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EVOLUTION OF AL-QUSAYR WATER PURIFICATION PLANT WHEN USING DIFFERENT CHEMICAL WORK SYSTEMS

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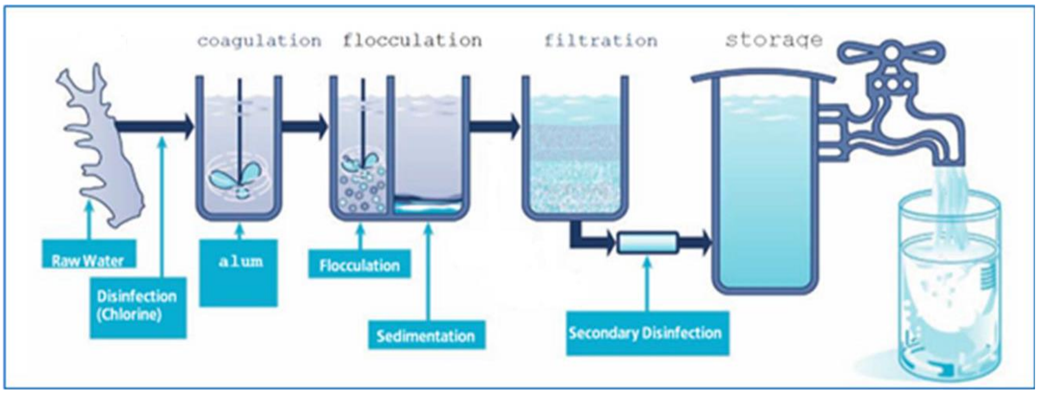
ABSTRACT

The research studied the chemical work system in AL-Qusayr plant, which includes sterilization and coagulation. Recently, the sterilization system was modified by replacing chlorine gas with calcium hypochlorite, which contains an active substance of 70%. Despite the advantages of gas sterilization, it was replaced by hypochlorite compounds due to the lack of cylinders, and work was done on new equipment for supplying powder, and studying the most important differences between the two methods. The coagulant (Aqueous Aluminum Sulfate) was added at the perfect dose 3 mg/l with the following indicators installed: PH = 6.8, coagulation time = 20 sec, flocculation time = 35 min. It was found that if the alum solution was not stirred in the tank during its consumption, or the stirring process took place at long intervals, the added dose would become incorrect, the dosing pumps would become clogged, and a loss in the coagulant would occur. Therefore, the research recommended the following points to obtain water with better specification: 1- The alum tank mixer must be operated every two hours for half an hour, so that the dosing pumps work more stable. 2- The discharge of the coagulant dosing pump should be stabilized by installing a Hertz converter with a value of (19.5 – 24.5) Hz within 24 hour, to control the amount of Aqueous Aluminum Sulfate solution dosed momentarily, so that the level of the solution decreases by 10 cm/h and the discharge is equivalent to 975 l/h.

KEYWORDS: Chemical action in water purification plants; Sterilization using calcium hypochlorite; Coagulation with aqueous aluminum sulfate; Install the coagulant dosing pump discharge

1. INTRODUCTION

Natural water in all its surface and ground forms is required to enter purification plants to improve its specifications and rid it of all impurities and pollutants present in it according to the sequence of operations shown in Figure (1). Chemicals play a key role in the purification process by adding chlorine compounds to perform sterilization work and chemical coagulants to collect Impurities in the form of flocculants that are easy to separate later in sedimentation basins. [1]



Fig(1):- Sequence of basins in drinking water purification plants

2. RESEARCH IMPORTANCE AND OBJECTIVES

The importance of the research is reflected in the study of the chemical work system and how it developed and its impact on the stages of work in the drinking water purification plant in Al-Qusayr city, which supplies the city of Hama with potable water, in addition to 65 communities benefiting from drinking water along the pipeline, including (Rastan, Talbiseh, Basirin, Al-Khalidiyah, Salamiyah, Al-Kafate, ...), [8], which mainly includes chlorine and alum (aqueous aluminum sulfate).

3. RESEARCH MATERIALS AND METHODS

3.1Chlorine in purification plants

In normal conditions, chlorine is a yellowish-green iridescent gas with a density equivalent to (2.5) times that of air. It can be found in liquid form under relatively low pressure (3.7 atmospheric pressure). [2] It has a high solubility in water. It is also a sterile substance, even if it is in low concentration. The dissolution of chlorine in water leads to the formation of two acids: hydrochloric acid and hypochlorous acid according to the 'Equation (1)': [2]

$$HCl + H2O \rightarrow HCl + HOCl \qquad (1)$$

Hydrochloric acid does not play a role in the sterilization process. As for hypochlorous acid, it is the effective agent in sterilization. It is usually referred to as free available chlorine. The percentage (50%) of hypochlorous acid dissociates at a water PH of approximately (7.5) to give hypochlorite anion OCl^-. The hypochlorous ion has no significant role in the sterilization process. [3]. Figure (2) shows the relationship of the ratio of HOCl to OCl^- in water at different values of PH. To ensure effective sterilization, the PH value of the water must be maintained so that 90% of the chlorine is in the HOCl state.

