# Optimization of quality parameters affecting changes in concentration of iron and manganese in water treatment plant

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**Abstract:** The aim of raw water treatment is supplying without any harmful chemical and pathogen agents, which can transfer via water. Each of raw water sources has its own contamination pattern. Therefore, water treatment should relate to desire standard of product. The existence of iron and manganese in water can cause considerable problem. Iron and manganese cause laundry and pipe become rusted, formation of sediment in water distribution system, dechlorination of water, interference in water treatment process such as disinfection, change the taste of water and also increase the growth of bacteria. In this study the temporal changes of concentration of iron and manganese during water treatment process in Ekbatan dam water treatment plant, has survived. By using *Multiple Stepwise Regression*, the relation between the concentration of iron and manganese in water treatment plant output and manageable water quality parameters that can have effect on the concentration of iron and manganese have been calculated. Sum of iron and manganese concentration in output of water treatment plant as objective function, minimized by using Genetic Algorithm (GA) method. Results show that temporal changes of iron and manganese during treatment process, with 95% probability are significant. The effective processes in decreasing the concentration of iron are axilator and gravity rapid sand filter. While only gravity rapid sand filter have had significant effect on decreasing of manganese. The effective parameters on concentration of iron and manganese concentration changes in output were changes of Electrical Conductivity (EC) and Turbidity (NTU) in input of treatment plant. However, changes of pH in below the filter and turbidity in input had effect on changes in concentration of manganese in output of treatment plant. Optimization by GA shows that if EC and turbidity in input and pH in below the filter were 333 $\mu S/cm$ , 117 NTU, and 6.8 respectively, Sum of concentration of iron and manganese in output will be minimized. So, with suitable technical operation in special step in water treatment plant, occur of impermissible iron and manganese concentration in output, can be avoided.

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**Keywords:** Water treatment plant, Iron and Manganese, Multiple Stepwise Regression, Genetic Algorithm

## 1. Introduction

### 1.1. Water contamination and treatment

The healthy and safe water is essential for human. The body of adult person needs 2 liters water daily for doing its vital functions. The public source of water supplying the water for drinking, providing food, washing, health issue, swimming, industrial usage and fire fighting. The aim of raw water treatment is supplying water without any harmful chemical and pathogen agent, which can transfer via water. In ancient time, Egyptian people kept the water in the big bowl to sedimentation of some materials and so had better in taste and in appearance. Chinese boiled the water for treatment. In Greece, Hippocrates (the father of medical science) about 400 years B.C understood that water can contain water born diseases. Therefore, he suggested that for purification of water to drinking, use boiling and textile filter. Maintenance of drinking water quality is one of the most important duties in any water treatment plant (Damikouka et al., 2007). Today, water treatment for omitting the pathogen and harmful chemical agent is more effective. Disinfection and filtration have been paid attention during recent years.

In two recent decades, there are many chemical and microbial contamination events internationally. Many of these events cause to illness and even to death. For example, incidence of Cryptosporidiosis in 1993 in Milwaukee is one of these events (Lisle and Rose, 1995). From these, water companies are looking for minimization of drinking water source contamination risk. Investigation of Rose and Lisle in 1995 to finding the reason of these events shows that there was a failing in water treatment plant. While in long term, the control of filtration and coagulation was weak. The weakness of treatment plant proved by increased turbidity of water in output of treatment plant (Lisle and Rose, 1995). Each of raw water supplies has its own contamination patterns. Therefore, water treatment should relate to desire standard of product (AWWA, 1990; WHO, 1993).

In water treatment plant removal of the bigger suspended materials, is the duty of bar rack and the smaller materials could be removed during coagulation and sedimentation. Although usually some small floc and the other suspended material would be remained. For omitting them and reducing bacteria to safe water production, filters be used. In this step, soluble and suspended materials are remained in filter bed and so water with high turbidity will be treated. Improvement in gravity rapid sand filter is contemporary with discovery of coagulation (addition of coagulant to water with high turbidity). The materials in water accumulate and rapidly settle down (Tebbut, 1998). In generally, water passes the flocculation and sedimentation reservoir and then goes to filter. The raw water by using chemical agents be treated to remove turbidity before entrance to filter (Shamim, 1990).

