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The Concept of Sustainable Groundwater Management in Supporting Industrial Estates

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ABSTRAK

Kebutuhan air di kawasan industri dapat dipenuhi dengan menggunakan air permukaan dan sumber air tanah. Akan tetapi, hal tersebut dapat menimbulkan permasalahan tersendiri untuk wilayah karena adanya peningkatan kebutuhan air. Kecamatan Sumberjaya merupakan salah satu kecamatan yang ada di Kabupaten Majalengka dan berdasarkan Peraturan Daerah Kabupaten Majalengka No 11 Tahun 2011 tentang RTRW Kabupaten Majalengka Tahun 2011 - 2031, Kecamatan Sumberjaya termasuk kedalam bagian PKL Jatiwangi dengan fungsi pelayanan salah satunya sebagai kawasan pengembangan industri, dimana sektor industri di kecamatan ini lebih memilih menggunakan sumberdaya air tanah untuk memenuhi kebutuhan air industri. Luas kawasan industri yang mencapai 329.700 m^2 akan membutuhkan air untuk industri sebesar 8.534.678 m^3/ tahun, dengan belum adanya arahan dalam pengelolaan air tanah yang berkelanjutan dikhawatirkan akan memberikan dampak hilangnya sumber air tanah dan terjadinya krisis atau kelangkaan sumber daya air. Dari hasil analisis terhadap potensi dan permasalahan yang ada di Kecamatan Sumberjaya, dalam membantu pemenuhan kebutuhan air industri selain dari air tanah, dapat menerapkan arahan konsep dalam konservasi air tanah dengan menggunakan metode perhitungan Pemanenan Air Hujan dan sumur imbuhan.

Kata Kunci: kebutuhan air kawasan industri, pemanenan air hujan, imbuhan

ABSTRACT

Water needs in industrial areas can be met by using surface water and groundwater sources. However, this can cause its own problems for the region due to increased water demand. The area of the industrial area in Sumberjaya Sub-district which reaches 329,700 m^2 will require water for industry amounting to 8,534,678 m^3/ year, with no direction in sustainable groundwater management it is feared that it will have an impact on the loss of groundwater resources and the occurrence of a crisis or scarcity of water resources. This research aims to find out directions in sustainable groundwater management that are appropriate, integrated, and can be applied to supporting industrial estates in Sumberjaya District, Majalengka Regency. This analysis was conducted using descriptive qualitative and descriptive quantitative approaches. We conducted this analysis using observation, interview, and secondary data collection methods. The analysis method in this research is the calculation method of rainwater harvesting (PAH) and the calculation of the recharge concept. From the results of the analysis of the potential and problems that exist in Sumberjaya Subdistrict, in helping to fulfil industrial water needs other than groundwater, can apply concept direction in groundwater conservation using the Rainwater Harvesting calculation method and recharge wells.

***Keywords*:** Industrial area water demand; Rainwater harvesting; Recharge

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1. INTRODUCTION

The development of industrial estates is expected to be able to create jobs, encourage growth, and improve the development of a region. Based on data from the Ministry of Home Affairs one data portal (https://e-database.kemendagri.go.id/), there are currently 734 industrial estates that have been and will be operating throughout Indonesia. The development of industrial estates causes water demand to continue increasing over time. With the limited water supply for industrial estates supplied by drinking water companies (PDAM/BUMD Air Minum), the dependence of industrial estates on groundwater is high.

Groundwater is water that is contained in the layer below the ground surface. The depth of groundwater is not the same in every place, depending on the type of soil and the position of the soil layer that stores the groundwater (Darwis, 2018). Most groundwater comes from rainwater that seeps into the ground, becomes groundwater, slowly flows to the sea, or flows directly into the ground or on the surface and joins the river flow. The amount of water that percolates into the ground depends on not only space and time but also on the steepness of the slope, the condition of the soil surface material, and the type and amount of vegetation and rainfall (Prastistho et al., 2018).

As an area develops, the demand for groundwater increases. This results in large-scale groundwater withdrawals. One of the activities that take large amounts of groundwater is industrial activity (Sihombing et al., 2022). In industrial activities, there are three functions of water: process water, utility water, and domestic water needs (Fauzi et al., 2018). Water consumption per type of industry is different due to differences in production stages and loads. The largest clean water needs are found in the beverage industry, food ingredients, food, industrial chemicals, and other chemicals. Meanwhile, the smallest water consumption is found in the wood, cement, lime, and jewelry industries (Valentino, 2013).

Groundwater withdrawal must be balanced to avoid having a negative impact on the environment. High groundwater withdrawals that exceed the recharge amount will cause a decrease in the water table and reduce the potential for groundwater in the aquifer. This will trigger negative impacts such as seawater intrusion, decreased groundwater quality, and land subsidence (Ulfah, 2018). The movement of soil grains below the ground surface causes the gradual or sudden lowering of the land surface, leading to land subsidence. Pumping water out of a confined aquifer increases the stress between soil grains even without any change in the load on the ground surface (Suwarno, 2017).

Another impact of overexploitation of groundwater is on wetland degradation, which is divided into two parts. The first is the reduction of base flow from the aquifer to the wetland, which leads to less groundwater recharge received by the wetland. The second is the expansion of the cone of depression, which causes groundwater in the wetland to infiltrate into the t-land aquifer, leading to the reduction of wetland surface water (Zhou et al., 2023).