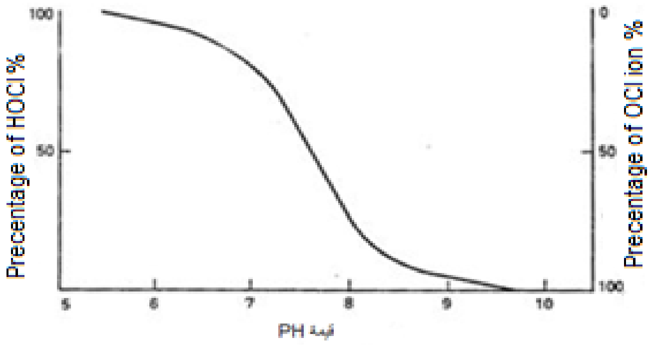


Fig.(2):- Relationship of the ratio of HOCl to OCl in water at different values of PH

3.2 Study area

Al-Qusayr Water Purification Plant. This project was established specifically to provide the city of Hama with potable water from the AL-Assi River (Hermel Spring). The station is located in the countryside of Homs, southwest of Al-Qusayr, on the Syrian-Lebanese border, with a production capacity of 144,000 m^3/day. The chemical work system at the station begins with the addition of all chemical additives for the first stage before the main distributor on the channel linking the receiving facility and the main distributor.

4. RESULTS AND DISCUSSION

The most important chemicals that are added at the plant are chlorine and alum (aqueous aluminum sulfate). [4] First, chlorine: Until 2019, the mechanism used was the sterilization system with chlorine gas, and its purpose was to sterilize (disinfect) water and kill all germs in it. The chlorine that was used in the station came in the form of cylinders (liquefied gas) weighing 900 kg. Without the weight of the metal and enough for three days. Chlorine is added at the station in two stages: The first: before the main distributor, and it is usually 4-6 kg/h. At the plant there is a primary gas chlorinator that gives approximately 6 kg to 6000 m^3 of water

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Fig.(4): -Chlorine gas cylinders

Fig.(3): -Primary chlorine gas devices

The second: at the end of treatment, usually 1-2 kg/h.[5]. Chlorine gas is added by means of chlorination devices, and no matter how different they are in shape or method of operation, they are consistent in the main principles that are summarized in relieving pressure on liquefied gas until it turns into gas, then passing this gas in a limited amount of water to dissolve it at a high rate, then injecting the solution into the main water pipe, provided that the solution pressure at the injection point is not less than three times the pressure in the water main pipe, in order to ensure the efficiency of the injection process. Chlorine gas is pumped from the cylinders to the water by means of polyethylene pipes or PVC pipes that are buried underground. An integrated, automatic sterilization system was installed that is programmed according to the system and recommended by international codes. It has been calibrated so that the amount of free chlorine at the entrance of the station is 1.5 mg/l and at the outlet of the plant within the range of(0.55-0.6) mg/l to ensure that water reaches homes in the city of Hama within the range of (0.4 -0.5) mg/l.[6]. Recently: the used mechanism became the sterilization system with calcium hypochlorite powder. This is due to the concentration of the active substance in the range of 65-70%. Calcium hypochlorite has great advantages that make it widely used great in many areas. This compound is considered to be soluble in water easily, and it has a great ability to sterilize, due to the presence of a large percentage of chlorine in its components. The chlorine currently used in the plant comes in the form of powder of calcium hypochlorite. Chlorine is added at the station in two stages:

The first stage: it is called the initial sterilization process**:** This process takes place immediately after entering the raw water and before the main distributor, and it is the first chemical addition to the raw water. Dry chlorine powder is added by means of powder dose feeding devices (feeders), designed and implemented at the beginning of the raw water entry channel. The number is 2, one of which is working and the other is reserve (it starts working directly when a defect occurs in the first device). Primary feeding devices give chlorine powder in the range of 12-24 kg/h, generally 13 kg/h is injected in the winter, and 18 kg/h is injected in the summer (due to evaporation). Sterilization is carried out with an appropriate dose of chlorine, according to the organic load of raw water, in the range of 1-2 mg.