**1.2. Iron and manganese in water and their problems**

Natural water becomes contaminated because of wastewater from industrial and mines. Heavy metals are important, because they are not degradable and so they are stable (Saxena and Souza, 2006). Iron and manganese are in many water supplies, so they can cause many problems. For example from electrical industries are full of Copper, Zinc, and Iron. The concentrations of these metals are more than international environment quality standard (Aslam et al., 2004). Heavy rainfall in catchments can increase the concentration of iron and manganese in lake of dam. After heavy rainfall, pollution and problems related to its treatment become increased. Following heavy rainfall, dirty water and associated water treatment problems increased as catchment surface erosion and dynamic mixing of the whole water column induced by the introduction of a large volume of rainwater runoff lead to marked increases in particulate matter (mainly carbonates) in the water body. Because of natural events such as erosion, the iron and manganese are in mineral sediment in lake. In this case, the important tip is mineral of catchment geology component. If the combination has much basaltic, thus there is much amount of iron in water. To solving this problem, the artificial aeration in Hinze dam is investigation. Artificial destratification is the process of adding energy to a water body to break down existing stratification, or more usually, to prevent the onset of stratification. By artificially preventing stratification, oxygen supply to the bottom waters of a storage can be maintained and thus prevent the release of iron and manganese from the sediments (Zaw and Chiswell, 1999). Anaerobic groundwater when directly pump from well contains much iron in the form of ferrous more than several milligrams per liter. Iron in the form of ferrous in exposure to atmosphere oxidized into ferric. In this state, its color becomes undesired brown red. Iron also increases the bacteria growth. These bacteria obtain energy from iron oxidization, and during this process, the viscous sediment covers the pipes (WHO, 2008). Iron and manganese often are in groundwater from wells in fishery, sand stone and alluvium sediments. In addition, water reservoir may contain iron and manganese. Hypolimnion dissolves iron and manganese from sediments in anaerobic condition and inversion period thus iron and manganese widespread in all of the depth (Viessman and Hammer, 2004). Iron and manganese are generally in water supplies in the form of suspension as hydrated oxide and either in the form soluble as bicarbonate. In natural water, iron may be in form of ferric, ferrous, soluble, colloid, and or insoluble (Punmia and Kumar, 1995). Naturally, manganese is available in some soil and can be washed into groundwater or into surface water supplies. The sediment of insoluble manganese in raw water in floor of water reservoirs settled. When the dissolved oxygen is little, manganic dioxide changes in to manganese ion. Manganese dioxide, which is not settled in the lake of dam, can easily be omitted by process like coagulation, sedimentation and filtration. Nevertheless, these processes could not omit manganese ion (soluble manganese). Manganese ion could be released in to water supply through treatment process. Dissolved manganese in the water supply system gradually oxidized in to manganese dioxide via disinfection and so can cause problems for consumers (Raveendran et al., 2001).

Iron and manganese cause problems such as sediment formation in distribution system and pipes, dechlorination of water, interference with treatment process such as disinfection, change the taste of water, and growth the bacteria. When these bacteria die, they cause bad smell and taste in water (Vayenas and Lyberatos, 1998). These autotrophic string bacteria use reduction iron as a energy supply and cause iron to be settled. This event causes decay of pipes (Viessman and Hammer, 2004). Manganese has effects on central nervous system in human (Vayenas and Lyberatos, 1998). Another problem from iron and manganese is clogging water softener. Iron in earth crust can be in form of ferric hydroxide and so being settled. Also this phenomenon can accrue with growth of iron bacteria. This growth produces slime and clogged the pores. Therefore, reduce the water transmission in aquifer (Gray, 2005). The above problems occur when iron and manganese be exposed to air or chemical agent such as household bleaching and change to insoluble form.

In the amount more than 0.3 mg/lit, iron cause erosion of laundry and pipe feature. There is not considerable taste in water If the concentration of iron be less than 0.3mg/lit. However it's maybe lead to increasing of turbidity and color in water. In the concentration more than 0.1mg/lit of manganese, the taste of water will change to undesired and also will cause stain in sanitary features and laundry. Manganese, like iron, causes accumulation of sediment in water distribution system. Usually concentration below 0.1mg/lit is acceptable for consumer. Even in concentration of 0.2mg/lit, manganese often produce cover in pipes which may separates in the form of black sediment. The amount of guideline based on health for manganese is four times more than acceptable level 0.1mg/lit (WHO, 2008). The first aim of this study is surveying of temporal changes during iron and manganese treatment in Ekbatan dam water treatment plant. The second aim is achieving the relation between manageable water quality parameters that can have effect on the concentration variation of iron and manganese in output of treatment plant. Using GA, objective function as sum of the iron and manganese in output is minimized. Since here, optimized amount of manageable water quality parameters that can have effect on the iron and manganese concentration in output is obtained. The final purpose is introduction of managerial and technical methods for reducing the iron and manganese concentration in output of water treatment plant.

