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Impact of the Condition of Drinking Water Supply Networks on the Quality of Water Intended for Consumption: The Case of the Network in the Commune of Daloa (Central West of Côte d'Ivoire)

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Abstract

The potability of drinking water depends not only on the source and the treatment system, but also on the quality of the waterworks. In fact, the quality of drinking water is considerably degraded by the dilapidated state and lack of maintenance of drinking water networks. In Côte d'Ivoire, the majority of drinking water networks in the various towns are ageing. In Daloa, despite the efforts made by the company in charge of water treatment and distribution to make the water drinkable, the water at consumers' taps is often colored, has an unpleasant aftertaste and settles after collection. As a result, people are concerned about the potability of tap water, and some are turning to alternative sources of drinking water of unknown quality. In order to determine the factors responsible for the deterioration in water color and taste, as well as the sectors of the network most affected, a diagnosis of the network's equipment was carried out. Water samples taken from the network were analyzed for color and turbidity. The diagnosis revealed that most of the equipment (suction pads, valves, drains and fire hydrants) is outdated and irregularly maintained. Analyses show that the water is more colored in cast-iron and PVC pipes than in asbestos cement pipes. Coloration values in the network range from 0 to 27 UVC for asbestos cement pipes, from 15 to 56 UCV for ductile iron pipes, and from 11 to 102 UCV for PVC pipes. On the over hand, turbidity values vary from 8.02 to 3.32 NTU for ductile cast iron pipes, 8.51 to 16.98 NTU for asbestos cement pipes and 0.9 to 6.98 NTU for PVC pipes. Old cast-iron pipes release ferric ions on contact with water, degrading their color. Old cast-iron pipes release ferric ions into the water, degrading its color. The high color values observed in the vicinity of drains are thought to be due to irregular maintenance of the network. In fact, after network maintenance, a reduction rate ranging from 2% to 73% is observed for turbidity, while for color, the rate varies from 5% to 72%. In short, the network's obsolescence and irregular maintenance contribute significantly to the deterioration of water quality.

Keywords

Pipe, Water Supply Network, Drinking Water, Daloa

1. Introduction

Water is a natural resource essential to life and sustainable socio-economic development. The quality of water to satisfy different needs varies from one use to another [1] [2]. Water quality can be deteriorated by anthropogenic activities such as the use of fertilizers, phytosanitary products, chemicals and assimilated products and industrial effluents. This deterioration in the quality of drinking water can therefore affect human health [3] [4] [5]. In addition, the ageing and lack of maintenance of drinking water networks are not without consequences for the quality of tap water [1] [6] [7] [8], whereas optimal management of drinking water supply networks requires supplying consumers with water that meets potability and quality standards, at lower cost and without service interruption [9] [10]. The phenomenon of obsolescence has affected the majority of drinking water supply networks in Côte d'Ivoire. In fact, these networks generally date back to the year they were commissioned, and undergo almost no regular renewal program, except in the event of pipe breaks. This could lead to a proliferation of malfunctions within the network and have a negative impact on consumer health [11]. Malfunctions in the network generally manifest themselves in leaks, breakages, discoloration of the water, and drops in pressure and hydraulic capacity within the network. In Daloa, despite the efforts made by the company in charge of water treatment and distribution to make the water drinkable, the water at consumers' taps is often colored, has an unpleasant aftertaste and settles after being collected in a container. Consumers of the commune's drinking water fear the color and taste of tap water, so much so that part of the population is turning to alternative sources of water, the quality of which is still unknown for direct consumption. To alleviate these problems, this study was initiated to determine the impact of the water supply network on drinking water quality. The study will be carried out in two stages. Firstly, a physical diagnosis of the network equipment will be carried out. Secondly and finally, an analysis of the color and turbidity of water samples taken from the network was carried out.

2. The Study Area

Daloa's drinking water supply network is fed by a weir built on the Lobo River, a tributary of the Sassandra River [12]. Daloa is the third largest city in Côte d'Ivoire. The reservoir is located 25 km from the town of Daloa [13], on the Daloa-Zaïbo road (**Figure 1**). The reservoir was commissioned in 1976 and is the main source of drinking water for the population of Daloa. The average quantity of water drawn from the reservoir is 16,200 m^3/day. The average depth of the reservoir is 3.5 m, with an average width of 74 m, a length of 4.3 km and a surface area of 30.3 ha. Volume at normal elevation (231.033 m) is 380,000 m^3 [14]. The river rises in the locality of Séguéla at an altitude of 340 m. The drinking water production plant is located 1 km from the mine. Here, the raw water is potabilized before being conveyed to the storage reservoir (25 km away) via two cast-iron feeder pipes with diameters of 500 and 300 mm. The climate in the study area is a mild transitional equatorial type, with a rainy season from March to October and average annual rainfall of around 1150 mm [14].

The town of Daloa is the economic center of the region. Anthropogenic activities in the watershed are very diverse. However, agriculture remains the main activity of the populations.

With a total length of 264,440.61 meters, Daloa's distribution network is made up of three types of material. Polyvinyl chloride (PVC) pipes account for 69% of the total length, ductile cast iron pipes for 28% and asbestos cement pipes for 3% (**Figure 2**).

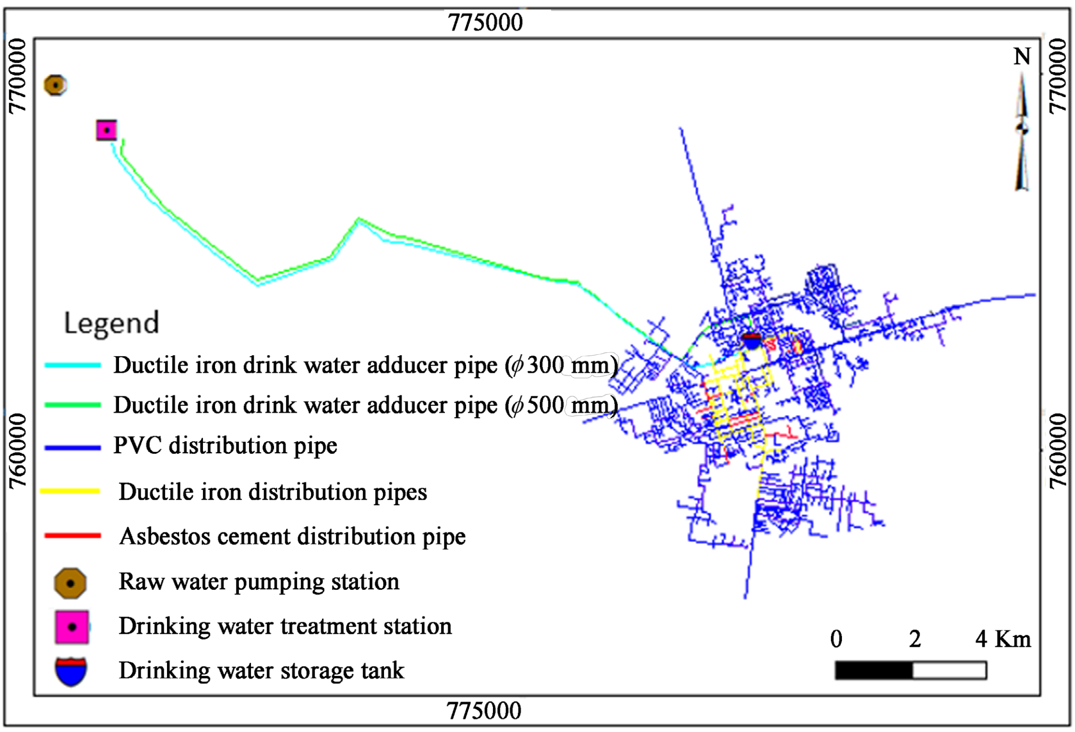


Figure 1. Presentation of the drinking water supply network of the municipality of Daloa.

