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Evaluation of Drinking Water-Supply System by Pdam Buru Regency, Maluku Province

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ABSTRACT

As an agency that operate and manage public water supply services in Buru Regency, PDAM Buru Regency still face a great challenge in providing water supply services to its customer. In this study, quality and quantity assesment is employed to see the status of water quality and quantity according to the required standard by by the Ministry of Public Work Regulation number 27/PRT/M/2016. Quality assesment is done through laboratory analysis on physical, chemical, and microbacterial parameters of the sampled water from source wells. Meanwhile, the quantity of the water supplied is analysis from secondary data of consumed water, particularly for domestic water demand. For water quality test, Laboratory report indicates than most of the test parameters are on permitted level according to Ministry of Health Regulation Number 492/MENKES/PER/IV/2010. As for quantity test, water demand per person per day is higher that standard requirement.
KEYWORDS: water, assesment, quality, quantity, supply system

1. INTRODUCTION

Drinking water is indispensable for human existence. Water quality is the most fundamental controlling factor when it comes to health and the state of diseases for both humans and animals. According to WHO report in [1], about 80% of all human diseases are caused by water. Pathogens present in drinking water including many viral, bacterial, and protozoan agents caused 2.5 million deaths from endemic diarrheal disease each year [2]. The most common diseases that can be transmitted through water are diarrheal diseases such asbacillary dysentery, typhoid, paratyphoid, cholera, salmonellosis, colibacillosis, amoebiasis, giardiasis, and cryptosporidiosis. There are many emerging waterborne diseases, such as cryptosporidiosis, cyclosporidiosis, fascioliasis, fasciolopsiasis, and giardiasis, which may also be acquired by food [3]

The quantity of the water supplies is as crucial as its quality. Generally, Indonesia is rich in water resources. It is reported in [4] that the total water availability in Indonesia is 690×10^9 m^3/ year, which is far more than water demand of 175×10^9 m^3/ year. Water scarcity in Indonesia is commonly caused by the lack or malfunctioning of infrastructure rather than absolute lack of water.

The drinking water supply services in Namlea, Buru Regency-Maluku Province, is carried out by the local water supply agency, PDAM Buru Regency. The need for clean water supply services is increasing from time to time, however this increase does not matched with service capabilities of the agency. This increase in the demand of water supply services is due to the growth of population and increasing in the quality of people's living condition.

2. METHODS

1. Description of Study Area and Existing Drinking Water Supply System

Namlea city is located on northeastern cost of Buru Island – Maluku Province. It is the capital of Buru Regency. Namlea is also the name of subdistrict which is astronomically located between latitudes 20°25' - 20°55' S, and longitudes 121°21' – 125°21' E, with 226.55 km^2 administration area [5].

Drinking water supply system (SPAM) in Namlea city is operated and managed by local water supply agency, called PDAM Buru Regency. This agency provides water supply in 4 service units including Namlea service unit, Waeyapo service unit, Waplau service unit, and Fena Laisela service unit. Drinking water provision is made from 6 shallow wells with the total capacity of the raw water souce is 145 litres/seconds. The data of raw water source and its location are shown in Table 1 and Figure 1 respectively, while the wells can be seen in Figure 2.

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Table 1. Raw water source of PDAM Buru Regency

No	Source	Location	Dimension of well		Capacity	Status
			Diameter	Depth		
1	Sumur PDAM 1	Lala village	180 cm	12 m	25 L/dt	Operated
2	Sumur PDAM 2	Lala village	170 cm	8 m	20 L/dt	Operated
3	Sumur PDAM 3	Karang Jaya village	170 cm	10 m	25 L/dt	Operated
4	Sumur PDAM 4	Karang Jaya village	200 cm	7 m	20 L/dt	Operated
5	Sumur Danau Ubung 1	Karang Jaya village	400×400 cm	6 m	30 L/dt	Operated
6	Sumur Danau Ubung 2	Karang Jaya village	400×400 cm	6 m	25 L/dt	Will be operated in 2019

Source: PDAM Buru Regency, 2019

Fig. 1: Location of raw water source of PDAM Buru Regency (*Google Earth, 2019*)

(a) Sumur 1

(b) Sumur 2

(c) Sumur 3

(d) Sumur 4

(e) Sumur Danau Ubung 1

(f) Sumur Danau Ubung 2

Fig. 2: Source Water Wells of PDAM Buru Regency

2. Data Collection

To analyze water quality, primary data in the form of source water samples were taken directly from existing wells (Sumur 2 and Sumur 4). These samples were then examined by Balai Laboratorium Kesehatan Provinsi Maluku. Meanwhile, secondary data were collected from PDAM Buru Regency and other related agencies to evaluate water quantity.

3. RESULTS AND DISCUSSION

1. Water Quality Evaluation

Water quality assessment was employed to water source's samples from Sumur 1 and Sumur 2. The examination procedures were performed based on Ministry of Health Regulation Number 492/MENKES/PER/IV/2010 concerning procedure of drinking water quality inspection [6]. The procedures of testing are grouped into physical, chemical and microbiological parameters. The laboratory report is depicted in Table 2. This table indicates that mostly of testing parameters are still in a tolerable range except for parameter of temperature and concentration of Lead. Since the temperature level is not the temperature of the sample at the In both water source, the concentration of Lead is equal to 0.2 mg/l which is higher than permitted limit (0.05 mg/l).

Table 2. Laboratory report on water quality examination

No	Parameter	Unit	Highest Concentration Permitted	Test Remarks	
				Sumur 2	Sumur 4
	A. Physical				
1.	Odor	-	odorless	odorless	odorless
2.	Taste	-	tasteless	tasteless	tasteless
3.	Color	TCU	50	5	5
4.	Temperature	°C	±3	**27**	**27**
5.	Turbidity	NTU	25	0	0

6.	Total Dissolved Solids (TDS)	Mg/l	1000	423	410
	B. Chemical				
	a. Inorganic chemical				
1.	Arsenic	mg/l	0.05	-	-
2.	Flourides	mg/l	1.5	0.0	0.0
3.	Chrome	mg/l	0.05	0.0	0.0
4.	Cadmium	mg/l	0.005	0.0	0.0
5.	Nitrite, (NO_2-)	mg/l	1	0.01	0.02
6.	Nitrate, (NO_3-)	mg/l	10	0.02	0.02
7.	Cyanide	mg/l	0.1	-	-
8.	Selenium	mg/l	0.01	-	-
9.	Iron	mg/l	1	< 0.01	< 0.02
10.	Hardness	mg/l	500	248.9	242.6
11.	Chloride	mg/l	250	54.9	53.1
12.	Manganese	mg/l	0.5	0.0	0.0
13.	pH		6.5-8.5	6.8	6.7
14.	Zinc	mg/l	15	0.0	0.0
15.	Sulphate	mg/l	400	7	5
16.	Lead	mg/l	0.05	**0.2**	**0.2**
	b. Organic chemical				
1.	Organic materials	mg/l	10	2.3	2.5
	C. Microbiological				
1.	E. Coli	Total/100 ml	0	0	0
2.	Total Coliforms	Total/100 ml	50	43	43

2. Water Quantity Evaluation

In this study, domestic water demand is taking into account for analyzing water quantity. Domestic water demand is water consumption by households and public hydrants. PDAM Report on December 2018 revealed that the total water usage of 3,437 household units is 79.176 m^3/month which means that average water usage is 23 m^3/month with 6 average members of household (data from real demand survey). Therefore, average water demand is 127.78 litres/person/day. This quantity of water supplied is higher than the standard required by the Ministry of Public Work Regulation number 27/PRT/M/2016 concerning the implementation of drinking water supply systems [7].

4. CONCLUSION AND RECOMMENDATIONS

Conclusion

In this study, drinking water supply system of PDAM Buru Regency is evaluated in terms of water quality and water quantity. Water quality assessment result indicates that water supplied is still contaminated by Lead. This means proper treatment is needed. For quantity aspect, PDAM Buru Regency already provide sufficient quantity of water to its customers.

Recommendations

Based on this study, recommendations with implementation including but not restricted to the following:

- To provide adequate and safe water for the customers, PDAM Buru Regency PDAM should maintain regular inspection on PDAM's source wells.

- Since raw water sources are shallow wells, the control of surrounding environment sanitation needs to be done to prevent deterioration in source water quality.

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Estimation of Water Losses in Intan Banjar Water Supply Company

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ABSTRACT

Water losses from water distribution networks have become a crucial problem. The water balance can be used to know to understand the quantity, source, and charge of water losses. The water balance calculation in this study uses the WB-Easy Calc program version 4.05. Based on the result, the percentage of water losses 34,81% with the composition of real losses as 30,61% and apparent losses of 4.21%. On the other hand, the financial impact by the water losses was deficit as Rp. 4.593.648.335. Furthermore, gets to the action for each one of the above main components of the water balance in order to reduce water losses.
KEYWORDS: Distribution , Water Balance, Water Losses, Financial impact

1. INTRODUCTION

Water is one of the important factors in determining human needs. Intan Banjar is a water supply company in Banjar Regency and Banjarbaru City with BNA (*Basic Need Approach*) is one of theirs service zones. Intan Banjar improves its service performance by reducing water losses. The level of water losses in the BNA (Basic Need Approach) is above the standard for maximum tolerance ministry of public work as 20% [1]. The high level of water losses greatly influences ability to supply clean water to consumers. Water balance is very important in the program to reducing water losses. The water balance can be used for assessing water losses conditions by knowing the details of the components water losses. Water balance is a water calculation method proposed by International Water Association (IWA) at a conference in Berlin in 2001. Being aware of the problem of different water balance formats, methods and leakage performance indicators, the IWA has developed a standard international water balance structure and terminology [2]. This standard format has meanwhile been adopted (with or without modifications) by national associations in a number of countries [3]. Water balance calculation in this study using the program WB-EasyCalc version 5.16. The aim of this research is to convince Intan Banjar of water supply company with still high of water losses that the introduction water balance will be an important first step towards to reduce water losses in Intan Banjar water supply company.

2. METHODS

The location of this research is urban water distribution network in Intan Banjar water supplay company in BNA (Basic Need Approach). In this research, calculation of water balance was used software WB EasyCalc version 5.16 to calculate the percentage of all the components of the water losses. The data needed to calculate the water balance in the WB-EasyCalc program is the system input volume data, metered consumption data, unmetered consumption data, unbilled meter consumption data, unbilled unmetered consumption data, unofficial consumption data, inaccurate data meters and data handling, data on the length of distribution and transmission pipes, official pipeline data, average pressure data, intermittent supply data, and financial data. The data used as input software comes from the report of Monthly production, distribution and Non Revenue Water for 122 days (from September 2018 to December 2018), and by quantitative research method through survey, interview and other observations. After that, the factors determined water losses can be known can action to reduce water losses.

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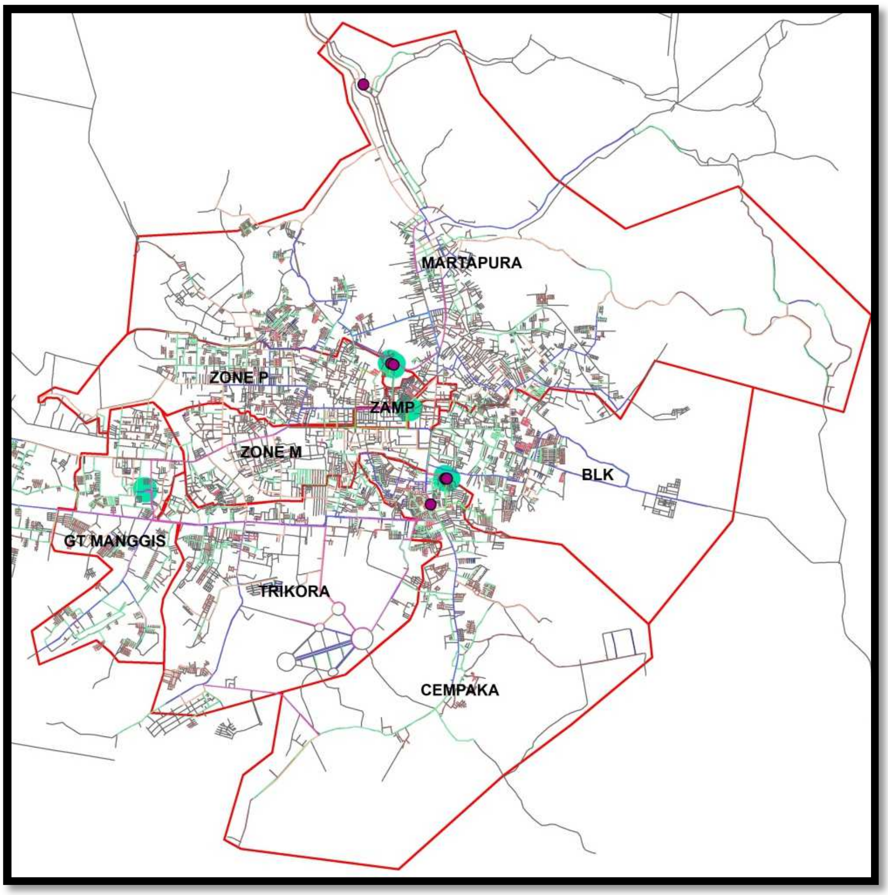

Fig. 1: Water Supply Distribution Zone in BNA (Basic Need Approach) Intan Banjar Company

3. RESULTS AND DISCUSSION.

The results of the water balance calculation in the BNA zone for 122 days from September 2018 to December 2018 using the WB-EasyCalc program version 5.16 are shown in Figure 2

<table>
<tr><td rowspan="7">System Input Volume
3.239.062 m3
Error Margin [+/-]:
1,4%</td><td rowspan="4">Authorized Consumption
2.111.439 m3
Error Margin [+/-]:
0,1%</td><td rowspan="2">Billed Authorized Consumption
2.097.044 m3</td><td>Billed Metered Consumption
2.097.044 m3</td><td rowspan="2">Revenue Water
2.097.044 m3</td></tr>
<tr><td>Billed Unmetered Consumption
0 m3</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption
14.395 m3
Error Margin [+/-]:
8,6%</td><td>Unbilled Metered Consumption
0 m3</td><td rowspan="5">Non-Revenue Water
1.142.018 m3
Error Margin [+/-]:
4,0%</td></tr>
<tr><td>Unbilled Unmetered Consumption
14.395 m3
Error Margin [+/-]: 8,6%</td></tr>
<tr><td rowspan="3">Water Losses
1.127.623 m3
Error Margin [+/-]:
4,1%</td><td rowspan="2">Commercial Losses
136.238 m3
Error Margin [+/-]:
8,2%</td><td>Unauthorized Consumption
4.685 m3
Error Margin [+/-]: 32,7%</td></tr>
<tr><td>Customer Meter Inaccuracies and Data Handling Errors
131.553 m3
Error Margin [+/-]: 8,4%</td></tr>
<tr><td colspan="2">Physical Losses
991.385 m3
Error Margin [+/-]: 4,8%</td></tr>
</table>

Fig. 2: Water Balance of BNA Zone in Intan Banjar Water Supply Company

Water balance in BNA zone in Intan Banjar water supply company can be described as:

- Annual system input volume September 2018 to December 2018 for BNA zone Intan Banjar water supply company from Pinus and Banjarbakula water treatment have distributed water as 3.239.062 m^3.
- Authorised consumption is the monthly volume of metered and unmetered water taken by registered customers, laboratories,etc. For example water used in fire hydrants and others. The Authorised consumption of the September 2018 to December 2018 as 2,111,439 m^3.
- Water losses as Annual system input volume reduced by Authorised consumption. Water losses consists of apparent losses and real losses. So the calculation for Water losses in the September 2018 to December 2018 for BNA zone is 3,239,062 - 2,111,439 = 1,127,623 m^3. When changed in percentage is 34.81%.
- Billed Authorised Consumption is the volume of metered or unmetered monthly water used by registered customers. In BNA zone during September 2018 to December 2018 currently has no billed unmeterd consumption and only a billed metered consumption meter as 2,097,044 m^3.
- Unbilled authorized consumption is authorised consumption reduced by billed authorised consumption. So calculation of unbilled authorized consumption in the September 2018 to December 2018 for BNA zone is 2,111,439 - 2,097,044 = 14,395 m^3.
- Revenue water is billed metered consumption plus billed unmetered consumption. So that the calculation for revenue water for September 2018 to December 2018 in the BNA zone is 2,097,044 + 0 = 2,097,044 m^3.
- Unbilled metered Consumption is water for customers with installed meters but the company dont't charge for collect water or free usage fees. At present, in the Intan Banjar company haven't unbilled metered consumption, so during September 2018 to December 2018 of unbilled meter consumption is 0 m^3.
- Unbilled unmetered consumption is all official consumption which is not billed or not metered. This component is used for water supplay company operations such as washing pipes, pipe tests, roads cleaning, etc. Unbilled unmetered consumption as Unbilled authorized consumption which is reduced by unbilled metered consumption. So the calculation during September 2018 to December 2018 is 14,495 - 0 = 14,395 m^3.
- Unauthorized consumption is unknown use of water. Unauthorized consumption is an illegal connection, bypass on the meter, Unauthorized use hydrant, etc. Unauthorized consumption in September 2018 to December 2018 BNA zone is 4,685 m^3.
- Customer metering inaccuracies and data handling errors ia an apparent loses due to customer meter inaccuracies and errors in meter reading. Inaccuracy of meters and data handling in September 2018 to December 2018 its value is 131,553 m^3.
- Commercial losses or Apparent losses are Unauthorized consumption plus meter inaccuracies and data handling. So that the calculation of Apparent losses in September 2018 to December 2018 for BNA zone is 4.685 + 131.553 = 136,238 m^3. When changed in the percentage is 4.21%.
- Physical losses sometimes called 'real losses' are the annual volumes lost through all types of leaks, bursts, and overflows in pipes, service reservoirs and service connection, up to the point of the customer meter. Real Losses as water losses reduced by apparent losses, so that the Calculation of real losses is 1.127.623 - 136.238 = 991,385 m^3. When changed in percentage, it is 30.61%.

The water losses consist of real and apparent losses. Real Losses are water losses in a distribution system indicated by real losses and apparent losses The losses of water in the distribution system to customers water supplay company that doesn't out water out of the system. The result from the water balance analysis, percentage of water losses is 34,81% with the composition of real losses 30,61% and apparent losses of 4.21%. So it is a matter of concern and action is required for water losses reduction. the percentage of water loss shown in the figure 3.

