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Research Article

Assessing the influence of climate change on water treatment Efficiency in Baghdad, Iraq

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Abstract

Predictions for the future indicate that climate change may worsen the water problem in Iraq. The impact of climate change on water supplies, the environment, and the economy, particularly the agricultural sector, is one of the region's most significant challenges. This paper analyzes the impact of climate change on water parameters and the implications for station operation and performance. The data was taken from the Al- Al-Qadisiya water treatment plant in Baghdad city for 2022. This research is the only one that discusses the design of water treatment plants using the GPS-X to design and simulate the plants and show the effect of climate change on plant operation. The results of evaluating the operational performance of water treatment plants indicate that the concentrations of all contaminants in the effluent water have consistently followed the established Iraqi standards in all scenarios. Some consequences of these variables (pH, turbidity, TDS, color, alkalinity, and hardness). The modeling and simulation of the water treatment plant, conducted using GPS-X, confirmed an acceptable level of performance characterized by a high degree of efficiency. The model was subjected to three scenarios, which showed that the concentrations of the pollutant parameters in the treated water stayed within the allowed limits.

Keywords: Water Treatment, Climate Change, GPS_x, Plants, Simulation

Introduction

The two primary goals of water treatment plants are to remove contaminants that are harmful to health and to eliminate contaminants that give water an unpleasant appearance, taste, or odor. Since many harmful toxins cannot be seen, smelled, or tasted, early water treatment operations focused on enhancing the water's appearance or consumer appeal, as many harmful toxins are odorless, tasteless, and invisible. (Dey et al., 2021)

An evaluation of the performance of a water treatment plant can be used to improve the way it works. The drinking water treatment process involves the elimination of contaminants and the deactivation of potentially harmful microorganisms present in untreated water, resulting in the manufacture of water that is sufficiently clean for human consumption and free from any possible health risks in both the immediate and longer term. Various methods are used to remove contaminants, including physical treatments like settling and filtering, chemical procedures like coagulation and disinfection, and slow sand filtration. In the context of municipal drinking water treatment, several treatments are implemented globally, considering factors like the season, the presence of pollutants, and the specific compounds found in the untreated water.(Wang et al., 2011). Water resources have had significant impacts from climate change, population expansion, and heightened human activity. These factors provide major challenges for organizations responsible for providing drinking water, particularly in developing nations. The effect of climate change is causing alterations in the quantity and caliber of water resources available to both human populations and ecological systems globally.(Bates et al., n.d.)

The effect of climate change is causing alterations in the quantity and caliber of water resources available to both human populations and ecological systems globally. The rise of risks and expenses for individuals, ecosystems, agricultural practices, energy generation, industrial operations, recreational activities, and the natural surroundings is visible. A water treatment facility's primary function is to ensure the provision of potable water to the public while eliminating any detrimental substances present in either a dissolved or suspended state. The removal of harmful chemicals is of greatest importance. The assessment of the operational efficiency of a water treatment facility has the potential to enhance its functionality. (Baruth et al., 2005)

Climate and water have close relationships on Earth. Involved in a large-scale exchange of mass and heat between the atmosphere, ocean, and land surface, water influences and is affected by climate. Every change in the climatic system affects the hydrologic system. The possible effects on water sources have received a lot of attention, but it is important to recognize the changes in water quality that are also present. The mobility and dilution of pollutants may be impacted by predicted variations in precipitation and temperature, as well as by changes in river flow. Higher water temperatures will change the speed of chemical reactions and when combined with a drop in water quality, the ecological status of freshwater (Andrade et al., 2018)

Climate change is not the only factor affecting water quality. Within the context of global change, the evolution of land use, deforestation, urbanization, and the carrying out of waterproofing measures in some regions may also contribute to the decline in water quality. However, it is frequently observed that urban, industrial, and agricultural human activities are primarily responsible for water pollution. as a result of these actions, the effect of climate change on surface water quality may cause deterioration. When the reduction of point source pollution occurs in several nations, climate change effects may lead to a rise in diffuse pollution. This increase may be due to various factors, such as urban or agricultural runoff, even if wastewater treatment facilities operate at their maximum capacity. (Bates et al., n.d.).

In this paper, using the GPS-x program to design and simulated the water treatment plants. Numerous domestic and international researchers investigated the capability of the GPS-X program to model and simulate any wastewater and water treatment system component or entire facility to achieve their research objectives(hatch, 2022). After calculating the complete sample results, plant data was utilized to construct and calibrate GPS-X models. Additionally, the current facility utilizes the GPS-X to increase capacity, operational efficiency, and effluent quality. They discovered that the calibrated model produces exact results that closely resemble the actual outcomes of the program (Mhashhash et al., 2018) . Simulations were done under various scenarios to examine the effects of related operational variables on the plant's capacity and performance regarding ultimate effluent quality. We can control the flow and any parameter that needs to change by the input section in the simulation.

Area of study and data

These papers take data from the AL Qadisiya water treatment station in the Karkh region. Al-Qadisiya station is a surface station located in the Karkh region with an area of about (48000 m2). The station serves the Al-Qadisiya area with drinking water and has a purification capacity of roughly 100,000 m3/day, making up about 8% of all the stations in Baghdad's purification capacity. Provide clear water to this region. The capacity of this station is divided into two branches; an old project with a capacity of about (149760 m3) was created, and A new project with a capacity of about (86400 m3) since 1976, the data taken from 1/1/2022 to 31/12/2022.