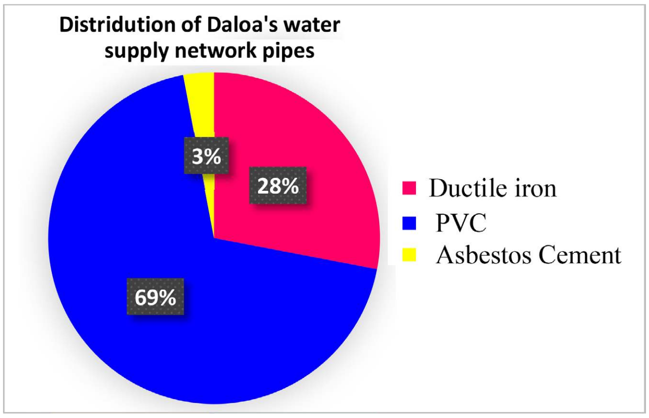


Figure 2. Material distribution on Daloa's drinking water supply network.

3. Materials and Methods

3.1. Equipment

3.1.1. Field Equipment

The equipment used in the field consisted of: a Garmin etrex 10 handheld GPS for taking geographical coordinates; a camera for taking photographs; survey sheets for carrying out the surveys; 1-liter (L) capacity bottles for water sampling in the network; a cooler for storing water samples; a beaker for water sampling and glass tubes for in situ analyses.

3.1.2. Laboratory Equipment

The equipment used in the laboratory was follows HACH 2100Q turbidity meter for measuring turbidity in water samples taken from the network; a HACH DR 1900 spectrophotometer for measuring the color of water samples taken from the network.

PAleontological STatistics (PAST) 3.20, Autocad 2017 and ArcGIS 10.4.1 were used for data processing.

3.2. Methods

3.2.1. Physical Diagnosis of the Network

The physical diagnosis of the drinking water supply network's various facilities involved a detailed visual assessment of the condition, operation and performance of the equipment used to transport and distribute drinking water. This includes reservoirs, pumping stations, pipes, valves, meters, water treatment devices.

In addition, during the physical diagnosis, the geographical coordinates of the various network equipment were collected to create a database.

3.2.2. Sampling

Samples were then collected in 1-liter plastic bottles and stored in a cooler containing ice. Samples were taken from the various types of material making up the entire network (**Figure 3**), and from fire hydrants and outlets before and after maintenance work.

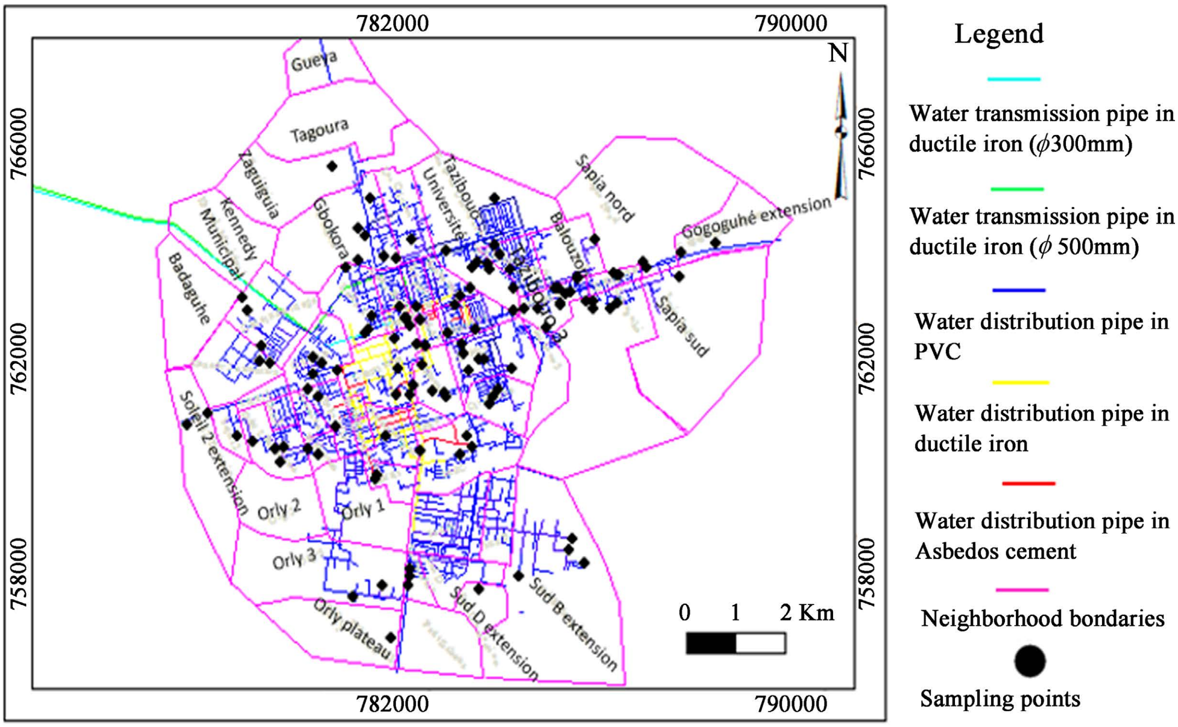


Figure 3. Sampling points on Daloa's drinking water supply network.

4. Results

4.1. Physical Diagnosis

4.1.1. Diagnosis of Suction Cups

All drinking water networks are made up of pipes that transport water from the source to the consumer's tap. During this process, air pockets can form and remain within the pipes. The main function of a suction cup within a drinking water network is to continuously evacuate air pockets trapped within the pipes. The physical diagnosis of the suction cups not only identified all the suction cups in the drinking water network, but also verified their physical state of operation. Figure 4 shows the distribution of suction cups on the Daloa commune's water supply network.

The diagnosis shows that 67% of air valves in the network are in good condition (BE); 28% are in poor working order and 5% are in poor condition (Figure 5).

4.1.2. Fire Hydrant Diagnosis

The operating status of all the network's fire hydrants is illustrated in Figure 6 and Figure 7.

The results of the diagnosis show that 37% of fire hydrants are out of service, 32% are located in high-pressure areas, 21% in low-pressure areas and 10% are not handled because they are located in areas difficult to reach by the network (Figure 7).

4.1.3. Drain Diagnostics

The operating status of the network's drains is illustrated in Figure 8.

