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Assessment of drinking water treatment and disinfection by-products

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ABSTRACT

Water treatment plants and disinfection by-products are a worldwide problem in the provision of drinking water with disinfectants. However, in countries like Ethiopia, studies on the condition of water treatment plants and the risks they pose are scarce. Hence, this study was designed to evaluate the drinking water treatment plants of Jimma Town. The WatPro v4 simulation was used to evaluate the performance of the water treatment plant and disinfection. The results show that the treatment efficiency of the study was estimated to be 69.75%, while giardia and virus were reduced by 22.6% and 75.34%, respectively, and did not meet the requirements for surface water treatment. Furthermore, the contact time of the water system did not meet the contact time requirement (it should be great than one), but it was 0.476 for this study, and the current water distribution network and treatment plant of Jimma town were underperforming and did not provide adequate water to the various demand categories. Due to the poor performance of water treatment plants, the health and economic well-being of the majority of the population is seriously affected, and some people refuse to drink it, preferring to treat it at home instead. Disinfection of drinking water (chlorination) causes some to react with naturally occurring organic matter or waterborne diseases, while others exist as free chlorine or residual chlorine, producing the disinfection by-products (DBP), increased risk of bladder cancer and other human health effects. Therefore, the study strongly suggests that DBP and their precursors be removed following chlorination. We believe that the study provided new and updated insights on the treatment condition and DBP risk, which could aid decision-makers, planners and stakeholders in monitoring actions to reduce the health risks associated with DBPs in drinking water.

1. Introduction

Raw water from the surface water, lake, or reservoirs is drawn into the plant through an intake structure for treatment and sent to the distribution system to reach or satisfy the customers (Koop and van Leeuwen, 2015). The main treatment process units that make up the conventional surface water treatment are water intake; screening; coagulation/flocculation; sedimentation; filtration, and disinfection. The coagulation and flocculation treatment unit process is used to remove color, turbidity, algae, and other microorganisms from surface waters (Loucks and van Beek, 2017). The addition of chemical coagulants to water forms precipitates or flocs that trap the contaminants. The most commonly used coagulants are aluminum sulfate and ferric sulfate, but other coagulants are also available (Popawala and Shah, 2011; Krueger et al., 2020; Richter et al., 2018). Coagulation can be either a primary coagulant or coagulant aid. Primary coagulants are used to destabilize and agglomerate particles which helps to add density to slowly settling flocs or increase the toughness and prevent the particles from collapsing in subsequent processes (Singh and Mahanta, 2021; Yahya et al., 2020). Salts of Aluminum or iron are the most commonly used coagulation chemicals in water treatment due to their effectiveness, relatively low cost, availability, and ease to handle, storage, and application (Capt et al., 2021).

The common design parameters that affect the efficiency of coagulation are mixing intensity and detention time (Muranho et al., 2014). The most common problems that usually occur in the coagulation process are under or over-dosing, mixing of insufficient energy, fouling or clogging of injectors or diffusers, and side reactions (Maiolo and Pantusa, 2019). Most of the time coagulation and flocculation inter counter as the pre-chlorination for surface water treatment plants and it may not be used for groundwater, whereas chlorination is common for both surface and groundwater sources typically to eliminate or inactivate microbiological populations (Anisha et al., 2016; Salunke et al., 2018; Mehta and Joshi, 2019).

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Table 1
Baffling conditions with their baffling factors.

Condition	Description	Df
Un baffled	None, agitated basin, very low length to width ratio, high inlet, and outlet flow velocities.	0.1
Poor	Single or multiple un baffled inlets and outlets, no intra-basin baffles.	0.3
Average	Baffled inlet or outlet with some intra-basin baffles.	0.5
Superior	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir, or perforated launders.	0.7

Source: EPA, water treatment manual; disinfection, 2011 (Koop and van Leeuwen, 2015) Evaluation of contact time for water system.

Table 2
Inactivation table of microorganisms or natural organic matter.

Disinfectants dosage (mg/l)	Giardia reduction (log(10))	Virus reduction (log(10))	Crypto reduction (log(10))
6	22.5643	75.3254	2
6.09444	22.7747	75.3254	2
6.13889	22.9882	75.3254	2
7.58333	23.183	75.3254	2
9.02778	23.4024	75.3254	2
10.4722	23.6027	75.3254	2
11.9176	23.8055	75.3254	2
13.3611	23.9881	75.3254	2
14.8056	24.196	75.3254	2
16.25	24.3832	75.3254	2

Table 3
Disinfectant by-products (DBPs) trihalomethanes (THMs) and haloacetic acids (HAAs).

Disinfectants dosage (mg/l)	TTHMs (ug/L))	HAA5 (ug/L)	Chlorite (ug/L)
6	0.0716945	1.45429	0
4.09444	0.0820115	1.92986	0
6.13889	0.0900406	2.3829	0
7.58333	0.0967059	2.82023	0
9.02778	0.102097	3.24909	0
10.4722	0.106796	3.66928	0
11.9167	0.110798	4.08421	0
13.3611	0.114425	4.4929	0
14.8056	0.117346	4.90108	0
16.25	0.120056	5.30447	0

Table 4
Treated water output summary of WatPro 4.0 simulation results.