## 2. Material and Methods

### 2.1. The studied water treatment plant

Ekbatan dam in Abshineh catchment area is for supplying water to drinking, industry, and agriculture consumption in Hamedan. Surface water from Ylfan and Ebero revers, after storing in Ekbatan dam's reservoir is conducted to treatment plant via intake pipe. In treatment plant, after physical treatment, chlorination and purification, water will be transported to drinking consumption. The purpose of treatment is removal of suspended and colloids materials and omitting the bad taste, color and pathogen agents from raw water and produce health and potable water upon standards. Water treatment plant as shown in figure 1 includes flash mixing pond, axilators and gravity rapid sand filters. Aluminum sulfate [$Al_2SO_4.14H_2O$] is used as coagulant. From the end of July until the end of October in some cases, the concentration of iron and manganese is more than permission level. The analysis of data has been done on four critical months: July, August, September, and October. Data were collected in 2004.

### 2.2. Data analysis

For data analysis, parameters such as pH, turbidity (NTU), temperature ($^0$C), electrical conductivity ($\mu s/cm$), free residual chlorine ($mg/lit$), iron ($mg/lit$), aluminum ($mg/lit$), and manganese ($mg/lit$) was recorded. These parameters were chosen because they are manageable and controllable during treatment process. Twenty samples were taken during four critical months from different part of treatment plant include intake valve, input, axilator, below the gravity rapid sand filter, and output. Sampling was upon standard method (APHA, 1991). Temporal concentration changes of iron and manganese during treatment were surveyed by factorial variance. Studied factors as following were surveyed.

- Time factor in four levels: July, August, September, and October
- Treatment step factor in five levels: intake valve, input, axilator, below the gravity rapid sand filter, and output

To finding the factors, which cause significant effect on iron and manganese concentration, Duncan's new multiple range test is used. Effective parameters on iron and manganese concentration in output of treatment plant and their relation were recognized by *Multiple Stepwise Regression* method. In multiple stepwise regression, independent variables one by one enter to regression equation. If their changes have significant effect on dependent variable changes, they remain in regression equation and partial regression coefficients will calculated for them. So ambiguity from Attributing dependent variable to each of independent variables is avoided. The calculation was done by SPSS software (Kinnear and Gray, 1999).

### 2.3. Genetic Algorithm and optimization of effective factors on iron and manganese in output

Today's, of the most important research field is improvement of investigation methods upon the natural evolution. Genetic algorithms and genetic programming can be considered a subset of evolutionary computation. Evolution means gradually improvement. Using genetic algorithms can be faster and more likely obtained global optimum solution with minimal involvement in the local optimization. Genetic Algorithm is a model of machine learning which its behavior is upon the natural evolution mechanism. An example of this application is multidimensional optimization which the different parameters are in the format of chromosome string. In this study, the optimization with GA is used for optimization of objective function. Therefore, partial regression coefficients which are obtained from multiple stepwise regression be optimized in order to objective function minimization.

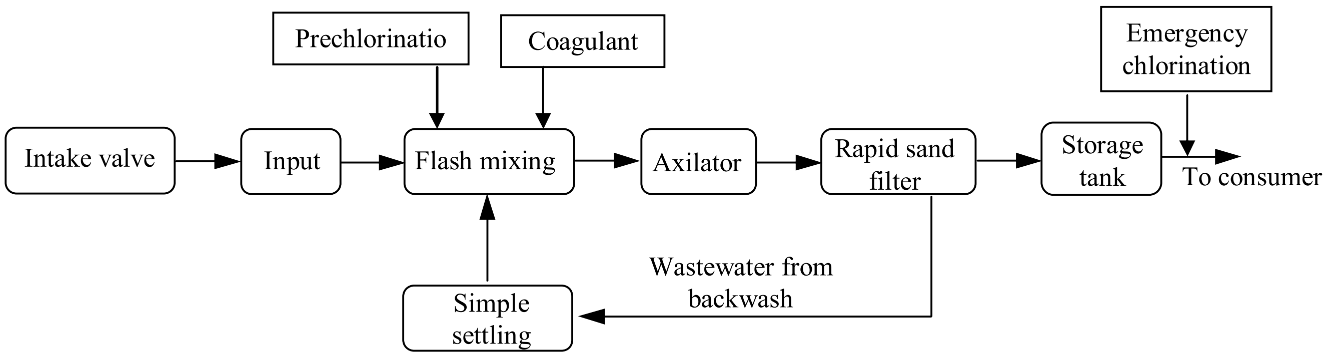


Figure 1. Process flow diagram for Ekbatan dam water treatment plant.