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Fig.(5): -Primary sterilization devices

The second stage: at the end of treatment, which is the final sterilization process: Here, sterilization is also done by means of powder dose feeding devices (feeders), designed and implemented at the end of the station near the tank located at the bottom of the station. The number is 2, one of which is working and the other is reserve (it starts working directly when a defect occurs in the first device). Feeding devices at the end of treatment give chlorine powder in the range of 3-8 kg/h. The water is tested after treatment from the tank located at the bottom of the station to determine the percentage of free chlorine in the water, and it is usually in the range of 0.4-0.5 mg/l, so the percentage of free chlorine is increased to 0.8-0.9 mg/l to ensure that it reaches the city of Hama with a concentration of (0.4- 0.5) mg/l. The dry calcium hypochlorite feeder is designed to deliver an accurate dose of chlorine, providing up to 50 kg of HTH per day. The tank container is filled with approximately 60% chlorine powder either manually or automatically and a high precision auger is used to inject the chlorine powder into the water. The two sterilizers are controlled by an electronic board.

Table (1): The most important differences between the sterilization system with "gas chlorine" and the sterilization system with "calcium hypochloride powder

The Index	Chlorine gas sterilization system	Sterilization system with calcium hypochloride powder
Solubility	The dissolution of gas atoms with water is faster than with powder	less powder dissolution
Evaporation	Less evaporation (we don't lose much dissolved chlorine)	The loss of powdered chlorine dissolved in water is greater
Mechanism corrosion	Pipes deteriorate over time	It causes corrosion in pipes, but less than gas
Validity	With great validity	Packages have a shelf life of one year
Manpower	It does not require manpower	You need a workforce and special clothing to protect the workers
Sedimentation	The gas does not precipitate, it dissolves directly with water	Leaves deposits
The focus	Its concentration is constant throughout the processing stages	Its focus diminishes from one stage to the next
Harm to humans and the environment	Gas damage is much greater, especially if a leak occurs in the cylinder	Less damage

In general, we find that sterilization using the gas system is the best, despite its danger, but replacing it with the calcium hypochloride powder system was due to the unavailability of gas cylinders, so work was done on new equipment for sterilization with powder. In the past, gas cylinders were more economical to use.

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Fig.(6): -Damage to pipes due to the use of gas

Second: Aluminum sulfate (alum) $Al2(SO_4)_3.18H_2O$: Its aim is to reduce the turbidity of the water, and the reaction takes place as follows: Alum is added to the water in ground tanks to become a solution with a concentration determined by the station's laboratory, and this solution is pumped by pumps to the exposed ductus before venturi stenosis. [7].

4.1 Determine the ideal dose of coagulant:

The process of determining the ideal dose is one of the most important stages necessary to obtain the best water specifications at the lowest cost, as the excessive dose of alum increases the cost of treatment and negative effects on the health of consumers, and at the same time the low dose (less than the ideal dose) leads to higher indicators Water specifications and reduce the station's work efficiency. The ideal dose of coagulants added in such stations is determined through the jar test, which expresses the first three stages of conventional treatment only. This test helps**:**

1- Estimating the added coagulant dose. 2 - Estimate the ideal water PH value. 3 - Selection of new chemicals for treatment. 4- Experimenting with different mixing speeds

In this experiment, four or six raw water samples were used with a mixer at different speeds to model the aforementioned treatment stages, and in order to determine one of the indicators (for example, the coagulant dose), all indicators are fixed and the coagulant dose is changed between the tested samples to reach the best dose. Below is a table showing an example of this experiment in order to determine he ideal dose.

Table (2): Jar Test experiment in order to determine the ideal dose.

pointer	Data of the jar test	Purification plant data
The number of mixer revolutions during coagulation	100 rpm	100 rpm
The number of mixer cycles during flocculation	20 rpm	20 rpm
PH of water	6.8	6.8
Water alkalinity	180 mg/l as	180 mg/l as
Coagulant dose	2,,2.5,,3,,3.5,,4,,4.5 mg/l	3 mg/l
coagulation time	20 sec	20 sec
flocculation time	35 min	35 min

The most important factors influencing the hydrolyzation of the coagulant are the dose of the coagulant and the pH value of the water. Given the inability to control the pH of the raw water in the traditional purification plants, work is being done to control the pH value of the coagulant solution water, which expands the range of the pH value of the raw water suitable for the coagulation process. The method of mixing the coagulant with water has a clear effect on the nature of the flocks formed. The most common form of alum is the powder. The solubility in water is 100/36.6 at 20°C**.**

The alum reacts in alkaline water containing calcium bicarbonate according to the equation (2):

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$$Al_2(SO_4)_3.18H_2O + 3Ca(HCO_3)_2 \rightarrow Al_2O_3.3H_2O \downarrow + 3CaSO_4 + 15H_2O + 6CO_2 \qquad (2)$$

It can also reacts with natural alkalinity according to the equation (3):

$$\mathrm{Al_2(SO_4)_3.18H_2O + 3CaCO_3.H_2CO_3 \rightarrow 2Al(OH)_3 + 3CaSO_4 + 15H_2O + 6CO_2} \qquad (3)$$