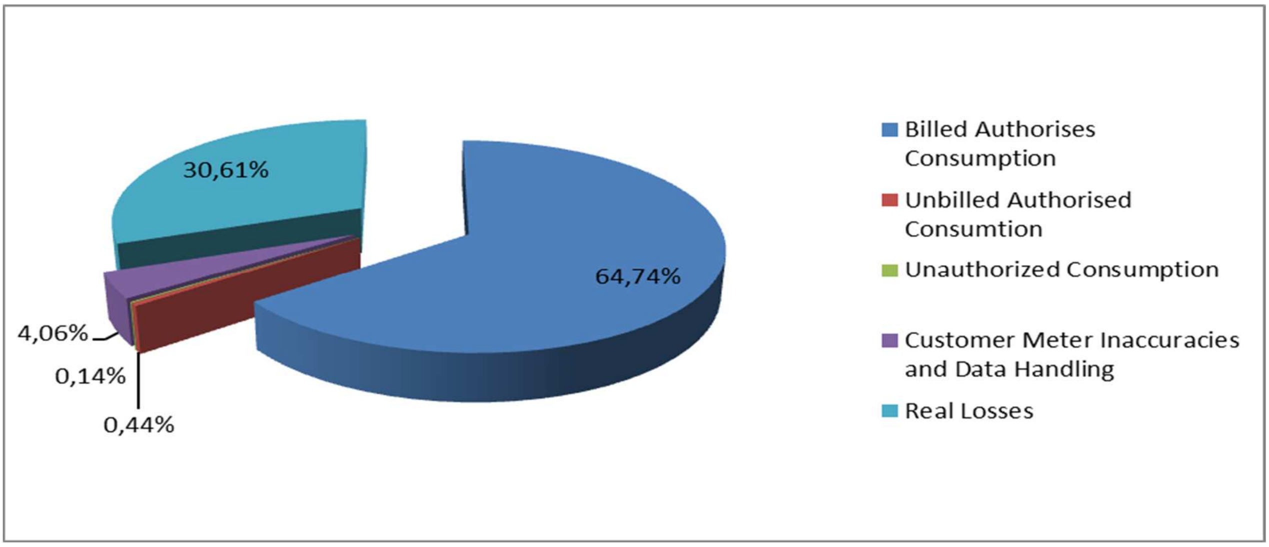

Fig. 3: Percentage of water losses rate

Based on the results of observations and interviews with the employees of Intan Banjar water supplay company, if the high real losses was caused by visible and invisible leakages (Background Leakage), pipe fittings connections, and in the connection pipe service to the customer's water meter. This is in accordance with the data in BNA zone has repaired 12.201 points of leakage. The leakage in BNA zone caused by many things including are high pressure, Imperfect pipe connection, Damage to the corrosive pipe, especially in the installed pipe for a long time, Pipe damage due to road repair and drainage projects. The Factor of Apparent losses in BNA zone caused by inccuracies meter reading customer and illegal connection. the figure 3 shown that in the greatest apparent losses caused by inccuracies meter reading customer as 4,06% and This is accordance with based on data from the customer meter accuracy survey that the margin error of customer meter is 5%. The inccuracies costomer meter happened because Intan Banjar water supplay company used class B water meter customer. Class B water meter is lower quality than class c water meter.

The accuracy of customer meters is equally important, with the main difference being that there are many more customer meters in operation—and each measures a relatively smaller flow—than production meters. The accuracy of customer mete-ring depends on several factors, including meter type, brand, and replacement policy, maintenance, and water quality. The water supplay company should establish guidelines for all of these factors to ensure accuracy of customer consumption data.

The water losses distribution system could in a loss of income for the Intan Banjar water suplay. Based on the water balance results using Easycalc Water Balance ver 5.16 it is estimated that water losses on September 2018 to December 2018 For the BNA zone as:

1. Apparent losses is 136.238 m^3
2. Real Losses is 991.385 m^3.
3. Total water losses are the sum of Apparent losses and real losses, namely 136,238 + 991,358 = so that the Calculation is 1.127.623 m^3

With each loss, the deficit of Intan Banjar water supply company could be calculated based on the average water sales rate per m3, and the average cost of production /distribution of water per m3 as shown in Table 1

.

Table 1. Average Sales Costs and Production/Distribution Cost

Uraian	Sep-18	Okt-18	Nov-18	Des-18	Average
Average Tariffs (Rp)	7.129	7.128	7.179	7.164	7.150
Production/Distribution Cost (Rp)	3.608	3.692	3.653	3.653	3.651

Deficit received by Intan Banjar water supply company due to water losses could be calculated on September 2018 to December 2018 as follows:

1. Apparent losses must be an air tariff per m^3 directly by the company. Deficit of Apparent losses can calculated Rp.7150, - x 136.238 m^3 = Rp. 974.101.700,-
2. The real losses water is a leakage of the distribution pipe which will not directly become the income of the water tariff per m^3, but will result in a loss of production / distribution costs. So that the losses due to real losses is: Rp. 3651, - x 991.385 m^3 = Rp. 3.619.546.635,-
3. The total deficit of Intan Banjar Company due to water losses is the total losses due to Apparent losses and real losses, so the total is Rp. 974.101.700,- + Rp. 3.619.546.635,- = Rp. 4.593.648.335,-

In this instance the action plan needs to deploy a strategy that will maximise benefits which follows the steps below:

- Tackle apparent losses with the minimum expenditure; reduce unauthorized consumption, meter reading and accounting errors at the first instance which will increase revenue.
- Simultaneously reduce leakage in order to save money in producing/buying less water.
- Invest savings in further reducing Apparent and Real Losses.

Reducing excessive losses results are more water being available for consumption that can be sold, Delaying the need for capital investments, Lower operating costs, Reducing commercial losses will generate more revenue [4].

4. CONCLUSION

This research investigated the problem of water losses in BNA (Basic Need Approach) zone of Intan Banjar water supply company as a case study. The results revealed that the typical value of water losses in BNA (Basic Need Approach) zone is approximately 34,81%, which is very high according to the goverment standards. From water balance calculations, composition of real losses as 30,61% and apparent losses of 4.21%. Also the results show that the main factors that contributed to water losses are the estimation method of water consumption due to meters inaccuracies, and leakages pipes in some parts of the network. On the other hand, the financial impact posed by the water losses was found to be a loss of income for company as Rp. 4.593.648.335,- on September 2018 to Desember 2018 period.

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Determination of Infiltration Rate Using Measurement of Double Ring Infiltrometer and Calculation of Horton Model in Balikpapan City

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ABSTRACT

This study aims to determine the ability of soil infiltration in the city of Balikpapan. The analysis begins by testing the infiltration rate in the field using the infiltrometer double ring. Measurements were made in 15 research locations spread across Balikpapan City. Location determination is seen from changes in land and soil type functions in Balikpapan City based on regional administrative maps, land type maps, land use maps and Balikpapan City RTRW. Furthermore, the results of field measurements are processed using the Horton model. The Horton model is one of the well-known infiltration models in hydrology. From the results of research at 15 locations, it was concluded that Balikpapan City had an infiltration rate between the range of 12 mm / hour to 240 mm / hour. Based on U.S. Soil Conservation, the infiltration rate classification in Balikpapan City is divided into four infiltration rate classes, namely fast, rather fast, medium and rather slow. Areas that have the potential to be rainwater catchment areas are seen from areas that have as many as 10 locations from 15 locations, namely Prapatan, Telaga Sari. Sources Rejo, Manggar Baru, Damai Baru, Kariangau, Gunung Sari Ulu, Margo Mulyo, Graha Indah and Mount Bahagia. So the area that has the potential as a catchment area is around 60% of all research locations.

KEYWORDS: Infiltration Rate, Horton Model, Balikpapan City

1. INTRODUCTION

The rapid development and settlements have caused a reduction in rainwater catchment areas. The reduction in rainwater catchment areas in urban areas will result in increased water runoff and cause flooding and inundation [1]. Infiltration is the process of water flowing into the soil and causing an increase in total water content, contributing to variations in water partitions and hydrological responses [2], [3], [4]. Infiltration is important in hydrology because this process regulates available water reserves for groundwater filling and controls water runoff and soil erosion [5]. Infiltration rate measurements generally use the Horton Model. The Horton model is one of the well-known infiltration models in hydrology compared to other models. Infiltration can be expressed in two dimensions, namely infiltration capacity and infiltration rate expressed in mm / hour. Infiltration capacity is the maximum infiltration rate for a particular type of soil, while the infiltration rate is the rate of infiltration whose value depends on soil conditions and rainfall intensity. The capacity of soil infiltration is the maximum rate of soil to absorb water under certain conditions [8]. Infiltration capacity occurs when the rain intensity exceeds the ability of the soil to absorb soil moisture. Conversely, if the rainfall intensity is smaller than the infiltration capacity, then the infiltration rate is the same as the rainfall rate. Infiltration rate data can be used to predict when a run-off will occur if a type of soil has received a certain amount of water, either through rainfall or irrigation from a water reservoir on the ground.

2. METHODS

Data Collection and Field Surveys

The preliminary data needed in this study are the map of the administrative area, the soil type map, the land use map and the map of the plan for the Balikpapan City Spatial Plan. The data is used as a basis for determining the location in Balikpapan to be used as the location for field data collection (primary data). Location determination seen from changes in land and soil type functions in Balikpapan City based on regional administrative maps, land types, land use maps and Balikpapan City RTRW. The research locations were 15 locations spread across 14 villages, namely Gunung Sari Ulu Village (GSU) and Sumber Rejo Village (SR) in Central Balikpapan Subdistrict, in Teritip Sub-District there are 2 research locations (T1 and T2) and Manggar Baru Village (MB) in Balikpapan East Sub-District, Sepinggan Baru Village (SB), Damai Baru Village (DB) and Gunung Bahagia Village (GB) in West Balikpapan Sub-District, Prapatan Village (Prap) and Telaga Sari Village (TS) in City Balikpapan Sub-District, Kelurahan Kariangau Village (Kari) and Kelurahan Margo Mulyo Village (MM) in West Balikpapan District, Karang Joang Village (KJ), Graha Indah Village (GI) and Batu Ampar Village in North Balikpapan Sub-District. The research locations spread across Balikpapan City can be seen in Figure 1.

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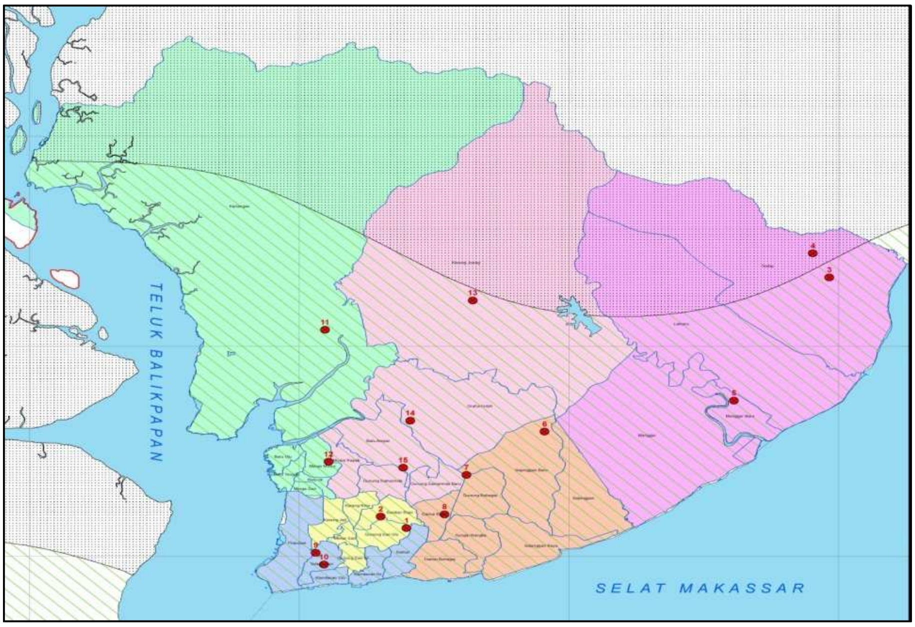

Fig. 1: Research Sites in Balikpapan City

Infiltration Rate Measurement

Conduct infiltration rate tests at 15 predetermined locations in the Balkpapan City area. Method The measurement of infiltration rate is carried out using a Double Ring Infiltrometer. Where the tool is made of steel, the diameter of the middle ring is 28 cm and the height is 30 cm, and the outer ring is 53 cm in diameter with a height of 30 cm. For certain purposes, ring sizes are often used larger or smaller. The use of a ring that is too small also causes a higher level of error [6]. Record the decrease in water at infiltration test points.

Processing of Measurement Data Results

From the measurements in the field data obtained in the form of the magnitude of the decrease in water from 15 research locations. The data is then processed and the infiltration rate data is obtained at each time (ft) and constant infiltration (fc). Analysis of infiltration rate and infiltration capacity will be carried out using the Horton model. The equation for calculating the infiltration rate and infiltration capacity is as follows:

$$f = fc + (fo - fc)e^{-Kt} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

f (t) = infiltration rate at t measured from the start of the experiment (cm / minute)
fc = constant infiltration rate (cm / minute)
f0 = infiltration rate at the beginning of measurement (cm / minute)
k = constant decrease in infiltration rate
e = exponential number (2,718)
t = time (minutes)

Qualitative assessment of the infiltration rate obtained is based on infiltration rate classification by U.S. Soil Conservation [7], which can be seen in Table 1.

Table 1. Classification of Infiltration Rate

Class	Infiltration Rate (mm / hour)
Very Fast	> 254
Fast	>127 - 254
Rather Fast	> 63 - 127
Medium	> 20 - 63
Rather Slow	> 5 - 20
Slow	1 - 5

Source: U.S. Soil Conservation (1951 dalam Kohnke, 1968).

3. RESULTS AND DISCUSSION

The rate of infiltration is obtained from the field using a Double Ring Infiltrometer. The data from the results of measuring the infiltration rate during the 5 minute interval from 15 location points in Balikpapan City can be seen in Table 2.

Table 2.
Field Measurement Results

No	Time (t) (minutes)	Difference in water level (cm)														
		GSU	SR	T1	T2	MB	SB	GB	DB	Prap	TS	Kari	MM	KJ	GI	BA
1	5	0,8	2,2	0,5	0,9	1,8	0,3	0,5	2,1	2,7	2,9	4	1	0,4	0,4	2
2	10	0,75	2	0,3	0,6	1,4	0,25	0,5	2,1	2,65	2,6	3,6	0,9	0,4	0,4	1,3
3	15	0,7	1,5	0,2	0,4	1,2	0,25	0,45	2	2,6	2,3	2,2	0,75	0,3	0,35	1,1
4	20	0,65	1,3	0,2	0,2	1,2	0,2	0,45	2	2,55	2,2	1	0,6	0,3	0,35	1,1
5	25	0,6	1	0,2	0,2	1,1	0,2	0,45	1,8	2,5	2,1	0,9	0,6	0,3	0,3	0,8
6	30	0,55	1	0,2	0,2	1,1	0,15	0,4	1,8	2,4	1,9	0,8	0,5	0,2	0,3	0,7
7	35	0,53	0,8	0,2	0,1	1,1	0,1	0,4	1,6	2,4	1,8	0,75	0,5	0,2	0,2	0,6
8	40	0,52	0,8	0,2	0,1	1	0,1	0,3	1,5	2,3	1,7	0,7	0,5	0,2	0,2	0,5
9	45	0,5	0,75	0,1	0,1	1	0,1	0,3	1,2	2,2	1,6	0,7	0,4	0,1	0,2	0,5
10	50	0,4	0,6	0,1	0,1	0,9	0,1	0,3	0,9	2	1,4	0,7	0,4	0,1	0,2	0,4
11	55	0,4	0,6	0,1	0,1	0,9	0,1	0,3	0,9	2	1,4	0,7	0,4	0,1	0,2	0,4
12	60	0,4	0,6	0,1	0,1	0,9	0,1	0,3	0,9	2	1,4	0,7	0,4	0,1	0,2	0,4

Table 1. shows that from the field measurements obtained a constant infiltration rate occurred in the 35th minute to the 50th minute. the constant infiltration rate occurred at 35 minutes at 3 locations, 40 minutes at 2 points, 45 minutes at 3 points and at 50 minutes at 7 points. The rate of infiltration rate reaches a constant influenced by soil texture and soil surface conditions. The longer it takes the soil to reach constant because the soil texture is sand or the composition is more like sand. The surface conditions of the land that have been held such as in the locations of SB, T2 and GI have resulted in faster soil infiltration rates.

The Horton model is one of the well-known infiltration models in hydrology. Horton acknowledges that infiltration capacity decreases with increasing time until it approaches a constant value. Horton stated that the decrease in infiltration capacity was more controlled by factors operating on the surface of the land compared to the flow process in the soil. Horton expressed his view that a decrease in infiltration capacity is more controlled by factors operating at the ground surface compared to the flow process in the soil. This model is very simple and more suitable for experimental data. The main weakness of this model lies in determining the parameters f0, fc, and k and is determined by data-fitting. Even so, with the advancement of computer systems this process can be done with a simple spreadsheet.

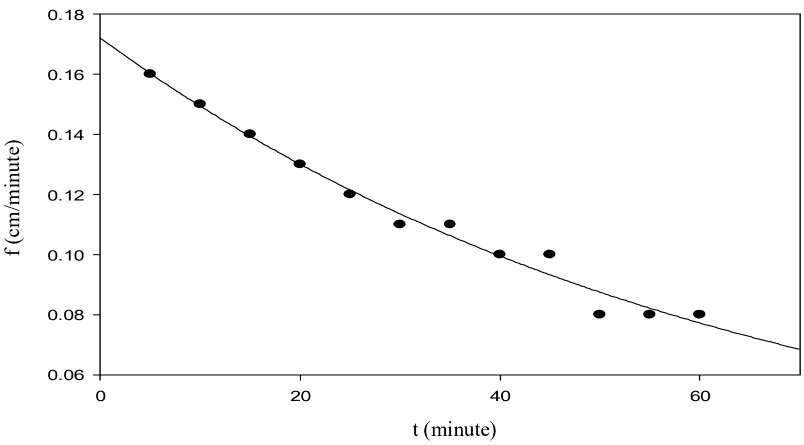

Fig. 2: Extension of the Horton Method Infiltration Curve

From the measurement results, the value of fo is unknown. To obtain the fo value, the data in Table 2 are taken and illustrated in the extension of the infiltration curve of the Horton equation using the sigmaplot application as shown in Figure 2. Figure 2 shows the extension of the Horton method infiltration fitting curve at the GSU location. Each location depicts the Horton infiltration fitting curve to get the value of fo per location point. From the analysis of the extension of the infiltration fitting curve above using the sigmaplot application, a fo value of 0.17 cm / minute was obtained for the GSU location.

Table 3.
Results of Horton Model Infiltration Rate Calculation at GSU Locations

No	Time (t) (minute)	Decrease (cm)	Infiltration rate (f) (cm/minute)	fc (cm/minute)	f-fc (cm/minute)	Log (f-fc)
	0		0,17	0,08	0,09	-1,036
1	5	0,80	0,16	0,08	0,08	-1,097
2	10	0,75	0,15	0,08	0,07	-1,155
3	15	0,70	0,14	0,08	0,06	-1,222
4	20	0,65	0,13	0,08	0,05	-1,301
5	25	0,60	0,12	0,08	0,04	-1,398
6	30	0,55	0,11	0,08	0,03	-1,523
7	35	0,53	0,11	0,08	0,03	-1,585
8	40	0,52	0,10	0,08	0,02	-1,620
9	45	0,50	0,10	0,08	0,02	-1,699
10	50	0,40	0,08	0,08	0,00	
11	55	0,40	0,08	0,08	0,00	
12	60	0,40	0,08	0,08	0,00	

Table 3 shows the results of calculating the infiltration rate at the GSU location. The data in Table 3 are then illustrated in a graph of the relationship between t (time) and log (f-fc) to find the gradient value (m) like Figure 3.

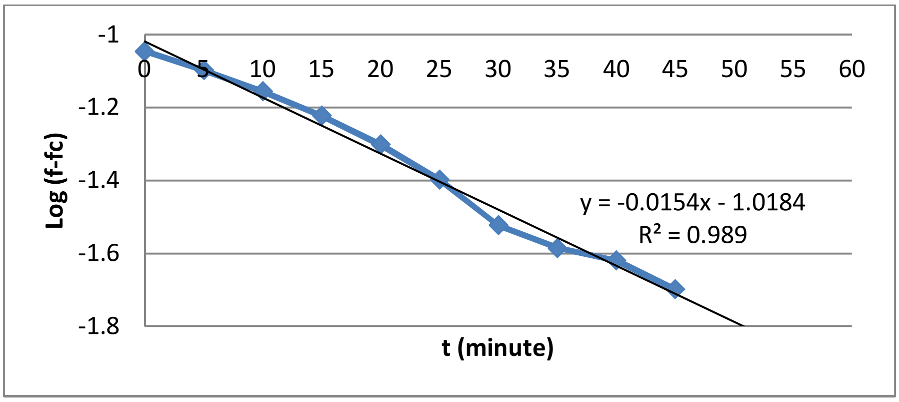

Fig. 3: Curve looking for the m gradient at the GSU location

Figure 3 shows a graph with a linear equation y = -0.0154x - 1.0184 which is the result of the Horton curve at the GSU location. From the linear equation, the m = -0,0154 gradient is obtained. To find the value of K, the formula K = -1/0.434 m is used so that the K value of 149.62 is obtained.