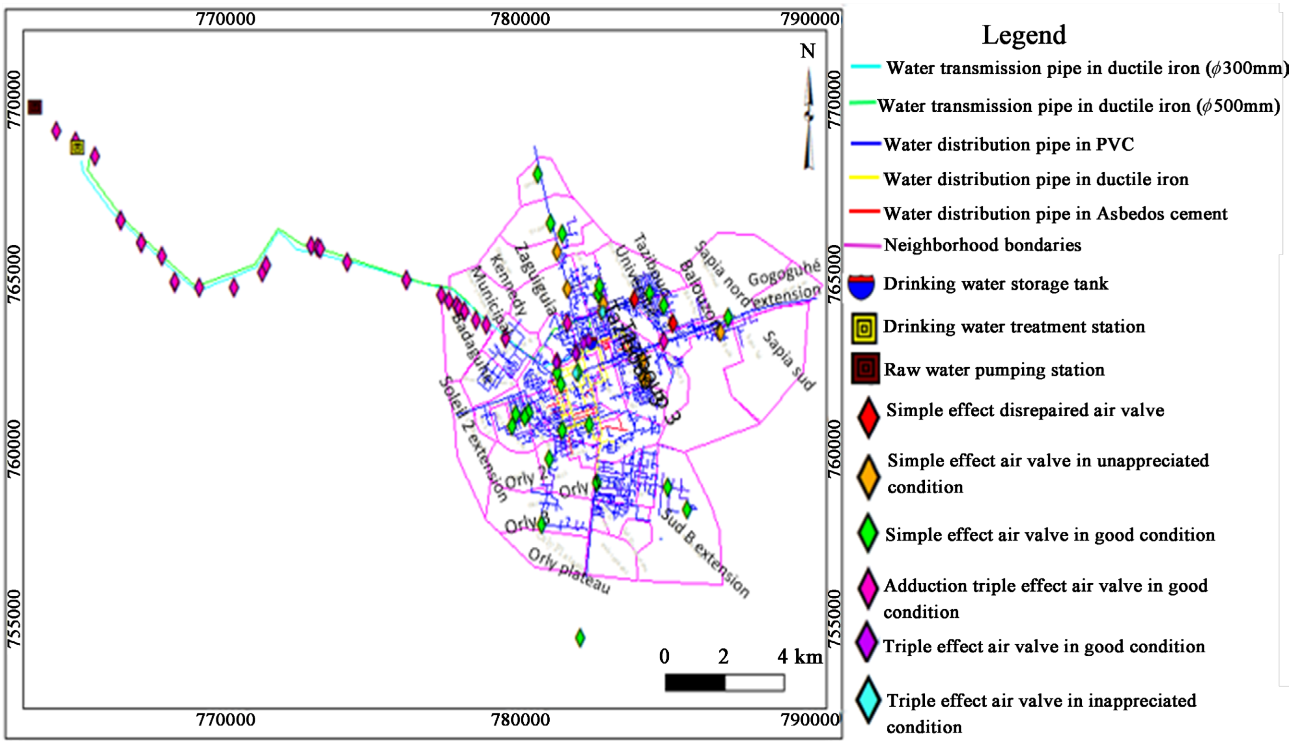
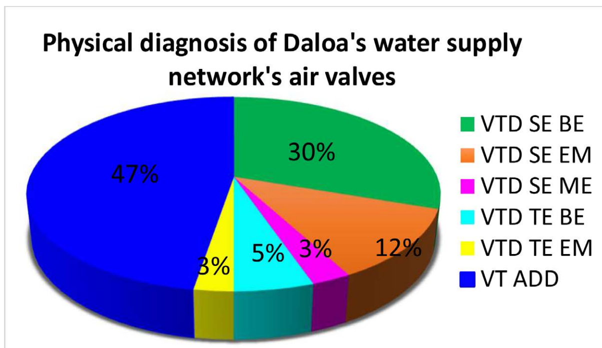


Figure 4. Répartition des ventouses du réseau d'AEP de la commune de Daloa.



VTD: Distribution network air valve; VT ADD: Supply network air valve; SE: Single-effect; TE: Triple effect; BE: Good Condition; EM: Unknown condition; ME: flawless.

Figure 5. Review of Daloa's drinking water network's air valves functioning.

The diagnosis revealed that: 56% of drains have been handled and are in good condition, 13% of drains are inaccessible, 5% of drains are located in areas of low pressure, and 2% are faulty (**Figure 9**).

4.2. Qualitative Diagnosis

The qualitative diagnosis of water samples taken from Daloa's drinking water network mainly concerns the two parameters feared by the population, such as color and turbidity.

4.2.1. Turbidity

On the water supply network, which is mainly made up of cast-iron pipes, the

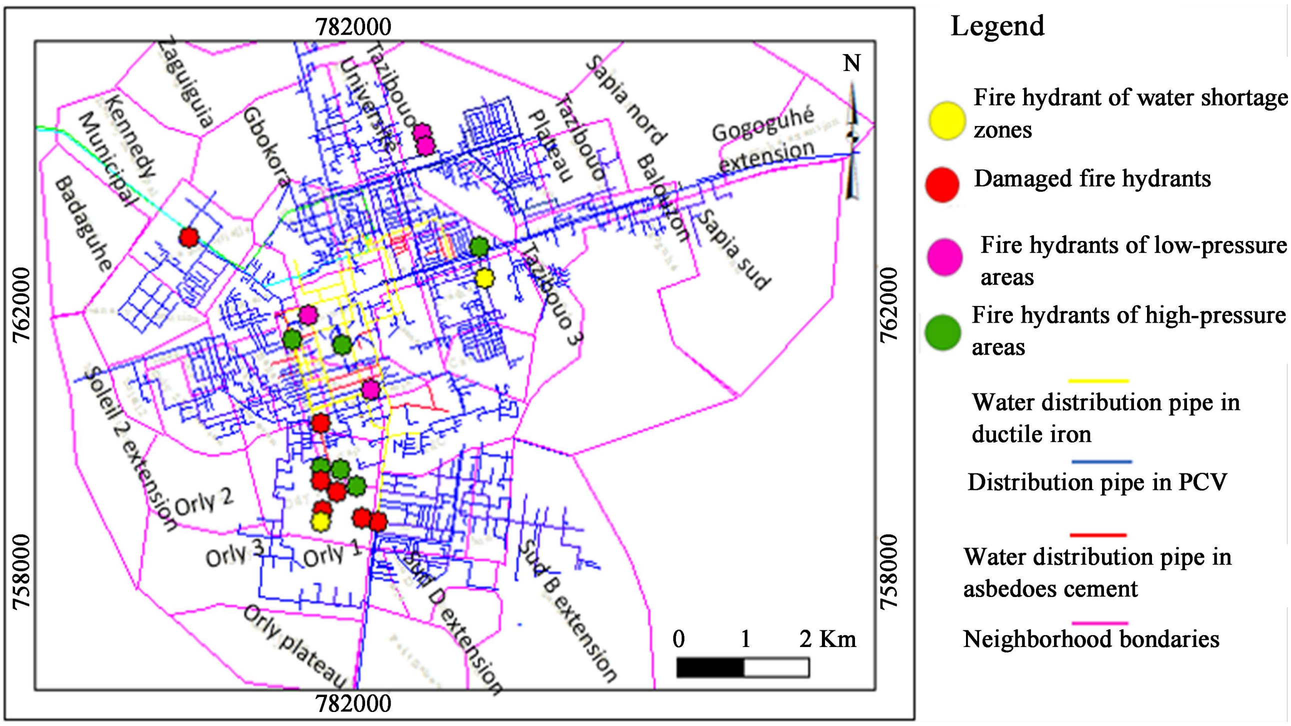


Figure 6. Location of fire hydrants on the Daloa drinking water network.