This is if the natural alkalinity of the water is sufficient, but if it is not sufficient, in this case slaked lime or sodium carbonate is added to adjust the PH value of the water according to the following reaction (4) , (5):

$$\mathrm{Al_2(SO_4)_3 + Ca(OH)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3} \qquad (4)$$

$$\mathrm{Al_2(SO_4)_3 + 3Na_2CO_3 + 3H_2O \rightarrow 3CO_2 + 3Na_2SO_4 + 2Al(OH)_3} \qquad (5)$$

The formed aluminum water is a gelatinous substance that collects fine atoms and some germs, as it increases in weight and facilitates its sedimentation in sedimentation basins. The gelatinous substance also forms a thin film on the surface of the sand in the filter ponds, thus impeding the passage of silt and bacteria that have not been deposited in the sedimentation ponds. One of the disadvantages of using alum is its increased sensitivity to temperature and pH of the treated water.

4.2 Stages of work on controlling the dose of alum:

The factors affecting the coagulation process were monitored, mainly the water PH value, which is directly related to the alum dose. It was found that the PH value of the resulting water varied throughout the day with relatively large differences, in addition to the percentage of pollutant disposal also varying, as shown in Figure (7).

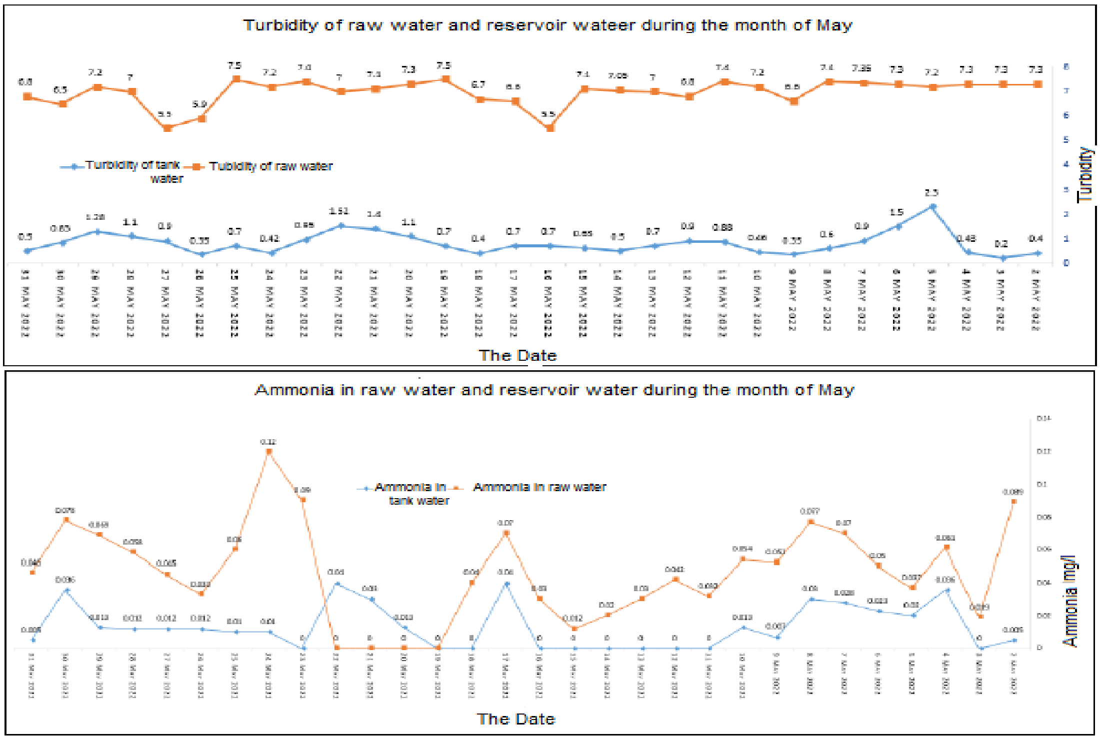

Fig.(7): -Turbidity and ammonia values in raw water and reservoir water during the month of May

The reason for the difference in these values is actually due to the addition of the alum dose. The following has been noted:

1- The alum solution must be well prepared (i.e. the alum powder should be well mixed during its emptying into the tanks for a sufficient period) and stirred continuously and with a certain tension throughout the period of consuming the solution from the tank. In the event that the preparation of the alum solution in the tanks was not good and the alum solution was not stirred in the tank during its consumption, or the stirring process took place at long intervals, the following results:

- It forms a sticky layer (which is the active substance) at the bottom of the tank and is difficult to get rid of.
- The added dose determined using the jar test becomes incorrect.
- Loss of alum.
- The formation of flukes with a poor structure.
- Clogged dosing pumps with sediment materials at the bottom of the tank.
- Make great efforts to get rid of the sedimented gelatinous substance.

Recently, work has been done to remove the sticky layer from the bottom of the tank, and the best methods have been reached to limit its formation by running a mixer for the alum tank every two hours for half an hour, so the work of the dosing pumps has become more stable.

