V DISSUSSION OF RESULTS

Alum Coagulation

During the test period the pH of surface water taken from Klong Prapa at the intake to Samsen WaterWorks ranged from 7.2 to 7.8, so additions of lime or sulfuric acid for the pH adjustment were not necessary.

Before the determination of variables affecting alum coagulation, the conditions of mixing and total settling time must be determined. The optimum mixing conditions and settling time were varied according to the technique and raw water utilized.

The fast mixing speed of 100 rpm for 60 seconds and the slow mixing speed of 40 rpm for 3 minutes provided a better clarification as shown in Fig. 13 and Fig. 14 respectively. The total settling time of 15 minutes was selected as the optimum time because the water being treated was stable and a very little increase in percentage of light transmission occurred thereafter, as shown in Fig.15.

Effect of Alum Dosage on Color and Turbidity Removal, pH, and Alkalinity of Raw Waters

The addition of 20 mg/l. $Al_2(SO_4)_3 . 18H_2O$ rapidly increased the percantage of light transmission of the raw water as indicated in Fig.16. A further increase of $Al_2(SO_4)_3 . 18H_2O$ to 30 mg/l., D_c resulted in a rapid change in the slope of the curves. The maximum increase of the percentage of light transmission was obtained by the addition of 40 mg/l. alum, D_T. A continuous addition of alum resulted in a lower percentage of light transmission because the excess alum utilized formed hydrolysis products of aluminium sulphate. Therefore utilization of excess alum gave two advantages: wasted of coagulant and production of supernatant of a less percentage of the transmission. A further increase of alum from D_c to D_T improved percentage of light transmission of water very little, therefore D_c was recommended as the optimum desage for the coagulation.

The addition of alum into the waters produced sulfuric acid and hydrolysis products of aluminium sulphate which reduced pH and neutralized alkalinity of raw waters as shown in Fig.17.

Effect of pH on Alum Coagulation

The optimum pH range for alum coagulation was 5.7 to 7.2 because this pH range provided rather high percentage of light transmission. The decrease or increase beyond this pH range yielded a relatively low percentage of light transmission as shown in Fig. 18.

Coagulation by Elecctrical Treatment Method

In the determination of color or turbidity expressed in percentage of light transmission at any depth of the settling column, the curves of similar characteristics were obtained. The relation could be approximately expressed in the empirical formula as $t = t/(a + bt) + c$. However, the curves of the rate of increase in percentage of light transmission were in parallel or in touch with each other in finality as indicated in Fig. 19 and Fig.20.

The value of percentage of light transmission, T, at the upper part of the settling column should be higher than that the lower part but it was shown in Fig. 19 that the value T at the depth of 70 cm increased more rapidly than that at the depth of 130 cm. from the bottom of the settling column within the first ten minutes. The reason was the flocs at the lower part of the cloumn settled nearly completely while those at the upper part continued settling.

It was observed that when the settling column was not completely filled with the effluent overflow, the sizes of flocs at the lower part of the column were larger than those at the upper part, because the flocs at the lower part completely agglomerated while those at upper part were in the process of agglomerating. The sizes of flocs obtained by electrical coagulation were larger than by alum coagulation. The flocs formed were soft, opaque, pale yellow or light brown depending upon the sources of raw waters. It was also observed that there was a circulation of flocs up and down the column because of tiny gas bubbles entrapped inside the flocs. The distance of the floc travel was approximately 30 cm. to 50 cm. It was expected that the bond of water molecules were broken by the suddenly released shock wave and formed hydrogen, oxygen and other gases. But finally the bubbles were destroyed. When the drag force on the floc particles was equal to their submerged weight, the flocs began to settle. The gas bubbles which occurred were transparent when entrapped inside the flocs. The rate of settling of flocs was roughly estimated to be 0.1-0.5 cm./sec.

The values were obtained from measuring the time the flocs began to settle in the column.

The correlation of the equation, $T = t/(a + bt) + c$, was suitable for application to both surface water and ground water.

Slope, $\frac{1}{a}$ at $t = 0$ and the saturation value, $(\frac{1}{b} + c)$ of the correlated equation was not constant for the water having the same characteristics and varied with diffrent raw waters having different characteristics.

The Initial percentage of light transmission, T_o, of the water being treated varied with different treatment conditions and depended upon the initial characteristics of the water.

Mechanisms of Electrical Coagulation and Floc Formation

The forces that tended to disperse the particles in the dispersion medium and hence led to stable colloidal suspension were hydration and electrical potentials. This hydration resulted in a protective shell of water molecules and an electrical double layer. This electrical double layer produced electrical potentials that acted as a barrier to the close approach of other particles. The result of instability of colloidal suspension might be the combined effects of

(a) the mechanical shock wave suddenly released by stored electrical energy that split the protective shell of water molecules surrounding the colloids

(b) the Brownian movement caused by the increase in temperature of liquid mass resulting in rapid and random movement of very small particles

(c) the electrical field lines which reduced or neutralized the charges on the surface of the particles;

(d) sonic vibration which caused the opportunity of collision among colloidal particles

(e) electrolysis but no metallic hydroxide being observed. The forces were expected to overcome the repulsion characteristics of the colloidal particles, double layer and thus permit the particles to stick to one other by Van der Waal forces and enmeshment, resulting in progressive agglomeration. However, the mechanism of transfer of electrieal energy could not be explained clearly but required further investigation.