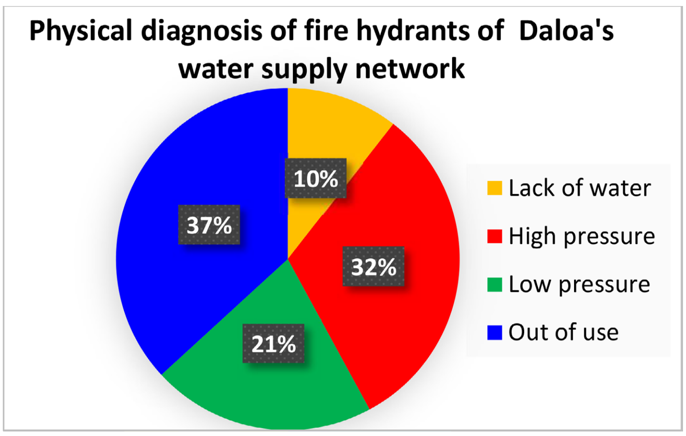


Figure 7. Review Daloa's drinking water network's fire hydrants functioning.

turbidity values recorded are in line with World Health Organization's (WHO) guide values, except at locations such as the conventional treatment unit, the compact station, B. Koukoguhé village and at the tank (**Figure 10**).

On the distribution network:

- Turbidity values recorded at cast-iron pipes do not exceed WHO guideline values;
- The high turbidity values observed at the reservoir are due to water mixing, and at Radio Tchrato are due to the fact that this point is located close to a drain (**Figure 11**).
- For asbestos cement pipes, the values recorded do not comply with the WHO guide value (**Figure 12**).

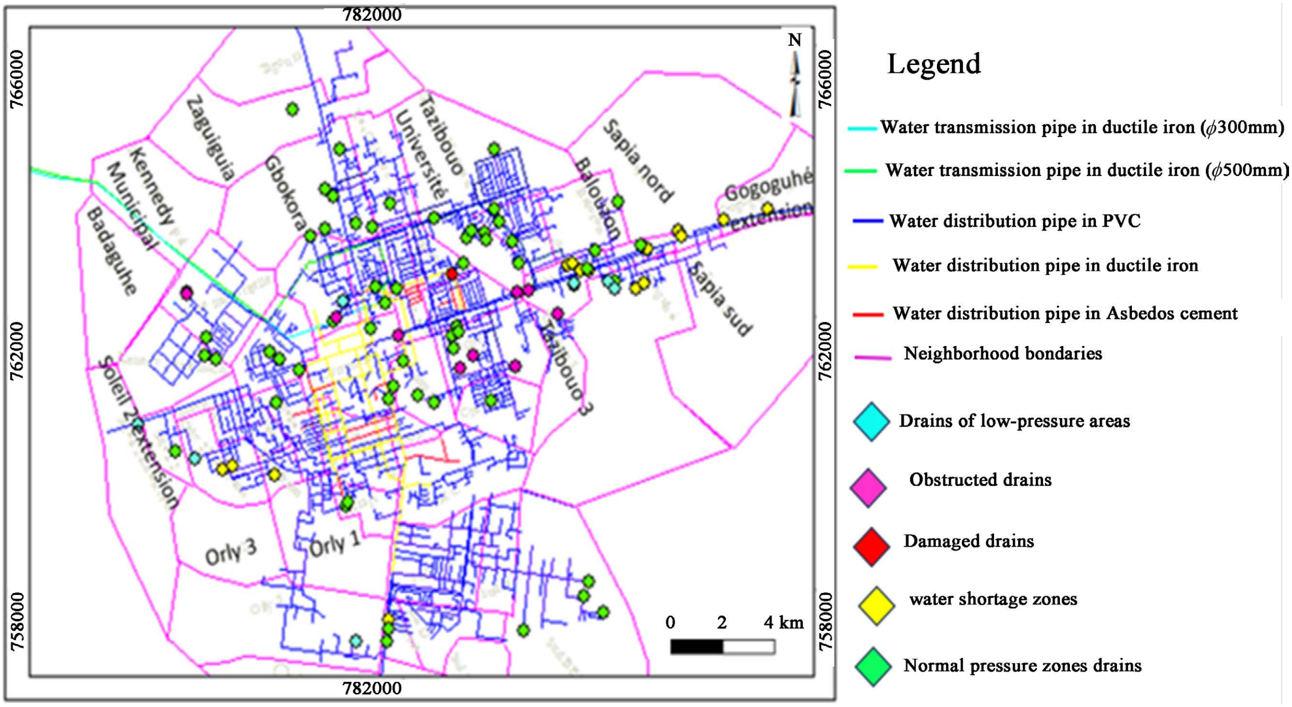


Figure 8. Emptying of the drinking water network in Daloa.

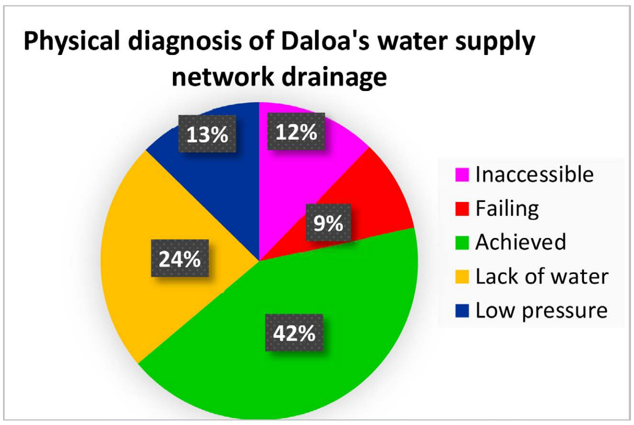


Figure 9. Assessment of drinking water network drainage operations.

In the case of PVC pipes, turbidity values that do not comply with WHO standards are recorded at the CHR crossroads, Petit Zakoua and Abattoir 2. These sampling points are generally located in low-lying areas of the network, close to drainage points (Figure 13).

4.2.2. Color

Figure 14 and Figure 15 show that water color values are above the WHO guide value throughout the supply network in cast-iron and PVC pipes. On the other hand, asbestos cement pipes show values both above and below the WHO standard.

4.3. Water Supply System Maintenance

Maintaining a drinking water supply network involves regular cleaning of the

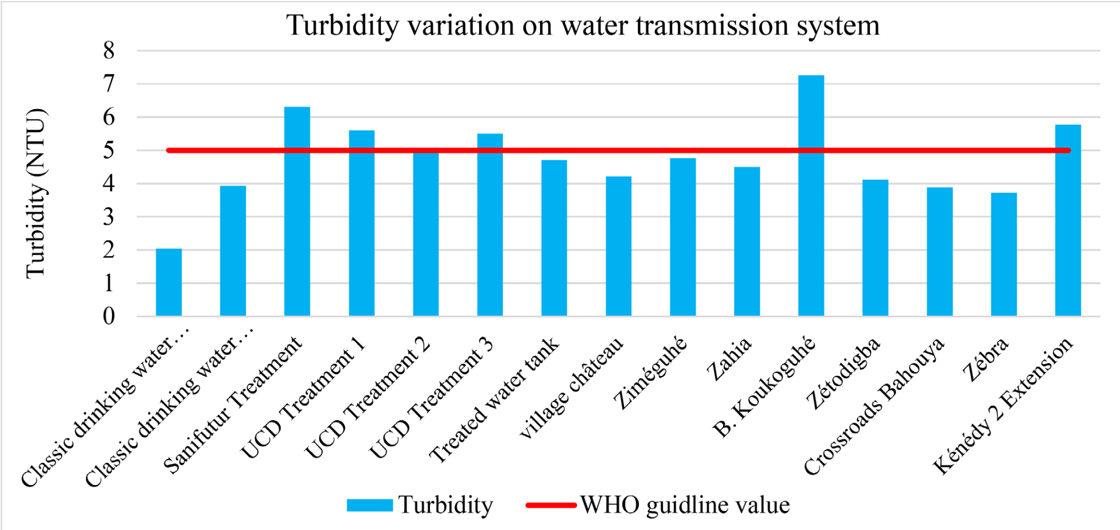


Figure 10. Turbidity variation on water transmission system.

