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The prospect of utilizing recycled wastewater in conserving freshwater usage in an industrial park

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Abstract. Recycled wastewater has been identified as an alternative source of domestic water. This paper assesses whether the utilization of recycled wastewater produced by an industrial park in Batam Island could reduce the freshwater extraction from the primary source. The analysis is carried out by probing the record of water usage and the sewage treatment plant's production in the industrial park for almost 2 years. The recycled wastewater's quality limits its usage only for gardening and toilet flushing. Even if it cannot cover all sorts of activities, utilizing recycled wastewater could conserve freshwater significantly. The industrial park also could reap another benefit by paying less for freshwater extraction. However, the existing plumbing system does not have a specific distribution line for both gardening and flushing. Therefore, the industrial park must rebuild the entire plumbing system lest the recycled wastewater would mix with the clean freshwater and prevent the workers from using it.

1 Background

Access to freshwater is an indispensable right for every human yet it is still unattainable for many people. WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) reported that many countries are still short of basic access to drinking water as illustrated in Fig. 1 [1].

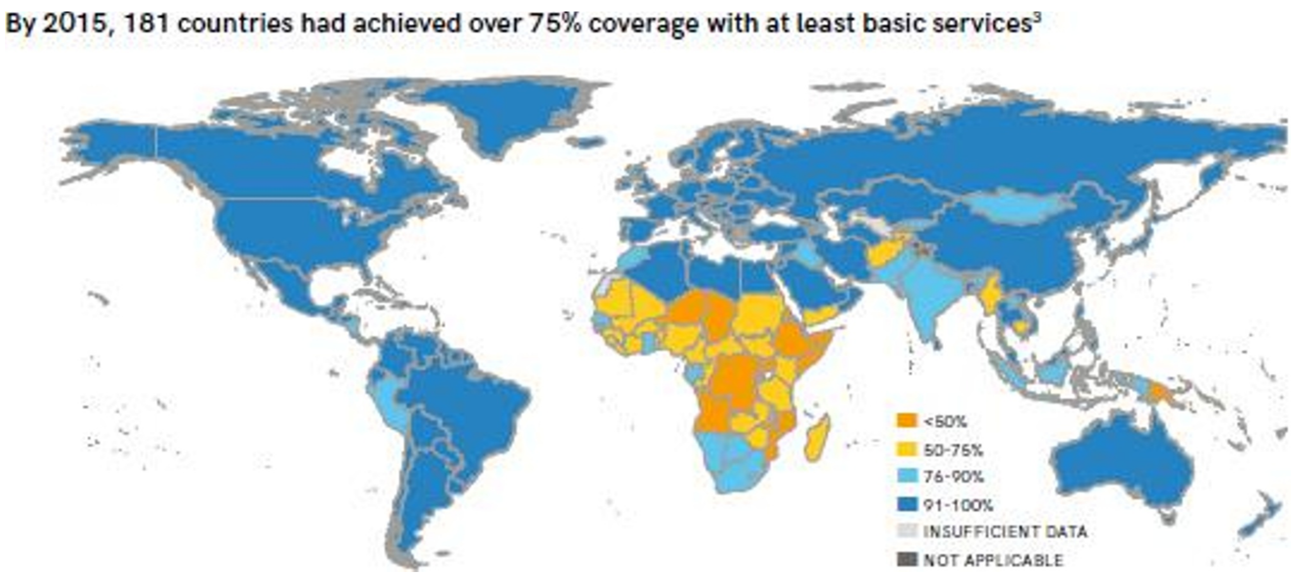

Fig. 1. The map of nations whose at least 75 % of the population has access to drinking water services [1].

Worse, even when people have access to freshwater they still couldn't satisfy their water demand stably. Fig. 2 indicates there are still many parts of the world which lack water for most of the time in a year. Water scarcity could affect 4 billion people or 71 % of the global population [2].

Indonesia also suffers from water scarcity in several regions as reported by several studies [3-7]. Water is used by numerous sectors such as agriculture, households, industry, etc. Because water is not always abundantly available and many stakeholders require it, it creates tension among various water users [8-9].