Parameter	Criteria	Value	Unit
Disinfectants			
Effluent Chlorine	4	2	mg/L
Effluent Chlorine Dioxide	0.8	0	mg/L
Effluent Chloramine's	1	0	mg/L
DBPs			
TTHMs	100	0.0918659	ug/L
HAA5s	100	2.49309	ug/L
Chlorite	1	0	mg/L
Total Giardia Reduction	6	23.0313	log(10)
Total Virus Reduction	7	75.3254	log(10)
Total Crypto Reduction	2	2	log(10)
Turbidity	0.5	1.25	NTU

The application of disinfectants in a potable water supply has been practiced for over a century and is considered one of the most effective methods of public health protection. Chlorine was once the disinfectant of choice, but other chemicals such as chlorine dioxide, chloramines, and ozone have recently been utilized to purify water (Bhatt and Paneria, 2017). Disinfection takes place in two ways in water treatment plants (primary and secondary). Primary disinfection achieves the desired level of microorganism killing or deactivation, and secondary disinfection maintains disinfectants residual in the finished drinking water to prevent the regrowth of microorganisms as water passes through the distribution system (Mala-Jetmarova et al., 2018; Chaudhari et al., 2017). Different chemicals are used in water treatment plants for disinfection of microorganisms that may alter residual chemicals, and this primary disinfection happens early in the source water treatment, prior to sedimentation or filtration (Mavi and Vaidya, 2018). No residue is produced in this treatment step, but the disinfectant (chlorine) or disinfection by-product used may be present in the stream of residual waste from the water treatment plant (filter backwash). Secondary disinfection occurs at the end of water source treatment when the finished drinking water is clear (Apreutesei et al., 2008). This disinfection step is used to maintain a disinfectant residue in the finished drinking water to prevent microbial re-growth, but this process does not produce any residue. However, water from the clear well (treated water in a reservoir) can be used to backwash the filter. As a result, the disinfectant added to the finished drinking water can be part of the filter backwash (Mehta, 2019; Desta and Befkadu, 2020). Chlorine and chloramines are effective secondary disinfectants, and when chlorine is added to water, it produces nascent oxygen, which kills the bacteria which is cheap and most reliable when dissolved it's in water, chlorine gas quickly forms hypochlorous acid (HOCl), which in turn, dissociates into hypochlorite ion (OCl^-) (Datturi et al., 2015; Onyango et al., 2010; Bhatt and Paneria, 2017).

Given the need for more assurance about the quality of the water the community consume, as well as the requirement for safer drinking water, the goal of this study was to evaluate the performance of treatment units and DBP formation for Jimma town water supply using WatPro v4 software. The findings of the study have a significant contribution to the decision-makers, practitioners and the community of Jimma and other areas in terms of examining the effectiveness of the water treatment plant, evaluating its efficiencies and identifying factors influencing components of the treatment plant.

2. Methods and materials

2.1. Study area description

The study area was found in Jimma town, which is located at a distance of 3450 km west of Finfinnee at 9°5′N and 36°33′E. Based on the 1:50,000 scale topographic map of the Ethiopian mapping authorities, the elevation of the town varies between 1760 and 2180 above mean sea level and with a total area of 3580 hectares.

2.2. Existing water treatment plant

The existing water treatment plant in Jimma town was used to treat drinking water and conveyed to the end-users via the distribution networks. The design of the treatment plant was having a pre-treatment unit, a horizontal roughing filtration unit and a rapid sand filtration unit. The chemicals like alum, lime, and chlorine were added to the water following its sequences (coagulation, flocculation, sedimentation, filtration, and chlorination). One of the popular methods of disinfection used for the town water treatment is disinfection by chlorine which has a great power of killing the diseases causing organisms (pathogens) but chlorination has its side effect as an emerging disinfection by-product. Thus, instead of chlorine if chlorine dioxide is used the amount of disinfection by-product is hugely reduced.

2.3. Water treatment simulation: WatPro

WatPro is a useful program for analyzing and designing a water treatment system. In this program, engineers can create a simulation of a water treatment plant and predict water quality with specific parameters. It is a steady-state water treatment-modeling program, with a focus

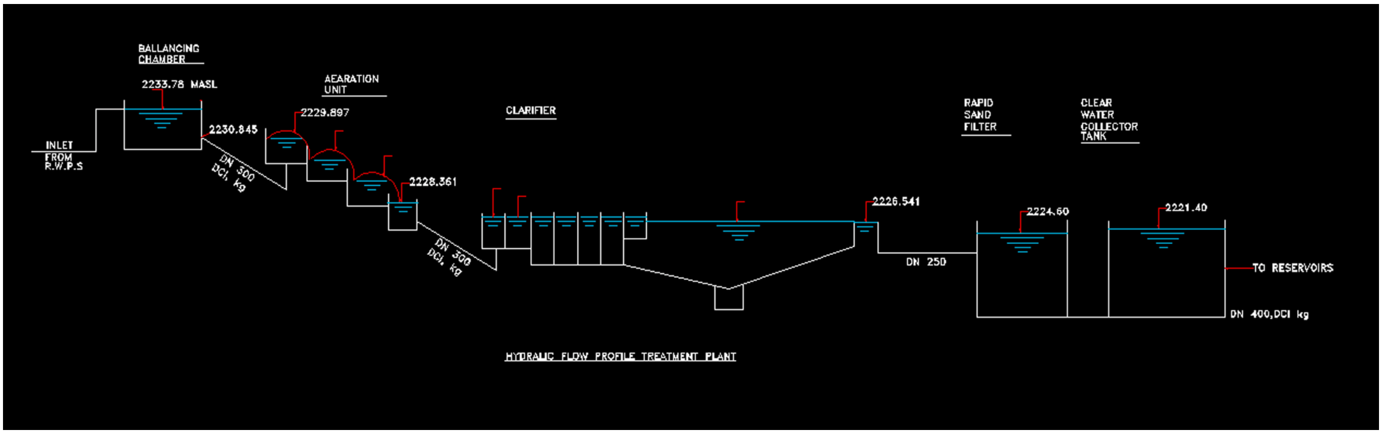

Fig. 1. Existing water treatment system layout of Jimma town.