## 3. Results

### 3.1. Iron and manganese changes

Figure 2 shows the mean concentration of iron and manganese in different treatment step include intake valve, input, axilator, below the gravity rapid sand filter, and output in different months include July, August, September, and October.

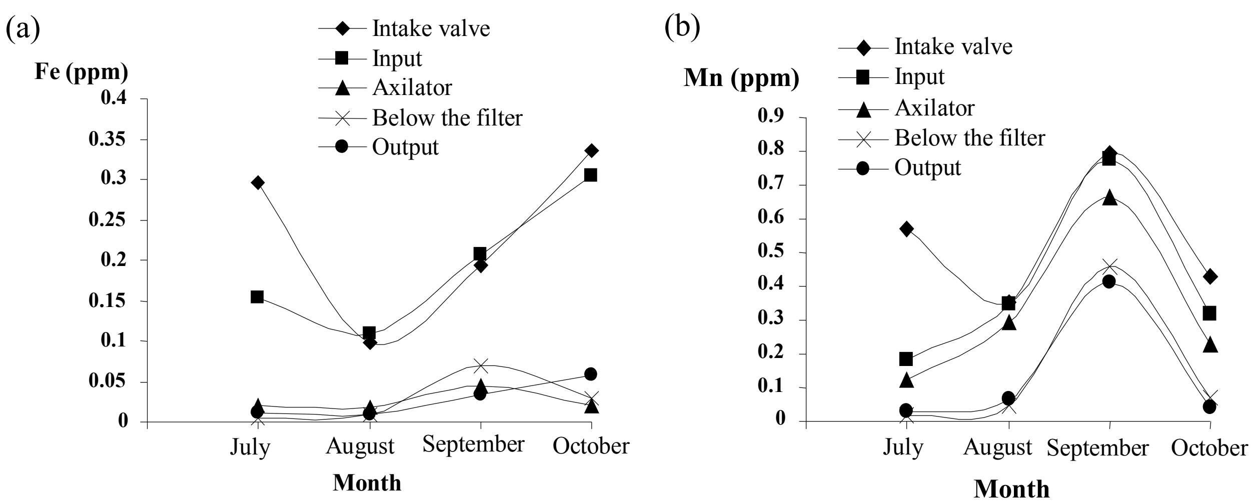


Figure 2. Concentration changes of iron and manganese [Iron, (a)] and [Manganese, (b)].

In order to surveying significant changes of iron and manganese concentration (mg/lit) in during treatment steps and passing time, a factorial plan is produced. These factors were (1) different treatment step (T.S) in five levels, including intake valve, input, axilator, below the gravity rapid sand filter, and output and (2) and time in four levels, including July, August, September, and October. It must be noted that in variance analysis method, data should be in order of normal distribution. Kolomogorov – Smirnov test showed that data are not upon normal distribution. The logarithm of data is used in order to normalization of distribution.

Results from variance analysis showed the change of treatment step and time factors, alters the concentration of iron and manganese in different steps of treatment duration of time with 99% probability. The interaction effect between different steps of treatment and different time (T.S*Month) on concentration of iron and manganese is not significant. It means that T.S factor has same main effect on all levels of time factor.