Numerous variables must be considered when selecting the optimal water treatment procedures for a specific water source. Several considerations must be considered, including the quantity of water requiring purification, the availability of suitable facilities, suitable operators and administrators, and the total number of consumers involved. (Clark et al., 2012) figure 1 show the location of AL Qadisiya plants by Google map.

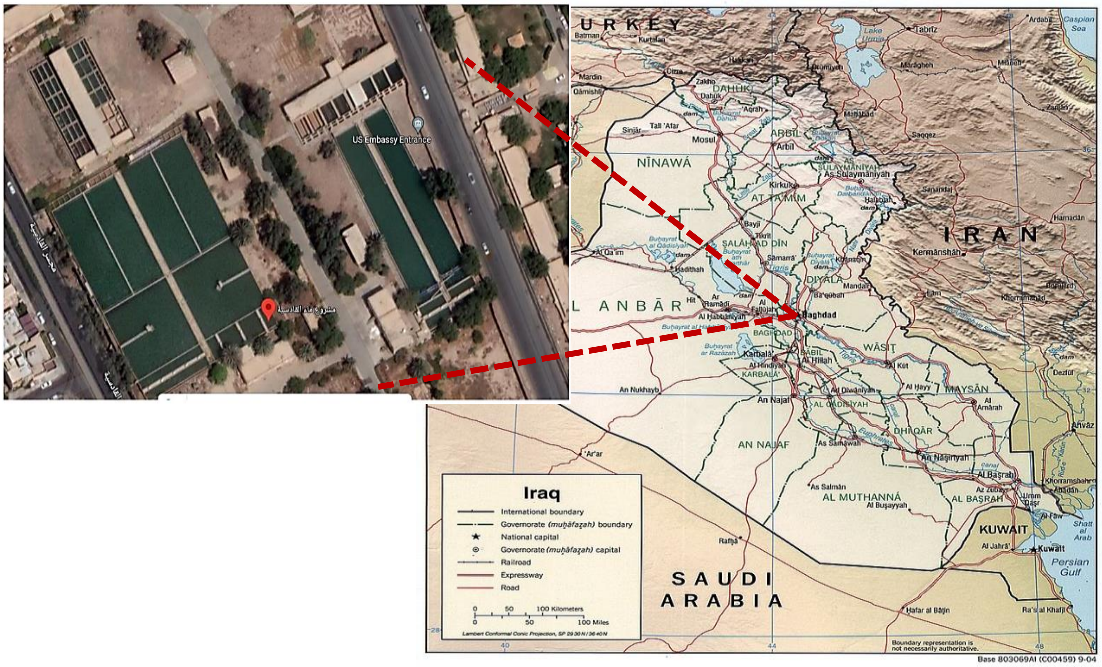

Figure 1. location of al-Qadisiya water treatment plants

The optimal water treatment plants consist of, **(**Coagulation, flocculation, sedimentation, filtration, and disinfection). During the coagulation and flocculation processes, the electrostatic charge of unsettled solids is neutralized or decreased. This process sets up the van der Waals force of attraction, leading to the gathering of particles by adding the chemical dosage, such as alum (Abbasi et al., 2021). Furthermore, During the flocculation stage, physical processes transform the tiny floc particles created by the rapid mix into larger floc aggregates; the clustering rate is determined by the velocity at which the particles collide, Additional chemicals might be applied to enhance the settling or filtering properties of the coagulated material. Anionic polymers are frequently employed to speed up the development of excellent flocs for settling; they can also increase the flocs' strength, weight, and density.

Separated and resolved clusters that have undergone flocculation and coagulation in water as part of the process under consideration. The flocs cluster and gather as refuse at the sedimentation tank's bottom. As the flocs settle to the bottom of the sedimentation tank, the effluent water is discharged through the tank's upper collecting basins. (Abbasi et al., 2021) the last step of water treatment is filtration and disinfection, Sand filtration is a widely used technique for purifying drinkable water, specifically targeting removing relatively large suspended particles. Water treatment often employs two primary categories of sand filters: rapid sand filters (RF) and slow sand filters (SF) (Al-Ansari, 2013). Figure 2 shows the treatment process.