2- It must be ensured that the alum solution dosing pump is stable (the amount of pumped solution is constant throughout the tank's consumption period) regardless of the height of the solution in the tank. The operation of the pump was established through the following stages, Figure (8).

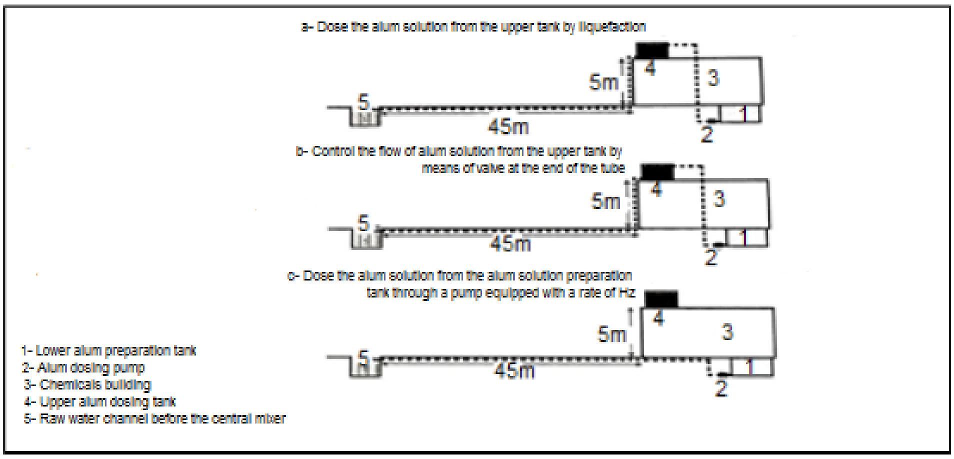

Fig.(8): -Stages of testing the stability of the alum dosing pump

a) The alum solution prepared in a lower tank was raised to a tank on the roof of a building for preparing chemicals and dosing it with liquefaction, and by following up the simultaneous decrease of the alum solution in the tank, it was observed that the decrease in the level of the alum solution decreases as the level of the solution in the tank decreases (when the tank is filled, the decrease is greatest).

b) Sugar was installed at the end of the pipeline in an attempt to control the decrease in the level of the alum solution, but it was found that this procedure was difficult in practice. When canceling the dosing mechanism from the upper alum tank and attempting to dosing from a lower tank by the installed pump, it was observed that the pump dosing was affected by the height of the alum solution in the tank. A Hertz changer was installed in the pump in order to control the amount of alum solution dosed momentarily, and the pump flow was monitored in case the tank was full for different values of the pump Hertz. Then the flow from the tank was followed up with a constant Hz of the pump in order to finish the entire solution from the tank, so we have curves that have the shape shown in Figure (9).

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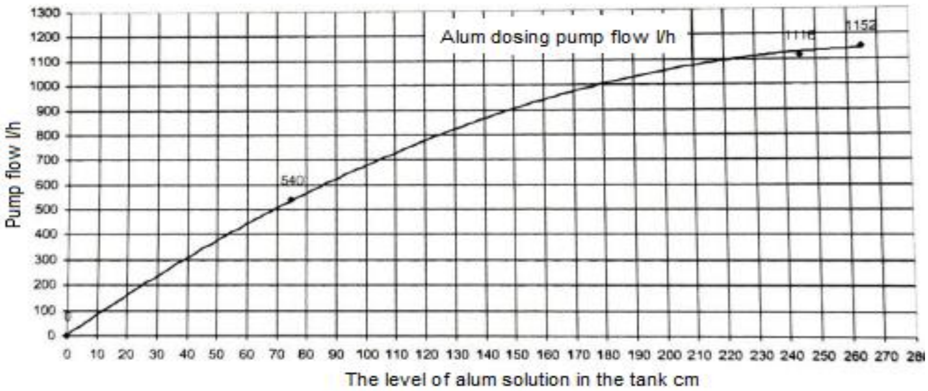

Fig.(9): -The relationship between the pump flow and the solution level in the tank

This indicates a change in the discharge of the pump in order to consume the reservoir, bearing in mind that the change in the discharge of the pump with time leads to: The fluctuation patterns formed are not stable, and thus the efficiency of precipitators and filters fluctuates, a loss in the amount of chlorine and alum added, as the amount of alum added affects the PH value of the water and thus the interaction of chlorine with this water, which sometimes limits the ability of chlorine to get rid of the bacterial load present in the water, the tank consumption was tested for variable values of pump Hz and we had the following results:

Table (3):- Experimenting with consumption rate of alum dosing tank for variable values of the pump HZ

Number of hours of tank consumption	HZ pump experimenter	Height of cumulative alum solution withdrawn from tank cm	Average pump flow l/h
1	20	124	1341.1
2			
3			
4			
5			
6			
7			
8			
9			
10	20.5	6	584.3
11	22	8	778.7
12	23	20	973.4
13			973.4
14	23	16	778.7
15			778.7
16	24	20	973.4
17			973.4
18	24	37	900.4
19			900.4
20			900.4
21			900.4
22	24	23	746.3
23	24	23	746.3
24			746.3

After several experiments, the following values of pump's HZ were reached until the level of alum solution decreased by 10 cm/h, and middle discharge of the pump equivalent to 975 l/h.