To recognize that which steps of treatment and which months have significant effect on concentration of iron and manganese, Duncan's New Multiple Range Test (DNMRT) is used for comparing the means. The results with 95%

probability showed that axilator and gravity rapid sand filter steps lead to significant effect on concentration changes of iron. Then reduction in concentration of iron is occur axilator and gravity rapid sand filter. Thus by improving operation and repairing in these two steps, the efficiency of reduction of iron concentration will be increased. Cakmakci et al (2010) expressed that, the iron concentration in gravity rapid sand filter output is a criterion for assessment of gravity rapid sand filter performance (Cakmakci et al., 2010). In this study, aeration occurs in intake valve and flash mixing pond steps. When the aeration associates with $pH \geq 7$, probability of manganese colloid form formation from manganese hydroxide is increased. Thus, the settle down of manganese will reduce and water treatment process cannot remove manganese. In such condition, strong oxidizing (such as chlorine) should be used. Considering that, in this case study chlorine is used for disinfection purpose, so the breakpoint chlorination should be design carefully. For this purpose, the concentration of used chlorine in oxidation of iron and manganese should be noted. It should be mention that breakpoint chlorination would not be defined carefully in Ekbatan dam water treatment plant. Therefore, it can have increasing effect on concentration of manganese in output. DNMRT method showed that gravity rapid sand filter is common step that causes significant change in concentration of iron and manganese during time with 99% probability.

One of the reasons in increasing the concentration of iron and manganese in dam's reservoir water is heavy rainfall in catchment. Following heavy rainfall, dirty water and associated water treatment problems increased as catchment surface erosion and dynamic mixing of the whole water column induced by the introduction of a large volume of rainwater runoff lead to marked increases in particulate matter (mainly carbonates) in the water body. Because of natural events such as erosion, the iron and manganese are in mineral sediment in lake. In this case, the important tip is mineral of catchment geology component. If the combination has much basaltic, thus there is much amount of iron in water (Zaw and Chiswell, 1999). Because of aeration and use of chlorine in this case study, iron and manganese oxidation occurs. Insoluble iron and manganese will be removed via axilators and gravity rapid sand filters. Generally, being exposured to chlorine for three to four minutes is sufficient for oxidation and thus sedimentation of iron. Reactions 1 and 2 show iron and manganese interaction with chlorine. With increasing the pH, oxidizing property of chlorine for $H_2S$, $Fe^{2+}$and $Mn^{2+}$ oxidation increases. If chlorine is used in order to disinfection of water contains phenol, the hazardous phenol chlorine produced. So chlorine dioxide used instead of chlorine in this case. Because of $H^+$ production during oxidation of 1 mg/lit of iron, $2.7\,{}^{mg}\!/_{lit}$ equivalent carbonate of alkalinity will be disappeared. One ${}^{mg}\!/_{lit}$ of chlorine only oxidized $1.6\,{}^{mg}\!/_{lit}$ of iron, while $1\,{}^{mg}\!/_{lit}$ of oxygen oxidizes 7 ${}^{mg}\!/_{lit}$ of iron.

$$2Fe^{2+} + Cl_2 + 6H_2O \Leftrightarrow 2Fe(OH)_3 \downarrow + 2Cl^- + 6H^+ \quad (1)$$

$$Mn^{2+} + Cl_2 + 2H_2O \Leftrightarrow MnO_2 \downarrow + 2Cl^- + 4H^+ \quad (2)$$

In practice, because of consuming some chlorine in another reaction, the amount of chlorine that is needed is more than the stochiometeric amounts. In stochiometery, 0.145 ppm oxygen oxidizes 1 ppm of iron and for oxidation of 1 ppm manganese, 0.2 ppm oxygen is needed. Interaction 3 and 4 show the iron and manganese interaction with oxygen. The advantage of using chlorine is that oxidizes iron more rapidly even in the pH lower than pH optimum range to oxidation with oxygen. Chemical agent for removing the manganese is two time more than iron. It should note that the oxidation of manganese has lower speed in comparing with iron.

$$4Fe^{2+} + O_2 + 10H_2O \Leftrightarrow 4Fe(OH)_3 \downarrow + 8H^+ \quad (3)$$

$$2Mn^{2+} + O_2 + 2H_2O \overset{Slow}{\Leftrightarrow} 2MnO_2 \downarrow + 4H^+ \quad (4)$$