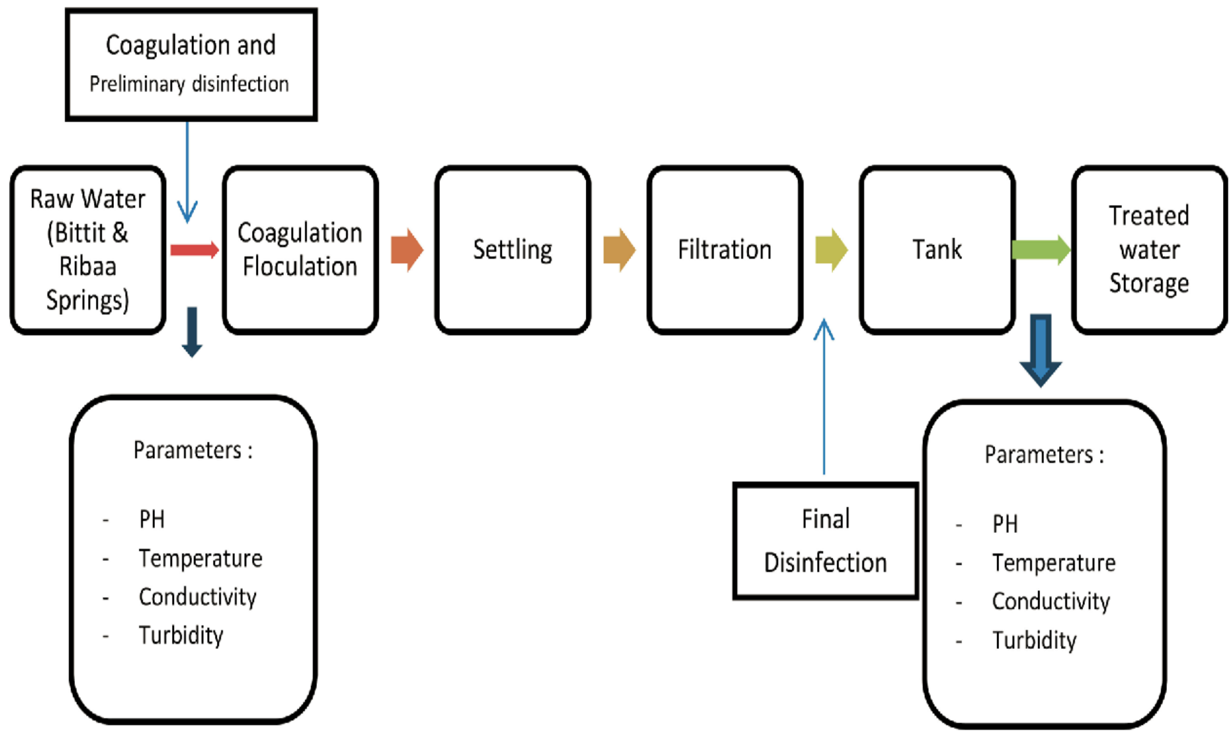

Figure 2. water treatment process

Some of the data collected from the station are (the volume of tanks and the number of tanks, Ph, turbidity, alkalinity, total dissolved solids and total suspended solids) to get the best result of effluent water that matches Iraqi standards. Three scenarios were applied in the water plane to show the effect of climate change on the plant operation by changing the number of tanks and parameters.

Table 1. some parameter uses in simulation

Parameter	Value
Temperature	14.75 C
Turbidity	19 NTU
Alkalinity	195.75mg/l
Hardness as CaCO3	294.75 mg/l
Calcium as Ca	70.5 mg/l
Chloride as CL	59.75 mg/l
Magnesium as Mg	25.25mg/l
pH	7.8
Color Hazen	<5
Total dissolve solids	549.75mg/l
Suspended solids	36mg/l
Nitrite as NO2	0.0043mg/l
Nitrate as NO3	0.8525mg/l

Different simulation software for water and wastewater treatment facilities, such as SIMBA, GPS-X, AQUASIM, Bio Win, STOAT, FOR, and WEST, promote these models. Simulation and modelling tools evaluate process methods, optimize designs, and conduct cost analyses. The GPS-X is the best software program to design and simulate the water treatment plan. In addition, it is the first version used for water treatment. (Al-Ansari, 2013) The GPS-X program is generally regarded as a useful software tool for evaluating the preliminary design of water and wastewater treatment plants (WTPs). Moreover, this software assists in explaining the efficacy of the plant in different situations. A conclusion may be made that validating development plans is a complex task. (*The Greenhouse Gas-Induced Climate Change Over the Indian Subcontinent as Projected by General Circu*, n.d.)

GPS X is a modular, multipurpose modelling environment for simulating municipal wastewater treatment plants. Enables investigating the complex interactions between various units' processes in the plant interactively and dynamically. The GPS-X program is generally regarded as a useful software tool for evaluating the preliminary design of wastewater treatment plants (WTPs). Moreover, this software assists in explaining the efficacy of the plant in different situations. The water treatment facilities of Al Qadisiya include two flocculation tanks, six sedimentation tanks with two branches, and eight filtration tanks. Figure 3 shows the layout of the water treatment facility as determined by the program, where scenario 1 (average flow) and scenario 2 (maximum flow) use the same number of tanks but differing parameter values. In addition, use half as many containers in scenario three's minimum flow. This scenario is used to control the impact of climate change on water sources by decreasing or increasing the flow rate and the amount of polluted particles.