Efforts can be made to overcome the above problems by applying the concept of sustainable groundwater management. This concept refers to the efficient management of existing groundwater resources as a source of water supply to meet current and long-term needs in an equitable manner and maintain their quality without overriding the risks associated with physical damage to aquifers, characteristics, storage capacity, and recovery ability for the needs of each generation (Raghavendra & Deka, 2015). In general, groundwater sustainability can be defined as'maintaining stable and dynamic groundwater storage over the long term' (Gleeson et al 2020 as cite in Elshall et al., 2020).

To effectively practice sustainable groundwater management, crucial steps involve awareness and monitoring of the status of groundwater in terms of both quantity and quality. Special attention needs to be paid to areas facing critical conditions as well as areas with high groundwater exploitation rates. In addition, implementation of water harvesting and aquifer recharge practices is important, along with well-deepening and rejuvenation measures and protection of water bodies. The next step is to implement regulations relating to groundwater management, supported by a system of incentives and disincentives. Intensive oversight is needed to monitor compliance with regulatory measures and provide appropriate responses to incentives and disincentives. Awareness in every government plan and broad public participation in the importance of groundwater are also key factors in achieving sustainable groundwater management (Raghavendra & Deka, 2015).

Achieving sustainable groundwater development can be done by balancing aquifer storage recharge inputs (groundwater resources) against discharge outputs for economic, environmental, and human (social) benefits (Hiscock et al., 2015), as shown in Figure 1.

In the research conducted, the author focuses more on how the industrial area minimizes groundwater extraction by utilizing rainwater that falls in the industrial area as a substitute for groundwater. In addition, in this study, groundwater recharge efforts were made as an effort to maintain aquifers in the industrial area. As a case example, the research was conducted in Sumberjaya Subdistrict, Majalengka Regency, with the justification for choosing the location being that in the 2011 Regional Regulation of Majalengka Regency concerning the RTRW of Majalengka Regency Year 2011–2031 in the spatial pattern plan, an industrial area development plan was established in the Bandung–Cirebon corridor, where Sumberjaya Subdistrict is located on the Bandung–Cirebon Road corridor. Industrial estates in Majalengka Regency are not only in Sumberjaya Sub-district; however, Sumberjaya Sub-district already has a Spatial Detail Plan document that stipulates an industrial estate plan in Sumberjaya Sub-district, reaching 329.27 ha. Industrial estates in Sumberjaya Sub-district are spread across small industries, medium industries, and large industries. The rapid development of industrial estates in this area has consequences for water demand that will increase, and groundwater withdrawals will also be greater.

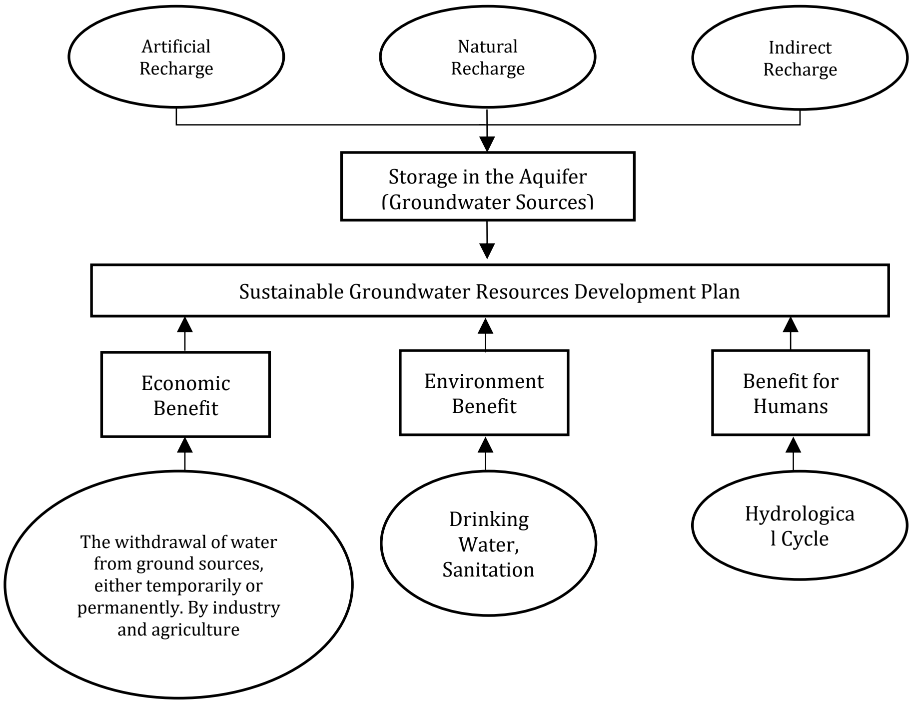

Figure 1. Sustainable Groundwater Resource Development Design (Hiscock et al., 2015)

This study complements several previous studies, such as research on sustainable groundwater extraction efforts, through six scenarios: Model a, which is with the scenario of limiting the growth rate of hotels, Model b, which is a scenario of limiting industrial water use, Model c, which is a scenario of conserving groundwater utilization by reducing domestic water use units, Model d, which is a scenario of conserving groundwater utilization by increasing the production capacity of PDAM Tirta Moedal, Model e, which is a scenario of conserving groundwater utilization with a combination of models a, b, c, and d (Susanto, 2014), Research on artificial recharge. The application of artificial recharge methods in the Bandung-Soreang Groundwater Basin, based on the results of research over a period of 23 years, is one method that is able to reduce the decline in groundwater levels and increase groundwater storage. Infiltration wells, infiltration trenches, and infiltration ponds can only be applied to free aquifers. While for depressed aquifers, the injection well method. (Purwoarminta et al., 2019).

