/L for aluminium sulphate. The chemical oxygen demand removal was 84.50% for aluminium sulphate and 56.76% for Poly aluminium chloride. However Poly aluminium chloride was efficient in removing turbidity, total suspended solids and colour.

In-line coagulation method was presented by Krystyna et al. (2009). Different types of coagulants were used in this study. FeCl$_3$, Al$_2$(SO$_4$)$_3$ and Fe$_2$(SO$_4$)$_3$ were used as coagulants. The in-line coagulation showed the improvement in water quality. The author suggested that the choice of coagulant was important for the amount of organic matter removal. The aluminium coagulant proved its highest efficiency for organic matter removal.

The dynamic model of a water treatment process was presented by GUO et al. (2009). The three basic processes coagulation, flocculation and sedimentation were analysed and the model development was discussed. To develop such models, flow equations for colloidal liquid were followed. The authors suggested that the developed model will provide a good simulation tool for nonlinear process analysis. In this paper also the authors described the water treatment process as nonlinear.

Coagulant dosage optimization in leachate treatment was discussed by Talebi et al. (2009). The coagulant used was ferrous sulphate. The water quality
parameters like chemical oxygen demand, colour and turbidity were analysed using the ferrous sulphate coagulant. The optimization tool called response surface methodology was used to find the optimal coagulant dosage. From the response surface methodology, the coagulant dosage was found as 10 g/l. Based on the study, the coagulant ferrous sulphate was identified to be the most efficient. The authors presented the usefulness of designing experiments for optimization issues.

Zheying et al. (2009) presented his view in developing mathematical model based on the reactive mechanism. In this study the authors focused on modelling water treatment process based on artificial intelligence because the modelling based reactive mechanism was very difficult. Neural network was used for coagulant dosing model. Two types of algorithms BP and LM were discussed in this research. Based on the experimental results, BP algorithm based neural network showed better prediction. The authors suggested this method for real time coagulant dosage control.

A simulation study for waste water treatment was discussed by Huang et al. (2009). This research presented a predictive scheme for coagulation process using fuzzy and neural network. The study was performed for paper plant waste water treatment. Waste water treatment process also has the nonlinear characteristics similar to the drinking water treatment process. Artificial intelligence was used to model the nonlinear relationship between pollutants’ removal rate and the chemical dosages. The optimization procedure included gradient descent algorithm method. Based on the analysis and study, the developed model showed better prediction capability.

Guan and Shang (2008) suggested the soft computing techniques called ANN and ANFIS for predicting the coagulant dosage. Poly Aluminum Chloride (PAC) was used as a coagulant in this research. This research is based on northern Taiwan’s surface Water Treatment Plant (WTP). The predictors were developed using both ANN and ANFIS. These predictors were capable of assisting treatment plant operators to determine the real-time coagulant dosage. The inputs to the
dosage predictor were the water quality parameters of each process in a WTP and prior coagulant dosage. The dosage predictor output was the optimal coagulant dosage. The input parameters include the coagulant dosage of yesterday, coagulant dosage day before yesterday, and the temperature, turbidity, color, pH in each of the raw, flocculation, sedimentation, and treated water. The dosage predictor developed using ANFIS was better than ANN.

The design of a predictive controller for a waste water treatment process was suggested by Sergiu et al. (2007). The objective of this research was to reduce the substrate concentration of effluent within the acceptable limits. Neural network was used as internal model of the process in the predictive controller. The model predictive control needs a reliable process model. The reliable process model improved the performance of model predictive control. Hence the neural network was chosen as internal process model for this control strategy.

Kathy et al. (2005) presented his article about the water treatment in cold region for contaminated water. This research concentrated on coagulation experiments and modelling methods for the water treatment process. The water quality parameters considered were pH, coagulant dosage and flow rate. This research showed that a simple laboratory set up could be used to predict the full scale water treatment process performance. The authors suggested that the laboratory set up can be tested in different operating conditions without affecting the real process.

Modelling methods of waste water treatment plants were introduced by Krist et al. (2004). White box modelling was applied in this field. The main applications were learning, process optimisation and design. This model was mainly aimed for municipal waste water systems. The author suggested that the waste water treatment plant may use black box, stochastic grey box and hybrid models for the prediction of effluent quality parameters. Based on the study, the author mentioned that in some cases white box models don’t provide accurate predictions. This issue was overcome by artificial intelligence.
A new method for suspended sediment concentration was discussed by Pavanelli and Bigi (2004). The normal procedure to find suspended sediment concentration was gravimetric method. This method was a direct measure of suspended sediment concentration in a water sample. The authors used Imhoff cones as an alternative indirect method for measuring suspended sediment concentration. From the analysis it was understood that there is a close relation between the turbidity and suspended sediment concentration.

The concept of process model and process inverse model was suggested by Holger et al. (2004). In this paper, artificial neural network was used to develop the coagulant dosage model and treated water turbidity model. Coagulant dosage model was called process inverse model and treated water turbidity model was called process model. The process inverse model assists the plant operators to determine the optimal coagulant dosage. The inputs to the process model were the raw water quality parameters and the applied alum dose and the outputs were the treated water quality parameters. The inputs to the process inverse model were the raw water quality parameters and the treated water quality parameters.