Table 4.
Initial Infiltration Rate (fo), Constant Infiltration Rate (fc) and Infiltration Capacity (f) With the Horton Method

No	Location	*fo* (cm/minute)	*fc* (cm/minute)	Gradient (m)	K	*f* (cm/minute)
1	GSU	0,172	0,08	-0,0154	149,620	0,088
2	SR	0,560	0,12	-0,0271	85,024	0,227
3	T1	0,158	0,02	-0,0193	119,386	0,039
4	T2	0,293	0,02	-0,0421	54,730	0,130
5	MB	0,438	0,18	-0,0233	98,890	0,230
6	SB	0,072	0,02	-0,0184	125,225	0,026
7	GB	0,109	0,06	-0,0107	215,341	0,061
8	DB	0,481	0,18	-0,0120	192,012	0,192
9	PRAP	0,563	0,40	-0,0117	196,936	0,406

No	Location	*fo* (cm/minute)	*fc* (cm/minute)	Gradient (m)	K	*f* (cm/minute)
10	TS	0,630	0,28	-0,0201	114,634	0,332
11	KARI	1,308	0,14	-0,0664	34,701	0,795
12	MM	0,245	0,08	-0,0255	90,359	0,117
13	KJ	0,049	0,02	-0,0154	149,620	0,022
14	GI	0,094	0,04	-0,0144	160,010	0,044
15	BA	0,092	0,02	-0,0154	149,620	0,026

Table 4 shows the results of calculating the initial infiltration rate (fo), constant infiltration rate (fc) and infiltration capacity (f) with the Horton method. The calculation steps for 14 other location points use the same steps as in Figure 1, Figure 2 and Table 3. The gradient values of 15 research location points are in the range of -0.0107 up to -0.0664, while the K values obtained are in the range 34,701 to 215,341. The value of the gradient obtained is inversely proportional to the value of K produced. The greater the gradient value, the smaller the value of K. By entering the value K into the Horton equation, the value of infiltration capacity will be obtained.

From Table 4, it can be concluded that Kariangau (Kari) Village has the highest initial infiltration rate of 1.308 cm/minute, while the lowest initial infiltration rate is in Sepinggan Baru Village (SB) which is 0.795 cm / minute. Constant infiltration rate is the maximum infiltration rate in situations where the ability of the soil has reached its maximum in absorbing water into the soil. The highest infiltration value that is highest is in the Prapatan (Prap) Village, which is 0.40 cm / minute. The lowest constant infiltration values are in Teritip Sub-District, Sepinggan Baru, Karang Joang and Batu Ampar which are 0.02 cm / minute. Infiltration capacity is the maximum infiltration rate obtained from a particular type of soil. The largest infiltration capacity is in Kariangau Village with a value of 0.795 cm / minute and the smallest is in Karang Joang Village with a value of 0.022 cm / minute.

The value of the constant infiltration rate affects the value of infiltration capacity. The greater the value of the constant infiltration rate, the greater the value of infiltration capacity. However, in the Kariangau (Kari) location, the value of infiltration capacity is higher than in the Prapatan location, even though the value of the Kariangau (Kari) infiltration rate is lower than the Prapatan (Prap) location. This is because the location of Kariangau (Kari) has the highest initial infiltration rate compared to other locations.

The difference in infiltration rate and infiltration capacity of each study location is influenced by factors operating at the ground level. These factors include soil type, soil surface conditions, soil structure, rainfall intensity, land use and land cover vegetation. High infiltration capacity is influenced by soil porosity and soil structure. Large soil porosity in Kariangau because of sandy clay soil and on oil palm plantation land. The structure of the land is broken because it is located on plantation land due to land management. Plant roots also play a role in the rate of infiltration, which is when the roots penetrate the soil can reach several inches. Plant root openings provide access to infiltration and increase infiltration rates.

Tabel 5.
Infiltration Rate Classification Results

No	Location	Infiltration Rate (cm/minute)	Infiltration Rate (mm/hour)	Class
1	GSU	0,08	48	Medium
2	SR	0,12	72	Rather Fast
3	T1	0,02	12	Rather Slow
4	T2	0,02	12	Rather Slow
5	MB	0,18	108	Rather Fast
6	SB	0,02	12	Rather Slow
7	GB	0,06	36	Medium
8	DB	0,18	108	Rather Fast
9	PRAP	0,4	240	Fast
10	TS	0,28	168	Fast
11	KARI	0,14	84	Rather Fast
12	MM	0,08	48	Medium
13	KJ	0,02	12	Rather Slow
14	GI	0,04	24	Medium
15	BA	0,02	12	Rather Slow

Table 5 shows the results of the infiltration rate classification in 15 research locations in Balikpapan City based on U.S. Soil Conservation. The infiltration rate classification in Balikpapan City is divided into four classes, namely fast, rather fast, medium and rather slow. The locations that included the rapid infiltration rate group were 2 (two) locations, namely Prapatan and Telaga Sari. The locations included in the infiltration rate group are rather fast, there are 4 (four) locations, namely Sumber Rejo, Manggar Baru, Damai Baru and Kariangau. Locations including the infiltration rate group are 4 (four), namely Gunung Sari Ulu, Gunung Bahagia, Margo Mulyo and Graha Indah. Locations which include the infiltration rate group are 5 (five), which are Teritip 1, Teritip 2, Karang Joang, Sepinggan Baru and Batu Ampar.

Based on the ability to absorb water with a speed of more than 1 meter per day, it was obtained an area that has the potential as a rainwater catchment area of 10 locations from 15 locations namely Prapatan, Telaga Sari. Sumber Rejo, Manggar Baru, Damai Baru, Kariangau, Gunung Sari Ulu, Margo Mulyo, Gunung Bahagia and Graha Indah. So the area that has the potential as a catchment area is around 60% of all research locations.

4. CONCLUSION

The results showed that the results of measurements of infiltration rates in the field showed that Balikpapan City had an infiltration rate between the range of 12 mm / hour to 240 mm / hour. Based on U.S. Soil Conservation, the infiltration rate classification in Balikpapan City is divided into four infiltration rate classes, namely fast, rather fast, medium and rather slow. Areas that have the potential to be rainwater catchment areas are seen from areas that have as many as 10 locations from 15 locations, namely Prapatan, Telaga Sari. Sources Rejo, Manggar Baru, Damai Baru, Kariangau, Gunung Sari Ulu, Margo Mulyo, Graha Indah and Mount Bahagia. So the area that has the potential as a catchment area is around 60% of all research locations.

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Physicochemical and Bacteriological Parameters of Surface Water Quality in part of West Côte d'Ivoire: Potential Resources for Drinking Water Production (Guessabo Lake)

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ABSTRACT

The main objective of this study was to know the hydrochemical functioning and the state of pollution of the waters of Guessabo Lake. To achieve this objective, twelve monthly sampling campaigns were conducted from November 2017 to October 2018 in seven (7) stations spread over the Lake. Parameters such as temperature, pH, conductivity, dissolved oxygen, redox potential, transparency and turbidity were measured *in situ*.
Orthophosphate, nitrate, nitrite, ammonium, total nitrogen, total phosphorus, chemical oxygen demand (COD) and five-day biochemical oxygen demand (BOD) were measured according to conventional chemistry methods. Microbiological quality was assessed by counting and / or identifying fecal indicator bacteria such as total coliforms, Escherichia coli (E. coli), Enterococcus and salmonella. The data were organized according to the four hydroclimatic seasons of the watercourse. The post-drought period recorded high values of nutrient salts (NO_3^-, NO_2^-, PO_4^-), total nitrogen, total phosphorus, COD, BOD and turbidity. The results of this study also show that the waters are threatened by biodegradable organic matter (COD / BOD <3). The principal component analysis of physicochemical and chemical data shows three class of water according to the seasons. The periods of low water and recession recorded concentrations that are within the limit of acceptability. The flood period is moderately polluted and the post-drought period is insufficiently polluted. The waters of the Lake have poor bacteriological quality. They contain permanently Salmonella, high average levels of total coliforms (22292 CFU / 100mL), Escherichia coli (316 CFU /100 mL) and intestinal enterococci (441 CFU / 100mL).
KEYWORDS: hydrochemistry, microbiological quality, hydroclimatic seasons, water resources

INTRODUCTION

Water is an essential and indispensable natural resource for the survival and development of humankind, but it is important to recognize both the positive and the negative aspects of water [1]. The quality of surface water in an area is largely determined by both natural processes (soil alteration and erosion) and anthropogenic inputs (municipal and industrial wastewater discharge). Anthropogenic discharges are a constant pollutant, while surface runoff is a seasonal phenomenon, largely affected by the climate in the basin [2, 3, 4]. Human activities are determinant of surface and groundwater quality through air pollution, effluent discharges, use of agricultural chemicals, soil erosion and land use. Underdeveloped countries suffer the impact of pollution due to the disorderly economic growth associated with the exploitation of natural resources. The risk that microbial contaminants caused to human health increases with population growth and poverty [5]. In Côte d'Ivoire, the demand for drinking water by the Ivorian population is constantly increasing beyond the available supply [6]. Another emerging issue, more specific to the city of Duékoué is to ensure its drinking water supply in a context of peri-urban rampant. The operating capacity of the surface water resource has become insufficient. The deficit in drinking water resources in the Duékoué area remains the main concern of the decision-maker. Guessabo Lake is one of the most interesting alternatives. However, its proximity too many settlements, villages, sub-prefectures, plantations and livestock farms could lead to the degradation of its waters. Another problem is the exploitation of the banks for agricultural purposes. In fact, the banks of the river are used by farmers during the retreat period [7]. In addition, it is used for fishing and recreational activities, drinking, swimming and for household activities including dishes, cooking and laundry. Domestic discharges (wastewater, garbage, feces, etc.) from residents are dumped directly into the waters of the lake. Livestock excretion and untreated human feces contribute to waterborne pathogens in rural watersheds [8]. No data describing the potential for microbial pollution in the waters of Guessabo Lake are available. The assessment of the quality of surface water is based on the measurement of physicochemical and chemical parameters as well as on the presence or absence of aquatic organisms and micro-organisms, indicators of a more or less good water quality [9]. This information can provide valuable insight for monitoring project design and further reduce the risk of pollution and human exposure. The present work proposes to evaluate the typology of

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the waters of Lake Guessabo through a physicochemical and bacteriological characterization with the intention of underlining its usefulness as a drinking water resource.

2. MATERIAL AND METHODS

2.1 Study area

The study area is in the western part of Côte d'Ivoire. Guessabo Lake is located between -7.01 and 6.729 latitude North and between -7.01 and -6.964 west longitude (Figure1). It is upstream of the Buyo dam built on the Sassandra River. It covers an area of 17Km^2. Its depths oscillate between 0.5m and 20m. The western region enjoys a humid tropical climate with a single rainy season and high annual rainfall. Annual rainfall rates are around 2000 mm in the study area [10]. There is a dry season lasting 4 months, from November to February and a rainy season from March to October. But there are four seasons hydroloclimatic including the December to January period of récession, a low-water period from February to April, a post-drought period from May to July and a great flood period from August to November [11]. The vegetation is dense moist forest marked by grassland areas [12]. This forest is severely degraded because of human activities. This forest area is largely dedicated to high value-added crops such as cocoa, rubber and coffee. This class of environment, however, is rather "holed" because of human activities and comes in three forms: semi-deciduous forest, dense evergreen forest and mountain forest which is a particularly humid environment. At the hydrographic level, most of the region remains furrowed by the tributaries of Sassandra. The 600-kilometer Sassandra Basin has its source in the Bayla region of Guinea. It receives two major tributaries that are Bafing and N'zo. Its catchment area is 75.000 Km^2 [13]. It is therefore a permanent watercourse. The main economic activities of this population revolve around agriculture and fishing. The soils are of ferritic type with medium fertility and constitute a wide area for the development of agriculture, which justifies the displacement of the cocoa loop in this zone. There are also soils developed on basic rocks potentially rich in mineral salts and hydromorphic soils located in the lowlands [12].

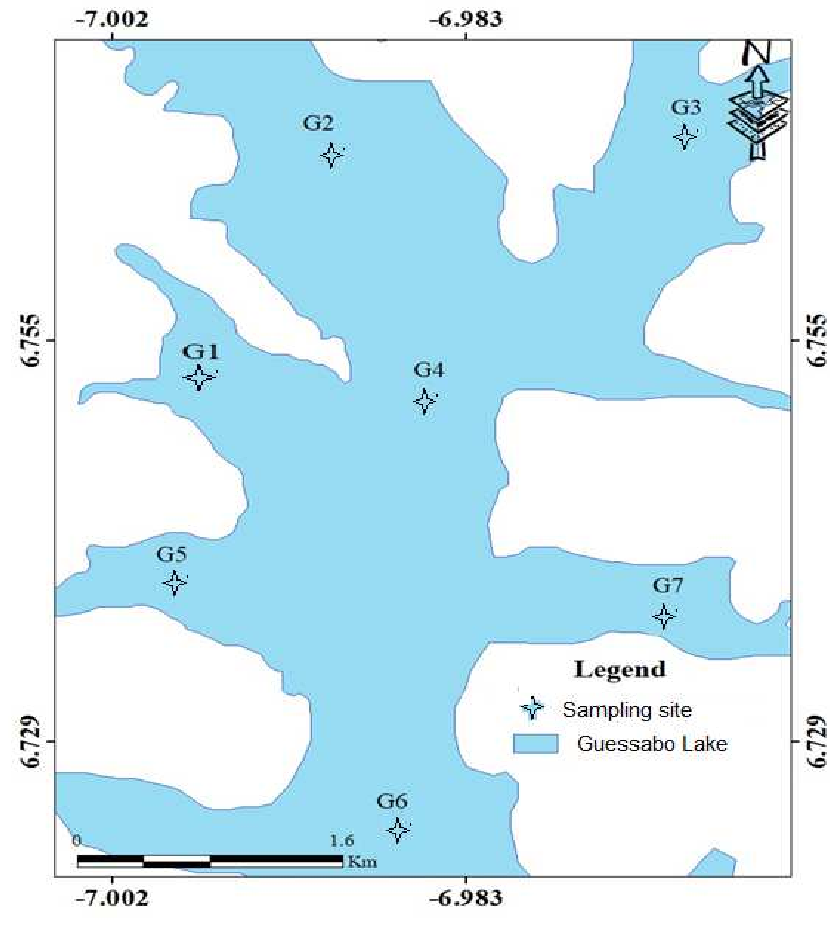

Figure 1: Location of sampling site

2.2 Sampling and analytical techniques.

For this study, seven sampling and monitoring stations were carefully selected, each located on Guessabo Lake. The choice of sampling stations was made based on the hydrographic network and the potential sources of pollution. The sampling frequency is monthly for one year, from November 2017 to October 2018, in order to obtain a fairly representative image of water quality and its seasonal and annual evolution. The samples were taken using a sampler integrated from the surface to a depth of 1m below and collected in plastic bottles and amber glasses to avoid photo-degradation of the parameter BOD5 sensitive to solar rays. Regarding the sampling of samples for microbiological analysis, they were made according to the four hydrological seasons of the study area. Samples were taken in sterile vials taking care not to contaminate or modify the samples. All samples are stored in a cooler at ± 4 ° C and transported to the laboratory. A total of 21 parameters were analyzed for the control and assessment of water quality in this study. Temperature, pH, dissolved oxygen (DO), conductivity, redox potential and Total dissolved solids were measured in situ using a multi parameter HANNA HI 9828PH / ORP / CE / DO. Transparency was also determined in situ with the Secchi disk. A portable turbidimeter was used to determine the turbidity of the water. Nitrate, nitrite, ammonium, ortho-phosphate and total phosphorus were estimated according to the standard standards (AFNOR standard ISO 7890-3, ISO 6777.T 90015, T900-23 respectively) after filtration of the samples on Whatman filter paper of 0.45 µm porosity. The spectrophotometer (SHIMADZU UV / visible - 1700 pharma) was used for these analyzes. The SO_4^{2-} is obtained by the nephelometry method. Kjeldahl nitrogen is determined by the Kjeldahl method after selenium mineralization prescribed by the AFNOR T 90-110 standard. The COD analysis protocol is based on the hot potassium dichromate mineralization and the determination of the excess dichromate by a solution of iron and ammonium sulfate II in the presence of ferroin used as an indicator (AFNOR NF T 90-101). The measurement of BOD5 was made using the WARBURG respirometer principle method, in which biomass respiration is directly measured by Oxytop. The microbiological parameters were determined by seeding the microbes in culture media specific to each type of bacteria. Thus, the following media were used for microbial search and enumeration: Hecktoen agar is the selective isolation medium used for salmonella. On Hektoen agar, Salmonella gives green colonies with black centers, which become completely black at the end of incubation. BEA agar (Bile Esculin Azide) for Enterococcus. For enumeration of total coliforms and Escherichia coli, Rapid'E agar is used during this analysis. This culture medium is a chromogenic medium that differentiates E. coli from other coliforms. On this medium, E. coli appear pink to purple while other coliforms are blue. Then, after incubation, pink and purple colonies only are counted for E. coli and all blue, pink and purple colonies are counted for total coliforms.

2.3 Statistical analysis

The Principal Component Analysis (PCA) allowed to establish a correlation between the physicochemical parameters, and a correlation between the physicochemical parameters and the seasons, in order to better visualize and facilitate the interpretation of the results. evaluate the physicochemical quality of the waters of Guessabo Lake. The physicochemical properties data of the water were subjected to ANOVA. The set of univariate and multivariate analyzes was performed with STATISTICA .13 and PAST 3.14 software.

3. RESULTS

Table 1 shows the seasonal values of the physicochemical parameters of water. Table 2 compares the average physicochemical water quality parameters for the seven Lake sampling stations for the 12-month study period to reveal spatial variation.

3.1 Physico-chemical parameters

The temperature varies between 24.27 and 31.20 ° C obtained respectively in November and August. The seasonal mean temperature varied between 25.86 ± 0.97 and 28.96 ± 0.86 ° C obtained during the post-water and recession periods, respectively. No significant variation is observed between seasons. Station 4 below the bridge recorded the highest temperature during the warm period. The transparency of the water column varied between 0.1 and 1.9 during the study period. The seasonal average fluctuated between 0.22 ± 0.05 and 0.82 ± 0.36 m obtained respectively during the post-drought and recession periods. Transparency is significantly low in the post-drought period compared to the recession and flood period ($p < 0.05$). The pH showed that the waters of Guessabo Lake was acidic and varied between 5.53 and 7.60 during the study period. The flood period had the lowest values of the study period with an average value of 6.34 ± 0.05. The temporal evolution of the conductivity of the waters analyzed was similar to that of total dissolved solids for all stations. The recorded values oscillated between 25 and 97µS.cm^{-1} during the study period. The minimum values were recorded during floods with an average value of 31.71µS.cm^{-1}. The conductivity of Guéssabo Lake waters increased during the low water and recession periods. Conductivity of the post-draught and flood period are significantly low compared to those of recession and low water ($P < 0.05$). Nevertheless, they remain in line with the French guideline values for fresh water intended for the production of drinking water. Dissolved oxygen levels range from 3.8 mg. L^{-1} and 7.8 mg. L^{-1}. The mean seasonal oxygen content was between 5.55 ± 0.80 and 5.93 ± 1.22 mg. L^{-1} obtained respectively during the post-draught and low-water periods. The turbidity varied between 12.00 and 108 NTU. Seasonal average concentration varied between 23.71 ± 7.11 and 69.62 ± 7.49 NTU obtained respectively during the periods of recession and post-drought. The nitrate concentrations recorded in this study are low and ranged from 0.01 to 15 mg. L^{-1}. The seasonal mean concentration varied between 1.30 ± 1.20 and 5.82 ± 2.28 mg. L^{-1} obtained during periods of low water and post-drought respectively. For all stations, the highest levels were recorded during the post-drought period. The high average values of NO_2^-, SO_4^{2-}, PO_4^{3-}, total nitrogen and total phosphorus were also obtained during the post-drought period and were respectively 40.00 ± 10.0 µg. L^{-1}; 0.96 ± 0.33 mg. L^{-1}, 25.06 ± 10.7 mg. L^{-1}; 19.71 ± 10.1 mg. L^{-1} and 9.8 ± 6.86 mg. L^{-1}. For ammonium, all stations have high levels during periods of low water and recession (dry season). The seasonal mean concentration varied between 0.15 ± 0.09 and 0.34 ± 0. 15mg.L^{-1}, obtained during periods of flooding and receding, respectively. The COD measured during the sampling period ranged from 8.9 to 131 mg. L^{-1}. As for BOD5, it oscillated between 5 and 64 mg. L^{-1}. The high values are obtained at stations 5 and 7. The low values are obtained during the recession period corresponding to the dry season and the high values are observed during the post-drought period corresponding to the rainy season. The post-drought period has significantly higher values ($P < 0.05$) than other seasons. In order to establish a relationship between the different physico-chemical and chemical pollution parameters, a principal component analysis was performed.