Other research that has been done is about sustainable planning in industrial areas, covering various aspects, one of which is land use and aspects of water conservation. In the land use aspect, green open space (RTH) is known as an area designated as a green area, which can be a park or sports field. Areas where plants can grow well and support the ecological balance of the surrounding area. (Sihombing et al., 2022). Research on the impact of industrial areas on the environment shows that industrial activities can disturb the balance of the environment. Direct negative impacts due to industry include air pollution, water pollution, and soil pollution (Fauzi et al., 2018). Groundwater, one of the water resources used in industrial areas in Semarang City, has decreased in quality. Uncontrolled groundwater extraction triggers seawater intrusion, leading to the decline in groundwater quality. Strategies for managing water resources in industrial areas require alignment of economic and environmental aspects, a business approach to environmental management, and the application of cleaner production. In industrial processes, cleaner production means increasing the efficiency of the use of raw materials and energy, preventing or replacing the use of hazardous and toxic materials, and reducing the amount and toxicity of all emissions and waste before leaving the process (Suhartono, 2018).

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Research on groundwater recharge can be done with the addition of rainwater/surface water infiltration or treated water from wastewater treatment plants (WWTP). Water flows to reach the water table with a diffusion mechanism aimed at increasing groundwater storage (Hastuti & Nuraeni, 2017).

Groundwater problems, especially the scarcity of groundwater resources and the decline in groundwater quality, will continue to occur if groundwater utilization is carried out without good groundwater management. Controlled and integrated groundwater utilization can also be realized in groundwater management that takes into account the main pillars of sustainable development and is related to the targets in the sustainable development goals. So, the principle of groundwater management in the future needs to be developed where the use of groundwater is only based on the fulfillment of needs with supporting principles, including

This research aims to find out directions in sustainable groundwater management that are appropriate, integrated, and can be applied to supporting industrial estates in Sumberjaya District, Majalengka Regency.

The novelty in this research is in the utilization of all potential water sources in the industrial area, including rainwater, as well as the use of wastewater produced by industrial activities in the area, so that the industrial area will become a water-sensitive area.

2. METHODS

This analysis was conducted using descriptive qualitative and descriptive quantitative approaches. We conducted this analysis using primary (observation and interview) and secondary data collection methods. The analysis method in this research is the calculation method of rainwater harvesting (PAH) and the calculation of the recharge concept.

2.1. Rainwater Harvesting Analysis

Calculating the quantity of rainwater that can be accommodated for domestic drinking water supply is based on the calculation of water supply and demand. The equation for calculating the potential amount of water that can be accommodated is:

$$\text{Supply} = \text{Rainfall} \times \text{Area} \times \text{Runoff Coeficient} \quad (1)$$

Source: (Worm, 2006)

Description:

Supply = Average water to be received in a year (m^3/year)
Rainfall = Average annual rainfall (mm)
Area = Rainwater catchment area (m^2)
Runoff coefficient = Runoff coefficient

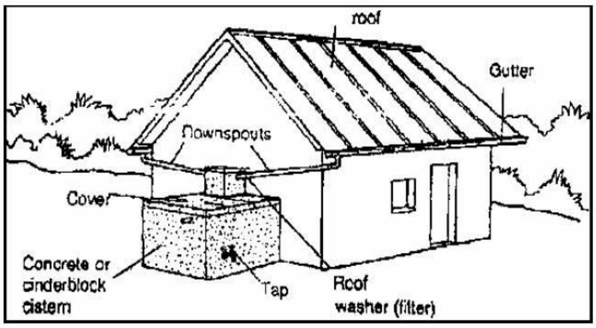

Figure 2. Illustration of the Rainwater Harvesting (PAH) Concept

The runoff coefficient depends on the type of roof on the building. For the analysis method of rainwater harvesting calculation in Sumberjaya Sub-district itself, assuming that large industrial areas in Sumberjaya Sub-district have galvanized sheet roof types, the runoff coefficient taken in this rainwater harvesting calculation is 0.9. Then multiply the runoff coefficient by the average rainfall and the capture area. For the capture area, due to the use of this PAH in buildings, the building area that becomes the capture area is 60% of the total area. This is based on the assumption that the maximum BCR of the building is 60% of the total area.