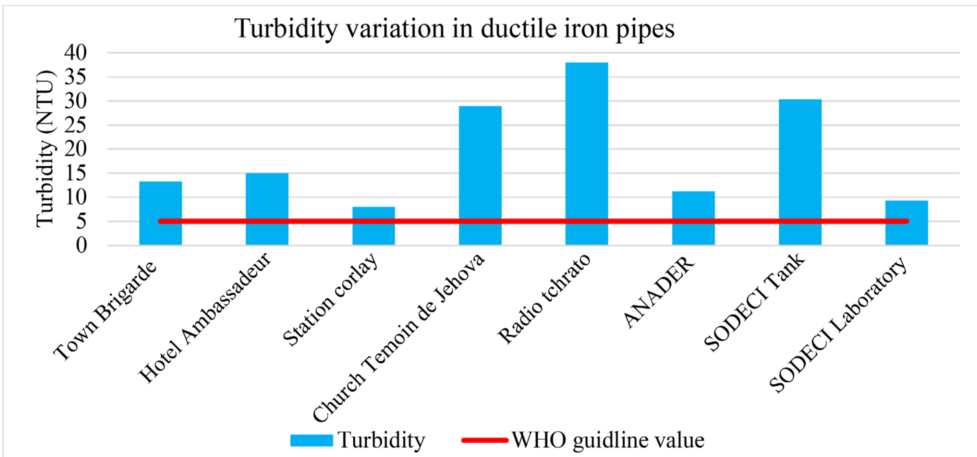


Figure 11. Turbidity variation in water distribution ductile iron pipes.

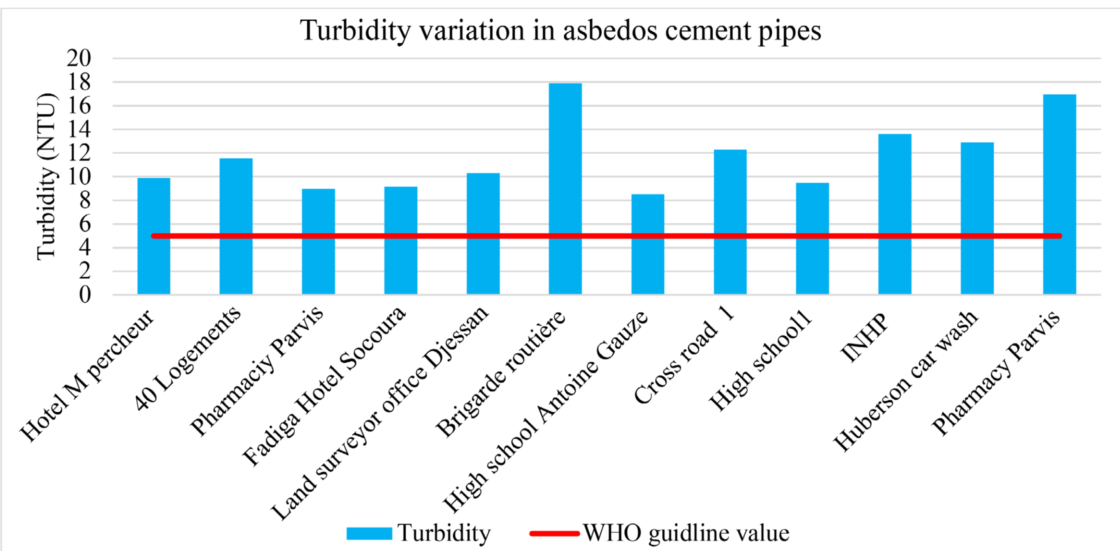


Figure 12. Turbidity variation in water distribution's asbedos cement pipes.

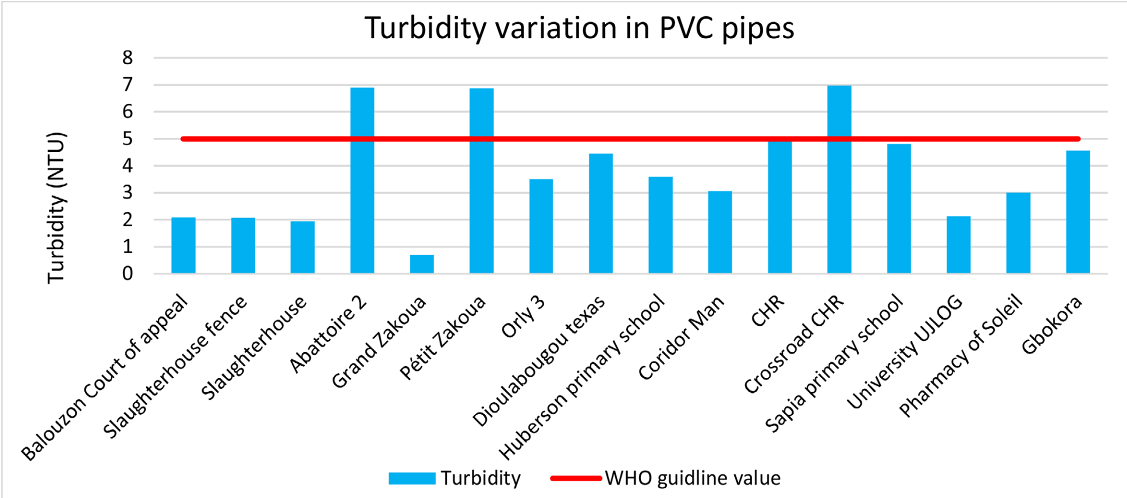


Figure 13. Turbidity variation in water distribution's PVC pipes.