Using aluminum sulfate as coagulant in axilators has effect role on floc containing iron and manganese. Therefore, hydroxides of iron and manganese that formed during aeration and chlorination easily can be settled. Distinguish the levels of time and treatment step factors which causes significant changes in concentration of iron and manganese is essential. Thus, the manager of water treatment plant can manage in suitable time and step. Because of rapid oxidation of iron exposing to chlorine and oxygen (reactions 1 and 3), so it is expected that before of water exiting from axilator with the detention time about 30 minutes, some of iron in the form of ferric hydroxide settle in axilator (because of low carbonate alkalinity in water). The 30 minutes is not sufficient for insoluble manganese formation (reactions 2 and 4), so axilator cannot have effective role in reduction of manganese concentration. Gravity rapid sand filter have significant effect on reduction concentration of iron and manganese. Some of iron hydroxide that passes from axilator, settle in gravity rapid sand filter. This lead to $Mn^{2+}$ and $Fe^{2+}$ ions, which are not oxidized, will be absorbed in to iron hydroxide in the filter media. Use of DNMRT method showed that temporal change of manganese related to sharply increasing of this metal in September. The quality of treatment plant input water become worse several days after rainfall in catchment. The reason of this event is dynamic mixing of the whole water column. The stratification in the end of summer and the low depth of lake cause manganese release from the lake sediments and being soluble. Therefore, soluble manganese comes to water treatment plant. Zaw and Chiswell (1999) obtained similar results on iron and manganese dynamics study in reservoir water. They found that if there is no destratification by artificial aeration, stratification will being regularly from the first of fall and continue during fall and winter.

**3.2. Effective quality parameters on concentration changes of iron and manganese in water treatment plant**

Figure 3 shows the mean concentration of quality parameters in different treatment step include intake valve, input, axilator, below the gravity rapid sand filter, and output in different months include July (1), August (2), September (3), and October (4).

Quality parameters that influence the concentration changes of iron and manganese in water treatment output were obtained using Multiple Stepwise Regression. Equations 1 and 2 show the relation and partial regression coefficients. Because the correlation does not meaning to the existence of casual relationship, so before establishing the correlation among different parameters, the significant of independent parameters effect on dependent parameter should be confirmed. The Multiple Stepwise Regression can do this at the same time. The input parameters for this regression are pH, temperature, turbidity, electrical conductivity, chlorine and aluminum in different steps of treatment plant. The criteria for choosing these parameters are the treatment plant manager's ability to make changes in their and probability of their effects on the concentration of iron and manganese in output.

After analysis by SPSS software and confirm the linear regression, Relationships between quality parameters and the amount of concentration of iron and manganese in output were obtained as equations 1 and 2.

$$\text{Concentration of Fe (Output)} = -1.837 + 1.032 * 10^{-3}\ \text{Tu (Input)} + 0.253\ \text{pH (Below the filter)} \qquad (1)$$

$$\text{Concentration of Mn (Output)} = -0.888 + 4.251 * 10^{-3}\ \text{EC (Input)} - 4.51 * 10^{-3}\ \text{Tu (Input)} \qquad (2)$$

Equation 1 shows that turbidity has direct relation with iron concentration in output. Turbidity in input can be due to presence of ferric hydroxide. Sedimentation of ferric hydroxide on the rapid sand filter media has positive effect on performance of filter. Nevertheless, in this study increasing the performance of filter could not compensate the negative effect of increasing the turbidity in input. Equation 1 shows the direct relation between pH and iron concentration in output. Because of aeration and existence of chlorine, all of the irons oxidize before gravity rapid sand filter. The ortho-phenanthroline reagent shows that there are not ferrous ions before entering filter. Therefore, increasing in pH increases the oxidation of manganese. Hence, because of fixed number of adsorption sites in gravity rapid sand filter, the less amount of ferric hydroxide is removed. Increasing of pH in the range of this case study increases oxidation of manganese but could not have significant effect on concentration of manganese in output. Equation 2 shows that amount of manganese concentration in output has direct relationship with electrical conductivity in the input. The presence soluble and insoluble salts can cause electrical conductivity in the input. In the input of treatment plant, manganese usually is soluble thus can cause increasing effect on electrical conductivity. Therefore, the direct relation between manganese concentration in output and electrical conductivity in input seems rational. On the other hand, increase in electrical conductivity due to increase of total dissolved solids has positive effect on coagulant performance in axilator. Results from DNMRT method showed that axilator did not have significant effect on the reduction of manganese. Thus changes in electrical conductivity in input, does not have effects on axilator performance to reduction of manganese. While the turbidity generally is due to insoluble salts such as ferric hydroxide. Therefore, increasing of turbidity in input can have some effects on gravity rapid sand filter performance to removal of manganese. Hence the vice versa relation between turbidity in input and manganese concentration in output is expected. Because of using aluminum sulfate as coagulant, the changes of pH should be in appropriate range. In this range, aluminum sulfate has minimum solubility. Optimum pH for this purpose in $25^{\circ C}$ is about 6. If pH increases out of 7.5, so output aluminum concentration would be more than 0.2ppm and thus it will be harmful for human health. Hence, if we would like increase the pH to better removal of iron and manganese, it should not that this increase should not lead to unauthorized concentration of aluminum in output. Figure 3 shows changes of quality parameters that influence the concentration changes of iron and manganese in water treatment output.