2.2. Recharge Well Analysis

The calculation of recharge is obtained from water infiltration in open spaces or green spaces, rainwater, and surface water multiplied by the average monthly rainfall. The basic concept of recharge itself means to re-charge or replace. It can be interpreted that recharge is an effort to replace water sources that have been used, especially groundwater sources. The calculation for the amount of water that can be recharged is based on the following formula:

$$\text{Supply} = \text{Rainfall} \times \text{Area} \quad (2)$$

Source: Regulation of the Minister of Public Works and Public Housing Republic of Indonesia Number 09/PRT/M/2015 concerning the Use of Water Resources, 2015

Description:
Supply = Average water to be received in a year (m^3/year)
Rainfall = Average annual rainfall (mm)
Area = Rainwater catchment area (m^2)

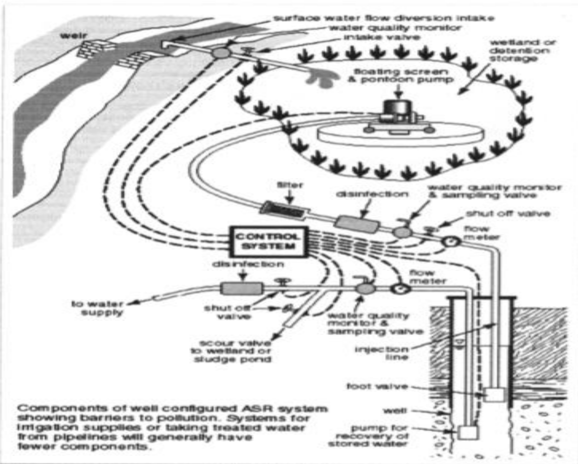

Figure 3. Illustration of the Infiltration Well Concept

3. RESULT AND DISCUSSION

3.1. Condition of Groundwater Utilisation System of Industrial Estate in Sumberjaya Sub-district

3.1.1. Industrial Area Profile

The distribution of industries in Sumberjaya Subdistrict is 55, with a distribution of small industries, medium industries, and several large industrial companies. For the profile of the industrial area taken, namely PT Embee Plumbon Tekstil and PT Kaldu Sari Nabati Majalengka, these two industries are two large industrial companies that have a considerable influence on the management of groundwater resource utilization in the Industrial Estate in Sumberjaya District (Figure 4).

3.1.2. Industrial Area Water Needs

Based on the profile of the industrial area above, the calculation of water requirements for industrial estates in Sumberjaya District is based on the land area, with the formula for the provisions of industrial water requirements as follows:

$$Q = \text{Industrial land area} \times \text{water requirement} \quad (3)$$

Source: (Departemen Permukiman, 2003)

Refer to the following table for the calculation of industrial water demand in Sumberjaya District in Table 1.

In fulfilling their need for water, these two industrial companies utilize groundwater sources through the construction of boreholes. The utilization of water through these boreholes has an impact on the availability of groundwater sources in the Sumberjaya Sub-district area, especially for Garawangi Village and Banjaran Village, but the companies themselves have not really responded to this impact. The company's response can only provide compensation in the form of CSR (corporate social responsibility). The company gives this CSR as a form of responsibility to the surrounding area. The CSR that has been provided by PT Kaldu Sari Nabati Indonesia is a borehole and water reservoir for each block in Banjaran Village.

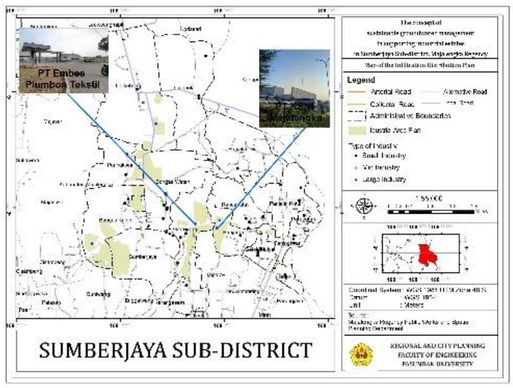

Figure 4. Distribution of Industries in Sumberjaya Sub-District

3.1.3. Condition of Groundwater Quality, Quantity, and Continuity in Industrial Areas

The results of the analyses related to the quality, quantity, and continuity of groundwater sources in Sumberjaya Sub-district can be seen in the following explanation in Table 2.

Table 1. Calculation of Water Needs for Industrial Areas in Sumberjaya Sub-district

Industrial type	Production Type	Number of Employies	Area (Ha)	Industrial Water Requirements	Industrial needs by area (1,0 l/s/Ha)
PT EMBEE Plumbon Tekstil	Apparel textiles (export materials)	3,500	7.56	7.56	653,184 l/day
PT Kaldu Sari Nabati-Majalengka	Food	2,500	33	33	2,851,200 l/day

Table 2. Groundwater Quality, Quantity, and Continuity Condition

Condition	Description
Quality	- Good enough (Compliance with industrial water standard) and can be used directly to fulfil needs. - There are several water sources with poor water quality and salty water (Kondang Block, Banjaran Village and Pajagan Block, Garawangi Village).
Quantity	- The quantity of groundwater sources is still available and sufficient to fulfil the needs of industry and community activities. - There has been no struggle over the utilisation of groundwater resources between industrial companies and the surrounding community. - The potential quantity of groundwater in Sumberjaya Sub-district itself is class B or has the potential for a discharge of 5 litres/second. - There are several groundwater sources that can only be taken with a drilling depth of 20 - 40 metres.
Continuity	- Obtained from the potential of rainfall and alternative water sources (rivers and reservoirs). - Potential Ciwaringin River with a discharge of 6.36 litres/second and Cikadongdong River with a discharge of 1.47 litres/second. - Will be assisted by the existence of PDAM which comes from the Jatigede Reservoir source.