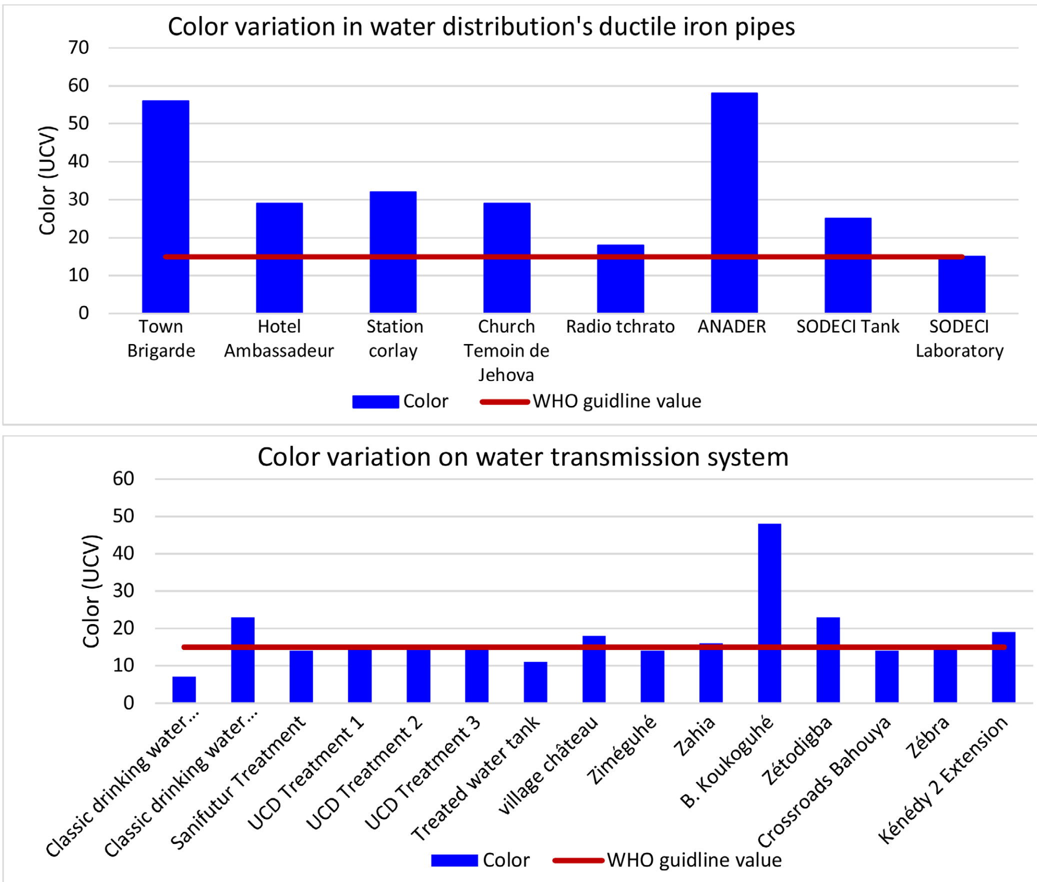
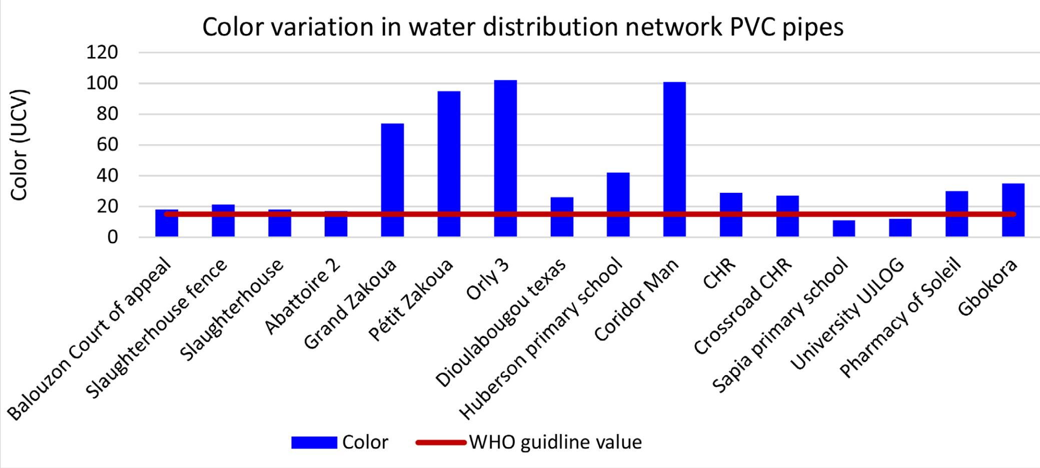


Figure 14. Color variation in ductile iron pipes.

pipes and other network equipment. Maintaining a drinking water supply network helps guarantee water availability and provide consumers with better-quality water. It minimizes service interruptions and contamination risks, and ensures that hydrants and fire hydrants function properly. After a complete overhaul of the Daloa commune's water supply network, we noted an improvement in turbidity and color at drains and hydrants. At fire hydrants, turbidity was reduced by 2% to 62% (**Figure 16**) and color by 5% to 72% (**Figure 17**).



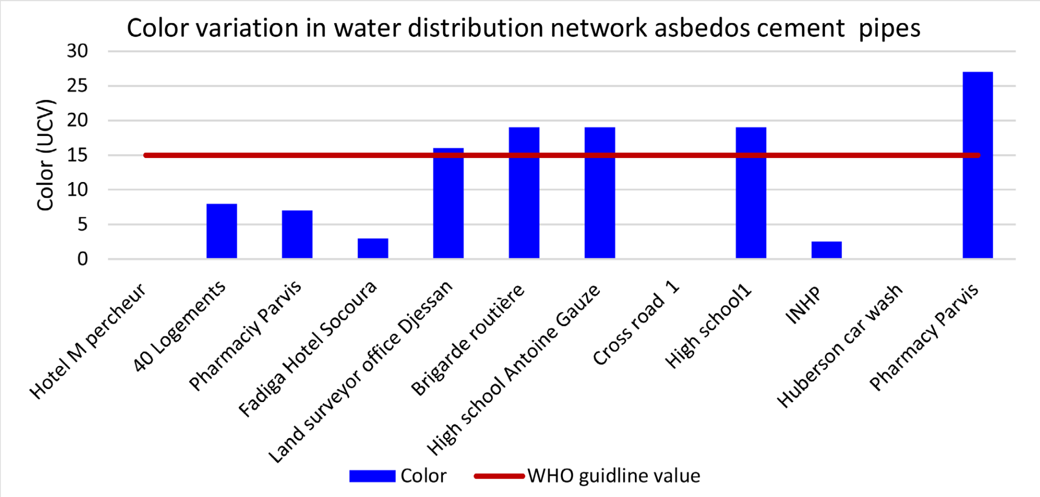


Figure 15. Color variation in water distribution's PVC and asbedos cement pipes.

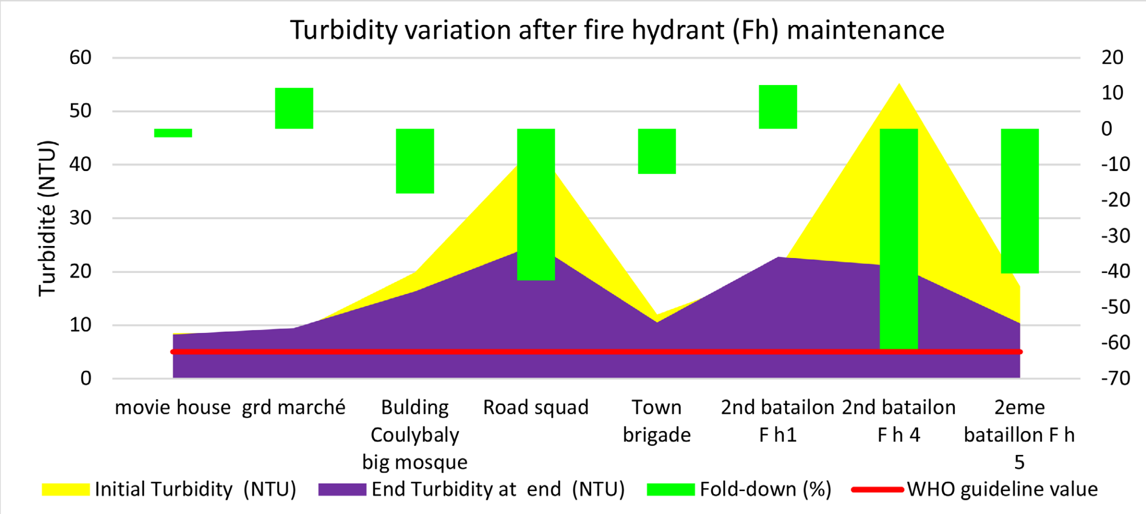


Figure 16. Turbidity reduction after handling fire hydrants.