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Table (4):- HZ values of pump to stabilize the decreasing level of the alum solution and the discharge of dosing pump

Number of hours of tank consumption	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tested pump HZ	19.5	19.5	19.5	19.5	19.5	20	20	20	20	23	23	23	23	24	24	24	24	24	24.5	24.5	24.5	24.5	24.5	24.5

At the beginning of pumping, the height of the alum solution in the tank is 265 cm, and it becomes 25 cm after the passage of 24 cm, so the height of the alum in the tank decreases by 10 cm every hour, which is equivalent to an average discharge of the pump of about 975 l / h.

3- The injection point of the alum solution must be placed in the appropriate place so that it mixes well before treatment begins. The correct placement of the injection point can be inferred from the stability of the quality of the water coming out of the precipitators, whether from the physicochemical or bacterial aspects. Note that if the alum injection point is in the wrong place, we have the following results: The results of water analyzes at the outlet of the precipitators are inconsistent, the formation of heterogeneous flukes in the sedimentation basins, the reaction of chlorine is not homogeneous between the sedimentation basins. To verify the correctness of choosing the location of the alum solution injection point in order to achieve complete mixing of the alum with water practically on the ground, the water specifications were monitored at the outlet of each precipitator separately. In the case of uniform distribution of the coagulant within the water entering the sediment. The most important indicators monitored are the turbidity and PH values.