Source: Field Observations and Interviews

Table 3. Rainfall in the Sumberjaya Sub-district Area

No	Name of UPTD	Station Name	No STS	DPL	Number of Rainy Days	Number of Raindrops			
						Total	Average	Minimum Rainfall	Maximum Rainfall
1	Jatiwangi	Leuweung Gede	38A	67	158	934	85	10	385
2		Pajajar	37A	486	172	1,670	152	10	720
3	Rajagaluh	Payung	48	449	184	1,761	160	-	866
4	Leuwimunding	Lame	40	90	150	1,270	115	5	515
5	Kadipaten	Karang Sambung	21	48,6	179	1,207	110	4	477
6		Pakumbahan	20	25.6	128	1,309	119	10	510
Average					**165**	**1,369**	**124**	**6**	**552**

Source: Majalengka Regency's PUTR Office 2021

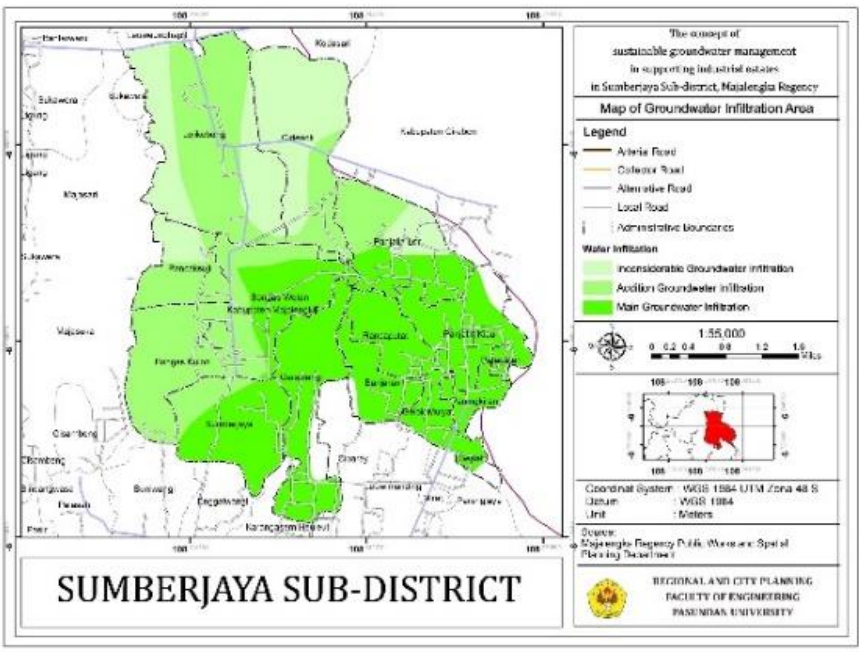

Figure 5. Map of Groundwater Infiltration Areas in Sumberjaya Sub-District

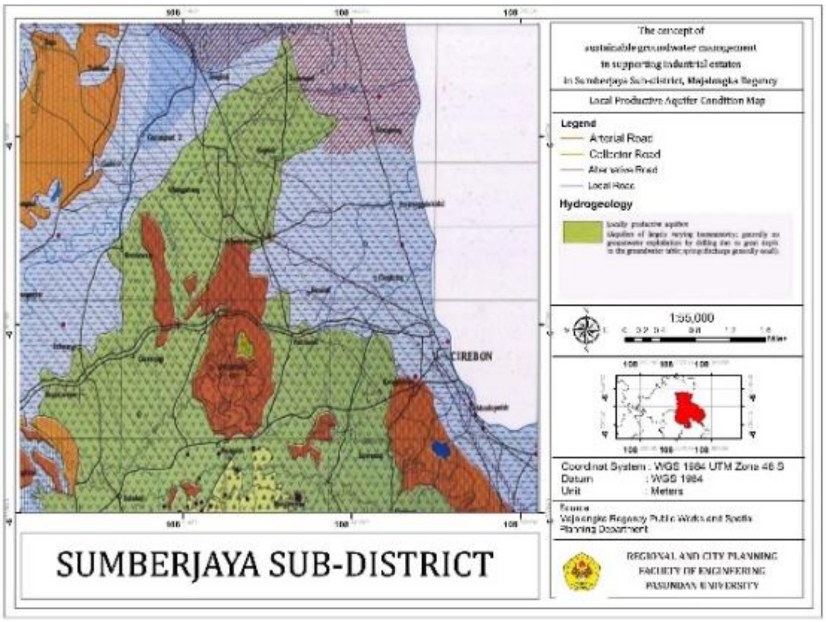

Figure 6. Local Productive Aquifer Condition Map of Sumberjaya Subdistrict

3.2. Potential Groundwater Supply System for Industrial Estates

Potential Groundwater Supply System for Industrial Estates

The potential that exists in Sumberjaya Sub-district related to the management of groundwater resource utilization by industrial estates are as follows:

3.2.1. Groundwater Infiltration Area

Sumberjaya Sub-district has a main groundwater recharge area that reaches 1,553.62 ha, or about 43.52% of the total area of Sumberjaya Sub-district. The largest main groundwater recharge area is in Garawangi Village, which reaches 300.70 ha. Bongas Kulon and Bongas Wetan villages have more water catchment areas, but due to clay soil conditions, groundwater absorption is less than optimal (Figure 5).