After draining the Daloa commune's water supply network, an improvement in water quality was observed, with a reduction in turbidity from 5% to 73% (**Figure 18**) and a reduction in color from 16% to 72% (**Figure 19**).

5. Discussion

The physical diagnosis reveals that the water supply network of Daloa includes some out-of-service equipment that prevents maintenance work from being carried out at certain points in the network. Lack of maintenance is a source of sludge accumulation in the network, constituting a potential source of color degradation and increased turbidity on water supply network.

The common feature observed between water from the treatment units and that passing through the inlet pipes is the high color and turbidity values. In fact, the non-operation of some of the pneumatic valves discharging settled flocs from the settling tank could lead to their resuspension and clogging of the filters. Consequently, the deterioration in water quality at the network inlet due to the

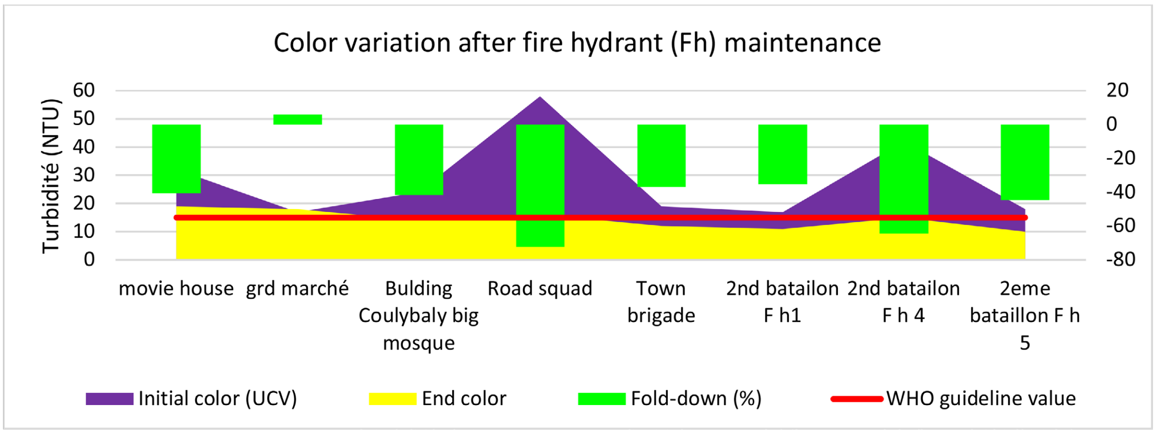


Figure 17. Color abatement after handling fire hydrants.

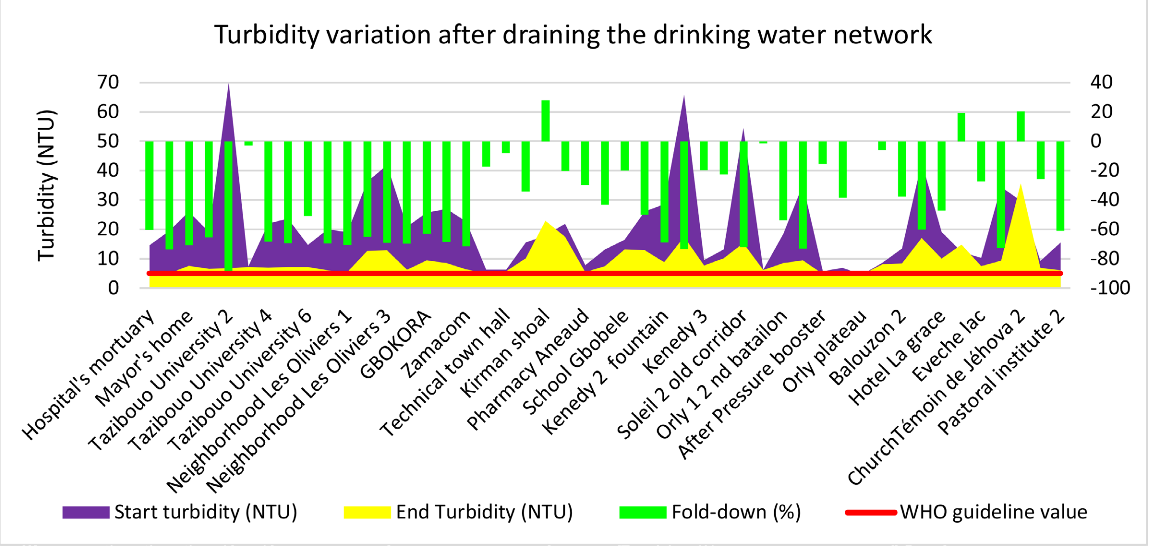


Figure 18. Turbidity reduction after drinking water network draining.

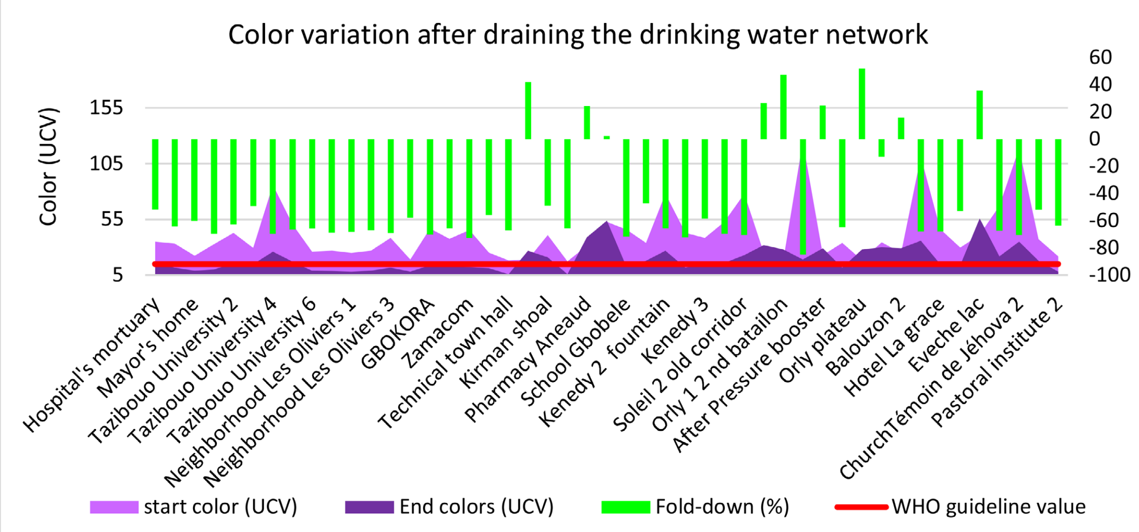


Figure 19. Color reduction after drinking water network draining.

reduced performance of the filtration system would be the result of the malfunctions observed. Secondly, the failure to carry out pump-outs would encourage the accumulation of sludge in the supply network. In addition, the incessant release of sludge into the water supply network over its entire length (25 km) and the physico-chemical reactions that can occur between the connecting pieces of the pipes (cast iron or steel) contribute to increasing the color and turbidity of the water.