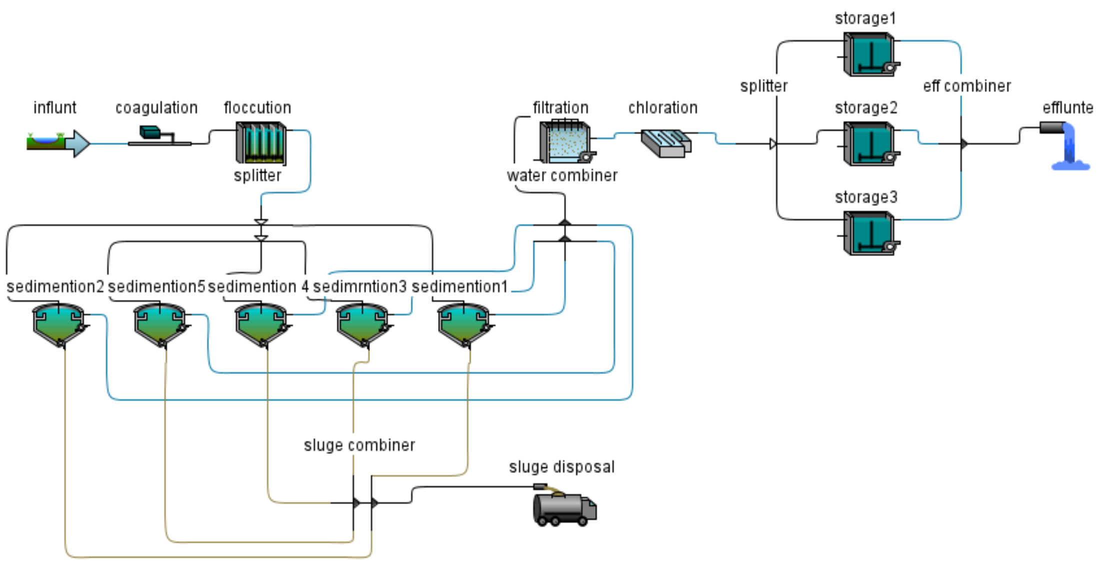

Figure 3. layout of water treatment by GPS-X

Figure 4 describes the water treatment unit used in GPS-X. This unit displays the quantity of water that passes through each unit and the necessary parameters (TSS, TDS, HRT for each tank, turbidity, color, TSS removal, pH, and hardness).

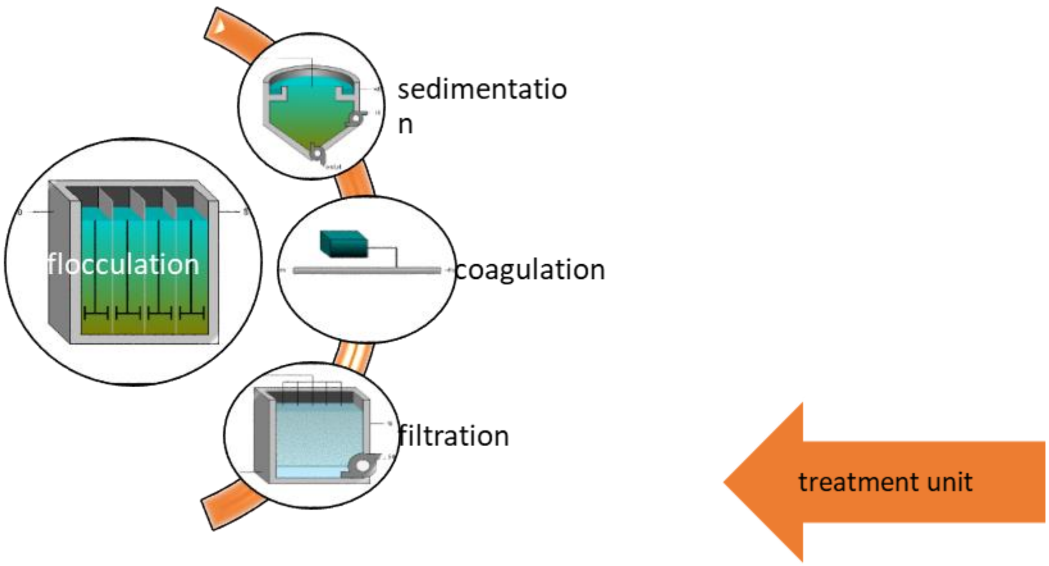

Figure 4. Treatment unit

Martial and methods

Climate change is not the only determinant impacting water quality, Incorporated within the framework of global change, the process of land use evolution, deforestation, urban expansion, and the implementation of waterproofing measures in some areas may also play a role in the deterioration of water quality. (Kundzewicz, 2008) According to previous research, there is much uncertainty about the predicted changes in precipitation and temperature over the period to come. According to estimates, the average global temperature increased by 0.8 C over the past century due to greenhouse gas emissions. In addition, scientists have determined that recent years have been the hottest in the past century. Due to the increase in global temperature in recent years, there has been non-uniformity in precipitation changes. (Guchi, 2015) description of changes includes temperature, precipitation, sea level, river flow, soil moisture, groundwater evaporation, and cryospheric features. The water cycle accelerates with time, as seen by growing evaporation and precipitation rates (Ahmed et al., 2020). The two factors that impact the climate change:

Temperature

The first thing to remember is that temperature (generally) significantly impacts nearly all physical-chemical equilibriums and biological responses. Evaporation and complexation are a few examples of water-related changes or actions that will be accelerated by raising water temperature. This widespread occurrence generates concentration. The quality of the water is greatly impacted by temperature changes and changes in the amount of dissolved compounds in the water. The concentration of some pollutants is reduced due to low water velocity (nutrient uptake and adsorption by aquatic plants, complexation of heavy metals on suspended particles, and settling) (Murdoch et al., 2000)