3.2.2. Local Productive Aquifer

The Sumberjaya Sub-district area's status as a local productive aquifer indicates that the area has productive and potential groundwater resources. However, the productive status of the aquifer, if utilised continuously without being accompanied by conservation efforts and sustainable groundwater management, will still cause water resources to be depleted and increasingly lost and cause critical aquifers, resulting in scarcity and shortage of groundwater resources (Figure 6).

3.2.3. Rainfall Potential

The potential for rainfall in the Sumberjaya Sub-District area is also one of the alternatives to sustainable water resource management. Table 3 shows the rainfall data from stations near the Sumberjaya Sub-district area.

In Table 3, it can be explained that in one year, the average number of observed rainy days is 165, with an average rainfall falling around 1,369 mm per year, with a minimum rainfall of 6 mm and a maximum rainfall of 552 mm.

3.3. Issues with Groundwater Supply Systems in Industrial Estates

3.3.1. Sumberjaya Sub-district is Designated as an Industrial Area

The draft document of RDTR Kadipaten-Sumberjaya Year 2021 explains that the entire area of -Sumberjaya Sub-district is planned for industrial development, with a total area of approximately 329.27 Ha. The industrial designation of Sumberjaya Sub-district will have both positive and negative impacts on the area. The region has a large number of employment opportunities and improved economic conditions. However, the development of this industrial area can also cause problems with the water source utilization system that supports the industrial production process. The greater the industrial development, the greater the demand for water, and the greater the utilization of groundwater resources. If industrial development does not include water conservation efforts or sustainable groundwater management, it can lead to water shortages and even water scarcity (Figure 7).

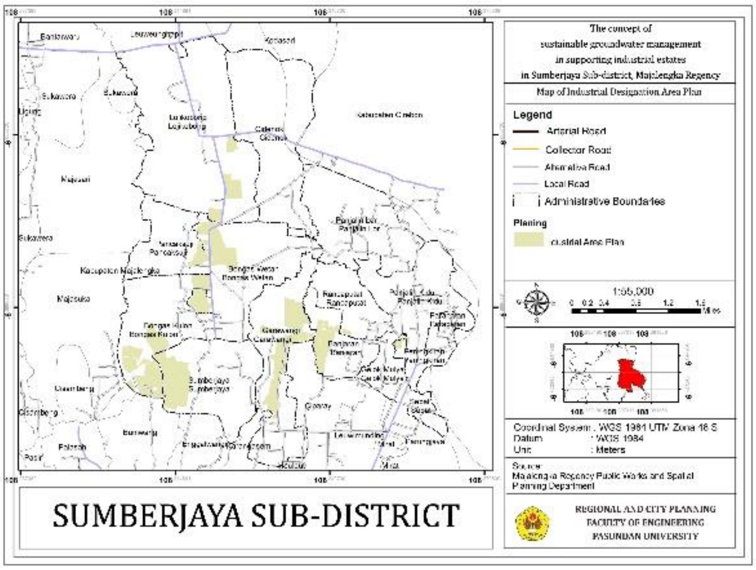

Figure 7. Map of Industrial Designation Area Plan in Sumberjaya Sub-district

3.3.2. There is No Policy on the Groundwater Management System

In the current condition, due to the absence of policies related to maximum drilling restrictions; in order to obtain maximum water sources, industrial companies drill at a depth of up to 100–300 meters. The large water demand also makes this industry not only have one borehole but several boreholes with the same depth, so that the water debit utilized from the groundwater source is very large. The sub-district and village governments expect a policy to limit land drilling and the utilization of groundwater resources.

3.3.3. PDAM has not yet been installed

At the end of 2021, in several villages in Kecamatan Sumberjaya, especially Banjaran Village, Bongas Kulon Village, Bongas Wetan Village, and Garawangi Village, there have been discussions and surveys from the Jatigede PDAM, but this has not been realized this year and is planned to be realized at the end of 2023. The Jatigede Reservoir water source provides the PDAM water supply that enters the Sumberjaya District area. PDAM Jatigede Reservoir has clean water service area coverage in Cirebon City, Cirebon Regency, Majalengka Regency, Sumedang Regency, and Indramayu Regency.

3.3.4. The Industrial Company is Less Responsive to the Surrounding Area

The village government wants industry to discuss the industrial activities that will be carried out, because the positive and negative impacts will be felt first by the people who live close to the industrial area.

3.4. Sustainable Groundwater Management Directions that Can be Applied to Support Industrial Areas in Sumberjaya Sub-district

The resulting sustainable groundwater management direction is in the form of groundwater conservation through the following activities:

3.4.1. Protecting the Source of the Groundwater Environment

The protection is intended to protect groundwater from various water pollution factors, such as waste and hazardous chemicals, so that the quality of groundwater sources is maintained. In the Sumberjaya Sub-district, the industrial companies that are the focus of the research produce more solid waste than liquid waste. To minimize the amount of waste that must be treated and discharged into the environment, the food industry must be able to manage its water needs properly (Rahmani, 2015).