3.2 Typology of a water resource

Figure 2a and 2b respectively show the correlation circle of the variables and the factorial map of the hydroclimatic seasons in the study area in the factorial plane F1-F2. The components (F1-F2) explain 57.38% of the variation of the data set. Factor 1 expresses 40.55% of the total variance, compared with 16.83% for the second factor (figure 2a). The correlation circle shows that the variables nitrite, nitrate, orthophosphate, sulfate, total phosphorus, total nitrogen and turbidity are negatively correlated with factor 1 while conductivity, redox potential, transparency, temperature and dissolved oxygen are positively correlated to this axis. This factor expresses mineralization by superficial contributions of anthropic origin. The superficial inputs are at the origin of the anthropic degradation of the water quality. The second factor is significantly correlated with the COD, BOD5, pH variables, the ammonium in its negative part. Factor 2 expresses organic pollution of water. The seasonal factor map shows that the post-drought period is characterized by high values of sulphate ions, phosphorus and nitrogen compounds (NO_2^-, NO_3^-, Kjeldahl nitrogen). The low water period is characterized by high values of pH, ammonium, conductivity and total dissolved solids. The factorial map of the seasons shows three types of water according to the seasons.

3.3 Bacterial contamination

Microbiological analyzes showed the presence of total coliform bacteria, faecal coliforms (E. coli), intestinal enterococci and salmonella in the waters of Guessabo Lake (table 3). Spatiotemporal changes in total coliforms, E. coli and Enterococci in the year 2018 for each study site were as depicted in figure 3. The desired parameters were present in 100% of the samples (28/28). Total coliform counts ranged from 3700 to 75000 CFU / 100 mL, with an average of 22292 CFU / 100 mL. E. Coli counts ranged from 10 to 1500 CFU / 100 mL, with an average of 317 CFU / 100 mL. Enterococci counts ranged from 40 to 1890 CFU / 100 mL, with an average of 441 CFU / mL. Total coliforms and E. coli had a similar evolution. The concentration of E. coli and total coliform water increased during the rainy season (post-draught and flood). The low concentration of coliforms was obtained during low water periods. Station 4 located under the bridge had a peak of E. coli during floods. The evolution of total coliform, E. coli and Enterococci at our study site showed a decreasing gradient from upstream to downstream. A first sector represented by the stations 1, 2, 3 and 4 is characterized by high values of total coliforms which oscillated between 16875 and 54750 CFU / 100mL, of E. Coli ranging from 187 to 672 CFU / 100mL and enterococci that fluctuated 435 and 860 UCF / 100mL. The second sector represented by stations 5, 6 and 7 is characterized by relatively lower values. Samples majority analyses were in class D.

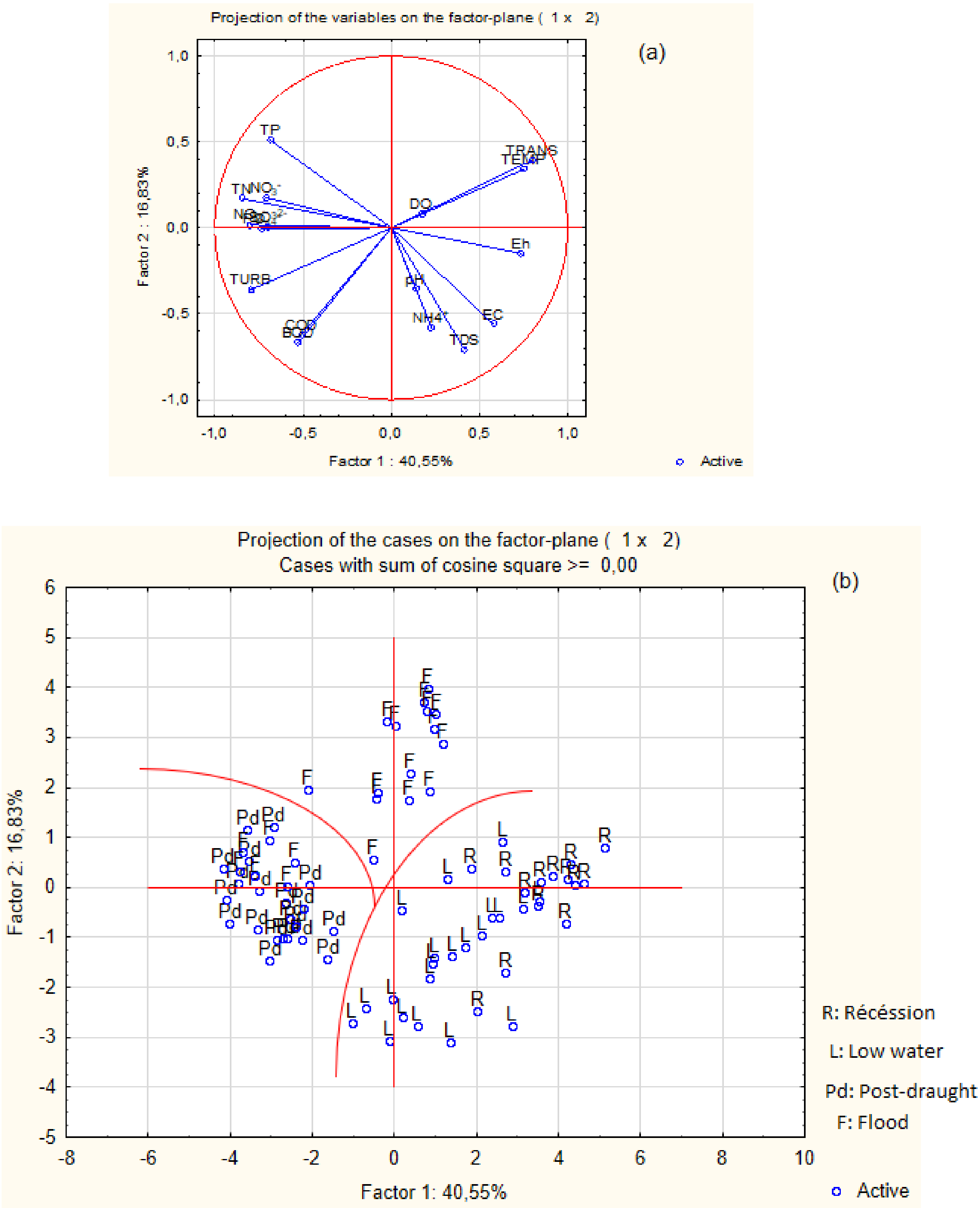

Figure 2: Correlation of the variables (a) and factorial design of the physicochemical parameters according to the seasons (b) TP: Total Phosphorus, TN: Total Nitrogen, TURB: Turbidity, TEMP: Temperature, Trans: Transparency

Citation: Kouamé Kouakou Benoit, Konan Kouakou séraphin, Attoungbre Kouakou severin, Konan Koffi Félix, Boussou Koffi Charles, Kouamé Kouamé Martin; 2019, Physicochemical and Bacteriological Parameters of Surface Water Quality in part of West Côte d'Ivoire: Potential Resources for Drinking Water Production (Guessabo Lake); Journal of Applied Environmental and Biological Sciences, 9(8)17-29, 2019.

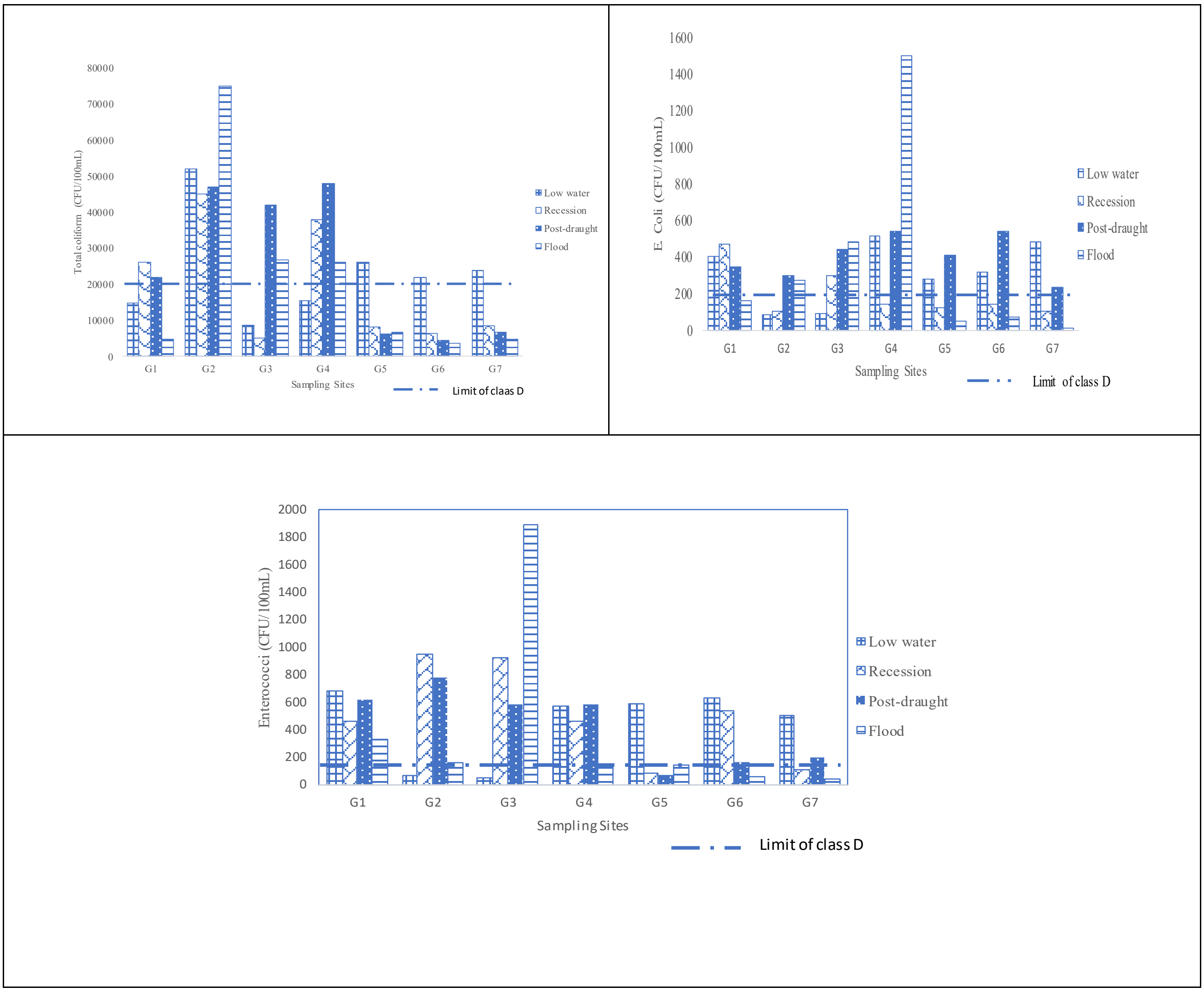

Figure 3: Graphical representation of distribution of bacteriological pollutants in the surface waters of Guessabo Lake.

Table 2: Seasonal variation of means of physicochemical parameters

Parameters	Récession		Low water		Post-drought		Flood		JORF (2017)
	Min-Max	Mean±$S.D$	Min-Max	Mean±$S.D$	Min-Max	Mean±$S.D$	Min-Max	Mean±$S.D$	
TEMP	28.20 29.90	28.96±0.41	25.04 27.71	26.63±0.76	24.41-27.48	25.86±0.97	24.27-1.20	27.85±1.89	≤25°C
pH	5.94-7.60	6.83±0.29	5.54-7.27	6.49±0.34	6.15-7.36	6.62±0.08	5.53-6.55	6.34±0.05	5.5-9
TRANS	0,20-1.80	0.82±0.36	0.20-0.90	0.52±0.19	0.10-0.30	0.22±0.05	0.15-1.90	0.77±0.41	-
TURB (NTU)	12.00 36.00	23.71±7.11	21.00 108.0	44.14±21.76	52.00-82.00	69.62±7.49	13.00 78.00	35.86±19.14	≤ 5
EC (µS.cm-1)	69.00 84.00	75.16±5.25	55.80 97.00	78.99±9.02	50.00-79.00	62.62±6.97	25.00 43.00	31.71±3.52	≤1100
DO (mg.L-1)	4.55-6.58	5.66±0.62	3.80-7,80	5.93±1.22	4.40-6.70	5.55±0.80	4.19-6.79	5.78±0.52	>5
TDS (mg.L-1)	32.00 42.00	37.0 ± 3.11	28.00 50.00	39.57±4.52	25.00-43.00	31.71±3.52	23.00 43.00	32.89±6.19	≤300
OPR (mV)	50.10-60.7	55,78±3,37	20.20 47.50	55.78±7.32	4.00-33.70	18.00±10.6	5.80-30.10	20.25±737	-
NO_3^- (mg.L-1)	0.01-2.50	1.46±0.82	0.08-6.40	1.30 ±1.20	1.90-15.00	5.82±2.28	0.50-11.10	4.01±3.11	≤50
NO_2^- (µ.L-1)	2.00-20.00	8.00±4.00	2.00-70.00	20.00±10.00	20.00-60.00	40.00±10.0	10.00-90.0	30.00±20.00	≤ 0.1
NH_4^+ (mg.L-1)	0.21-0.81	0.34±0.15	0.08-0.87	0.27±0.16	0.03-0.28	0.17±0.05	0.02-0.46	0.15±0.09	≤ 1.5
PO_4^{3-} (mg.L-1)	0.03-0.70	0.35±0.21	0.11-1.04	0.37±0.27	0.54-1.620	0.96±0.33	0.12-1.86	0.62±0.50	≤ 0,5
SO_4^{2-} (mg.L-1)	1.14-15.29	5.49±4.13	0.20-48.95	12.20±11.13	5.54-40.77	25.06±10.7	0.10-38.62	12.52±11.52	≤ 250
NTK (mg.L-1)	1.00-4.00	3.78±0.89	1.00-11.00	4.81±3.40	10.00-51.00	19.71±10.1	2.00-29.00	16.78±7.75	≤ 2
TP (mg.L-1)	0.02-0.48	0.28±0.14	0.25-2.00	0.87±0.45	1.30-21.90	9.8±6.86	3.68-2.50	14.88±8.26	≤ 0.7
COD (mg.L-1)	8.90-50.00	22.62±12.15	15.40-93.0	44.87±24.28	23.20-131.0	77.52±28.58	9.10-54.00	25.25±13.88	≤ 30
BOD5 (mg.L-1)	5.00-22.50	10.09±5.53	6.20-42.00	20.17±10.95	9.20-64.70	36.34±13.55	4.10-3.24	12.30±7.46	≤ 3

Table 3: Statistical values of microbiological parameters

		S1	S2	S3	S4	S5	S6	S7
Total coliforms	Mean	16875	54750	20625	31875	11775	9175	10975
	min	4700	45000	5200	15500	6200	3700	4800
	max	26000	75000	42000	48000	26000	22000	24000
	GM	141.1	53591.2	14964.6	29280.7	9700.9	6985.3	8973.3
E. Coli	Mean	342.5	187.5	327.5	672.5	215	267,5	205
	min	160	80	90	140	50	70	10
	max	470	300	480	1500	410	540	480
	GM	318	159.5	274.7	490.4	162	202.8	102.5
Enterococci	Mean	522.5	490	860	435	220	347.5	212.5
	mim	330	70	50	130	70	60	40
	max	680	950	1890	580	590	630	500
	GM	502.9	301.9	473.8	374.9	146.6	239	144.8
Salmonella	Présence/Total	4/4	4/4	4/4	4/4	4/4	4/4	4/4

GM: geometric mean

Table 1: Spatiotemporal variation of physicochemical parameters:

Parameters	Seasons	S1	S2	S3	S4	S5	S6	S7
Temperature	Récession	28.87±0.27	28.71±0.51	28.75±0.25	29.43±0.46	29.10 ±0.00	28.79±0.29	29.04±0.04
	low-water	26.46±0.63	27.01±0.54	26.39±0.70	26.59±02.37	26.55±0.66	26.71±0.24	26.74±0.13
	Post-drought	25.87±0.73	25.83±0.86	25.85±0.89	26.12±0.54	25.94±0.25	25.88±0.64	25.51±0.46
	Flood	27.19±1.05	27.43±1.39	28.24±1.06	28.09±1.04	27.91±0.95	28.37±1.16	27.77±0.90
pH	Récession	6.53±0.59	6.63±0.48	6.67±0.31	7.02±0.54	6.83 ±0.54	7.09±0.51	7.03±0.36
	low-water	6.12±0.29	6.33±0.19	6.50±0.16	6.56±0.08	6.86±0.21	6.60±0.08	6.50±0.34
	Post-drought	6.54±0.21	6.38 ± 0.10	6.61±0.26	6.71±0.28	6.68±0.33	6.67±0.25	6.73±0.39
	Flood	6.05±0.21	6.19±0.11	6.20 ±0.06	6.26±0.03	6.30±0.08	6.33±0.02	6.21±0.09
Transparency (m)	Récession	0.62±0.07	1.40 ±0.40	0.87±0.03	0.89±0.09	0.77±0.13	0.87±0.04	0.30 ±0.10
	low-water	0.68±0.11	0.67±0.12	0.40 ±0.05	0.54±0.07	0.57±0.07	0.51±0.16	0.29±0.05
	Post-drought	0.22±0.04	0.17±0.0 4	0.22±0.02	0.18±0.02	0.22±0.04	0.23±0.03	0.27±0.02
	Flood	0.76±0.19	0.74±0.20	0.82±0.21	0.86±0.25	0.70±0.16	0.77±0.19	0.61±0.16
Turbidity (NTU)	Récession	29.00±4.00	16.00±2.00	22.50 ±1.50	14.50 ±2.50	26.50 ±2.50	23.50 ± 1.50	34. 00 ± 2.00
	low-water	39. 00 ±11.67	40.33±13.38	48.33±11.46	48.00±12.09	32.33±8.09	48.66±10.86	35.67±1.45
	Post-drought	68. 00 ± 8.32	74. 00 ± 3.51	69. 00 ± 3.00	72.33±2.84	69.67±2.90	71. 00 ± 4.60	63.33±4.80
	Flood	36.50 ±12.00	38. 00 ± 12.64	35.25±11.98	34.50 ± 14.88	35.75±7.82	32.75±7.08	38.25±6.07
Conductivity ($\mu S.cm^{-1}$)	Récession	69.35±0.35	76.00±4.00	74.85±3.85	78. 00 ± 6.00	75.80 ± 4.80	75.50 ± 3.50	76.65±5.65
	low-water	75.65±3.75	82.67±4.70	82.00±4.04	80. 00 ± 3,05	66.67 ± 5.43	86.67±5.17	84.33±6.43
	Post-drought	59.67±6.12	61.00±2.00	67.00±6.03	59.67±3.84	62.67±4.80	61.67±3.48	66.67±2.40
	Flood	64.40±5.10	68.4±5.01	68.92±5.64	69.4±4.78	70.00±5.98	69.30±4.96	68.77±5.58
Dissolved Oxygen (DO)	Récession	6.20 ±0.30	5.75±0.83	6.23±0.29	5.69±0.19	5.74±0.23	5.22±0.29	4.76±0.21
	low-water	6.47±0.67	6.73±0.92	5.60 ± 0.90	6.30±0.62	5.60 ± 1.04	5.87±0.20	4.97±0.52
	Post-drought	5.56±0.59	5.7±0.40	5.60±0.56	5.64±0.38	5.51±0.56	5.59±0.52	5.20 ± 0.72
	Flood	6.14±0.28	5.82±0.25	6.07±0.21	5.70±0.2	5.78±0.19	5.73±0.14	5.23±0.37
Saturation DO (%)	Récession	78.44±2.44	72.75±7.24	78.82±2.53	71.99±1.65	72.63±2.00	66.05±2.53	60.23±1.18
	low-water	81.86±5.84	85.15±8.02	70.85±7.85	77.71±5.40	70.85±9.07	74.27±1.74	62.88±4.53
	Post-drought	70.34±5.14	71.12±3.48	70.85±9.07	71.36±3.31	69.71±9.07	70.73±4.53	65.79±6.28
	Flood	77.68±2.44	73.78±2.18	76.80±1.83	71.12±1.74	73.13±1.66	72.50±1.22	66.17±3.23
TDS ($mg.L^{-1}$)	Récession	33. 00 ±1.00	38.00±2.00	36. 00 ± 2.00	39.00±2.00	36.00±3.00	38. 00 ±2.00	39. 00 ± 3.00
	low-water	37.67±1.85	41.33±2.03	40.33±1.76	40.00±2.00	33.67±2.84	41. 00 ±2.08	43. 00 ± 3.60
	Post-drought	29.67±2.90	30.67±0.67	3.33±3.84	31.33±0.88	32.00±2.30	31. 00 ± 1.53	34.00±1.53
	Flood	30.25±3.35	33.50 ±3.37	33.00±3.89	33.25±2.8	33.5±3.77	33.50±3.28	33.25±3.56
Eh (mV)	Récession	60.30±0.40	59.25±0.15	57.70±0.50	55.55±0.35	53.85±0.45	52.80 ± 0.70	51,00±0,90
	low-water	39.27±4.12	37.53±3.43	36.43±3.47	33.40 ±6.56	29.66±4.90	34.6±4.41	34.8±4.79
	Post-drought	16.93±6.91	20.33±7.79	18.03±7.09	18.2±7.44	17.53±6.25	17.5±7.96	17.5±7.35
	Flood	34.47±8.76	33.90 ± 8.90	33.52±7.9	30.62±8.46	31.95±7.32	30.25±7.85	30.00±7.76
NO_3^- ($mg.L^{-1}$)	Récession	1.80±0.40	1.15±0.05	0.05±0.04	1.90±0.30	2.15±0.35	1.50±0.70	1.70±0.80
	low-water	0.845±0.32	2.31±2.04	2.08±1.75	0.53±0.34	1.29±1.00	0.90±0.79	1.33±1.18
	Post-drought	7.20±1.21	6.70±0.45	4.96±0.86	4.66±1.42	5.10±1.05	7.60±3.71	5.20±1.75
	Flood	5.675±2.076	5.075±1.392	3.250±1.358	4.175±2.359	3.65±1.474	2.875±1.476	3.400±1.265
	Récession	15.00±3.00	5,00 ± 2.00	5.00 ± 1.00	9.50 ± 4.00	9.00±3.00	5.00 ± 3.00	6.50±3.50

NO_2^- (µg.L^{-1})	low-water	42.00 ± 13.61	17.00 ± 11.24	21.00 ± 3.46	17.00 ± 4.36	30.66 ± 9.17	15.33 ± 5.69	21.00 ± 2.30
	Post-drought	46.33 ± 7.53	47.66±4.97	$39.00 \pm 8,32$	$40.33 \pm 8,11$	$37.00 \pm 4,93$	42.66±1.33	$34,24 \pm 6,25$
	Flood	35.50 ± 15.05	35.25 ± 13.07	28.25 ± 10.66	38.50 ± 18.90	36.75 ± 16.14	36.25 ± 16.51	33.25 ± 13.54
NH_4^+ (mg.L^{-1})	Récession	0.27±0.06	0.27±0.06	0.35±0.02	0.31±0.01	0.24±0.01	0.36±0.04	0.61±0.20
	low-water	0.45±0.20	0.25±0.03	0.36±0.03	0.23±0.07	0.29±0.05	0.16±0.03	0.18±0.05
	Post-drought	0.15±0.01	0.17±0.00	0.23±0.02	0.17±0.01	0.17±0.01	0.10±0.05	0.20±0.04
	Flood	0.15±0.01	0.13±0.05	0.14±0.03	0.14±0.04	0.13±0.03	0.19±0.09	0.10±0.02
PO_4^{3-} (mg.L^{-1})	Récession	0.37±0.22	0.22±0.19	0,43±0.16	0.47±0.17	0.47±0.23	0.18±0.12	0.31±0.01
	low-water	0.33±0.14	0.43±0.27	0.38±0.23	0.50±0.27	0.32±0.11	0.29±0.08	0.33±0.10
	Post-drought	1.11±0.20	1.06±0.27	0.73±0.11	1.08±0.27	1.00±0.15	0.95±0.23	0.79±0.13
	Flood	0.70±0.39	0.70±0.37	0.48±0.18	0.60±0.35	0.64±0.33	0.56±0.27	0.66±0.11
Total Phosphorus (mg.L^{-1})	Récession	0.18±0.08	0.27±0.20	0.29±0.03	0.29±0.11	0.21±0.19	0.37±0.05	0.31±0.10
	low-water	0.68±0.22	0.86±0.10	0.79±0.16	1.23±0.39	0.71±0.18	0.79±0.10	1.01±0.51
	Post-drought	7.00±0.27	8.46±3.60	7.56±3.64	10.26±4.44	12.300±5.89	13.33±5.95	9.76±4.11
	Crue	17.46±4.92	16.37±5.70	8.45±1.60	17.05±6.52	17.78±4.85	15.55±3.75	13.51±2.20
NTK (mg.L^{-1})	Récession	2.50 ± 0.50	3.00 ± 1.00	1.50 ± 0.50	3.00 ± 0.00	3.50 ± 0.50	2.50 ± 0.50	3.50 ± 0.50
	Low water	4.00 ± 1.50	5.00 ± 2.10	4.00 ± 1.70	5.60 ± 2.00	6.60 ± 2.80	4.30 ± 3.30	4.00 ± 1.50
	Post-drought	15.33±2.90	18.30 ± 2.90	21.30 ± 4.10	16.30 ± 4.40	13.30 ± 2.40	30.30 ± 11.60	23.00 ± 690
	Flood	15.70 ± 3.90	15.20 ± 4.60	14.20 ± 3.80	21.50 ± 4.80	17.50 ± 3.60	18.00 ± 3.30	15.20 ± 490
SO_4^{2-} (mg.L^{-1})	Récession	8.22±7.07	3.25±1.63	10.22±2.66	2.38±0.12	5.09±1.69	5.51±0.41	3.69±0.49
	Low water	10.82±3.68	23.69±12.79	11.52±4.09	11.26±4.64	7.853±0.93	11.57±10.07	7.77±3.40
	Post-drought	27.64±6.08	20.91±8.94	23.21±7.16	25.70±5.76	28.23±6.82	30.02±5.47	19.70±7.66
	Flood	10.58±6.40	17.30±7.21	8.87±3.44	15.18±8.27	14.61±6.52	12.78±6.98	8.34±3.29

4. DISCUSSION

4.1 Physico-chemical parameters

The high value of the water temperature in the dry season (recession) is a characteristic of tropical waters.

At the space level, station 4 recorded the highest temperature during the warm period. Although located under the bridge, these high values would be due to the mechanical mixing of water swells that hit the pillars of the bridge [14]. The low transparency of the water during the post-drought period could be explained by the presence of colloidal particles carried by the first rains [15, 16]. Principal Component Analysis (PCA) also showed that temperature is an important factor influencing transparency because it is significantly correlated. Indeed, the increase in temperature decreases the density of the water, which would lead to the sedimentation of suspended materials, hence the increase in transparency in the dry season (low water period). However, turbidity averages were well above the standard required for a surface area for drinking water production (<5NTU) [17]. The low pH values obtained during the flood period are due to the arrival of the waters of the various tributaries charged with suspended matter. The presence of humic matter would increase the acidity of the lake at this time. Also, this state of affairs could explain the similar temporal evolution of the conductivity of the analyzed waters to that of the dissolved total solids for all the stations. The low conductivity of lake water (70.74 ± 13.10 µs.cm^{-1}) suggests a very low dissolution of minerals in the watershed [11].The increase in the conductivity of the waters of Lake Guéssabo during the low-water and receding periods will be on the one hand to the intense evaporation which induces a strong mineralization of water in salts, which increased the conductivity of the waters of Guessabo [18]. On the other hand, the strong mineralization of the water during the dry period could be explained by the interconnection that exists between the rivers and the groundwater. Indeed, according to [19] on the Bandama River Basin, surface water would drain groundwater (crack). In addition, [20] confirmed that the interaction between surface water and groundwater occurs from the water table to the river during a period of low water. Dissolved oxygen levels ranged from 3.8 mg. L^{-1} to 7.8 mg. L^{-1}. These values showed that the lake water is moderately oxygenated. The low concentration of dissolved oxygen in floodwaters may be explained by the fact that Guessabo Lake is fed exclusively by inland waters and is loaded with colloidal particles. Indeed, the high turbidity of the waters with an average (69.29 ± 7.49NTU) caused a low transparency (0.22 ± 0.05m) reducing the penetration of the light in the water preventing the photosynthesis to compensate the losses due to the respiration of organisms and the oxidation of detrital organic matter that they carry. There is a slight increase in the dissolved oxygen content during the low water period. This increase during this period is due to the photosynthesis phenomenon which intensifies during the dry season and outweighs the other phenomena, which causes an increase in the concentration of dissolved oxygen in the lake water [21]. Our results are in agreement with those of [11] Ossey and al (2007) obtained in the same waters. The redox potential of the waters remained positive during the study period indicating the oxidative character of the waters. Nitrate concentrations recorded in this study was low. The minimum values are observed during periods of low water and recession for the seven stations. The highest levels are recorded during the post-drought period. This temporal evolution of nitrate has also been observed in the work of [4]. Nitrate inputs may be related to leaching of agricultural soils upstream of the watershed. According to [18], if nitrate levels exceed 1.5 mg. L^{-1}, there is likely to have been leaching of agricultural land or discharge of domestic wastewater. However, the nitrate, nitrite and sulphate values remain low compared to the respective guideline values required for freshwater intended for the production of drinking water [17]. As a result, the waters studied are not subject to a risk of pollution by these elements. On the other hand, PO_4^{3-}, total nitrogen Kedhjal and total phosphorus record values higher than the norms evoked. The high values of these parameters in Guessabo Lake may be due to soil erosion and runoff, which are remarkably high during the months of heavy rainfall following the low water period during which shorelines are used by local residents. For various food crops. Heavy rains cause flooding, carrying nutrients, silt and household waste into water bodies [22]. For ammonium, all stations have high levels during recession and low water season (dry season). The increase in NH4+ levels in this period is related to the bacterial decomposition of nitrogenous organic matter due to the slight increases in temperature recorded during these periods and the natural reduction of nitrates. For the seven stations, the lowest levels are recorded during floods. Ammonium is absorbed preferentially when the algae simultaneously have NH_4^+ and NO_3^-[18, 23]; This explains the low levels measured during this period when macrophytes invaded the water column, without neglecting the part of nitrification due to a slight increase in dissolved oxygen after the post-drought period. Also, high concentrations of NH4+ indicate possible bacterial pollution by animal waste [24]. The high COD and BOD5 values in the rainy season highlight the contribution of rain-leaching in the input of organic matter to water from the watershed. These high concentrations of organic matter induce a high oxygen consumption for their degradation, which leads to high oxygen demand values [25]. The decrease would be due to two reasons; on the one hand, the high concentration of organic matter causes a slowdown in the process of dissolution of atmospheric oxygen in water and, on the other hand, it consumes a large amount of dissolved oxygen for its decomposition into CO_2, CH_4 and SO_4. [26]. Moreover, in waters rich in organic matter, aquatic organisms develop strongly and consume oxygen for their development [27]. The principal component analysis shows a correlation between the parameters COD, BOD5, pH and ammonium. This relationship would indicate that the accumulation of organic matter reflects the pH reduction of lake water. This reduction can be related to the production of CO_2 and SO_4 gases in the process of decomposition of organic matter at the bottom of the lake. In fact, these gases can be transformed into acid forms (HCO_3, H_2SO_4) in different forms of chemical reactions [28]. In terms of quality for fresh water intended for the production of drinking water, it appears that the values of BOD_5 are beyond the reference guide value of the French Republic [17], which means that the waters of Lake Guessabo are of poor quality in reference to this parameter. The magnitude of oxygen demand in Guessabo Lake during the study period is lower than that of [29] in the Ebrié lagoon and similar to that of [21] in the Aghien lagoon.

4.2 Bacterial contamination

Total coliforms and E. coli have a similar evolution, reflecting the fact that detection of one bacterium indicates a high probability of presence of the other. Increasing the concentration in water of E. coli and total coliforms in the rainy season (post-flood and low water) can be interpreted as resulting from an increase in contributions through leaching and overflowing cesspools at the rise of the water table. It can also result from the decrease of solar radiation and its bactericidal effect [30, 31]. This phenomenon is reinforced by the high turbidity of the lake water at this time, indicating that organic colloid and sediment mixtures were the most important transport vector for pathogens [8]. The low concentration of coliforms during the low water period results from a combination of environmental, physical, chemical and biological factors, including solar radiation, pH, metal toxicity, interspecific competition and predation pressure [32]. Station 4 located under the bridge has a peak of E.Coli during floods, this increase is attributable to the droppings of birds that have made their nests under the bridge. According to [33], the average fecal coliform level in Guessabo Lake indicates generally poor water quality. Indeed, 57% (16/28) of the samples are in the bad class (figure 3) with reference to this parameter. Regarding enterococci, 60.7% (17/28) of the samples are in the bad class and 100% of salmonella in the water during the study period, testifies to the poor water quality. They are very persistent and their presence is a good indicator of the vulnerability of the lake. Also, the lake water resources are strongly influenced by human activities, with the presence of fecal coliform bacteria type Escherichia coli and enterococci which are the consequence of a recent anthropogenic pollution [34].The permanent presence of salmonella during the study period is worrying as this kind of pathogen is able to multiply and allow, starting from a small quantity of microorganism at the beginning, to constitute a sufficiently large number to trigger an infection in the host. They are also capable of producing a quantity of toxic substances sufficient to cause disorders in the latter. This bacterial contamination may be due to blind human defecation and the poor system of waste disposal in the region. Live populations in the vicinity of the watercourse must be informed during awareness programs on the effects of polluted water on their health and that of their children.

CONCLUSION

The main objective of this study was to know the hydrochemical functioning and the state of pollution of the waters of Guessabo lake. At the end of this work, it appears that this lake is subjected to a supply of nutrients essentially of exogenous origin linked to throughfall of the watershed, the peaks are reached during the period post-draught level (May to July) corresponding to the great rainy season. From a bacteriological point of view, the waters of Guessabo Lake have high concentrations of intestinal enterococci, E. Coli and total coliforms indicating fecal pollution in humans and animals. The permanent presence of germs such as salmonella indicates increased pollution. Parameters such as BOD5 and COD are also high and reflect the multiple constraints to which the water resource is subject. These waters need to be protected and managed in a rational way not only for the preservation of the water resource but also for the protection of the aquatic ecosystem and its biological potentialities. Therefore, the study concludes that there is a potential risk of contracting waterborne diseases and other ailments by those using the untreated water. As concerns here potential for the production of drinking water, authority should be used a good technology for treatment to the highly water polluted.

Conflicts of Interest

The authors declare they have no competing interest.

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Evaluation of Drainage System for Inundation Problems at Subdistricts of Lowokwaru Malang City

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ABSTRACT

Malang is a city in East Java with the level of development of rapid settlement areas, the region has grown in areas of land rainwater. The consequence of this development is the emergence of some new inundation in urban areas, one of them in Subdistrict Lowokwaru. Carrying amount inundation problems that occurred during 2018 in the Subdistrict Lowokwaru 4 times. Largely due to the drainage conditions are not maintained and are filled with trash and sediment. The conditions resulted in reduced sewer capacity and are not able to drain rainwater discharge and wastewater. Evaluation of drainage system in Subdistrict Lowokwaru include hydrological analysis is data consistency test, data homogeneity test, average rainfall analysis, the maximum daily rainfall plan analysis, the goodness of fittest, rain intensity distribution analysis, and rain intensity curve analysis. Also, hydraulics analysis and evaluate sewer capacity. The analysis showed that there are 21 sewers in condition without sediment that capacity is insufficient and 23 sewers in conditions with sediment are not met or sewer capacity is not technically eligible. It is necessary for a handling plan as an attempt to deal with the sewer capacity to drain the runoff discharge.
KEYWORDS: Inundation, Subdistrict Lowokwaru, Malang City, Drainage Systems, Sewers

1. INTRODUCTION

Malang became one city in East Java with the rapid rate of development, one aspect of the rapidly growing residential area, where the whole corner of the city of Malang is emerging a new residential area and shop. The region is growing in some places, both in the hills and in the area of natural water reservoirs (retarding basin). The area that originally serves as a conservation area that can absorb/accommodate while rainwater is now changed into the area woke up. The consequence of this development is the emergence of some new inundation in urban areas, even on the road.

Subdistrict Lowokwaru is one area that often occurs puddle. Data from Kota Malang Dalam Angka 2018 the carrying amount of inundation problems occurred during 2017 in the Subdistrict Lowokwaru 4 times. Largely due to the drainage conditions are not maintained so many sewers are filled with trash and sediment. The conditions resulted in reduced sewer capacity and are not able to drain rainwater discharge and wastewater. Land-use change is an awakened area that also results in lower catchment areas and rainwater.

The problem of this research is how the technical condition of the drainage system at the location of inundation in Subdistrict Lowokwaru. While the purpose of this study was to evaluate the technical condition of drainage sewers in locations that occur inundation in Subdistrict Lowokwaru by calculating hydrology, discharge runoff and sewer capacity.

2. METHODOLOGY

This study uses a survey approach, while according to the level of explanation is a descriptive study. This is done to describe the condition of the drainage system performance as well as the influence and develop handle strategies appropriate to the issues raised. Stages of the activities carried out are observation, data collection, analysis, and interpretation of data to determine an indication of the problem as a basis for determining the ideal solution as well as set standards and correlation.

The data used is the data that is both qualitative and quantitative. Sources of qualitative data based on information from respondents who becomes the object of research. While quantitative data in the form of numbers or count are processed based on information from the public, institutions, the management board and the results of field observations obtained during the research process.

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3. STUDY AREA

The research location is in the Subdistrict of Lowokwaru Malang city located in the northern city of Malang and adjacent to the Subdistrict Karangploso Malang. Subdsitrict Lowokwaru has an altitude between 200-499 meters above sea level with slopes on the plateau is quite varied, in some places a plain area with a slope of 2-5%, while the hills of the valley section average slope of 8-15%.

The drainage system in Subdistrict Lowokwaru generally used the river as a sewer for final discharge. In Malang city is traversed by five (5) major rivers namely: Brantas River, Amprong River, Bango River, Metro River, and Sukun River. As for the Watershed is divided into three parts, namely:

1. Metro Watershed
2. Brantas Watershed
3. Bango Watershed

Division of Watershed in the Subdistrict Lowokwaru can be seen in Figure 1.