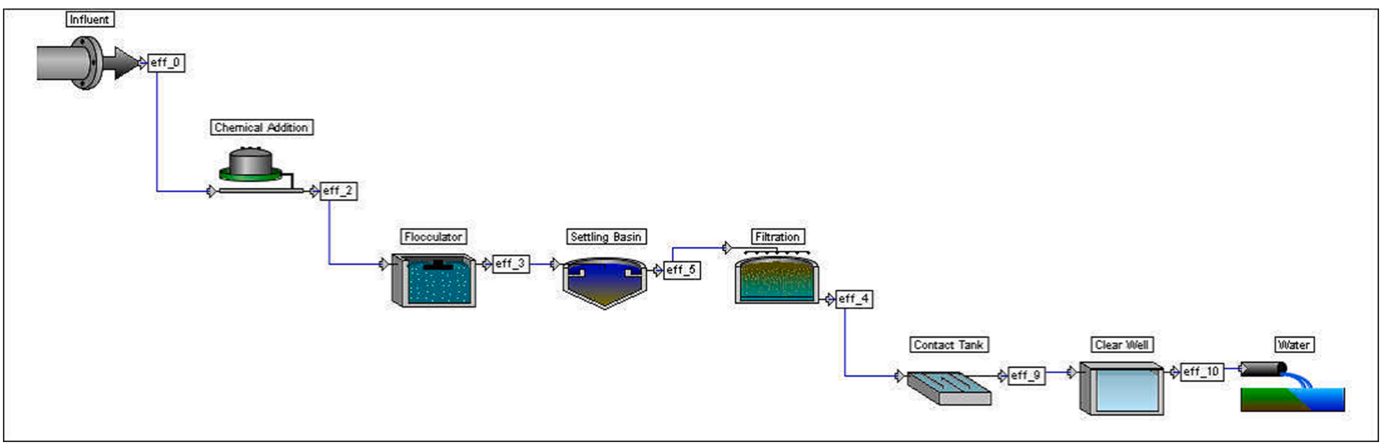

Fig. 2. Process flow diagram of the Jimma town drinking water treatment plants using chlorination.

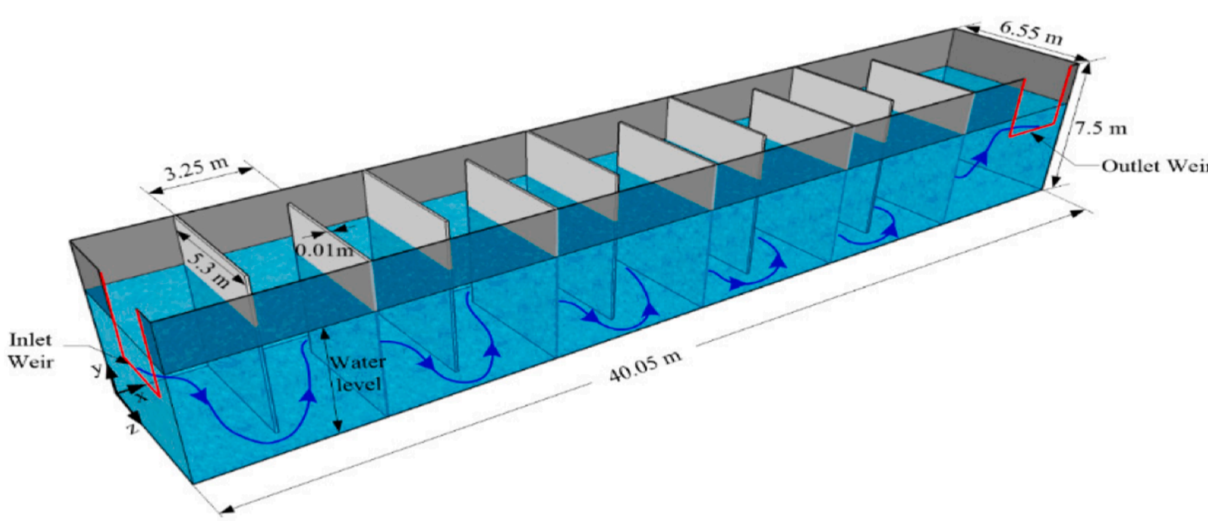

Fig. 3. Data entry window of flocculator generated by WatPro 4.0.

on disinfection and disinfection by-products. Although other aspects of water treatment processes are supported, these are of lesser significance within the package's scope. The information in this section is taken from the WatPro user guide (Hydromantic, 2004). WatPro 4.0 used raw water quality parameters to simulate water treatment i.e. pH, turbidity, residual chlorine, and chemical dosages (e.g. Alum, ferric chloride, lime, ammonia) and design and operating characteristics of process tanks. WatPro was required for the simulation of water treatment to identify the formation of DBPs (trihalomethanes chlorite (THMs), haloacetic acids (HAAs), chlorate, calculate contact time (Ct) for any location in the treatment system, and compare the inactivation of viruses and Giardia by chlorine, ozone, chlorine dioxide, and chloramines.