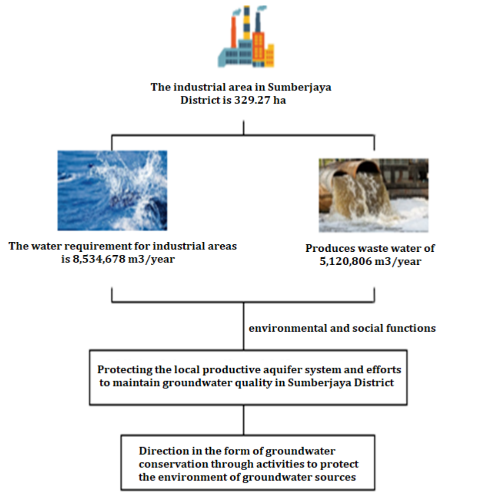

Figure 8. Groundwater Management Flow in Sumberjaya Sub-district

3.4.2. Groundwater Conservation and Saving

Groundwater Conservation and Saving Groundwater conservation through groundwater preservation and saving activities is implemented using the following methods:

a. Rainwater Harvesting (PAH)

Rainwater harvesting is obtained by utilizing the roof of the building as an alternative water source. The potential volume of rainwater in industrial plants can be fully utilized without any wasted rainwater volume (Suwarno, 2021) (Table 4 and Figure 9).

With an average value of rainfall in one year of 1,358.50 mm and a building roof area of 1,975,620 m, then the results show that the industrial water demand in one year reaches 8,534,678 m^3, with a water demand of 711,223 m^3 for each month. And for the amount of rainwater that can be harvested in one year of 2,415,491.79 m^3, about 28.30% of industrial water needs can be met through the concept of rainwater harvesting so that groundwater availability can be maintained.

The concept of PAH for this industrial area can be designed where rainwater is flowed from the roof of the factory through the channel to the rainwater storage tank as a water storage area located underground equipped with filtration designed to clean water and odors. This concept is applied in the study of PAH as clean water for industry in Semarang City (Suwarno, 2017). The use of rainwater as water for industrial purposes requires additional processes tailored to the type of industry, but the most commonly used process is the filtration method (Gunawan & Ismail, 2020).

3.4.3. Recharge Wells

Recharge is an effort to replace water sources that have been used, especially groundwater sources. This concept is carried out with the aim of maintaining a balance between the utilization and return of groundwater. Unlike rainwater harvesting that utilizes the roofs of buildings, the recharge well concept uses the entire area, with as much rainwater as possible being utilized and combined with the utilization of surface runoff. The recharge technique has succeeded in managing the impact of groundwater exploitation in urban areas by maintaining the quantity, viability, and quality of groundwater (Dillon et al., 2018; Purwoarminta, Fajar Lubis, and Maria, 2019) (Table 5 and Figure 10).

These calculations yield the direction scheme using the affix method as follows Figure 10.

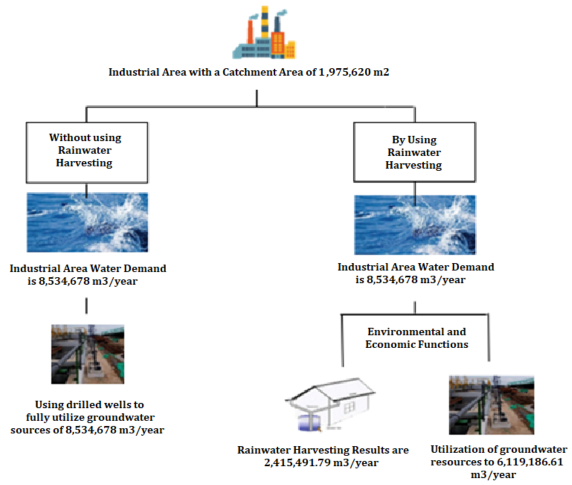

Figure 9. Schematic Direction of Rainwater Harvesting Method

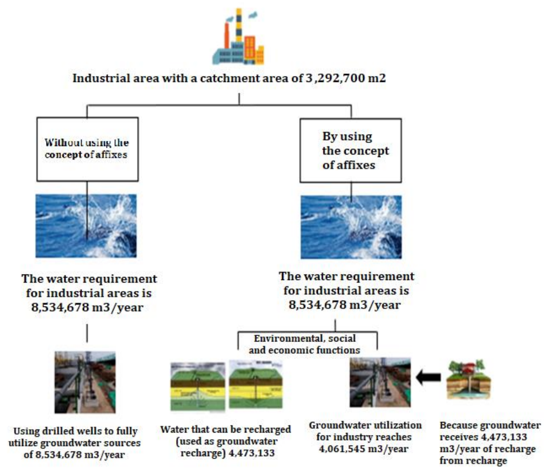

Figure 10. Schematic of Infiltration Method Direction

The industrial area reaches 3,292,700 m^2, or about 329.27 ha, and the average rainfall in one year is 1,358.50 mm, so the amount of water that can be put into recharge in one year is 4,473,133 m^3. The existence of this recharge means that about 52% of groundwater can be replaced after being utilized by

8,534,678 m^3 to meet industrial needs. These recharge wells are distributed assuming that they will be applied in several villages adjacent to the industrial estate development plan, considering factors such as the availability of sufficient surface water and rainfall, suitable geological and hydrogeological conditions, and the availability of land for well construction (Ministry of Public Works, 2015). The industrial estate development plan in Sumberjaya sub-district is located in 7 villages, including Bongas Kulon Village, Bongas Wetan Village, Lojikobong Village, Banjaran Village, Garawangi Village, Pancaksuji Village, and Sumberjaya Village (Figure 11).