Increasing air temperatures affect the timing and seasonality of snowfall and discharge, resulting in more precipitation during the winter. As opposed to snow, melting occurs earlier in the winter and spring. These modifications will likely affect the magnitude and timing of seasonal peak flows, including shifting spring runoff peak periods forward and decreasing summer low flows. Air temperature increases impact water quality, including biogeochemical cycling, primary production, solubility, reaction rates, and bacteria survival. (Amanullah et al..,2020)

Increases in water temperature impede the capacity of surface waters to store oxygen, which may reduce the productivity of streams already affected by biological oxygen demand (BOD). The duration and intensity of stratification significantly affect seasonal changes in surface water quality. (Xia et al., 2015)

Precipitation

Researchers have discovered a significant positive correlation between river nutrient loading and elevated volumes of nutrients originating from outside sources. Warmer temperatures would accelerate soil processes, such as the decomposition of organic matter, increasing nutrient concentrations in rivers. Due to stream soil erosion, more frequent and intense rainfall events will also result in greater concentrations of suspended particles. When stream flow is reduced, there is less capacity for dilution, which results in higher nutrient concentrations entering reservoirs from point pollution sources. The effect of climate change on streamflow, lake levels, and groundwater recharge is primarily determined by precipitation. (Ling et al., 2013)

Results

Analyses of raw and treated water samples were conducted to determine the efficacy of this facility in treating and removing pollutant components from water. This model uses actual station data that has been calibrated to approximate the actual situation as possible. Then, compare the results with the water standard to ensure the station's performance and determine how reliable these WTP plans can be.

Changes in flow rate and the concentration of polluted particulate in water result from climate change for plants. The station data will be divided into four seasons to show the impact of changes in climate on the water parameter and the WTP planet. The outcome of this scenario is displayed below. After calibration and adjustment, the parameter and chemical dose make the program's results more accurate than the actual data figure 4 show the difference between actual and simulated parameter which indicates the simulation data is more effaced than actual. As a result, it conforms to Iraqi water standards. Figure 5 clarifies that a simulation model's efficiency for removing total dissolved solid, NO2, NO3, and conductivity is more effective than actual plans.

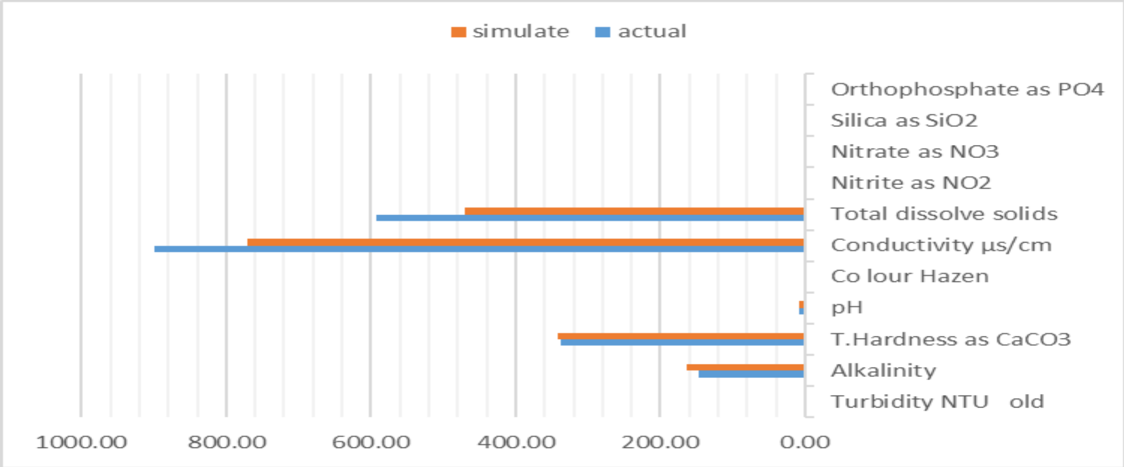

Figure 5. Difference between actual and simulated data

In scenario one for the winter season, the river's discharge will increase, as a result increasing pollution particles. the increase in water discharge rate significantly impacted water quality. During the heavy rainfall, the concentrations of metals, certain organic compounds, faecal coliform bacteria, and nitrates increased. In addition, floods can cause the displacement of pollutants between polluted soils and sediments, And the soil erosion brought on by flooding brings a significant amount of nutrients, pathogens, and pollutants into the aquatic environment.

The figure 6 shows the relationship between parameter and time, the figure showed that the parameter changes constantly with the change of time and change in season. the result in this scenario matches the Iraq standard and global requirement for water treatment, allowing this scenario to be used in all water station cases. It illustrates the relationship between total suspended solids and time. Consequently, the variation in the quantity of TSS is considered with the variation in simulation duration. This analysis specifies the time but also considers the effluent flow in relationship to the treatment procedure duration. The time calculation is based on the population of Al Qadisiya in 2022 based on the data. For instance, the relationship between the duration of the procedure and the quantity of solids is illustrated. Consequently, the modelling results indicated that increasing the simulation duration increased the removal of TSS, so the overall efficiency of the treatment system also increased.