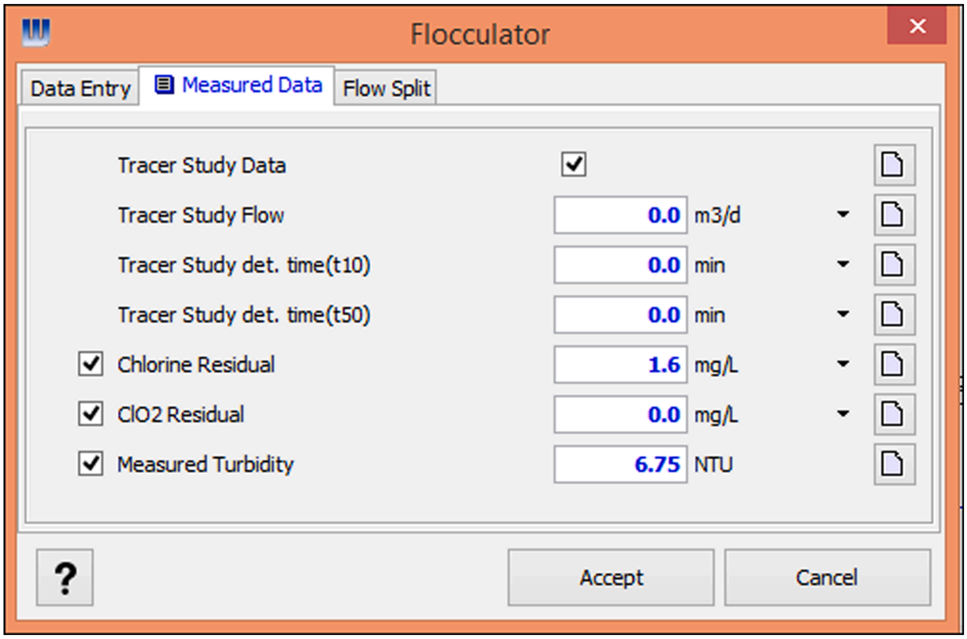

Fig. 4. Schematic chlorine contact tank (CCT). Source: Chlorination contact tank dimension consideration (Benson et al., 2017).

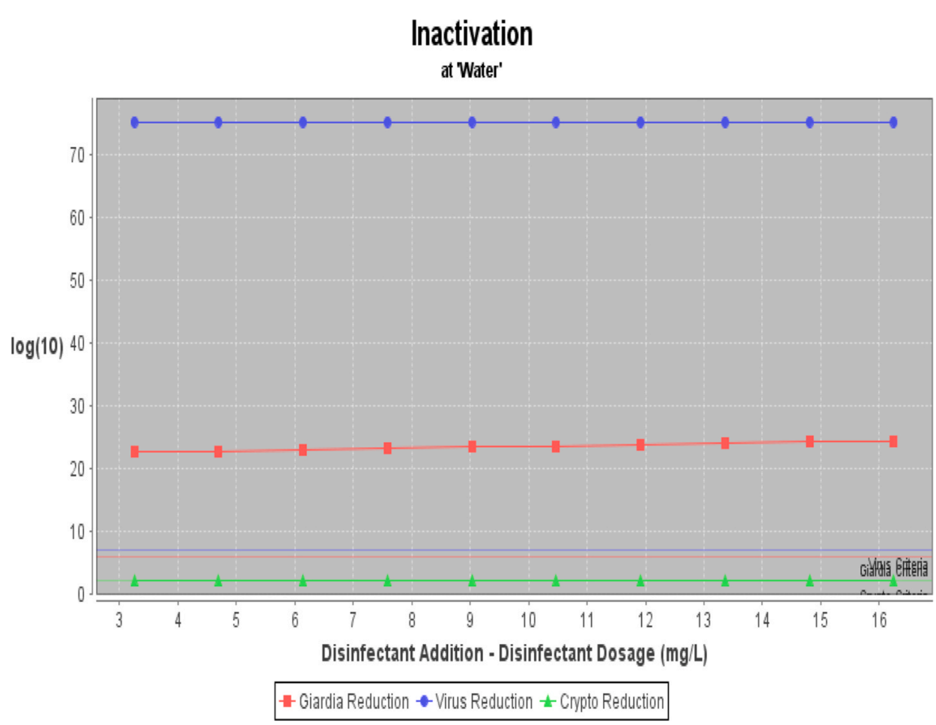

Fig. 5. Inactivation graph of microorganisms or natural organic matter graph.

Generally, WatPro can be used to model the formation of DBP, calculating chlorine contact time (Ct) for any location in the treatment system, optimizing plant operation by allowing chemical addition points to be varied or by tank baffling and estimating treated water quality for a proposed change in plant operation.

The findings of this study contribute to our understanding of the performance of water treatment plants and support the use of water treatment simulators as development tools for disinfection processes.