The main cause of water quality deterioration in metal pipes such as cast iron is pipe corrosion. In fact, corrosion reactions lead to the release of metal ions into the water, resulting in the precipitation of ferric ions, which can cause the walls of ferrous metal pipes to pierce, resulting in the formation of incrustations (reduction in diameter). In addition, red water problems, the appearance of metallic taste and increased concentrations of dissolved metals result from pipe corrosion [15].

Asbestos cement pipes are not subject to corrosion problems; this is a considerable advantage compared to cast iron metal pipes. However, on contact with water, the material (asbestos cement) releases calcium hydroxide $Ca(OH)_2$, which is said to have carcinogenic effects on consumer health. This is reflected in the high turbidity values and low color values. This can lead to an increase in alkalinity, calcium content and a release of magnesium, silica and hydroxide from asbestos ($Mg_3Si_2O_5(OH)_4$) [1]. However, in the vicinity of pump-outs, the accumulation of sludge in the pipes increases the color and turbidity of the water.

PVC pipes are not as prone to corrosion as asbestos cement pipes. The increase in turbidity and color in PVC pipes can be explained by the lack of purging in the network and the transit of water from one type of material to another. In PVC pipes, the corrosion of cast-iron or steel fittings and the transit of water from cast-iron to PVC pipes increase the color and turbidity of the water, as well as the concentration of ferric ions. The increase in organoleptic parameters could then be a source of taste development within the network [16] [17].

On the water supply network, the high turbidity values in village B Koukoguhé are thought to be due to the accumulation of mud after a long stay in the section. The discrepancy between the turbidity values of the cast-iron pipes and those observed in the supply network would be due to the fact that the supply network is fairly recent (installed in 2012), while the distribution network, which is fairly old (installed since 1967), would be affected by pipe corrosion.

6. Conclusion

In this study, we analyzed the factors that degrade the physical and organoleptic characteristics of the drinking water supply network in the commune of Daloa. Samples were analyzed for two physico-chemical parameters: turbidity and color. The results showed that color and turbidity did not meet the WHO 2017 guide values for either the supply or distribution network. After network maintenance, an abatement rate ranging from 2% to 73% was observed for turbidity, while for color, the rate varied from 5% to 72%. Lack of network maintenance leads to the accumulation of sludge in the network, and is one of the main causes of water discoloration, taste and deposits at the consumer's tap. It appears that color and turbidity are determining factors in the deterioration of water quality in the drinking water supply network.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Erramli, H., Dermaj, A., Driss, C., Moustafa, D. Najjat, H. and Srhiri, A. (2014) Étude de la dégradation d'une canalisation de conduite d'eau en béton armé. *Afrique Science*, **10**, 1-9.

[2] Kanakoudis, V., Tsitsifli, S., Samaras, P. and Anastasios, I.Z. (2014) Water Pipe Networks Performance Assessment: Benchmarking Eight Cases across the EU Mediterranean Basin. *Water Quality, Exposure and Health*, **7**, 99-108. https://doi.org/10.1007/s12403-014-0113-y

[3] Essoyeke, B. (2014) Nouvelle approche pour le dimensionnement et l'optimisation de la gestion des réservoirs et de la qualité de l'eau potable dans les réseaux de distribution. Rapport de thèse, Université de Montréal, Montréal, 185 p.

[4] Fofana, O., Kouassi, E.A. and Avy, S.K. (2017) Cartographie et identification des activités sources de nuisances et de pollutions dans le bassin versant du barrage du Kan de Bouake (Côte d'Ivoire). *European Scientific Journal*, **13**, Article 303. https://doi.org/10.19044/esj.2017.v13n5p303

[5] Charles, G. (2017) Modèles d'optimisation stochastique pour le problème de gestion de réservoirs. Université de Montréal, Montréal, 191 p.

[6] Renaud, E., Khedhaouiria, D., Clauzier, M., Nafi, A., Wittner, C. and Werey, C. (2012) Réduction des fuites dans les réseaux d'alimentation en eau potable Systèmes d'indicateurs et méthodologies pour la définition, la conduite et l'évaluation des

politiques de lutte contre les fuites dans les réseaux d'eau potable. Rapport de recherche, 62 p.

[7] Holguin-Gonzalez, J.E., Boets, P., Alvarado, A., Cisneros, F., Carrasco, M.C., Wyseure, G., Nopens, I. and Goethals, P.L.M. (2013) Integrating Hydraulic, Physico-chemical and Ecological Models to Assess the Effectiveness of Water Quality Management Strategies for the River Cuenca in Ecuador. *Ecological Modelling*, **254**, 1-14. https://doi.org/10.1016/j.ecolmodel.2013.01.011

[8] Karim, C. (2014) Maîtrise des pertes sur les réseaux d'eau potable, mise en place d'un modèle de fuite multi-états en secteur hydraulique instrumenté. Rapport de thèse, école doctorale mathématique et informatique, Université de Bordeaux, Bordeaux, 134 p.

[9] Allal, M.A., Abdelbaki, C. and Djelloul, S.S.M. (2012) Une approche qualité totale pour la gestion des réseaux d'alimentation en eau potable: Cas du groupement urbain de Tlemcen (Algérie). Editions universitaires européennes, Saarbrücken, 168 p.

[10] Large, A. (2013) Optimisation du renouvellement des canalisations. Rapport de première année de thèse: revue bibliographique et cadre méthodologique. IRSTEA et Université de Bordeaux, Bordeaux, 109 p.

[11] Wilfried, G.K. (2014) Milieuu urbain et accès à l'eau potable: Cas de Daloa Centre-Ouest Côte d'Ivoire. Broché, 388 p.

[12] Yao, A.B. (2015) Evaluation des potentialités en eau du bassin versant de la Lobo en vue d'une gestion rationnelle (Centre-ouest de la Côte d'Ivoire). Thèse de Doctorat, Université Nangui Abrogoua, Abidjan, 192 p.

[13] Gautier, K.W. (2012) Milieu urbain et accès a l'eau potable: cas de Daloa (Centre-Ouest de la Côte d'Ivoire). In: Géographie. Université Félix Houphouët Boigny, Abidjan, 364 p.

[14] Koffi, B. (2022) Fonctionnement hydroclimatique du bassin versant de la rivière Lobo à Nibéhibé: Modélisation de la sédimentation dans la zone de captage pour l'approvisionnement en eau potable de la ville de Daloa (Centre-Ouest de la Côte d'Ivoire). Université Jean Lorougnon Guédé, Daloa, 257 p.

[15] Gnamba, F.M., Oulai, J.G.K., Wilfried, N. and Yeï, M.S. (2020) Modélisation hydraulique du réseau d'adduction d'eau potable (AEP) de la ville de Korhogo. *International Journal of Innovation and Scientific Research*, **52**, 17 p.

[16] Santé Canada (2015) Recommandations pour la qualité de l'eau potable au Canada: Document technique—Le pH. Bureau de la qualité de l'eau et de l'air, Direction générale de la santé environnementale et de la sécurité des consommateurs, Santé Canada, Ottawa, 48 p.

[17] Alla, D.A., Atta, K.J.M. and Yassi, G.A. (2018). Les risques naturels et leurs manifestations dans une ville secondaire: érosion et inondation à Daloa (Centre-Ouest de la Côte d'Ivoire). *Revue de Géographie Tropicale et de l'Environnement*, **2**, 101-113.