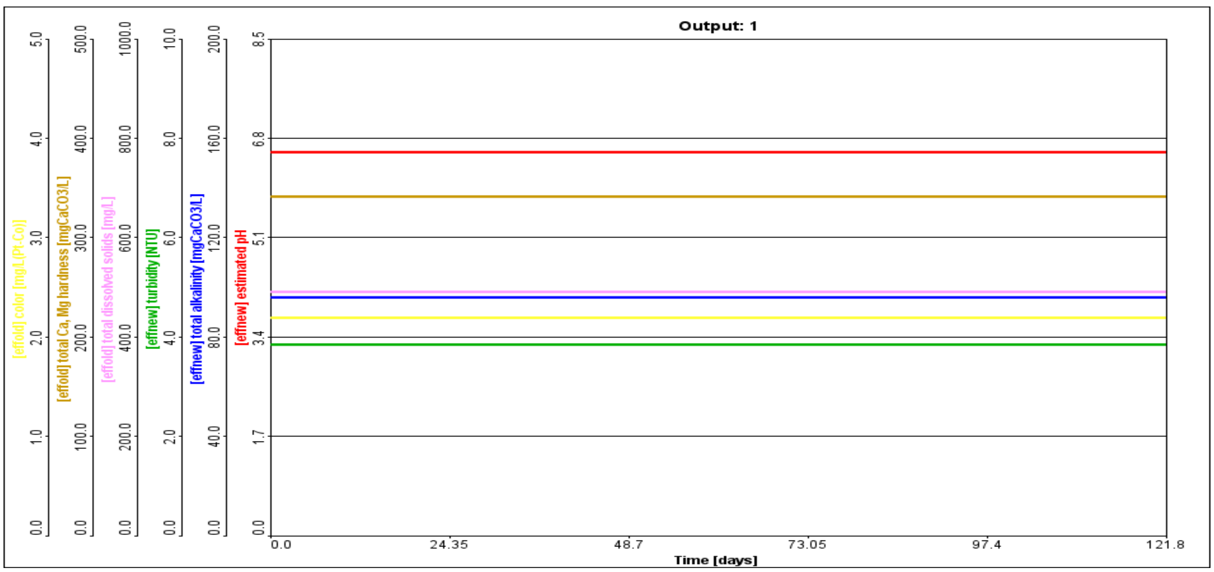

Figure 6. Relationship between treated parameter and time

From the simulation of water plants, the hydraulic retention time for the flocculation unit is (39.1 -87.71) min for both parts. the typical range for HRT in flocculation is 20-60 minutes, depending on the qualities of the raw water, and the temperature of the water. (Xia et al., 2015) Furthermore, the HRT for the sedimentation tank from the simulation is about (5-10 hours) for each tank to get the best result for settling all suspended particles, not removal by flocculation process. otherwise, The HRT requirement for a sedimentation tank is between 4 and 9 hours in the summer and autumn. Even though the facility retains large quantities of sludge that must be handled, this standard improves the removal process's efficacy. Low levels of dissolved oxygen in the water during a dry season may have contributed to the rising temperature observed by the researchers. Additionally, higher alkalinity during the summer is believed to accelerate the decomposition rate (Ling et al., 2013).

Figure 7 show the difference between for season, the flow in autumn is the highest value compared with other seasons. It can be concluded from the graph below that the highest possible concentration of a parameter under warm conditions will impact the growth of aquatic vegetation. However, heated water can eliminate adjacent plant life and pathogens.