2.4. *Input data used for treatment plant simulation*

The data required for a drinking water treatment simulation are the characteristics of water, the layout of the water treatment plant, and the required chemicals. These data were obtained from the Jimma town water supply office and used as input to WatPro. The other data such as water quality (pH, turbidity, and residual chlorine) was obtained from the town's water supply laboratory technician. These input data included daily recorded data which had been obtained since operation and maintenance for each treatment unit, as well as availability and method of shipment of treatment chemical types and chemical dosage,

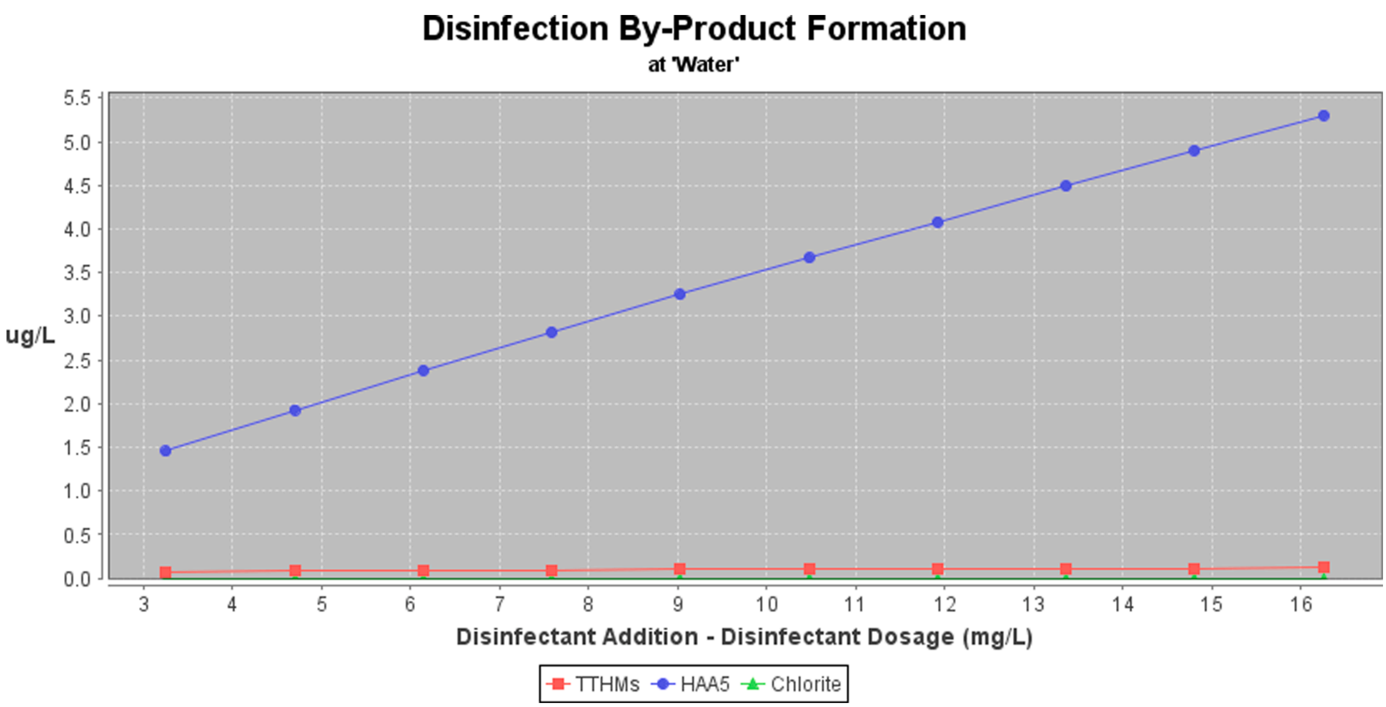

Fig. 6. Formation of disinfection by-products trihalomethanes, haloacetic, and chlorite graph.

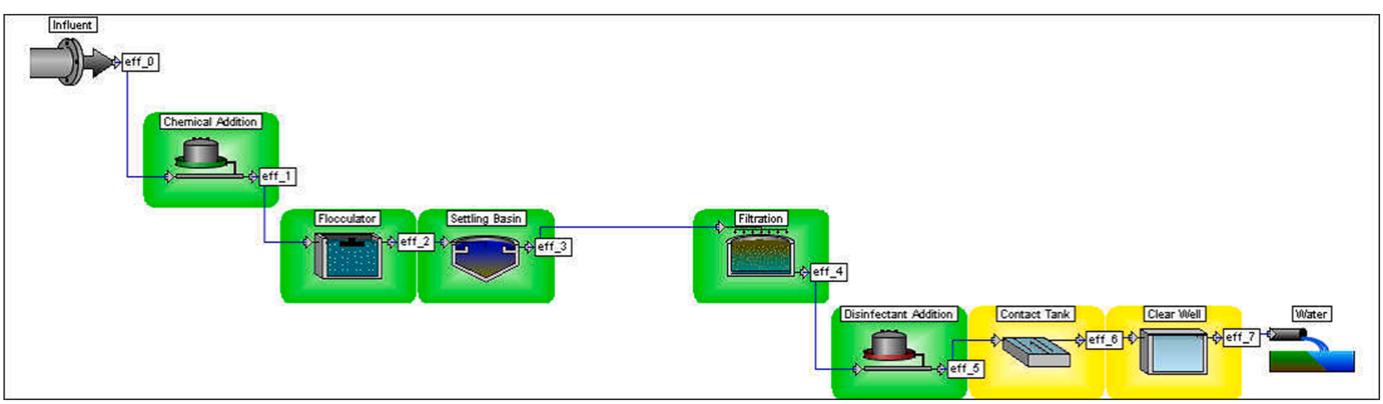

Fig. 7. Water treatment steps of Jimma water treatment plant using process simulator WatPro 4.0.

such as CaO, and $Ca(OH)_2$, Soda ash, Na_2CO_3, Ferric sulfate, Chlorine, Sulfuric acid, H_2SO_4, Sodium hexametaphosphate and others.