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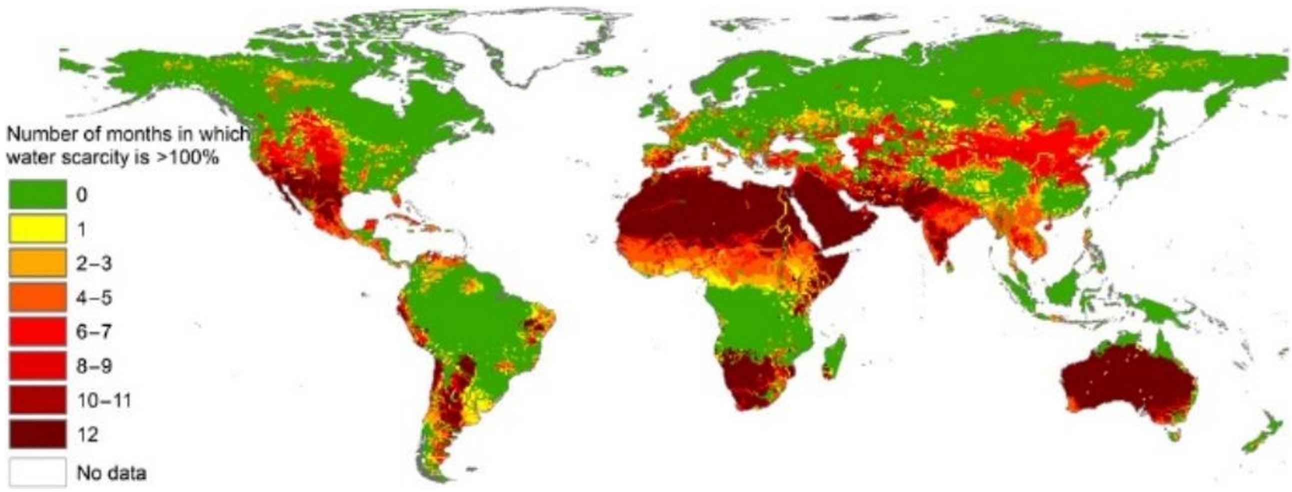

Fig. 2. Countries and their severity in the water scarcity throughout the year.

Industry requires abundant water in its activity for various purposes. An industrial park is an area dedicated to the industry sector. Due to the concentration of the factories within, an industrial park tends to consume a lot of water. Consequently, it could cause water shortage in the larger area or it could aggravate the scarcity [10-11].

Global freshwater scarcity is a serious threat which looms over every nation in the world. Indonesia is not an exception as elaborated in the previous paragraph. Solutions must be formulated and an alternative is by reutilizing recycled wastewater (RWW) for daily use. The practice has been researched and implemented extensively for various purposes such as toilet flushing or irrigation [12-14]. Therefore, it is also potentially implemented in an industrial park to reduce water usage.

Reuse is beneficial for all stakeholders. It helps to conserve natural freshwater which is under a lot of stress due to the ever-increasing water demand. It also reduces the water expense for the users. Considering those potential benefits, this paper investigates the prospect of RWW reuse in an industrial park. It analyzes how its effectiveness in reducing its water extraction when the RWW is utilized to meet the water demand.

2 Methods

The research is performed in an industrial park in Indonesia. Its satellite imagery is shown in Fig. 3 (inside the red line). The name of the industrial park will not be revealed here and is only available upon request. According to its official website, its area is 320 ha rented by 59 tenants who operate factories. The website also elaborates on its supporting infrastructures such as a water treatment plant (WTP) with 4500 m^3/day capacity and a sewage treatment plant (STP) with 10000 m^3/day capacity.

The industrial park satisfies its daily water demand by extracting freshwater from a lake which is located next to it. The lake water is drawn by the water supplier and treated first by the WTP before being distributed to the people.

The domestic sewage inside the industrial park is collected from each building and then distributed through the pipe network until it reaches the STP. The sewage is treated here and the effluent is discharged outside the industrial park. According to the industrial park's staff, the treated wastewater has not been utilized for daily use.

Fig. 3. The aerial view of the industrial park.

The authors requested data about the number of the industrial park's occupants. Most of them are factory workers and the rest are the industrial park managerial staffs, maintenance workers, etc. Their numbers are presented in **Table** 1.

Table 1. The number of persons in the industrial park.

	2021	2022
Factory workers (persons)	36358	37268
Dormitory occupants (persons)	5642	5732
Total (persons)	42000	43000

Only some of the factory workers live in the dormitory inside the industrial park. The rest live in the city where the industrial park resides. The time they spend in their dormitory room varies depending on their factory shift.

The water usage for various purposes was collected from multiple approaches. Below is the data obtained and the method to obtain them:

1. The water usage of the factories and the dormitories was identified from the water bill paid to the water

supplier. It contains the water volume extracted from the lake.
2. The RWW volume was identified by installing the flowmeter at the STP's outlet. The volume is recorded daily in October.
3. The gardening water usage was acquired by measuring the water used by the water trucks.

The water bill from the factories and the dormitories was requested to figure out the quantity of each water usage.