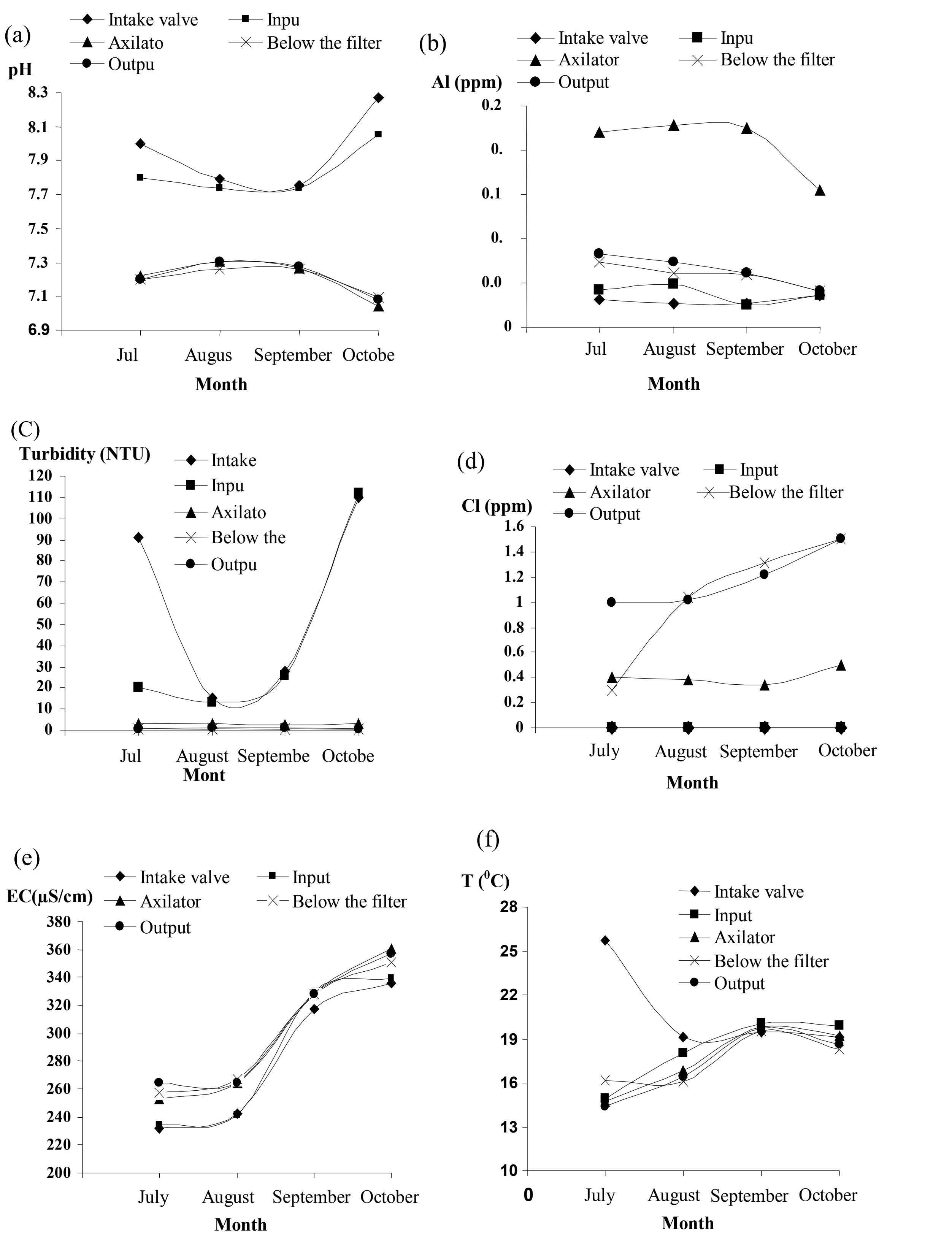


Figure 3. Quality Parameters in water treatment plant include [pH, (a)], [Mean concentration of aluminum, (b)], [Mean turbidity, (c)], [Mean concentration of chlorine, (d)], [Electrical conductivity, (e)] and [Temperature, (f)].