According to the Jimma town water service office, there is no sufficient laboratory equipment for the analysis of disinfection and disinfection by-products such as haloacetic acids (HAAs), trihalomethanes (THMs), and chromite. Consequently, the study used WatPro v4.0 simulation to determine the condition of disinfection by-products formation and the presence of a number of microorganisms that would harm public health.

2.5. Simulation and evaluation of disinfection processes

A water treatment simulation was established for the disinfection processes (Chlorination) after the treatment plant of the town. The simulation of chlorination was performed using the water treatment simulator WatPro v4 tool and three inactivation parameters were designated by the simulator tool, which evaluated the disinfection performance for reduction of total giardia, reduction of a virus, and reduction of crypto. The advantage of simulation analysis is that it provides a convenient way to gain a broad understanding of the operational performance of the disinfection process. The quality of effluent treated water quality was employed to determine differences in water quality among the three processes. The formation of DBPs, (THMs and HAAs) in DBP effluent has been used to discover the convenience of each disinfection process.

2.6. Evaluation of water treatment plant's unit processes capability

The major unit processes included flocculation, sedimentation, filtration, and disinfection units. Hence, the capabilities of major unit processes were determined by using the following formulas:

a) Flocculation basin capability $= \frac{\text{Basin volume(m3)}}{\text{Detention time}}$ (2.1)
b) Sedimentation basin capability = Basin surface area (m^2) * surface over flow rate (m/s) (2.2)
c) Filtration basin capability = Filter bed area (m^2) * Filter loading rate (L/min/m^2) (2.3)
d) Chlorine contact time

To inactivate viruses and bacteria using free chlorine, the disinfection treatment required before the first customer must be evaluated. As per the result obtained from a laboratory expert on the water quality of Jimma water supply, the water at the entry point to the distribution system has free chlorine residual of 1.6 mg/L and the chlorine is in contact with the water for 3 min between chlorine injection and entry point to the distribution system, CT is computed as follow;

Water treatment plants feature a number of treatment units, particularly flocculation, sedimentation, filtration, and disinfection being the most common. Equations 2.1, 2.2, and 2.3, as described below, were used to determine the capabilities of these major treatment unit's processes:

$$CT = Concentration\ of\ free\ chlorine\ \left(C_{mg/L}\right) * contact\ time\ (minutes) \quad (2.4)$$

a) Contact tank

In a water treatment plant, raw water is contacted with chlorine in a multi-chamber contact tank for a sufficient length of time to disinfect pathogenic microorganisms at the final treatment step. Despite the fact that viscous and turbulence effects are undeniably important in the flow structure, chlorine contact tank's (CCTs) have traditionally been designed using the concept of plug flow, in which the fluid parcels are assumed to move with evenly distributed streamlines across the entire section of the chlorine contact tank's chambers. The flow structure in CCTs may contain recirculating flow zones that can lead to the formation of jet flow adjacent to the internal baffles and this reduces the hydraulic, mixing and energy efficiencies of the flow-through system. Therefore, CCTs with low disinfection are not preferred and improvements in mixing efficiencies have been investigated through various design alternatives as shown in Fig. 3.

The effective contact time was related to both the volume of the contact tank and its design/structure. In the absence of any tracer test data for the tank, an estimate from the effective contact time can:

$$Effective\ contact\ time\ (minutes) = tank\ volume\ \left(m^3\right) x\, 60\, x\, D_f / flow\ \left(m^3 / h\right) \quad (2.5)$$

D_f is a factor related to the efficiency of the system to minimize short-circuiting through the tank.

Contact time is a measurement of the length of time it takes for chlorine or other disinfectants to kill giardia at a given disinfectant concentration. An operator measures the amount of contact time available at the plant before the water goes out to the public to ensure that 99.9% of giardia is either removed with filtration or inactivated with chlorine before the water gets to the public. As per the Jimma water supply service office, no measurements have been taken for the CT evaluation of the water system. However, this study tried to confirm the evaluation of CT for the water supply system of the town by the following steps;

Step 1: Determine the time available in the basin at peak flow

$$\text{Time(min)} = \frac{\text{basin volume (m3)} * \text{baffling factor}}{\text{peak hourly flow } (m3/\text{min})} \quad (2.6)$$

Step 3: Find the required Contact Time (CT) from the tables at peak flow

Determine the CT required by the Environmental Protection Agency, by looking up the CT from the CT tables provided in the EPA guidance manual using the measurements that have been taken from the water quality expert; 6.5 pH, 20 °C of temperature, and 1.6 chlorine concentration.