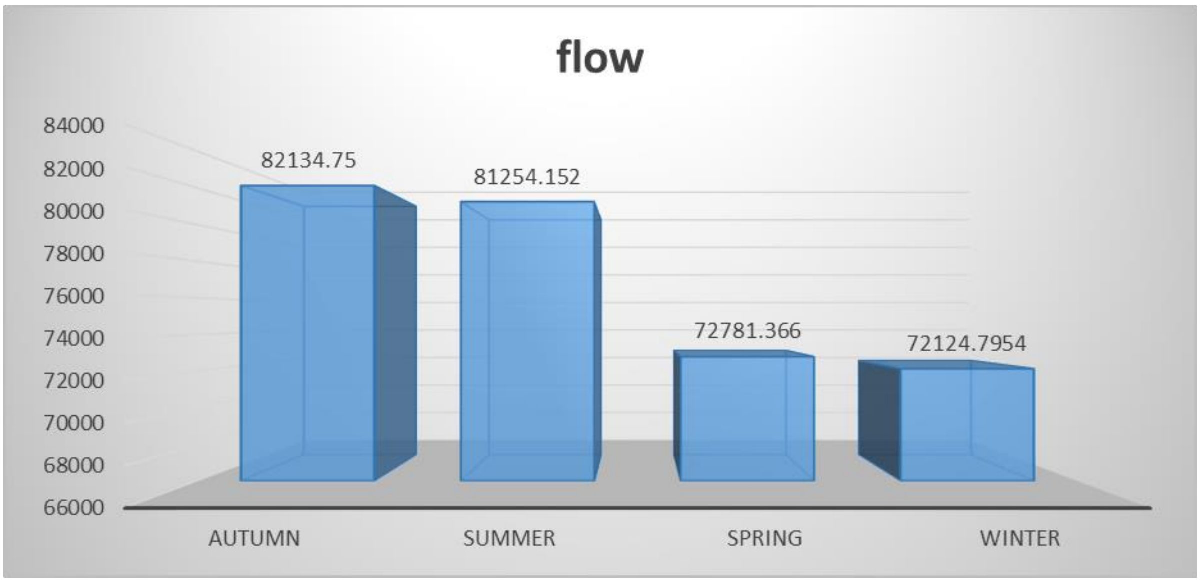

Figure 7. Flow in a different season

Figure 8 clarifies the difference in total dissolved solids and total alkalinity for each season. It shows that the total dissolved solid increases in summer and spring when water temperature increases. Low levels of dissolved solids in the water during a dry season may have contributed to the researchers' observation of an increased temperature. Additionally, elevated alkalinity during the summer is believed to accelerate the decomposition rate. The decrease in turbidity following the monsoon season occurs more significantly at higher levels of suspended particles than at higher levels of total dissolved solids in ponds or the discharge of organic from residences or local effluents.

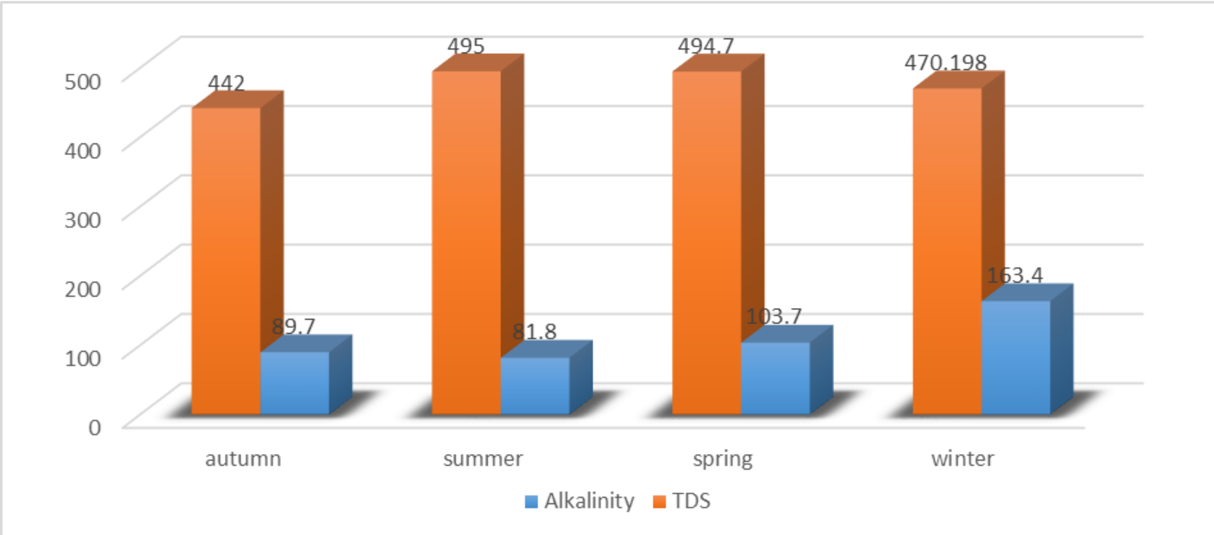

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Figure 8. alkalinity and TDS in four seasons

The other two scenarios can be used to represent the impact of climate change on the operation of plants during different seasons. The difference between the three scenarios is the parameter and number of basins after calibrating and validation of the parameter to assure the reliability of this model. It concludes that climate change affects water by altering the discharge and quantity of Polluted particles in unfiltered water. This simulation can be used to achieve the best water treatment results. It can use this simulation in average, maximum, and minimum flow. Figure 9 shows the difference between the three scenarios. The flow rate in scenario two is the highest value compared with another scenario, about 94021m3 /day in summer and spring.