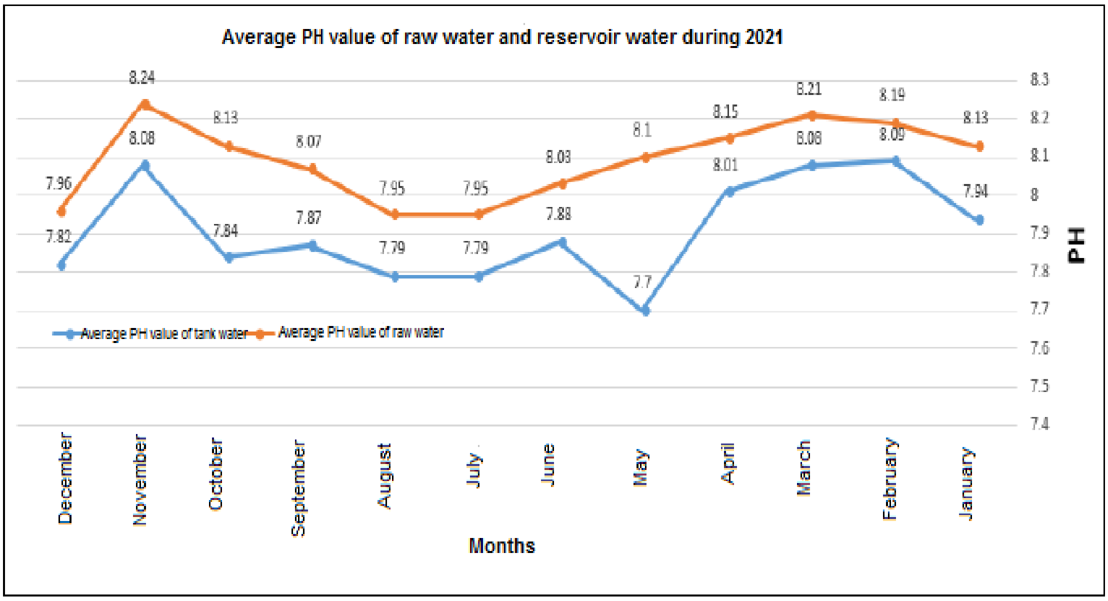

Fig. (10):- Average PH of raw and tank water during 2021

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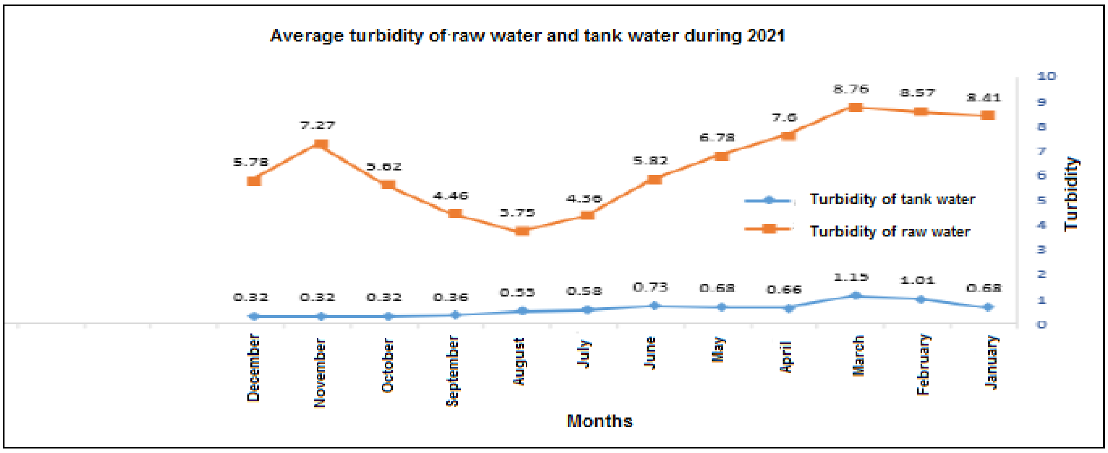

Fig. (11):- Average turbidity of raw and tank water during 2021

5. CONCLUSIONS AND RECOMMENDATIONS

After operating the station with the stability of the discharge of the alum dosing pump by installing the Hertz converter within the range (19.5-24.5) Hz, an increase in the efficiency of the filters was observed, and the following results were reached:

1- Reducing the consumption of both alum and energy used in filter washing operations as a result of reducing washing operations and the duration of the washing process, in addition to reducing the amount of water used in filter washing. As shown in Figure (12).

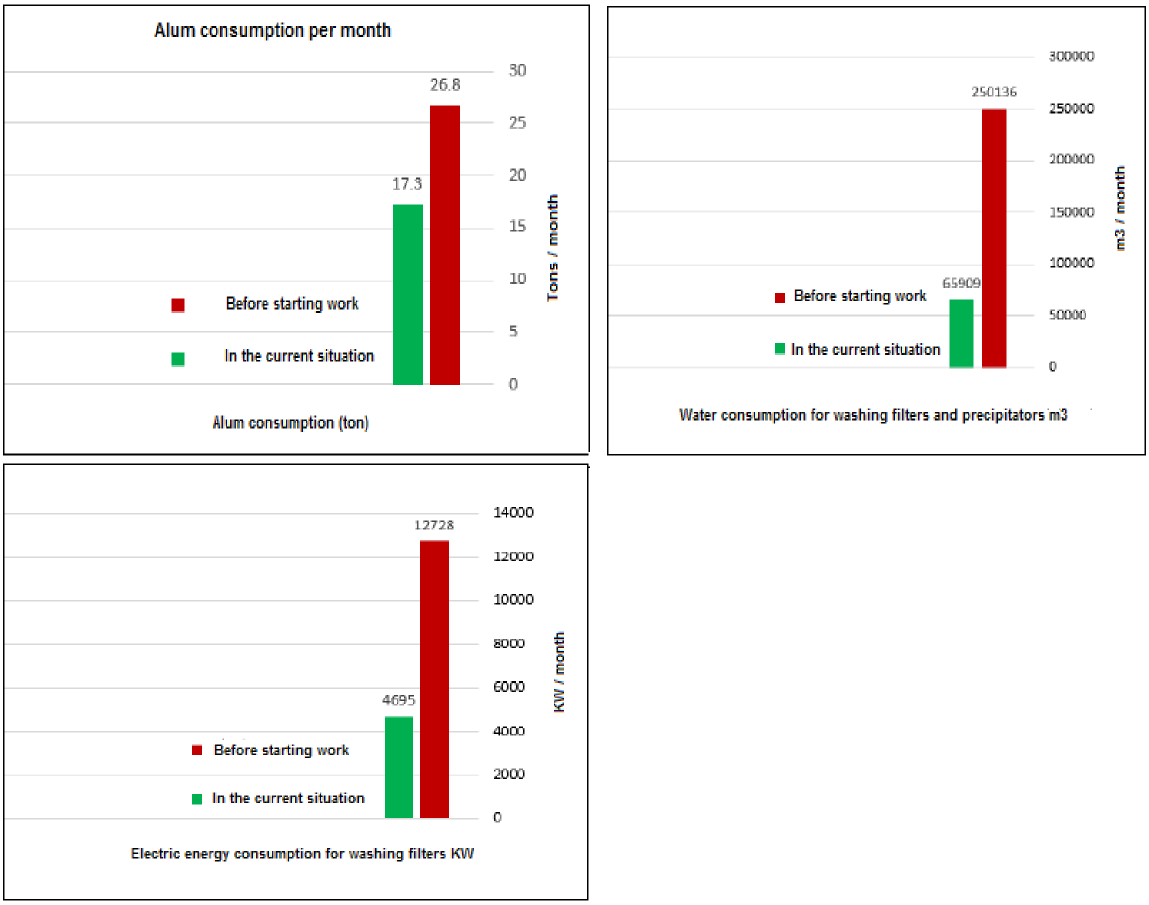

Fig. (12):- Effect of alum dosing pump discharge stability on: Alum consumption, water consumption and electric energy for filter washing

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2- Reducing the effort exerted by the station workers in: filter washing operations as a result of reducing the number of washing operations and the duration of the washing process, removing sediment from the alum solution preparation basins, and removing silt at the bottom of the filters as a result of the filters not exceeding the required number of working hours and thus the flocculant does not penetrate the sand layer and collect it below Each filter, as well as in the removal of siltation of pure water tanks.