Step 4: Does your water system meet CT requirements

Compute the inactivation ratio by dividing the actual contact time by the required contact time. If the ratio is greater than 1, then the water system met its contact time requirements.

$$\text{Inactivation ratio} = \frac{\text{Actual contact time}}{\text{required contact time}} \quad (2.7)$$

2.7. Evaluation of existing plant efficiency

Most importantly, it is wise to verify if the treatment and supply systems are efficiently performing their objectives. The core purpose of the system is to produce at least 99 L/s of clean water as given in the design report. Thus, 99 l/s or 8553.6 m^3/day. However, it is identified that the current practical operation works at 170 × 1 pump or 4080 m^3/day. Note that it does not bring any difference if it starts two (2) sets of raw water pumps because due to the dissolved iron and manganese as well as other organic constituents in the raw water, it cannot expect the capacity of the clarifiers to hold more than this. However, only 2846 m^3 of clean water every day in the distribution system (the current plant capacity). However, the treatment plant efficiency of the town can be estimated as below;

$$\text{plant efficiency rate} = \frac{\text{water consumed}}{\text{water produced}} * 100 \quad (2.8)$$

3. Results and discussions

3.1. Performance of unit processes for water treatment plant

3.1.1. Flocculation

As per the design report document of DH Consultant, the total volume of flocculator for eight units was 720 m^3 and the detention time of the units was found to be 30 min. This time was found within the maximum recommended design range of 20–30 min. Thus, flocculation time does not allow the flocs to settle and form a scum on the walls and bottoms of the flocculator. The mixing energy (velocity gradient) from the design report was 86.1 s^{-1}. It was within the recommended design range of the 45–90 s^{-1}. The head loss of the entire unit was 0.098 m, which was smaller than the design range of 0.35–0.5 m. Thus, parts of the design parameters were within the recommended design range. This indicates that there was sufficient mixing and dispersion of coagulant chemicals with the raw water. By using Eq. 2.2, the capacity of the coagulation tank was determined to be 34,560 m^3/d. This shows that the capacity of flocculation was greater than the current maximum water demand of the town (34,560 m^3/d > 6584.16 m^3/d). Therefore, the Flocculation chamber works well, which is reflected in the supplementary result obtained from WatPro v4.

3.1.2. Sedimentation

The total area of the two rectangular sedimentation basins is 120 m^2. The detention time (from the design report) was 4 h. This detention time was much longer than the designed value of 3 h. This indicates that the flocculated water is spending more time than the required design and the plant is operating at about half of the designed flow to the sedimentation basin. From Eq. 3.10, sedimentation capability was found to be 3000 m^3/d. This shows that the performance of the sedimentation basin is below the town's maximum day demand (6584.16 m^3/d). Operators reported that routine removal of sludge from sedimentation basins was not carried out. The sludge was removed once in three months. The sludge deposit in the settling basin was almost half of the total depth. This indicates that too much flocs have accumulated at the bottom of the basin for a long period, resulting in septic and sludge accumulation. This could result in short-circuits that limit sedimentation performance as a result obtained from WatPro v4 simulator indicates. Therefore, proper hydraulic load adjustment and sludge removal cycle planning are essential.

3.1.3. Filtration

The filtration rates (from the design report of the DH Consultant) were averaged 3.5 m/h. This indicates that the filter was operating below the recommended design load range of 5–15 m/h. The lower filter-load factors reduced the potential for filter performance. This allows the filter to operate at a higher load factor and generate more filtered water than the present quantity. From Eq. 2.3, the filtration capability was 4354.56 m^3/d. As a result, the municipal filter basin was not performing in good condition to meet the maximum water demand. Therefore, proper adjustment of the filter loading rate and filtration capacity is paramount to improving it and delivering the amount of water demand by the town population.

3.1.4. Chlorine contact time

As per the information suggested under Section 2.6 and using Eq. (2.5), the chlorine contact time result was 4.8 mg-min/L. The results were below the required contact time of 6 mg-min/L. Therefore, this result indicates that the chlorine added was inadequate because the contact time of chlorine was shorter than the standard value i.e. $4.8 > 6$ mg-min/L. This means that to inactivate viruses and bacteria with free chlorine, the disinfection treatment required before the first customer must be at least 6 mg - minutes per liter (6 mg-min/L) (www.doh.wa.gov/drinkingwater). Therefore, in the case of disinfection by chlorine, the chlorine contact time was not sufficient to inactivate the pathogen because the contact time achieved was shorter than the required contact time and the disinfection efficiency was inadequate. Hence, with the required contact time value of 6 mg-min/L, it is necessary to adjust the free chlorine residual concentration or the chlorine contact time.

3.1.5. Contact tank

As per the information suggested under Section 2.5 and by using Eq. (2.6), the result of the contact tank was 24 mg-min/L. Thus, this value shows that contact tanks were used at a contact time of 24 mg-min/L to disinfect drinking water prior to distribution. Therefore, the contact time required for the chlorine contact tank requires 24 mg-min/L to achieve the disinfection efficiency.

3.2. Contact time for water system

As described clearly under Section 2.7 and in Eq. (2.8), the result of the inactivation ratio for the water supply system of the town was 0.476. This shows that the value obtained (inactivation ratio) was less than the required contact time ($0.476 < 1$), which means that the disinfection efficiency of the water system is poor. Therefore, this value meets the rules for treating surface water. The inactivation ratio must be greater than 1 to ensure contact time for the efficiency of the water system. These insights show that the water supply system is not functioning well because of it did not meet the required contact time.

3.3. Existing plant efficiency

In the same way, as discussed under Section 2.8 and Eq. (2.8), the result of the existing plant efficiency was 69.75%. This indicates that the treatment plant of the town performs its duty at an efficiency rate of 69.75%. Since the plant performs poorly, the health life of the people is inevitably exposed to too many problems. Therefore, the existing treatment plant efficiency of the town is almost not performing in good condition to ensure the drinking water quality of the town.