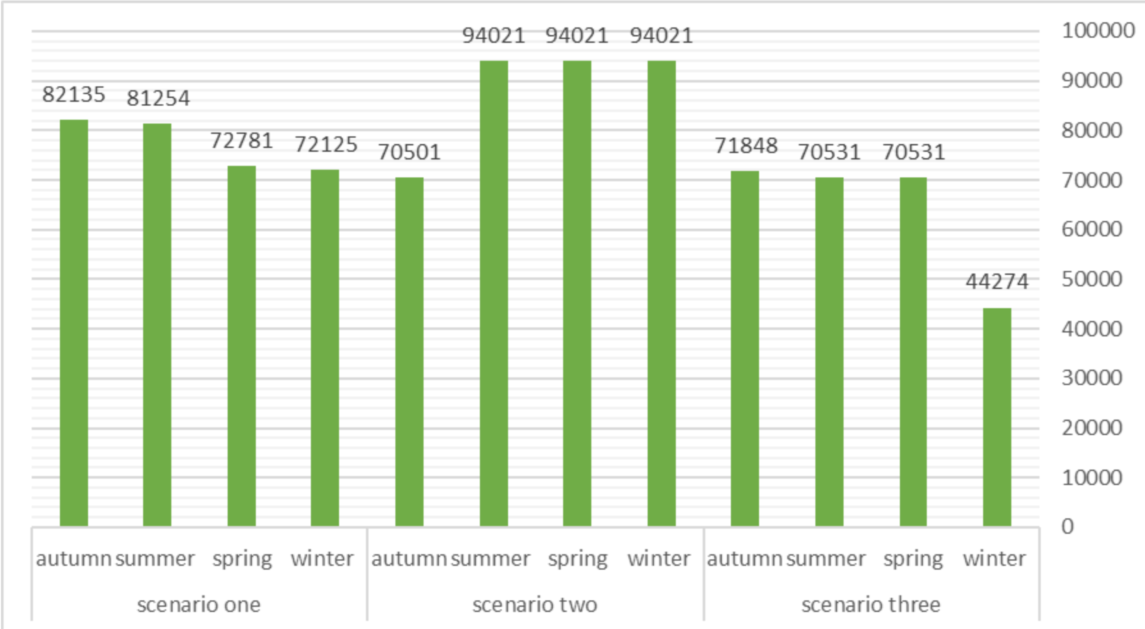

Figure 9. The flowrate in three scenarios

Figure 10 represents a meticulous diagram of the entire design of the Al-Qadisiya water treatment facility.

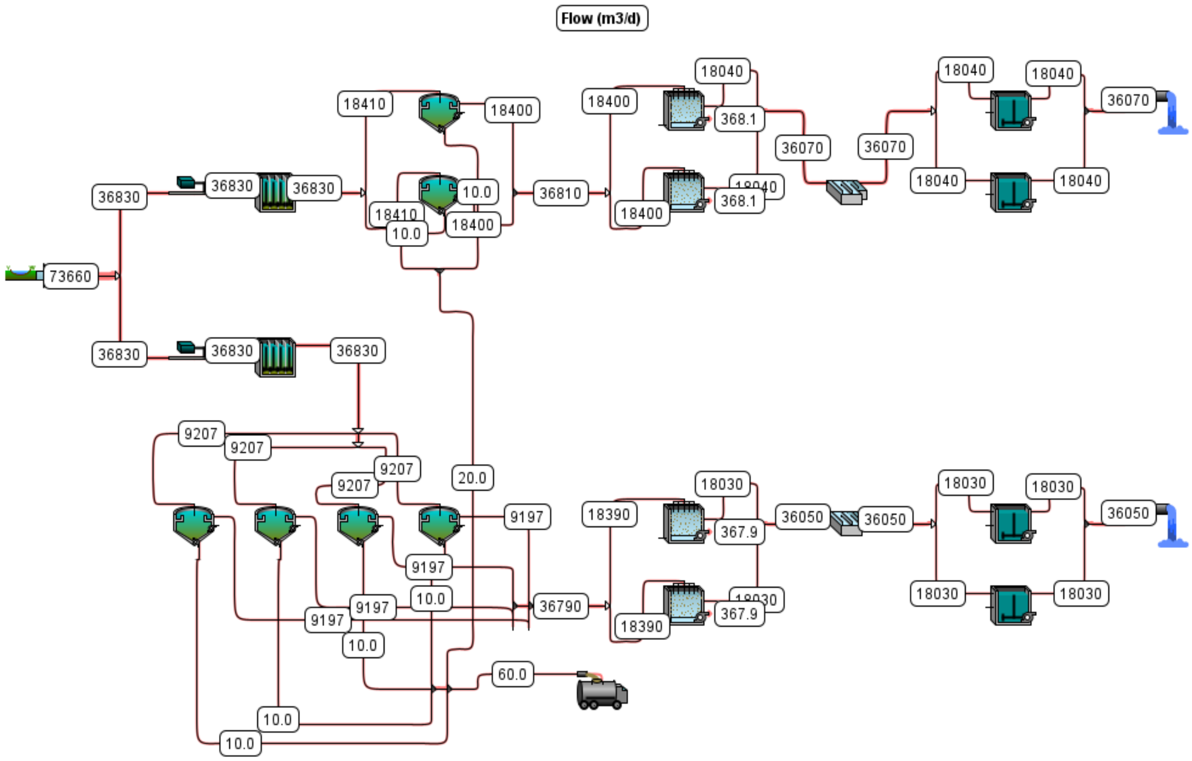

Figure 10. flowrate in al-Qadisiya water plants

Conclusion

To protect water, it is necessary to eliminate contaminants sufficiently through water treatment. Thus, Al-Qadisiya WTP is one of the Iraqi facilities whose operation needs to be completed. Therefore, the design must consider certain parameters in the influent that must be controlled to increase the plant's efficacy. The water undergoing treatment at the facility in 2022 satisfies the specified requirements for effluent concentrations. This observation suggests that the facility has satisfactory operational efficiency. There are recommendations for improved performance regarding the design criteria, management issues, and operational issues. The excess flow rate must be treated by introducing a new idea to improve the plant's organic and suspended solid removal. It can Use GPS-X to solve the water problem and use the program with different situations to simulate the water plant with different scenarios to get the best simulation result.

Lastly, monitoring and maintenance should be performed, and the operator responsible for maintaining the treatment facility. The frequent maintenance of plant units is essential for keeping their function, preventing damage, and ensuring efficient operation. As long as relying on a single line is not harming the plant's performance, it is recommended to undertake maintenance activities regularly, which will be reduced.

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