### 3.3. Optimization of partial regression coefficients by GA

Turbidity is common in equations 1 and 2. However, it has different sign. Thus, quality parameters amounts of equations 1 and 2 should be calculated in order to minimization of equation 3 as objective function.

$$0 \text{ ppm} \leq S = \text{Concentration of Fe (Output)} + \text{Concentration of Mn (Output)} \leq 0.4 \text{ ppm} \quad (3)$$

Conditions for optimization based on WHO water quality standard and above statements explain as follow (Equations 4, 5, and 6).

$$0 \text{ ppm} \leq \text{Concentration of Fe (Output)} \leq 0.3 \text{ ppm} \quad (4)$$

$$0 \text{ ppm} \leq \text{Concentration of Mn (Output)} \leq 0.1 \text{ ppm} \quad (5)$$

$$6.5 \leq pH \leq 7.5 \quad (6)$$

Results from optimization of objective function (S) are illustrated in table 1.

Table 1. Optimized quality parameters effective on concentration changes of iron and manganese

| Quality parameter | EC (Input) | Tu (Input) | pH (Below the filter) |
|---|---|---|---|
| Optimized amount | 333 $\mu S/cm$ | 117 NTU | 6.8 |

The manger of water treatment plant can applies the following approaches to achieve optimized points.

- When there is not sufficient turbidity for appropriate performance of coagulation, with the laboratory confirmation, turbidity is close to optimum amount by addition some material such as clay.
- If there are several intake valves, use intake valve is that close to optimum conditions of water quality.
- Considering to results from Zaw and Chiswell (1999), the artificial aeration of reservoir can have significant effect on stratification process. It should be mentioned that, although aeration process can increase the oxidation of iron but aeration during long time might have negative effects on reduction of entrance manganese in to intake valve of dam (19).
- Using of lime to pH control in axilator does not increase a lot pH.

## Discussions

Concentration of iron and manganese during water treatment process has significant changes. Axilator and gravity rapid sand filter were effective on iron concentration changes. Whereas only gravity rapid sand filter was effective on manganese concentration changes. Iron hydroxide sedimentation on gravity rapid sand filter media, increase gravity rapid sand filter performance to absorb iron and manganese.

Because of aeration and use of chlorine in flash mixing pond, oxidation process of iron and manganese occurred. While in order to manganese oxidation, more oxidizing agents and time are needed. On the other hand, aeration and high pH (more than 7) may change the manganese from hydroxide form to colloid form. Therefore, in such conditions the breakpoint chlorination should be carefully calculated. The above reasons, removal efficiency of iron is more than removal efficiency of manganese in Ekbatan dam water treatment plant. Time factor had significant effect on concentration of iron and manganese. Temporal changes in concentration of iron and manganese does not have regular procedure. The changes of manganese concentration had sharp increase in September. Then manganese concentration returns to its usual conditions. The reason of this event is dynamic mixing of the whole water column. The stratification in the end of summer and the low depth of lake cause manganese release from the lake sediments and being soluble. Therefore, soluble manganese comes to water treatment plant. The above reasons the manganese concentration in output of water treatment plant in September has been more than allowable amount. Surveying of interaction effect between time factor and treatment steps factor shows that time factor has same effect on all levels of treatment steps factor.

Multiple stepwise regression shows the qualitative parameters which are effective on concentration of iron and manganese in treatment plant output. Changes in turbidity and electrical conductivity in water treatment input are effective on concentration changes of manganese in water treatment output. Whereas changes in turbidity in input and pH below the filter have effects on changes of concentration of iron in water treatment plant output. The GA method was used to calculate optimum amounts of partial regression coefficients in equations 1 and 2. For this purpose, the objective function (S) as sum of the concentration of iron and manganese in treatment plant output was minimized. The optimum amounts of electrical conductivity and turbidity in input were $333 \mu S / cm$ and 117 NTU, respectively. The optimum amount of pH in below the gravity rapid sand filter was 6.8. Hence, use of lime to increase alkalinity in axilator must be done carefully.

The high amount of turbidity and electrical conductivity has good effects on axilator performance. When there is not sufficient turbidity for appropriate performance of coagulation, with the laboratory confirmation, operator can adds clay to improve axilator performance. The optimized amount of pH can prevent of high solubility of aluminum sulfate. In addition, in the calculated optimum pH, the probability of manganese colloid formation will decreased.

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