3 Results and Discussions

Fig. 4 presents the water usage of the industrial park which is classified based on its location i.e. the factory (red line) and the dormitory (blue line). The total of both is represented by the black line. More people are working in the factory than in the dormitory (see **Table** 1) thus the former's usage is much greater.

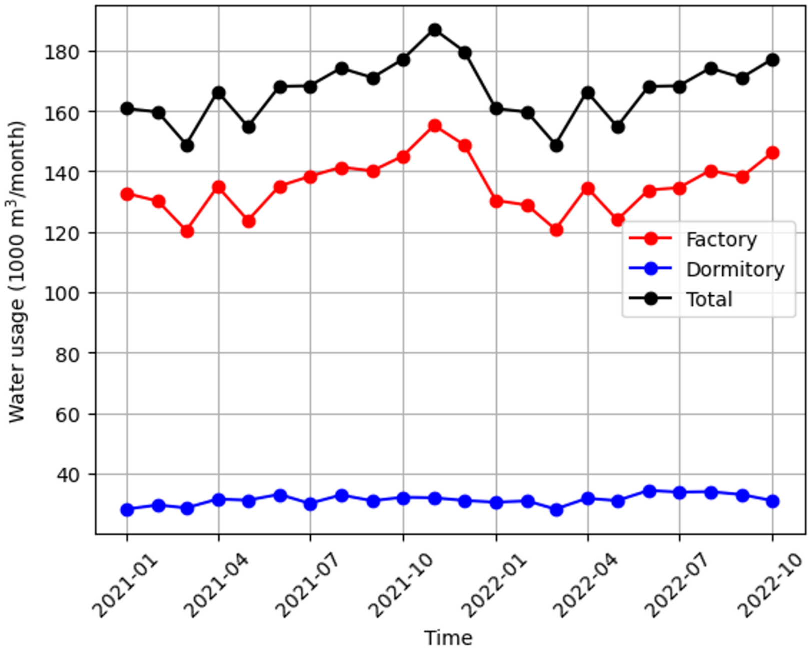

Fig. 4. The amount of water usage for various purposes within the industrial park.

Within these 22 months of observation (**Fig. 4**), the monthly average of the water usage of the industrial park is displayed in **Table 2**.

Table 2. The average monthly water usage in the industrial park.

Location	Monthly average (m^3/month)
Factory	135335.41
Dormitory	31279.27
Total	166614.68

The average water demand from January 2021 until October 2022 for each person in the industrial park is revealed in **Fig. 5** while the values are in **Table 3**.

Table 3. The average water usage per day per person in the industrial park throughout the observation.

Location	Average per capita (litre/day/person)
Factory	126.16
Dormitory	181.15
Total	129.19

The national standard estimated a worker in a factory could use 70 litre/day/person [15]. The result in **Table 3** (126.16 litre/day/person) is much larger. The possible causes are the current factory uses up more water than in the past or/and the pandemic instils higher sanitation standards.

Based on the National Statistics, the population of Batam City in 2020 is 1196396 persons [16]. And, according to the national guideline about freshwater usage, a city with more than 1 million persons is categorized as a metropolitan city and its water demand is > 150 litre/day/person [17]. The dormitory's water demand is 181.15 litre/day/person (**Table 3**) thus the number makes sense.

The STP's production was monitored for one full month in October. The volume of the RWW is illustrated in **Fig. 6**. The measurement showed the STP produced 160163 m^3 of RWW in October which translates into 5166.55 m^3/day. Because the measurement period is only 1 month, this value will be assumed constant throughout the year.

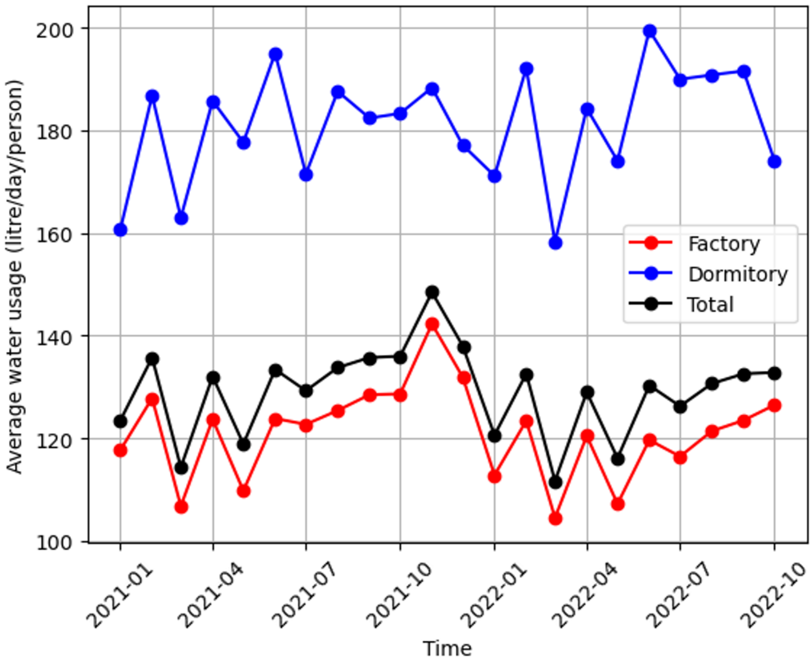

Fig. 5. The average water usage per day per person.