3.4. Treatment requirements

According to the surface water treatment regulations, all community and noncommunist public water systems that use a surface water source or groundwater, a direct influence of surface water must achieve a minimum of 99.9% (3-log) removal and/or inactivation of Giardia cysts, and a minimum of 99.99% (4-log) removal and/or inactivation of viruses. However, the result obtained from the treatment plant simulated by WatPro shows that the results obtained are lower than the standard stated above. Thus, result from the WatPro for Giardia reduction and/ inactivation is 22.6% (log-3) and for viruses removal and / inactivation is 75.34% (log-4). Therefore, such a result complies with the treatment requirements i.e. surface water treatment rule so that in case of giardia, viruses, and crypto inactivation and/or removal the treatment plant of the town does not have good performance. For various amounts of disinfectants, the following are the results tabulated (Table 2):

Hence, from the above table, it is a fact that the amount of disinfectant can affect the reduction and / inactivation of Giardia (log-3) but for the reduction and/ inactivation of viruses (log-4) and for crypto reduction it is almost constant. Therefore, it is recommended that in order to increase the reduction/ or inactivation of giardia the disinfectant dosage should be enhanced. The following graph (Fig. 4) shows more details of the above statement.

3.5. Disinfection by-product (DBP) formation

While chlorine has been effective for reducing most microbial pathogens to safe levels, but it reacts with natural products in water to form trihalomethanes (THMs) and haloacetic acids (HAAs) as disinfectant by-products (DBPs). Therefore, as the result obtained from the WTP simulation the values of those DBPs are tabulated as below (Table 3);

From Table 3, the result (numerical value) of disinfection by-products tabulated indicates that there was the existence of disinfection by-products (disease-causing pathogens) in the treatment plant of the town. Thus, as the disinfectant dosage increases the value of Trihalomethanes and Haloacetic acid increases except for that of chlorite. So that their (disinfect by-product) existence may cause many effects on the health life of the population. Therefore, the performance of the treatment plant in the town did not have a good manner to treat the drinking water to maintain the health life of the people. For more detail, the above table is illustrated in the following graph (Fig. 5);

The ongoing implemented treatment processes including chlorination have been evaluated and simulated using WatPro 4.0 simulator for Jimma town water treatment plants. The evaluation of the treatment processes was based on the potential for DBPs production and the disinfecting effectiveness. Output summary for the treated water was presented in Table 4. Due to health risk factors, the DBP criteria score was the highest. Hence, DBP's generation potential is crucial in the safety of water disinfection assessment mandates.

Effluent treated water quality obtained through the simulation of the current chlorination process shows that this disinfection technique may involve serious flaws. Operation conditions like temperature, pH, and contact time may have considerable influence on the disinfection success of chlorination respecting pathogens elimination. Regarding DBPs generation, these factors have low or no significant impacts. The temperature of the treated water was considered 20 °C for simulation purposes during all treatment plant steps. Moreover, the water treatment simulator software WatPro v4 has no temperature and time retention control tool specific for chlorination contact tanks.

The flocculation-sedimentation basin's performance is inefficient; the reasons for this are high levels of suspended solids, which require a high chemical dosage, and, as a result, large DBP was generated in this effluent water. As compared to the recent study on Assessment of Treatment Plant Performance and Water Quality Gondar, Ethiopia (Krueger et al., 2020), the study suggests that the Jimma town WTP units and process operation need to be improved, re-designed to enhance the plant efficiency and DBP's formation drinking water (Eqs. (2.4), (2.7)).

4. Conclusions

The current capacity of the raw water pumps delivering water to the treatment plant was 2851.2 m^3/d. In contrast, the current maximum water demand of the town was 6584.16 m^3/d. This shows that the current raw water pump's capacity did not satisfy the required peak daily water demand of the town.

The major capability of the unit process of the treatment plant was found. Except for the sedimentation and filtration basin (their capacity is less than the current peak daily demand i.e. 3000 $m^3/d < 6584.16$ m^3/d and 4354.56 $m^3/d < 6584.16$ m^3/d, the other units have enough capacity owning to their higher capabilities than the current maximum day demand of the town.

The contact time of the water system of the town was smaller than that of the inactivation ratio i.e. $0.467 < 1$. This indicates that the effective measurements of the disinfection operation are low and hence the treatment plant performs its service at a rate of 69.75%. This indicates that the existing treatment plant efficiency in the town is not in a good performance to ensure the drinking water quality of the town (Table 1).

The disinfection by-product was formed in the water distribution system since chlorine is used in the treatment plant. Inactivation and/or removal of Giardia and virus computed were lower than that of the surface water treatment standards. In general, it can be summarized that the current water distribution network and treatment plant of Jimma town are inefficient and do not provide adequate water to meet the needs of various demand categories of the town. This is a clue that the treatment bearings typical contribute a great deal to the formation of disinfection by-products in drinking water due to the carefulness addition of chlorine, as well as the coagulation/sedimentation/flocculation process and the timely maintenance or operation of residual chlorine in the distribution system as described in Figs. 1, 2, 6, 7.

Furthermore, to study the possible causes of Total trihalomethanes (TTHM), a full evaluation of the efficiency of water treatment plants, as well as operating practices of the water treatment processes and the piped distribution network, is advised Total trihalomethanes.

Declaration of Competing Interest

We the authors declare that we have no conflict of interest concerning the research, authorship, and/or publication of this article and any financial interest.

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