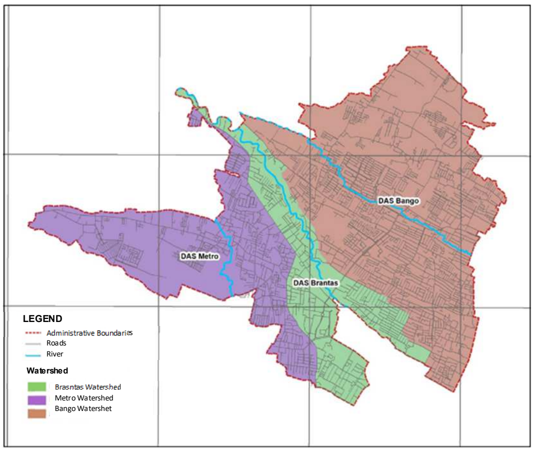

Fig. 1: Watershed Map in the Subdistrict Lowokwaru

4. RESULTS AND DISCUSSION

4.1 Hydrology

Rainfall data used is the data maximum precipitation affecting the five weather stations with the research site over the past 10 years.

Table 4.1 Maximum Daily Rainfall Data Each Weather Station

No.	Years	Weather Station (mm)			
		Karangploso (ST.1)	Dau (ST.2)	Sukun (ST.3)	Ciliwung (ST.4)
1	2008	104	110	130	95
2	2009	69	110	108	73
3	2010	68	144	178	186
4	2011	91	85	83	113
5	2012	108	97	169	138
6	2013	77	85	101	97
7	2014	105	100	134	125
8	2015	67	65	170	96
9	2016	97	94	122	64
10	2017	93	105	132	104
Average		**88**	**100**	**133**	**109**

Source: BMKG Karangploso Malang, 2019

The analysis of these data consistency and homogeneity of the data for accuracy and ensure that data is not contained significant deviations.

- Average rainfall analysis

The analysis was calculated using the Thiessen Polygon method, the analysis is done from the calculation Thiessen coefficient obtained by dividing each area influence rainfall station (Figure 2).

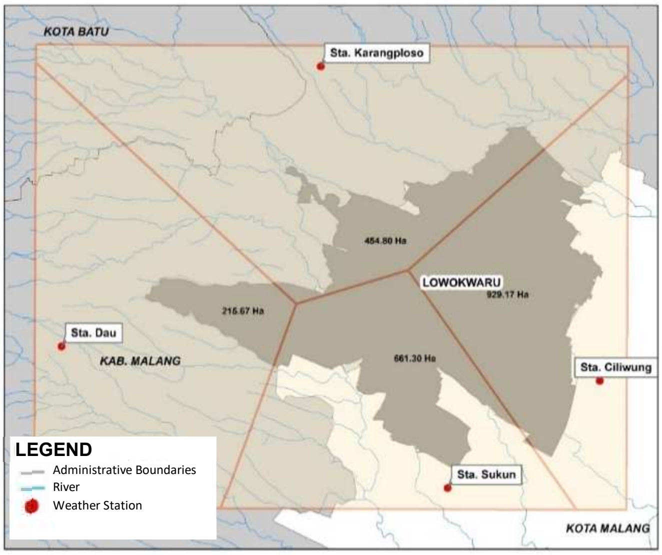

Fig. 2: Map Thiessen Polygon Subdistrict Lowokwaru

- The maximum daily rainfall plan analysis

The maximum daily rainfall plan analysis is done by using two methods: Method Gumbel and Log Person III. From this method were analyzed Goodness of fit test using the Chi-square test and Smirnov-Kolmogorov test thus concluded that the appropriate distribution is the Gumbel method.

- Rain intensity distribution analysis

Results distribution Gumbel method then calculate the rainfall intensity analysis by 3 methods: Van Breen, Bell, and Hasper Weduwen Method. Calculation Result elected rain intensity distribution is Van Breen Method of calculation with the PUH 5 years for the secondary sewer.

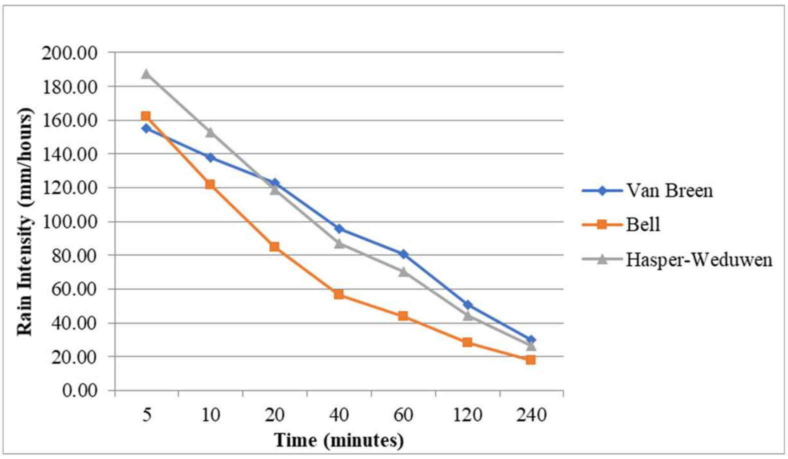

Fig. 3: Comparison Graph of Rain Intensity PUH 5 Years

- Rain intensity curve analysis

Rain Intensity Curve Analysis using a method Talbot, Sherman and Ishiguro. The calculation of the three methods has a method that has the greatest rainfall intensity arch.

Table 4.2 Difference in Rain Intensity of the Talbot, Sherman, and Ishiguro Methods for PUH 5 Years

t (minutes)	I (mm/hours)	I Talbot	I - I Talbot	I Sherman	I - I Sherman	I Ishiguro	I - I Ishiguro
5	165,47	161,44	4,03	199,69	34,22	197,50	32,03
10	140,87	147,65	6,78	148,37	7,50	151,48	10,61
20	127,46	126,11	1,35	110,25	17,21	113,94	13,52
40	97,27	97,62	0,35	81,92	15,35	84,37	12,90
60	81,62	79,63	1,99	68,85	12,77	70,36	11,26
120	50,31	51,28	0,97	51,16	0,85	51,17	0,86
240	30,19	29,95	0,23	38,01	7,82	36,93	6,74
Total	693,19		15,70		95,72		87,93
Average			***2,24***		13,67		12,56

Source: Analysis, 2019

Talbot method was chosen as a rain intensity formula because has a delta (A) smallest and can give optimum results. So that the formula used to calculate the amount of rain intensity using the equation:

$$I = \frac{8864{,}48}{t + 52{,}55}$$

4.2 Hydraulics

- Analysis of Existing Debit

Hydraulics analysis is used to determine the ability of the sewer to accommodate the runoff discharge. The analysis is done based on existing data obtained from the primary data and secondary data. The primary data is a length, the width of the base, the width of the surface, the depth of the sewer, and sediment.

Calculation of sewer discharge conducted with two types of conditions that the sewer conditions without sediment and with sediment. Sewer discharge is obtained from the calculation of flow velocity multiplied by the channel cross-sectional area.

- Discharge rainwater runoff analysis

Discharge rainwater runoff is influenced by land use in the catchment area, the variables that influence is runoff length, runoff slope, manning coefficient, assumption of water velocity in a sewer, drainage time, selected rainfall intensity PUH 5 years, and drainage coefficient.

- Wastewater discharge analysis

Subdistrict Lowokwaru drainage system is a mixed drainage system between rainwater and wastewater. Based on the number of residents in the catchment area as well as the extent of the need of clean water per person per day plus non-domestic water needs, it can be calculated the amount of wastewater into the sewer.

- Evaluation of drainage system capacity

Evaluation of the capacity of the drainage system is reviewed based on the total discharge amount of rainfall-runoff and wastewater discharge on existing conditions and then compared to sewer discharge. Evaluation of the capacity of the drainage system needs to be done to determine whether the condition of the existing sewer is still in accordance with the requirements or necessary for the development.

The evaluation results indicate the sewer capacity there are 21 sewers in condition without sediment that capacity is insufficient and 23 sewers in conditions with sediment are not met or sewer capacity is not technically eligible. It is necessary for a handling plan as an attempt to deal with the sewer capacity to drain the runoff discharge.

- Alternative Treatment

Based on the evaluation result in conditions with sediment to maximize sewer capacity and reduce the inundation, it needs to dredge sediment and calculated sewer dimensions based on the rainwater runoff.

5. CONCLUSION

According to analysis carried out on the evaluation of drainage system for inundation problems at Subdistricts Lowokwaru, it can be concluded as follows:

a. Sewer problems in the Subdistrict Lowokwaru form of sewer blockage due to garbage, sediment at the bottom of the sewer, and sewer inlet which is higher than the road.
b. Based on the evaluation result of the sewer there are 21 sewers in condition without sediment that capacity is insufficient and 23 sewers in conditions with sediment are not met or sewer capacity is not technically eligible.
c. The handling plan is in the form of cleaning and dredging of trash and sediment, as well as the calculation of the ideal sewer dimensions to drain the discharge runoff accordingly.

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The Effects of Soil Conditions on Bio-pore Infiltration Hole Needs and Potential Runoff Reduction as an Alternative Sustainable Urban Drainage

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ABSTRACT

This study aims to analyze the effect of type, compaction, and the cover of vegetation on the soil to the hydraulic conductivity to determine the need for bio-pore infiltration holes (BIH) of different soil types. The methods used in this study are the measurement of infiltration rate on the ground surface which will be used as a reference for determining the runoff coefficient and the analysis of calculating hydraulic conductivity in the BIH using the Porchet method to determine the optimum capacity of holes in delivering water. The result shows that with the same soil conditions, for example, vegetated and compacted soil, on the silty soil tends to have lower BIH land use ratio to inundation area than clayey soil in order to achieve the same amount of reduced runoff water ratio.
KEYWORDS: *bio-pore infiltration hole, compaction, hydraulic conductivity, inundation, soil, vegetation cover*

INTRODUCTION

Nowadays, along with the development of population, urban expansion continues, where it can threaten natural dynamics, resource availability and environmental quality [1], including human intervention through both greenhouse gas emissions and land cover changes which cause global climate change and can affect the hydrological cycle [2, 3]. According to Apollonio et al., expansion of development in urban areas causes a reduction in water catchment areas, resulting in an increase in runoff and causing flooding and inundation [4], which still occurs in a number of large cities in Indonesia such as Jakarta and Surabaya.

Zhou explained that a sustainable urban drainage system (SUDS) was promoted as an alternative to the conventional drainage concept [5], which in Indonesia is better known as environmental drainage. This system installed based on natural hydrological cycle process which use some portion of urban landscape like vegetated land surfaces with purposes to reduce flood impacts by encouraging infiltration of stormwater to the ground, filtering the pollutants from source, and also temporarily storing water [6, 7, 8]. One of the potential sustainable drainage concepts is bio-pore infiltration hole (BIH). BIH is one of the SUDS technologies that can be used as an alternative effort to improve environmental hydrological functions to overcome flooding and inundation by increasing water absorption in the soil so that it can potentially be a conservation of water in the soil [9].

Water absorption by land is one of the important factors in designing and determining the needs of the amount of BIH so that in the context of BIH application, it must be known in advance how the soil conditions from the flood area and inundation that want to be reduced by BIH. This is because an area does not necessarily have the same type and characteristics of the land as other regions, even though it is in a city [10]. This study aims to analyze the effect of type, compaction and cover of vegetation on the soil on the infiltration rate and hydraulic conductivity to determine the need for bio-pore infiltration holes (BIH) of different soil types.

METHODS

Initial Data Collection & Field Surveys

The preliminary data needed in the study were the soil type map, inundation survey data, rainfall height and intensity of Surabaya city from their respective city departments. Those data are used as the basis for surveying and determining some locations at Surabaya that will be used as field tests, especially BIH tests. The chosen locations for this study are Kenjeran Beach Amusement Park and Lempung Urban Forest, Surabaya, that can be seen on Figure 1. Some soil were sampled from those locations to be tested in laboratorium to determine the texture soil class. Each of the locations will be divided into 4 test plots, where the conditioning on each plot described in Table 1.

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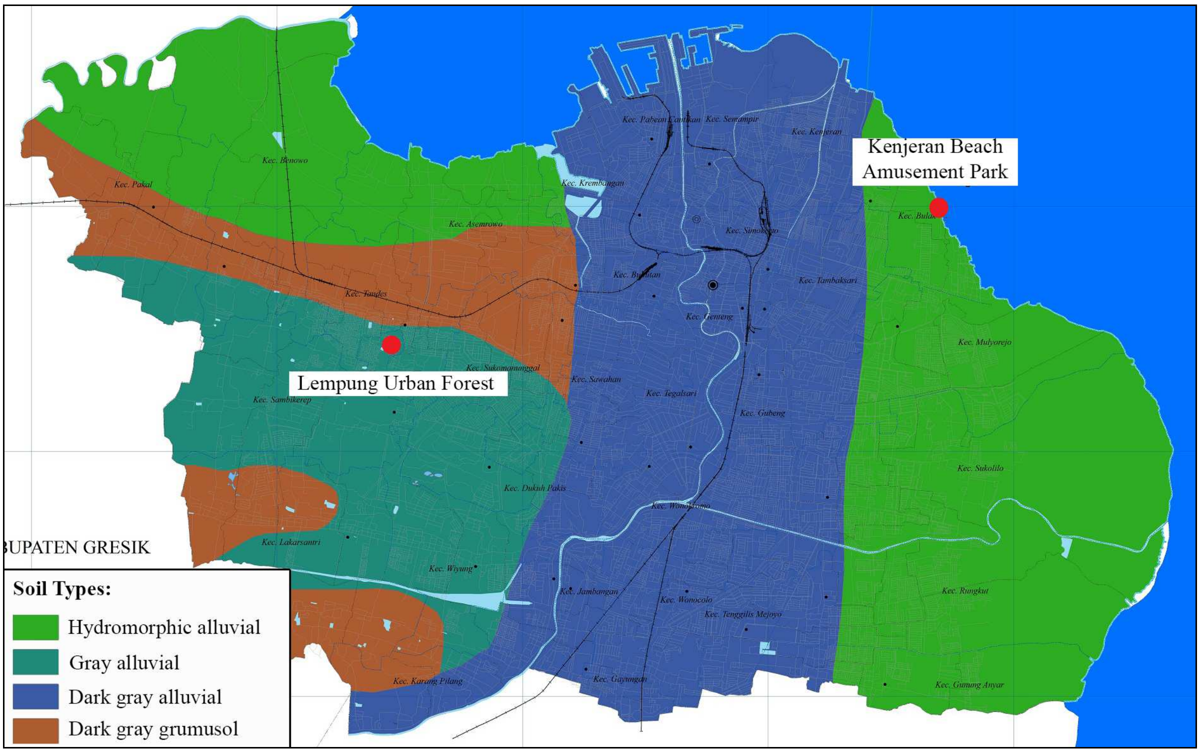

Fig. 1: Test field locations on map of soil types at Surabaya City

Table 1. Conditioning on each test plots

Numb.	Location	Vegetation cover	
		With	Without
1	Kenjeran Beach Amusement Park	No compaction (K1)	No compaction (K3)
		With compaction (K2)	With compaction (K4)
2	Lempung Urban Forest	No compaction (L1)	No compaction (L3)
		With compaction (L2)	With compaction (L4)

Test Fields Preparations

These preparations include compacting soils, measuring the infiltration rate, and creating BIH. Four out of eight areas will be compacted by stamper with durations around 30 seconds based on Gregory et al. [11]. After that, infiltration rate measurement will be conducted at every test plots using single-ring infiltrometer. Then, BIH will be constructed in every test plots by boring it using auger hand bore with the sizes of the hole about 10 cm of diameter and 100 cm of depth. After that, that hole will be covered using a pored casing pipe with the same size as the hole.

Hydraulic Conductivity Measurements

Hydraulic conductivity will be measured using inverse auger hole method [12],[13], with some small modification, which single-ring infiltrometer and ruler will be used to measure surface water level changes instead of using measurement tape. Water will be added to the system and maintained in the same water level after it changes in several minutes. Measurement will be stopped if changes in the surface water level of the system remain the same after the last three tries.

Initial Data Analyses

Hydraulic conductivity analysis will be conducted using Porchet method from all gathered data measurements in the field. Comparisons between control plots (K3 for Kenjeran Beach Amusement Park and L3 for Lempung Urban Forest) with other test plots also will be analyzed to know the influence of soil conditioning (vegetation cover and compaction) on hydraulic conductivity. The equation for calculating hydraulic conductivity is as follows:

$$K = \frac{D}{4} \times \frac{\ln\left(h_0 + \frac{D}{4}\right) - \ln\left(h_t + \frac{D}{4}\right)}{t} \tag{2}$$

Equation (2) can be modified to determining the water absorption rate into the hole as follows:

$$\begin{aligned} \Delta Q &= K.\Delta A \\ &= K.\ (A_0 - A_t) \\ &= K.\pi.D\ [(h_0 - h_t) + D/4] \end{aligned} \tag{3}$$

information:
K = Hydraulic conductivity (cm/hr)
h_0 = Initial surface water level (cm)
h_t = Constant surface water level (cm)
t = time (hr)
D = Diameter of hole (cm)

Meteorological data such as rainfall height in last 10 years and rainfall intensity in last 13 months gathered from nearest weather station will be used to determine the average value of each data and to calculate runoff coefficient from each test plot along with infiltration rate measurement on the field of study and depression loss values from UDFCD (Urban Drainage Flood Control District, USA). Based on Guo and Urbonas, the calculation of runoff coefficient is done by using some equations [14] which can be reviewed below:

- The equation for calculating the rainfall volume is as follows:

$$V_P = PA \tag{3}$$

- The equation for calculating the runoff volume is as follows:

$$V_R = (P - D_L - F)\ A \tag{4}$$

- The equation for calculating the runoff coefficient is as follows:

$$C = \frac{V_R}{V_P} \tag{5}$$

information:
V_P = rainfall volume (m^3)
V_R = runoff volume (m^3)
P = rainfall height (m)
A = watershed (m^2)
C = runoff coefficient
D_L = depression losses (m)
F = infiltration height (m)

Analysis of Bio-pore Infiltration Hole Needs and Runoff Reduction

In this analysis, the need for bio-pore infiltration holes (BIH) will be determined by adjusting Regulation of Environmental Ministry Numb. 12/2009 concerning the provisions of the distance between bio-pores, so it is assumed that every 1 m^2 area will be installed with 1 BIH, and how much runoff volume can be reduced, and the assumption that the land used has undergone compaction. The analysis was carried out at 3 locations as representatives referring to the inundation data survey obtained from the Public Works Departement of Highways and Drainage on Surabaya City as well as a map of soil types. Then, determining the broad portion of the location that can be used BIH installations such as green lanes, schoolyards, offices and so on, is done using Google Earth software. The calculation of BIH land use ratio to inundation area is done by using the equation below:

$$\%\ A_{BIH} = A_{BIH} / A_{in} \tag{6}$$

information:
$\%A_{BIH}$ = BIH land use ratio to inundation area
A_{BIH} = bio-pore infiltration hole land use (m^2)
A_{in} = inundation area (m^2)

For the calculation of runoff reduction is done by using the equation which can be reviewed below:

$$\% \text{ Reduction} = (V_{BIH} \times \text{number of BIH needed}) / V_{R\ in} \tag{7}$$

information:
V_{BIH} = bio-pore infiltration hole volume (m^3)
$V_{R\ in}$ = initial runoff volume before BIH applied (m^3)

RESULTS AND DISCUSSION

Soil Texture of Test Fields

Based on the results of laboratory analysis, the soil sampled from the study site was dominated by fine-sized particles, where the soil in Kenjeran Beach Amusement Park was dominated by silt particles, while Lempung Urban Forest was dominated by clay particles. For the particle composition of the soil sampled can be seen in Table 2.