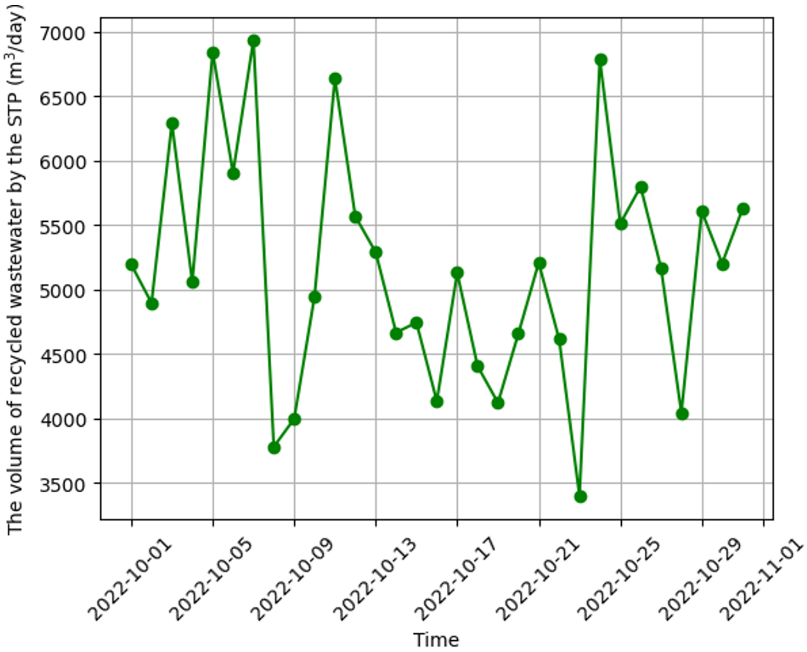

Fig. 6. The observation of the recycled wastewater production.

The water from the STP and WTP was tested to determine whether it is safe. The quality standard is Government Regulation 22 of 2021 Protection and Management of Environment [18]. The regulation classifies water into 4 classes, Class 1 is the best quality and it is safe for drinking water. Conversely, Class 4 is the worst and it is only suitable for plant watering.

Table 4 compares the quality of the RWW and the WTP. The examination revealed the former is generally comparable to the latter. The water from WTP has excellent quality because all parameters are in Class 1. The water from STP also generally falls in Class 1 although some parameters fall in lower classes.

Since the paper does not focus on the topic of water quality. the authors do not probe if the RWW is safe for various activities. Because the RWW's quality is generally satisfactory, the paper assumes the RWW is feasibly applicable for gardening and flushing, but not for non-flushing human usage e.g. bathing, handwashing, etc.

According to multiple references, flushing demands approximately 30 litres/day [19-22]. The rate is multiplied by the total residents in the industrial park i.e. 43000 persons (see **Table** 1) thus the flushing water usage is estimatedly at 1290 m^3/day or 38700 m^3/month.

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Table 4. The comparison of the water quality produced by the STP and WTP benchmarked with Government Regulation 22 of 2021.

Class 1	Class 2	Class 3	Class 4	< Class 4

	Parameter	Unit	STP	WTP
1	Temperature	°C	29.20	28.1
2	Total dissolved solids (TDS)	mg/L	186	94
3	Total suspended solids (TSS)	mg/L	44	15.28
4	Colour	Pt-Co Unit	-	2
5	Degree of acidity (pH)		6.61	6.1
6	Biochemical Oxygen Needs (BOD)	mg/L	-	-
7	Chemical Oxygen Needs (COD)	mg/L	-	-
8	Dissolved oxygen (DO)	mg/L	-	-
9	Sulfate (SO42-)	mg/L	-	6.54
10	Chloride (Cl-)	mg/L	-	16.45
11	Nitrate (as N)	mg/L	< 0.5	<0.05
12	Nitrite (as N)	mg/L	0.11	<0.004
13	Ammonia (as N)	mg/L	0.78	< 0.07
14	Total nitrogen	mg/L	-	-
15	Total Phosphate (as P)	mg/L	-	< 0.03
16	Fluoride (F-)	mg/L	0.12	< 0.02
17	Sulfur as H2S	mg/L	-	-
18	Cyanide (CN-)	mg/L	< 0.008	< 0.008
19	Free chlorine	mg/L	< 0.002	2.29
20	Barium (Ba) dissolved	mg/L	<0.10	-
21	Boron (B) dissolved	mg/L	-	-
22	Mercury (Hg) dissolved	mg/L	< 0.0001	< 0.0001

Table 5 (continued). The comparison of the water quality produced by the STP and WTP benchmarked with Government Regulation 22 of 2021.