Effects of Flow Rate

In the determination the percentage of light transmission was increased when the effluent overflow was decreased as shown in Fig. 24 and Fig. 36. At the initial settling time the water being treated gave a less percentage of light transmission than before it was treated because it was in the phase of floc agglomeration. After settling 30 to 50 minutes there was a slow or constant increase in percent transmission. A sligh change in percentage of light transmission was the same for a variety of raw waters.

Althouth electrical coagulation was feasible for various effluent overflows, there was an optimum flow rate depended upon the conditions and final qualities required.

According to Fig. 36 the effluent overflow of 1.7 and 3.8 l./min could not yield 98 percent transmission at 30 minutes settling time except the flow rate of 1.0 l./min. When extending the settling time to 60 minutes the flow rate of 1.7 l./min reached 98 percent transmission.

Effects of Power Supply

When the effluent overflow was fixed at 1.5 l./min while the power supply was varied to 240 W, the result provided a better percentage of light transmission than the power supply which was determined at other values as indicated in Fig. 28. But power supply of 240 W was not the optimum power supply because it was the function of many variables, for example, the effluent overflow, total settling time and final degree of treatment required.

According to the tests no. 29, 30, and 32, the following conditions were observed.

1. The removal of total iron was 85 percent to nearly 100 percent for both surface and ground water.

2. There was a slight change in pH and specific conductivity.

3. The total hardness could be removed from 5 to 10 percent for surface water and 7 to 12 percent for ground water.

4. Total solids could be removed from 4 to 8 percent for surface water and about 10 percent for ground water.

5. Chloride could be removed from 34 to 40 percent for surface water and about 3 percent for ground water.

6. Fluoride was not changed for both surface and ground water.

Effects of Mixing

Mixing provided a rate of increase in percent transmission and a clearer supernatant as indicated in Fig. 29. The effects of the speeds of the stirrers on electrical coagulation were shown in Fig. 30 to 32 and Fig. 41 to 43. The increase in the speeds of the stirrers provided the proability of collision among particles. The low percentage of light transmission of final clarified water could be improved by mixing.

Sludge Volume

The sludge volume percentage varied according to the composition of the raw waters utilized. The sludge volume of surface water taken from Klong Prapa was about 2 to 3 percent and ground water 8 to 12 percent. The sludge produced gave no odor. This might be because living microorganisms were shocked by the mechanical shock wave, sonic vibration, and heat accumulated in the electrical column, hence a biological examination should be carried out subsequently.

The sludge was expected to be a good fertilizer if the fertilizing value was increased.

Power Loss in the Equipment

Power Loss in the equpment was about 30 percent because only one electrical column unit could be used whereas, ideally, varions units should have been used and connected in parallel.

Heat Loss in the Electrical Column

The increase in water temperature was due to the heat loss in the electrical column during the operation and could be minimized by controlling the effluent overflow and power supply.

Comparison of Treatment Costs Between Alum Coagulation and Electrical Coagulation

The optimum $Al_2(SO_4)_3 \cdot 18H_2O$ for coagulation was 30 to 40 mg/1., therefore the cost for clarification using liquid $Al_2(SO_4)_3 \cdot 18H_2O$ from the department of Science, Ministry of Industry was 0.041to 0.055฿/m^3 (0.002to0.0027 \$/m^3), while the minimum cost of electrical treatment was 0.19฿/m^3 (0.01 \$/m^3), but this was not the optimum cost.

Although the cost of electrical treatment was higher than by alum coagulation, but, considered as a whole, the electrical method gave better treatment results than alum coagulatuon

Comparison Between Alum and Electrical Coagulation

1. The alum coagulation method was obtained by controlling the following parameters: mixing speed and mixing time, total settling time, pH and alum dosage, which were derived from a Jar test in the laboratory. But electrical coagulation required the control of power supply and effluent overflow and total settling time.

2. The final percent transmission by electrical coagulation was higher than that by alum coagulation.

3. Electrical coagulation gave a shorter settling time than by alum coagulation.

4. The pH of the treated water tended to be acid side by alum coagulation while electrical coagulation provided a slight change.

5. The percentage of total iron removal by electrical coagulation was higher than by alum coagulation.

6. Color could be removed sucessfully by electrical coagulation than by alum coagulation.

7. There were tiny gas bubbles entrapped in the flocs in electrical coagulation but the phenomena could not occur in alum coagulation.

Foreseeable Applications of Electrical Treatment

1. The electrical coagulation could be used as a potable unit in a small community because of its easy control and might replace the present clarification unit as far as costs are concerned.

2. It could be used to clean up the pond covered with algae by method of thermosyphon when installed on the moving pontoon.

3. It might be used to reduce river sediment suspensions when larger unit was installed.

4. It might be used to reduce the suspended and colloidal matters in domestic and industrial wastes before entering the biological units.

5. Sludge produced might be used as fertilizers.