Table 2. Soil texture of test fields

Plot	Soil Texture	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
K1	Silty clay loam (0-25 cm)	0.011	0.120	63.652	36.217
	Landfill (26-100 cm)				
K2	Silt loam (0-25 cm)	0.167	4.707	74.428	20.698
	Landfill (26-100 cm)				
K3	Silt loam (0-30 cm)	5.387	13.960	64.026	16.627
	Landfill (31-100 cm)				
K4	Silt loam (0-30 cm)	0.423	1.843	81.456	16.278
	Landfill (31-100 cm)				
L1	Clay (0-100 cm)	0.284	20.308	19.376	60.031
L2	Clay (0-100 cm)	0.980	31.285	11.092	56.643
L3	Clay (0-100 cm)	0.713	14.759	23.166	61.362
L4	Clay (0-100 cm)	0.709	27.051	11.276	60.964

Hydraulic Conductivity Analysis

This analysis was carried out to determine the ability of the soil surface to drain water into the soil, and examine the effect of soil conditions namely soil type, land density and vegetation cover on hydraulic conductivity. The constant hydraulic conductivity from each test plot can be seen at Table 3.

Table 3. The constant hydraulic conductivity from each test plot

Test plot	K(cm/hr)	Q (cm^3/hr)
K1	20.89	24,616.54
K2	10.91	11,572.43
K3	16.88	16,914.78
K4	8.88	8,019.52
L1	12.39	9,736.42
L2	5.40	3,286.12
L3	10.85	7,674.78
L4	4.75	2,610.69

From Table 3 data above, it can be seen that test plot with the highest hydraulic conductivity value and water absorption rate is plot K1 with silty, vegetated and uncompacted soil. Meanwhile the smallest one is plot L4 with clayey, non-vegetated and compacted soil. For the comparison of hydraulic conductivity from conditioned test plots with control plots can be seen at Table 4.

From the Table 4 data, it can be seen that there are significant differences related to the effect of research variables or conditioning on soil with the hydraulic conductivity on each plot. If those data reviewed by the effect of compaction, the compacted plots have a lower constant hydraulic conductivity than the control plots which are not compacted. The previous study by Zhang et al. confirms this with some laboratory experiments [15]. Also, this confirmed with some explanation from Gregory et al. before, that compaction affects the physical properties of the soil while reducing the porosity and pore distribution in the soil [11].

Table 4. Comparison of hydraulic conductivity with control plot

Test plot	K (cm/hr)	Soil Conditioning	Control plot	K of control plot (cm/hr)	Difference (%)
K1	20.89	Vegetated	K3	16.88	+ 23.76
K2	10.91	Vegetated & Compacted	K3	16.88	- 35.37
K4	8.88	Compacted	K3	16.88	- 47.39
L1	12.39	Vegetated	L3	10.85	+ 14.19
L2	5.40	Vegetated & Compacted	L3	10.85	- 50.23
L4	4.75	Compacted	L3	10.85	- 56.22

At Kenjeran Beach Amusement Park, the constant hydraulic conductivity at plot K2 is 35.37% lower than the plot K3 and that on the plot K4 is 47.39% lower than the plot K3. Meanwhile at Lempung Urban Forest, the constant hydraulic conductivity at plot L2 is 50.23% lower than the plot L3 and that on the plot L4 is 56.22% lower than the plot L3.

From the vegetation cover existence, the vegetated plots have a higher constant hydraulic conductivity than the other plots which are not vegetated. This was confirmed by Gadi et al. that higher vegetation density in the soil results in higher hydraulic conductivity value [16]. Exception occurs on the soil conditioning that coupling both vegetation cover and compaction. Vegetation presences on the compacted soils cannot uplift the hydraulic conductivity value and that value is smaller compared to the control plots. But, it still higher compared to the test plots that only compacted and not vegetated.

At Kenjeran Beach Amusement Park, the constant hydraulic conductivity at plot K1 is 23.76% higher than the plot K3 and that on the plot K2 is 35.37% lower than the plot K3. Meanwhile at Lempung Urban Forest, the constant hydraulic conductivity at plot L1 is 14.19% higher than the plot L3 and that on the plot L2 is 50.23% lower than the plot L3.

Runoff Coefficient of Test plots

The average of rainfall height in the last 10 years and rainfall duration in the last 13 month calculated by data from nearest weather stations at Surabaya City are 99.61 mm and 2.28 hours, respectively. Based on test plot conditions, using UDFCD guideline book, the depression losses value for every vegetated soil are 0.35 in or 8.89 mm and 0.4 in or 10.16 mm for bare soils. The runoff coefficient of each test plot can be calculated together with all those data above and infiltration rate measurement.

Infiltration rate measurement is conducted to determine the constant infiltration rate from each test plot. After that, those data will be multiplied with average rainfall duration at Surabaya City to find the constant infiltration height. The result of measurements and infiltration height calculations can be seen at Table 5.

Table 5. The constant infiltration height from each test plot

Test plot	f (mm/hr)	F (mm)
K1	8.000	18.24
K2	1.999	4.5372
K3	1.999	4.5372
K4	1.333	3.03997
L1	1.500	3.42
L2	0.125	0.285
L3	1.000	2.28
L4	0.0625	0.1425

From Table 5 above, it can be seen that test plot with the highest constant infiltration rate and infiltration height in 2,28 hr is plot K1 with silty, vegetated and uncompacted soil. Meanwhile the smallest one is plot L4 with clayey, non-vegetated and compacted soil. For the result of runoff coefficient calculation can be seen in Table 6.

Based on Table 6 data, the plot that generates the highest runoff is the L4 plot with clay-textured, bare and compacted soil at 0.089308 m^3, while the plot with the lowest runoff volume is on K1 plots with silt-textured, with vegetation cover and uncompacted soil by 0.07248 m^3. The trends also happened with the runoff coefficient. The plot that has the biggest runoff coefficient value is the L4 plot with 0,896572, while the plot with the lowest runoff coefficient value is on K1 plot with 0,727638.

Table 6. The runoff coefficients of test plots

Plot	F (mm)	D_L (mm)	(P-D_L-F) (mm)	V_R (m^3)	C
K1	18.24	8.89	72.48	0.07248	0.727638
K2	4.5372	8.89	86.1828	0.086183	0.865202
K3	4.5372	10.16	84.9128	0.084913	0.852453
K4	3.03997	10.16	86.41003	0.08641	0.867483
L1	3.42	8.89	87.3	0.0873	0.876418
L2	0.285	8.89	90.435	0.090435	0.907891
L3	2.28	10.16	87.17	0.08717	0.875113
L4	0.1425	10.16	89.3075	0.089308	0.896572

Analysis of Bio-pore Infiltration Hole Needs and Runoff Reduction

There are 3 locations that are used as representatives or samples for analysis of reduction based on inundation data and map of soil types, namely Arif Rahman Hakim St. with hydromorphic alluvial soil types, Satelit Selatan St. with gray alluvial soil types, and Imam Bonjol St. with dark gray alluvial soil. All these locations can be seen on Figure 2.

Fig. 2: Sample of inundation area at Surabaya City

The selection of these three locations is due to the existence of a green lane on the left, right, and or median of the road in the form of land overgrown by vegetation, where the place can be used for bio-pore expansion, so on Arif Rahman Hakim St., the characteristics of the land are represented by plot K2 (silty, vegetated and compacted soil) and for Satelit Selatan St. and Imam Bonjol St.'s characteristic soil is represented by plot L2 (clayey, vegetated and compacted soil). The results of the analysis can be seen in Table 7.

Based on Table 7, in terms of the amount of land use for BIH and the BIH needs, for silty soils, the percentage of land (% A_{BIH}) that can be used on Arif Rahman Hakim St. for the installation of BIH is 8.73% or 17 m^2 out of inundation areas in there, so the BIH needed that can be installed are 17 pieces. For clay soil, the percentage of land that can be used on Satelit Selatan St. for BIH installation of 25.97% or 177 m^2 out of 681.60 m^2 with BIH needed about 177 pieces and on Imam Bonjol St. the percentage of land that can be used is 4.09% or 420 m^2 out of 10,275.24 m^2 with BIH needed about 420 pieces.

Table 7. Bio-pore infiltration hole needs and runoff reduction from representative locations at Surabaya City

Location	A_{in} (m^2)	A_{BIH} (m^2)	BIH needs	% A_{BIH}	$V_{R\ in}$ (m^3)	Σ V_{BIH} (m^3)	% Runoff Red.
Arif Rahman Hakim St.	194.74	17	17	8.73%	16.78	0.449	2.67%
Satelit Selatan St.	681.60	177	177	25.97%	61.64	1.326	2.15%
Imam Bonjol St.	10,275.24	420	420	4.09%	929.24	3.147	0.34%

In regards to the reduction of runoff volume, for silty soils, the percentage of runoff reduction at Arif Rahman Hakim St. after the installation of BIH is 2.67%. For clay soil, the percentage of runoff reduction at Satelit Selatan St. after the installation of BIH is 2.15% and on Imam Bonjol St. the percentage of runoff reduction after the installation of BIH is 0.34%. Based on these calculations, to achieve the same amount of reduced runoff percentage, 2% or more for example, BIH land use ratio to inundation area on the silty soil tends to be lower than clayey soil when those type of soils are handled in same conditions (vegetated and compacted soils).

Because the compaction was only based on the duration and only have 2 variations between compacted and non-compacted soils, potentially the soils are not compacted enough or have a low degree of compaction, thus area needed for BIH installation and the amount of BIH may be higher on the land or soil with higher degree of compaction for reducing a small percentage of runoff water, especially in big cities with high land uses and in the tropical climate like Surabaya City.

CONCLUSION

The results of the study show that all three research variables have a significant influence on hydraulic conductivity and BIH requirements. Compaction can reduce the hydraulic conductivity in the range of 35.37 - 47.39% on silty soil and 50.23 - 56.22 on clayey soil. The presence of vegetation cover can increase the hydraulic conductivity around 23.76% on silty soil and 14.19% on clayey soil. With the same soil conditions, for example, vegetated and compacted soil, on the silty soil tends to have lower BIH land use ratio to inundation area and less BIH requirements than clayey soil in order to achieve the same amount of reduced runoff water ratio. However, this may be only applicable to the land or area that not have a high degree of compaction because the compaction variables were not on the wide range. And, that possibility requires further research.

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Evaluation of Water Distribution Network and Efforts for Improvement for the City of Banyuwangi

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ABSTRACT

The drinking water sector is the aspect of development that has a pivotal function to support the welfare of society. This is due to health, lifestyle, residential environment conditions and comfort in daily life. The service of the piped water supply system (SPAM-JP) for the service of the capital city of Banyuwangi Regency covers 5 Subdistricts, with 44% clean water service coverage, installed production capacity of 405 liters/second and operating 330 liters/second, to service 34,319 Connection Units with customers domestic (Household) as many as 32,271 units and non-domestic as many as 2,046 units of connection. In addition, the level of continuity has not yet been achieved, this can be seen in some service areas during peak hours not flowing, besides the level of water loss is 25%. In anticipating all problems in the service, research is conducted by analyzing the technical aspects, financial aspects, and institutional aspects. In analyzing each aspect, it was used the appropriate method and updated data. The technical aspects was done by calculating water balance uses easy calk, network analysis using epanet 2.0 and determining improvement efforts. In the institutional aspects was done by the assessment of BPSPAM, while the financial aspects by analyzing the investment costs of network improvements required and alternative funding. The evaluation of existing conditions is that the production and distribution units are not optimal, in the water balance the water loss is 25%, from the HR assessment there is no activity to improve the existing HR and efforts to improve the distribution network include general improvements in the form of pipe replacement and DMA formation in all service areas and managements, namely by increasing HR and developing computer-based information systems.

KEYWORDS: Drinking water, continuity, water loss.

I. INTRODUCTION

The drinking water sector is an aspect of development that has an important function in supporting the level of community welfare. This is due to health, lifestyle, residential environment conditions and comfort in daily life. So that along with the increase in population, it also increases the demand for water.

Drinking water supply system by PDAM with five sub-districts. fulfillment of PDAM drinking water services using five springs and five drill well [1], until 2018 the production capacity 405 liters/ second and operates 330 liter/second, to serve 34,319 SR units, with domestic customers (households) as many as 32,271 units, service coverage 41% while water leakage rates 25%. For continuity still not fulfilled with the frequent water does not flow in the peak hours of use.

Increasing the service of drinking water supply, PDAM must have an effort to meet the criteria in terms of quantity, quality and continuity. One effort to improve water supply services is to optimize the drinking water distribution system by evaluating distribution network systems, water loss rates and water stability indexes in the distribution system.

According to PP No: 122 of 2015 concerning drinking water supply system paragraph 1 which says SPAM is held to provide drinking water services to the public to fulfill the people's right to drinking water [2]. In addition, to support universal access (100-0-100) and the Sustainable Development Goals (SDGs) until 2030, namely clean water and proper sanitation. So to get access to 100% drinking water, research is carried out to help contribute ideas in order to improve drinking water services in Banyuwangi Regency with the research title: "Existing Evaluation and efforts to improve the distribution network of Banyuwangi District PDAM (Banyuwangi City Study Area).

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II. RESEARCH METHODS

1. Study location

The research location is the Banyuwangi City area which is part of the PDAM service in Banyuwangi Regency covering five sub-districts consisting of Banyuwangi District, Kabat District, Glagah District, Giri District, Kalipuro District.

2. Method

In the preparation of this study is to evaluate drinking water services and infrastructure of drinking water management systems (SPAM) that have been built to determine strategies in an effort to improve drinking water services in Banyuwangi Regency PDAM in the service area of Banyuwangi City through the improvement of the existing distribution network. The achievement indicators can be identified by analyzing the service data and the conditions of the existing SPAM infrastructure from the Banyuwangi Regency PDAM for the Banyuwangi City area, the research methods implemented can be described as follows:

a. **Data collection.**

Data collected are primary data and secondary data obtained from the relevant agencies in the form of documentation, statistical maps and so on.

- Secondary data.
  That is to see all installations / networks in PDAM Banyuwangi Regency and other equipment that have an effect on the distribution system with the aim of knowing the existing network conditions of the PDAM Banyuwangi Regency
- Primary data
  Primary data is data obtained by conducting interviews directly with respondents or by filling out questionnaires and direct goals towards the object of research. Primary data includes:
  1) Field survey
     That is to see a.ll installations / networks in PDAM Banyuwangi Regency and other equipment that have an effect on the distribution system with the aim of knowing the existing network conditions of the PDAM Banyuwangi Regency.

  2) Conduct questionnaires for customers PDAM and non customers PDAM
     In sampling from members of the population at random, the number of 398 samples circulated is calculated using a formula (Slovin, 1960) quoted in sugiyono, 2018 [3]. Calculation of the comparison of PDAM customers is 44% and non-customers is 57%.

b. **Evaluation and discussion**

Data obtained at the data collection stage will then be processed to obtain results in accordance with the research objectives. Data analysis or evaluation is based on the technical aspects that include:

- Water balance related to NRW
  Understanding the amount of water entering the system, official water consumption and water loss and calculating the components of water loss in the water balance are expected to help the PDAM make priority handling by making a water balance (WB) using WB-Easy Calc 2018 software [4].
- Distribution Network.
  Analyzing distribution systems related to production and distribution capacity to meet the needs of drinking water by analyzing water pressure, piping conditions from existing data using the epanet 2.0 application[5].

III. RESULTS AND DISCUSSION

A. Real Need Survey

PDAM Customer Respondents

- Based on the survey results, it can be evaluated that the majority of PDAM customer respondents in 1 (one) house are 4.45 people, which are then rounded up to 4 (four) people, with the main job being civil servants / TNI / Polri / Private Employees and entrepreneurs who have a monthly income of more than Rp. 2,132,779.35 (Banyuwangi Regency minimum wage according to East Java Governor Decree No: 188/665 / KPTS / 013/2018 concerning Regency / City minimum wages in East Java in 2019). Water use is used for all household activities with an average consumption per month of 18,660 liters (18.66 cubic meters).
- The level of customer satisfaction in terms of the quality of water obtained all states in general clear, but in certain conditions or situations the level of community and water pressure decreases.

Non Customer PDAM

- All non-PDAM customers use groundwater sources from both bore wells and dug wells and to fulfill daily life needs. and for responses to the PDAM if there is a government program to expand PDAM network installations, with a majority of 71% interested.

B. Evaluation of Technical Aspects of Drinking Water in Urban Areas

a. Calculation of Water Balance (Water Balance)

Water balance is very important in the program to reduce water loss. Because the water balance can be used as a framework for assessing water loss conditions, it can also show the magnitude of each component of the water balance, including the sources and costs of water loss and future planning. Calculation of water balance in this study using the WB-EasyCalc version 5.16 program.

Based on data from water balance analysis using the WB-EasyCalc version 5.16 program. the current condition of the percentage of water loss is 25% with a composition of physical water loss of 22%, and non-physical water loss of 3%.

b. Evaluate with Epanet

Evaluation with epanet as illustrated below, with the results of the value of the speed of the flow of the existing network, some of which meet the criteria of minimum 0.3 to a maximum of 3 m / sec [6], and some do not meet or exceed the maximum limit due to elevation which is too steep or because of the small diameter of the pipe therefore after analyzing the existing main distribution pipeline network through simulation using epanet 2.0 software, improvement efforts are needed and are guided by the Minister of Public Works Regulation No: 27 of 2016 concerning the provision of drinking water systems.

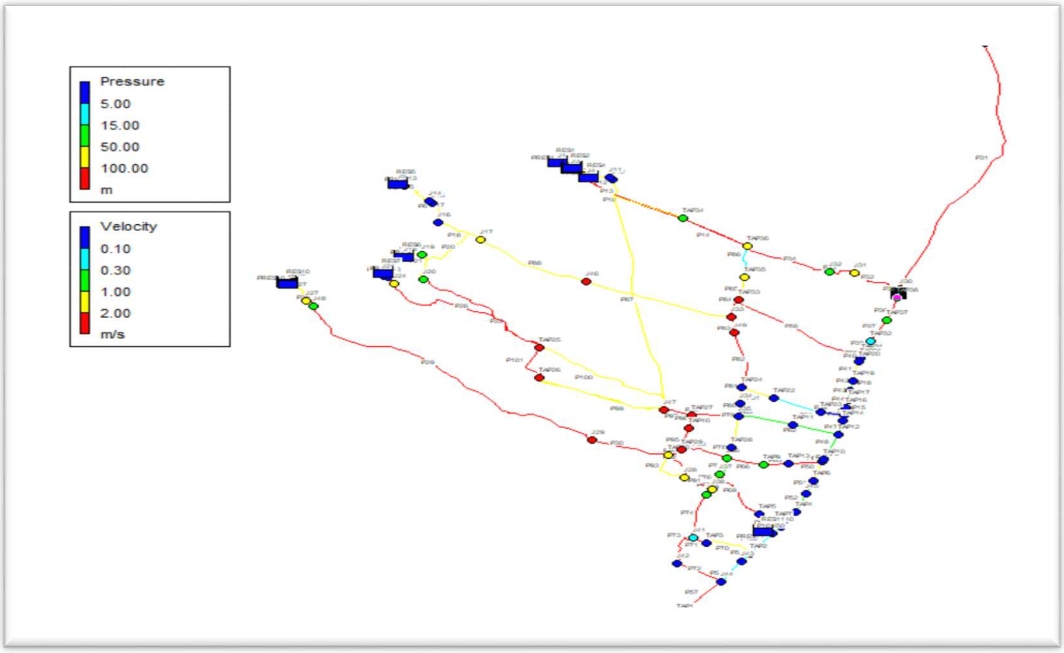

Fig. 1: Simulation results of the main distribution network (Existing)

c. Pipeline network repair with Epanet 2.0 simulation.