Application of data mining in water treatment plants was proposed by Hyeon et al. (2004). Data mining technique finds mapping using automatic approach through searching and analysis processing. Human influence was reduced in this method. Machine learning technique was followed in this method. The authors suggested for the use of decision tree to find the coagulant type. The coagulant dosage was determined using the prediction models based on the input conditions. The proposed method was suited for the input variations. Coagulant dosage system using the data mining concepts and artificial intelligence techniques were suggested for automatic coagulant dosage control.

The neural network predictors were used in many applications in addition to drinking water treatment process. Predictor implementation in waste water treatment was discussed by Zeng et al. (2003). This research explored the usage of neural network in the predictive control scheme for the coagulation
process of waste water treatment in a paper mill. Multi-layer back-propagation neural network was used to develop the nonlinear relationships between the variables used in this study. The model was developed to find the chemical dosages required for the pollutants. The neural network used the gradient descent algorithm method for optimization procedure. The developed model showed good performance in prediction.

Different techniques of coagulation control were presented by Fletcher et al. (2002). The authors expressed their views about inferential approach for optimal coagulant dosage control. This method was highly site dependant. If inferential method is followed the entire range of data should be covered to give the accurate result. Finally the author suggested for automatic jar testing method for optimal alum dosage control.

Van and Rietveld (2002) modelled the water treatment process using a different environment called stimela. The method was mainly used to maintain the water quality. The authors mentioned that the model can be used in model predictive control. The data were made available to every one who works for the treatment plant using internet technology. The database management and the decision systems were made easy by this method.

Artificial Neural Network is the only technique which has been used by many authors for their researches in water treatment. Another coagulation control in water treatment process for drinking water which uses artificial neural network was discussed by Nicolas and Thierry (2001). The author has mentioned that modelling of water treatment using traditional method is difficult due to the complex chemical and physical phenomena. This study also showed that the water treatment process is nonlinear. The model developed did not show the dynamics of the process. The authors stressed the need for treated water parameters model mainly to know the treated water turbidity and it was concluded that the performance depends purely on the quality of training data.
The possibility of applying automatic dosage control was studied by R.-F. Yu et al. (2000). ANN was used to model the coagulant dosage. Five process parameters were used in the model development. The five parameters were turbidity of raw water, pH of raw water, conductivity of raw water, treated water turbidity, and alum dosage. Other methods were also tested in this research that included regression model and time series model to predict alum dosage. Based on the study, the dosage model using regression technique showed poor performance over the other models.

Many researchers used artificial neural networks for the predictor development. Qing and Stephen (1999) also used neural network for the dosage prediction. The authors mentioned that the water treatment process is nonlinear. This is mainly due to chemical reactions which are very complex in nature. Because of the nonlinear nature of the process conventional controllers can not be used. Based on this study the feedforward network was concluded as the best network for the chosen plant. The author developed the neural network using software. The major parts of the software were plant forward reference model and plant inverse model. This software behaved like a controller and took raw water parameters and calculated the optimal coagulant dosage. The author mentioned that the software can be used in the real time for controlling coagulant dosage.

Automatic coagulant dosage was discussed by Evans et al. (1998). In this study also feedforward controller using neural network was analysed. The neural network acts as a prediction model for coagulant dosing system. The future work was mentioned to develop fuzzy neural based dosing system. The authors suggested a model for predicting the treated water colour and turbidity as a future work. This model can use raw water quality parameters as inputs. This model can be used in a model predictive algorithm to find the optimal coagulant dosage.

Neural network based coagulant dosage predictor was suggested by Claude et al. (1997). The developed models used feedforward network with a quasi-Newton method. The first model can be used all through the year which is
called annual model. The inputs to the model were the raw water pH, raw water turbidity, and raw water temperature and raw water conductivity. Other types of models were based on the different seasons. Four different types of models were developed based on different seasons. The models based seasons were compared with the model which can be used all through the year. The seasonal models showed better results on training and testing data. These models help the operator to run the process without any basic knowledge. The above models don’t have any impact on the process dynamics.

2.3 CONCLUSIONS FROM THE LITERATURE REVIEW

- Water treatment process is highly nonlinear.
- Coagulant dosage control is difficult with conventional controllers.
- Coagulant dosage not only depends on the turbidity of water but also on various other water quality parameters.
- Coagulant dosage control is site dependent. Developing coagulant dosage control scheme depends on lot of data which describes the water treatment process.
- Process model and process inverse model has been suggested by few researchers for predicting the treated water quality parameters and optimal coagulant dosage.
- In many research articles coagulant dosage was predicted using artificial intelligence.
- Coagulant dosage automation is suggested by many researchers for future implementation.
- Feedback control is difficult because of the nature of the water treatment process.

Based on the papers analysed a new algorithm was proposed to implement the feedback control strategy for coagulant dosage control. In this work a virtual feedback control strategy similar to a feedback control was
developed using soft computing techniques and tested in a laboratory based water treatment plant.

2.4 SUMMARY

An extensive review was carried out in the area of water treatment process and Artificial Intelligence. The key aspect of this chapter was to review and analyse the various methods, algorithms developed and models developed for the water treatment process. Finally a new approach for feed back control strategy is proposed in this chapter.