3- Increasing the investment life of the mechanical and electrical equipment used in the process of preparing the alum solution and washing the filters as a result of the decrease in the frequency of its operation, as shown in Figure (13).

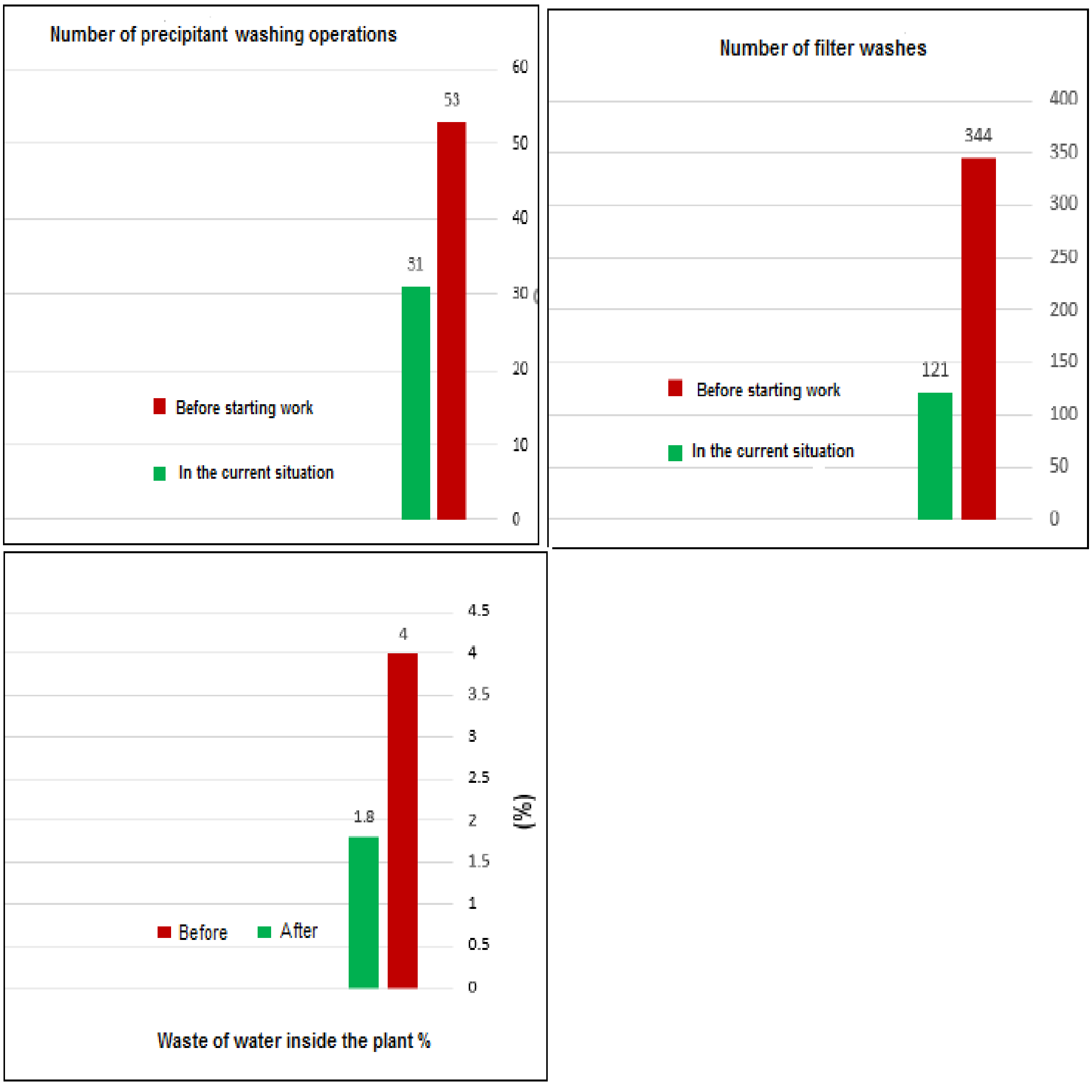

Fig. (13):- The effect of the stability of the alum dosing pump discharge on: the number of washing precipitators and filters and the amount of wasted water

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