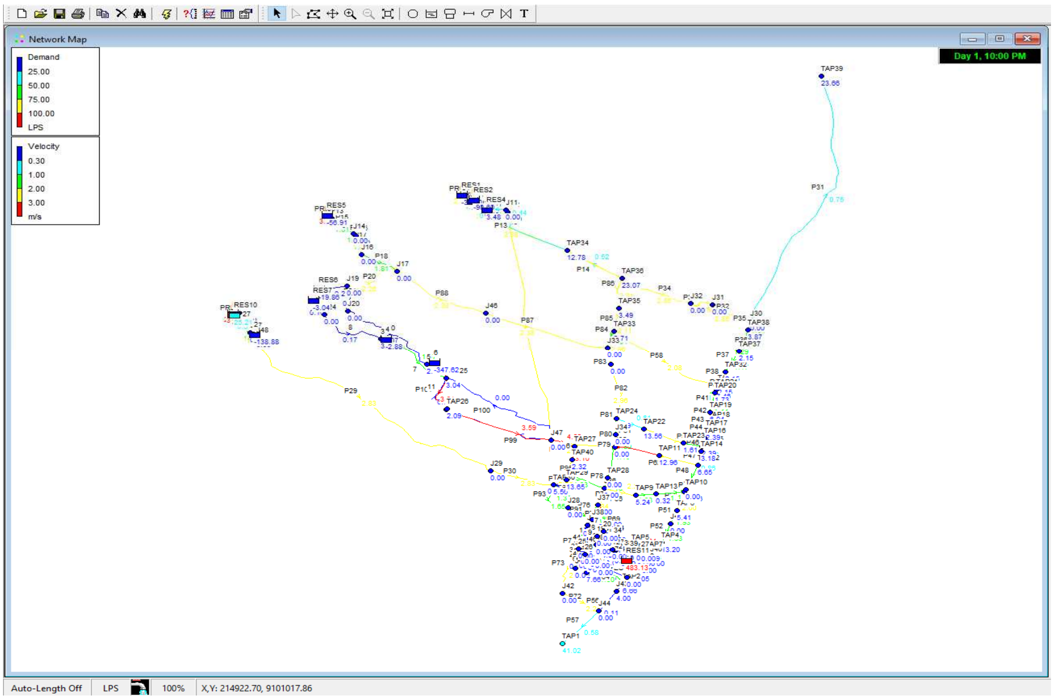

Fig. 2: Repair of the main distribution network

Epanet simulation results, pressure at minimum water consumption hours (01:00) at all service areas still meet the standards of more than 10 m. The peak water consumption hours (17:00) still meet the standards. This is due to the addition of BPT in the upper area to reduce or isolate the pressure so that the pipe does not leak. In addition, the replacement of pipes with different diameters in order to regulate the speed.

d. Simulation with the establishment of the Meter Area District (DMA)

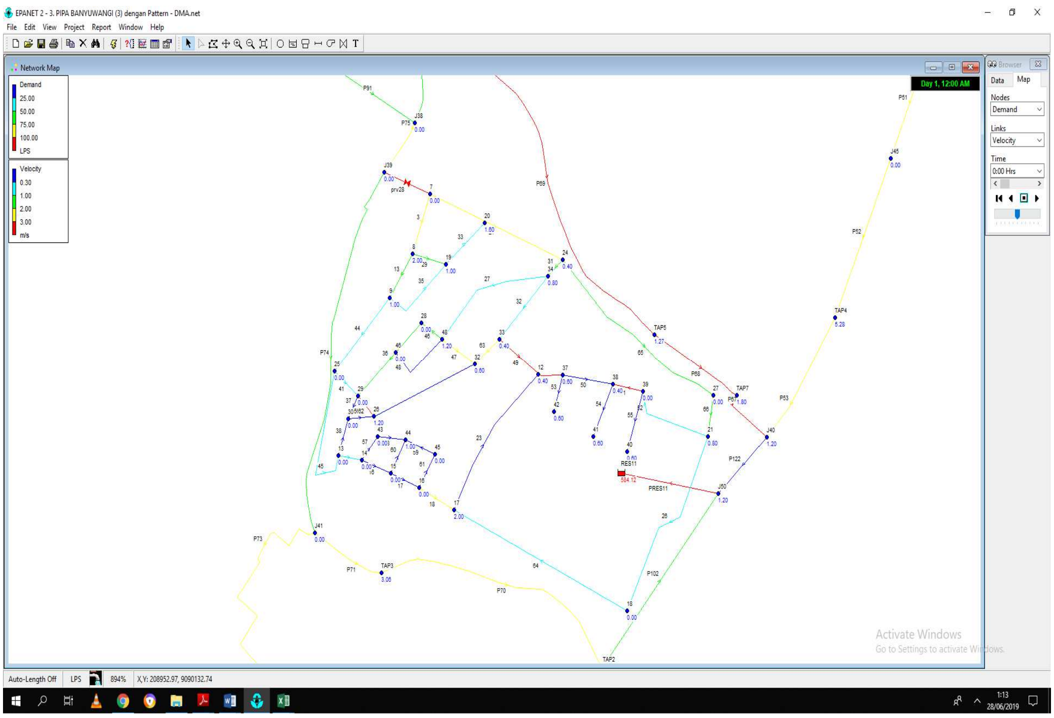

Fig. 3: Simulation with the establishment of the Meter Area District (DMA)

Running results in the Sobo area which are formed by DMA can be known, namely for the value of pressure (velocity) and the velocity of the pipe (velocity), velocity (velocity), based on the Epanet simulation results, there are many distribution pipelines in this service area Flow[7].
In addition, with the formation of DMA can facilitate monitoring of water usage by customers, simplify the search for distribution pipeline leakage, facilitate scheduling of production meter replacement, master meter and customer meter, facilitate illegal connection tracking (illegal connection), distribution network system optimization (pressure management)

IV. CONCLUSIONS

Based on the analysis that has been done can be concluded, among others:
- With water balance, water loss can be 25% with a composition of physical water loss of 22%, and non-physical water loss of 3%. So that the volume of water in the pipeline distribution network decreases and does not reach the PDAM customers.
- With epanet 2.0 simulation on the existing distribution network, repairs are needed to meet or comply with the Minister of Public Works Regulation No: 27 of 2016 concerning the operation of drinking water supply systems.

So it can be concluded that technical steps are needed to overcome these problems, among others, by establishing a service zone (DMA) and replacing old pipes but still operating, one of which is the replacement of artificial pipes in the Dutch era which are still operating.

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Basic Concept of Area Designation and Distribution of Green Open Spaces

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ABSTRACT

The scientific basis used is that the activities of human life require energy of 28 MJ / person / day and produce carbon dioxide of 2,600 g / person / day. Absorption of carbon dioxide by plants is taken at 3 g / m2 / day. The assumption of the dimensions of the biosphere ecosystem as an active absorber of carbon dioxide is the thickness of the aquatic, soil and leaf canopy, respectively 0.1 m and the thickness of the air layer 3 m. The results obtained are that each population requires a plant area of 25 m2 or in the range of 20-30 m2. Plant area in places near the waters is wider than in places far from the waters. Rows of plants with longitudinal directions (north-south trajectory) are more advantageous than transverse directions (east-west trajectory). So plant area and plant area distribution are not evenly distributed in urban areas. Through the greening of the city the implications for the aspects of urban development, both superstructure and infrastructure, were also presented. Thus this paper is at the same time a contribution to the development of environmental science and technology in supporting life activities on an ongoing basis.

KEYWORDS: active absorber, carbon dioxide, superstructure, infrastructure

1. INTRODUCTION

Global warming is mainly due to the accumulation of carbon dioxide in the air from various sources of life activities. Carbon dioxide accumulation can be suppressed by natural biological methods, which is greening. The legality of urban greening refers to the two existing regulations in Indonesia. Instruction of the Minister of Home Affairs [1] stipulates that green open space in urban areas is 40% of the city area. Law 41/1999 [2] stipulates that the forest area is at least 30% of the watershed and or island area with a proportional distribution. The basis for determining plant area is unknown, besides the distribution is not explained, so that it can complicate the application in the field. This paper discusses the approach of (1) determination of plant area and (2) distribution of plant area within the framework of preserving the quality of the global environment.

2. Green open space area formulation

Human life activities require minimum energy of 28 MJ / person / day. Human energy is obtained from food sources (for life) and fuel (for activities) as much as 40% and 60%, respectively. Food and fuel can be expressed as carbohydrates. One carbohydrate molecule produces energy of 2.8 MJ. So human energy needs are equivalent to carbohydrate requirements of 10 molecules / person / day [3].

All carbon dioxide output is wasted in the environment. Carbon dioxide is partially absorbed by water in ponds, reservoirs, waterways, rivers and the sea. The ability of water to absorb carbon dioxide in addition to depending on climatological aspects is also the quality of water that needs attention in relation to human activities. The higher the level of water pollution by organic substances, the more water is saturated with carbon dioxide so that the water's ability to absorb carbon dioxide becomes small. This means that the ability of waters to absorb carbon dioxide is a full influence factor so it is difficult to calculate accurately.

Some of the carbon dioxide emissions will be absorbed by the soil. As with water, the ability of the soil to absorb carbon dioxide is a full influence factor. The land must not be covered with cement, asphalt, buildings and not polluted. In addition, physical, chemical and life characteristics in the soil are complex. Under these conditions it is difficult to make accurate calculations of the ability of the soil to absorb carbon dioxide.

The air is the most flexible reservoir of carbon dioxide. In addition to the volume of air is much greater than water and soil, the air can move carbon dioxide in various directions horizontally and vertically. Climate and weather factors make it difficult to calculate the ability of air to absorb carbon dioxide.

The difficulty of predicting the ability of the environment for absorption of substances is simplified by the world ecosystem model [4-6]. The world ecosystem is reduced and made compartmentally for a certain area. The physical compartment of the ecosystem consists of air compartments, water compartments and soil compartments. In each of these physical compartments living compartments can be added with a variety of proportions. Based on the idea of a world ecosystem model, the following approaches can be made for certain areas of the city ecosystem:

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- Air compartments taken as high as 3 m. An altitude of 3 m is taken assuming that the layer of air that absorbs active carbon dioxide is 2 x the height of the average human nose (1.5 m).
- Water compartments taken as deep as 0.1 m. 0.1 m water depth is taken based on the greatest possible zone of reaeration of air into the water for active absorption of carbon dioxide.
- Land compartments taken as deep as 0.1 m. A soil depth of 0.1 m is taken based on the greatest possibility of water unsaturation zones for active absorption of carbon dioxide.

Thus the proportion of compartment volume in the volume of urban ecosystems for carbon dioxide absorption shows:

Air Vol + Water Vol + Land Vol = ecosystem Vol

(3 x A) air + (0.1 x A) waters + (0.1 x A) land = (3.2 x A) ecosystem

In a certain ecosystem area, then A is the same for each compartment, then the proportion of the volume of the air, water and soil compartments for carbon dioxide absorption:

Vol air = 94% Vol ecosystem

Vol waters = 3% Vol ecosystems

Soil Vol = 3% Vol ecosystem

The volumetric proportion of carbon dioxide uptake shows that air is the largest exhaust media for carbon dioxide. If all carbon dioxide is discharged into the air then the negative impact caused is the greenhouse effect, which is an increase in the surface temperature of the earth.

To reduce the increase in the surface temperature of the earth from carbon dioxide, this study was conducted biologically. Among the components of biological creatures that need carbon dioxide are chlorophyll biota. In the study of green open space, plants become the mainstay for carrying out photosynthesis conversion. Thus, plants are placed as compartments of urban ecosystems. Plants as carbon dioxide absorbent compartments are calculated for leaf canopy. The approach to a specific area of the city's ecosystem is now:

- Air compartments as high as 3 m.
- Ground compartment 0.1 m deep.
- Water compartments as deep as 0.1 m.
- Plant compartments taken 0.1 m thick canopy. The thickness of the leaf canopy was taken as the closest average estimate for various plant species.

Thus the proportion of compartment volume in the volume of urban ecosystems for carbon dioxide absorption shows:

Air Vol + Water Vol + Land Vol + Plant Vol = Ecosystem Vol

(3 x A) air + (0.1 x A) waters + (0.1 x A) soil + (0.1 x A) vegetation = (3.3 x A) ecosystem

In a certain ecosystem area, then A is the same for each compartment, then the proportion of the volume of the air, water, soil and plant compartments for carbon dioxide absorption:

Vol air = 91% Vol ecosystem

Vol waters = 3% Vol ecosystems

Soil Vol = 3% Vol ecosystem

Plant Vol = 3% Vol ecosystem

Comparison of the proportion of air volume decreases to the same extent for the volume of plants (3%). That is, assuming the average thickness of the canopy is appropriate. Besides that, the amount of 3% of air volume absorbing carbon dioxide is taken over by plants. This is realistic in a biological effort to reduce the surface temperature of the earth due to the accumulation of carbon dioxide in the air.

The ability of plants to absorb carbon dioxide is certain. It is generally identified that plants are able to absorb carbon dioxide by a maximum of 6 g / m2 / day in ideal conditions. Under conditions of environmental uncertainty, an average ability of plants is 3 g / m2 / day. Volume of plants absorb carbon dioxide by 3%. The result of carbon dioxide in human life is 2,600 g / person / day. Thus each resident needs a plant area (leaf canopy area) of: 1 person = 3% x 2,600 g / person / day: 3 g / m2 / day equals 25 m2 plant area.

3. Correction of plant area

The maintenance of urban plants by pressing the leaves becomes mandatory with the following objectives. The first goal is to maximize the absorption of carbon dioxide. Ecologically, the ability of plant functions to be maximized when falling solar energy can be absorbed efficiently. For each type of plant a high efficiency of solar energy will be obtained for the conditions of the rough canopy, leaf layers and leaf trimming at the bottom. Crude headlines allow sunlight to be captured by many leaves. Layered leaves allow the catch to be absorbed maximally. The lower leaves lack solar energy so that the carbohydrates that are formed will be overhauled into carbon dioxide. To prevent loss of carbohydrates, the correct pressing pattern is from the bottom. Pressing of the lower leaves should not be carried out simultaneously for a group / series of plants. Pressing alternately should be made alternately in a set / series of plants. For plants that have been squeezed clearly will grow faster than those that have not been pressed, because the reshuffle of carbohydrate plants are not as much as plants that have not been pressed. The difference in growth will make the canopy / series of plants become coarse and produce a configuration of layers in layers.

The second goal concerns the practice that has been done so far [7,8]. The topping of the leaves is done to prevent the disruption of city utilities, fears of vegetation collapse during the rainy season, consideration of other disturbances such as fire. In that framework, the pressing of the upper part of the plant should be done. Even so the pressing of the upper leaves is still recommended to use a pattern of alternating or selective and alternating time so that it is not completely contrary to the first goal. Whatever is done with the upper leaf stripping is a consequence of reducing the ability of plants to absorb carbon dioxide.

In the condition of pressing the lower leaf is the same as pressing the top leaf, then the need for plant area is not needed correction factor. But taking into account practical practices (not requiring equilibrium measurement of upper and lower leaf pressing) the plant area needs a correction factor. So far there is no scientific basis to support the determination of the aforementioned correction factors, except practical considerations of maintenance in the field. For example, the City Parks Department is only able to maintain 20% of the plant area, so for the pressing of the upper leaves, a correction factor of 1.2 is required and for the correction of the lower leaves, a correction factor of 0.8 is required; both of which are in equation 6). To simplify the problem of determining plant area, the following formula is taken: 1 soul equals (20-30) m2 plant area.

4. Distribution of plants

The distribution of plants can be approximated by the photosynthetic conversion formula (equation 4). Absorption of carbon dioxide by plants requires water to produce carbohydrates (expressed as plant growth) and oxygen. To maintain plants continuously, the distribution of plants should be more in the available waters. Thus the distribution of plants does not need to be evenly distributed within the city.

In line with this, it is known ecologically that the absorption of carbon dioxide to produce carbohydrates depends on solar energy. The intensity parameter (which shows the amount of energy received per unit area per unit time) will determine the best path for plants for the same unit area. In the morning, afternoon and evening, a series of plants in the longitudinal direction (north-south trajectory) will be more beneficial than transverse direction (east-west trajectory). Longitudinal direction allows each plant to be treated the same sunshine throughout the day.

Related to the intensity of sunlight for plant growth is topography. The intensity of sunlight is higher in the mountains (around 1.75 g cal / cm2 / min) compared to the lowlands (around 1.50 g cal / cm2 / min). In the framework of ongoing maintenance of plants, the distribution of plants should be more at high places in an urban ecosystem.

5. Green open space

Examples of concrete applications for the city of Surabaya will be explored below. The city has 3 waterways, namely S. Surabaya, K. Wonokromo and K. Mas. The river channel divides the city into 3 zones, namely west, east and south. The west and east zones relate to the sea and the south zones relate only to land. The city topography shows the west zone and the south zone are higher than the east zone.

The spread of green open space should be more in the west zone and east zone than the south zone. Specifically, mangrove forests must be maintained in the north coast region in the west zone and the east coast area in the east zone. The distribution of green open space is more propagated in the west zone in the west and in the south zone more in the south (both at the highest topography of each zone). Longitudinal directed plant trails. Thus the green open space is spread unevenly and a rough canopy profile will appear.

The area of green open space is determined based on the population of the city of Surabaya. If the city currently has a population of 3 million and an increase of 1 million / 30 years, 60-90 km2 of green open space is needed at this time and an additional 20-30 km2 every 30 years. The city of Surabaya has an area of 340 km2 and currently requires an area of green open space of at least 20% of the city area and an increase of up to 40% of the area of the city until the age of 1 coming generation of residents.

6. Conclusions on green open space layout and its implications

Overview of green open space in an area can be approached by the reaction of carbohydrate respiration and photosynthesis of carbon dioxide in a hypothetical ecosystem model. The different assumptions used in the ecosystem model will result in differences in the needs of the wide green open space, but do not affect the following characteristics:

(1) Respiration and photosynthesis reactions make the relationship between population and plant area. The population of each region is not the same and so is the area of green open space.

This conclusion has implications for the spatial planning of a population area (urban and rural). As long as the area is fixed and the population increases, the provision of green open space must increase. The increase in the area of green open space is practically impossible to the extent of the area (100%). This requires a study of the new ecosystem structure of a region, which establishes the proportion of the area's land use. Whatever will be produced in the new ecosystem order, the direct implication of the dynamics of green open space is that the superstructure development policy (housing and buildings) needs to be directed vertically. The environmental advantage of this policy is the improvement of air quality through air turbulence mechanisms.

(2) Photosynthesis reactions direct the spread of plant area based on water availability, topography. The distribution of plant area is uneven in each region.

This conclusion has implications for the direction of spatial planning of population activities. Housing and building developments need to be directed at flat topographic areas and far from watersheds. The environmental advantage of this policy is the improvement of water quality through spatial mechanisms (away from pollutant sources).

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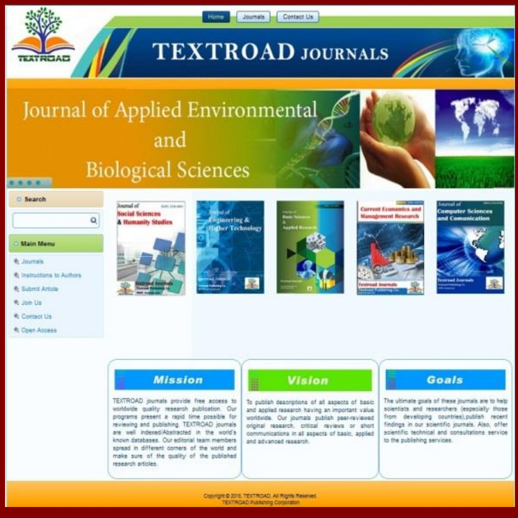

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1. Makarewicz, J.C., T. Lewis and P. Bertram, 1995. Epilimnetic phytoplankton and zooplankton biomass and species composition in Lake Michigan, 1983-1992. U.S. EPA Great Lakes National Program, Chicago, IL. EPA 905-R-95-009.

Conference Proceedings:

1. Stock, A., 2004. Signal Transduction in Bacteria. In the Proceedings of the 2004 Markey Scholars Conference, pp: 80-89.

A Thesis:

1. Strunk, J.L., 1991. The extraction of mercury from sediment and the geochemical partitioning of mercury in sediments from Lake Superior, M. S. thesis, Michigan State Univ., East Lansing, MI.

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