Class 1	Class 2	Class 3	Class 4	< Class 4

	Parameter	Unit	STP	WTP
23	Arsen (As) dissolved	mg/L	< 0.0001	< 0.0001
24	Selenium (Se) dissolved	mg/L	< 0.0001	-
25	Iron (Fe) dissolved	mg/L	0.54	< 0.07
26	Dissolved cadmium (CD)	mg/L	< 0.001	< 0.001
27	Cobalt (CO) dissolved	mg/L	< 0.11	-
28	Manganese (Mn) dissolved	mg/L	< 0.09	< 0.009
29	Nickel (Ni) dissolved	mg/L	0.11	< 0.05
30	Zinc (Zn) dissolved	mg/L	0.21	< 0.01
31	Copper (Cu) dissolved	mg/L	< 0.02	< 0.02
32	Lead (Pb) dissolved	mg/L	< 0.005	< 0.005
33	Chromium hexavalent (Cr- (vi))	mg/L	< 0.02	< 0.05
34	Oil and fat	mg/L	< 1	-
35	Total detergent	mg/L	< 0.05	< 0.05
36	Phenol	mg/L	< 0.001	-
37	Fecal Coliform	MPN/100mL	-	0
38	Total Coliform	MPN/100mL	4268	0

Based on the interview with the industrial park staff, the water required for gardening is about 25 litres/m^2/week. There are roughly 38 hectares of the green area hence gardening takes up 9500 m^3/week or 38000 m^3/month of water.

Not all water from the STP can be utilized. It is only sufficient for gardening and flushing thus the volume is 38000 m^3/month and 38700 m^3/month respectively. The total is 76700 m^3/month.

The elaboration of how the RWW can be utilized to partially satisfy the industrial park's water usage is illustrated in **Table 6** and **Fig. 7** provides a visual comparison. They show although there is plenty of RWW available in the industrial park, only part of it can be reused because the RWW's quality is not up to the standard and the industrial park's inhabitant must not be willing to use the RWW for various activities such as bathing, laundry, dishwashing, etc. The study estimates 160163 m^3/month – 76700 m^3/month = 83463 m^3/month of the RWW (52.22 % of the produced effluent) cannot be used and must be discharged instead.

Note that the non-toilet volume is computed by subtracting the toilet usage (38700 m^3/month) and the gardening usage (38000 m^3/month). from the monthly average water usage (166614.68 m^3/month in **Table 2**, rounded to 166615 m^3/month).

Table 6. The comparison and the breakdown of the RWW volume and the water usage volume.

Supply	Volume (m^3/month)	Demand	Volume (m^3/month)
RWW	160163	Gardening	38000
		Toilet	38700
		Non-toilet	89915
Total	160163	Total	166615

Fig. 7. The volume of various water demands vs the RWW.

Although not all the RWW can be utilized, the usage of the RWW is still beneficial for the industrial park. The analysis roughly approximates the RWW can save up 76700 m^3/month if it is redistributed to water the plants and to flush the toilets. It is about 76700 m^3/month / 166615 m^3/month * 100 % = 46.03 %. It suggests that RWW usage can potentially reduce 46.03 % of the total freshwater extraction. It implies the industrial park could save about 46.03 % of its water budget.

Of course, the industrial park management must also provide extra efforts to utilize the reclaimed water. The management seemingly has to improve the RWW quality. Furthermore, the management also has to install the new plumbing system to distribute the RWW to the toilets. Whether it is financially and technically feasible for the industrial park to carry them out is outside the scope of this paper. On the other hand, it is ecologically beneficial to conserve the extraction of a such significant quantity of water from a natural water body.

4 Conclusions

Although the STP produces 160163 m^3/month of RWW every month, the industrial park can only utilize 76700 m^3/month of it. The water quality and the people's unwillingness are the main factors which rule out the reuse of the whole RWW. Despite this, the industrial park can still potentially save 46.03 % of the freshwater extraction volume if it utilizes the RWW for gardening and toilet flushing.

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