Table 4. Calculation Results with the Concept of Rainwater Harvesting (PAH)

Months	Monthly Rainfall (mm)	Area (Ha)	Area (m^2)	Building Roof Area 60% of area	Roof Drainage Coefficient	Amount of Rainwater harvested (litres)	Amount of Rainwater harvested (m^3)	Industrial Water Demand/month (m^3)	Surplus/Deficit
January	23.50	329.27	3,292,700	1,975,620	0.9	41,784,363	41,784	711,223	(669,439)
February	38.33	329.27	3,292,700	1,975,620	0.9	68,158,890	68,159	711,223	(643,064)
March	22.00	329.27	3,292,700	1,975,620	0.9	39,117,276	39,117	711,223	(672,106)
April	22.33	329.27	3,292,700	1,975,620	0.9	39,709,962	39,710	711,223	(671,513)
May	24.33	329.27	3,292,700	1,975,620	0.9	43,266,078	43,266	711,223	(667,957)
June	6.50	329.27	3,292,700	1,975,620	0.9	11,557,377	11,557	711,223	(699,666)
July	0.00	329.27	3,292,700	1,975,620	0.9	-	-	711,223	(711,223)
August	35.50	329.27	3,292,700	1,975,620	0.9	63,121,059	63,121	711,223	(648,102)
September	54.50	329.27	3,292,700	1,975,620	0.9	96,904,161	96,904	711,223	(614,319)
October	103.50	329.27	3,292,700	1,975,620	0.9	184,029,003	184,029	711,223	(527,194)
November	496.00	329.27	3,292,700	1,975,620	0.9	881,916,768	881,917	711,223	170,694
December	532.00	329.27	3,292,700	1,975,620	0.9	945,926,856	945,927	711,223	234,704
Total	**1,358.50**	**329.27**	**3,292,700**	**1,975,620**	**0.9**	**2,415,491,793**	**2,415,491.79**	**8,534,678.40**	**6,119,186.61**

Source: Analysis Results, 2022

Table 5. Calculation Results with the Infiltration Concept

Months	Monthly Rainfall (mm)	Area (Ha)	Area (m^2)	Amount of Rainwater harvested (litres)	Amount of Rainwater harvested (m^3)	Industrial Water Demand/month (m^3)	Surplus/ Deficit
January	23.50	329.27	3,292,700	77,378,450	77,378.45	711,223	(663,845)
February	38.33	329.27	3,292,700	126,220,166.7	126,220.17	711,223	(585,003)
March	22.00	329.27	3,292,700	72,439,400	72,439.4	711,223	(638,784)
April	22.33	329.27	3,292,700	73,536,966.67	73,536,966.67	711,223	(637,686)
May	24.33	329.27	3,292,700	80,122,366.67	80,122,367	711,223	(631,101)
June	6.50	329.27	3,292,700	21,402,550	21m402.55	711,223	(689,821)
July	0.00	329.27	3,292,700	0	0	711,223	(711,223)
August	35.50	329.27	3,292,700	116,890,850	116,890.85	711,223	(594,332)
September	54.50	329.27	3,292,700	179,452,150	179,452.15	711,223	(594,332)
October	103.50	329.27	3,292,700	340,794,450	340,794.45	711,223	(531,771)
November	496.00	329.27	3,292,700	1,633,179,200	1,633,17.20	711,223	921,956
December	532.00	329.27	3,292,700	1,751,716,400	1,751,716.40	711,223	1.040,493
Total	**1,358.50**	**329.27**	**3,292,700**	**4,473,132,950**	**4,473,133**	**8,534,678.40**	**4,061,545.45**

Source: Analysis Results, 2022

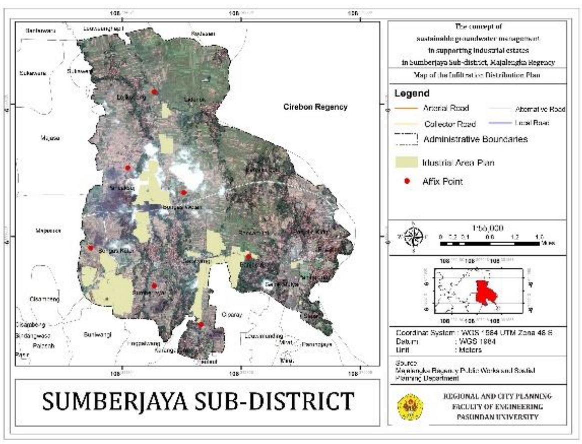

Figure 11. Map of the Infiltration Distribution Plan in Sumberjaya Sub-District

3.4.4. Combined Concept

This concept aims to optimise groundwater conservation as a groundwater management system.

The amount of rainwater that can be harvested in one year reaches 2,415,491.79 m^3, and for the amount of water that can be added with an area taken at 40% of the total area of the industrial area, or around 1,317,080 m^2, or 131.7 ha, the amount of water that can be added in one year is 1,789,253 m^3. From this concept, the result is that groundwater utilization is helped by around 4,204,544.79 m^3/year.

3.4.5. Environmental Preservation and Protection

Preservation and protection of the environment in Sumberjaya Sub-district with the potential that the area has a major water catchment area, one of which can use vegetative methods or tree planting. The definition of vegetative methods is controlling or utilizing the role and function of plants. Vegetative methods can also be interpreted as land rehabilitation and conservation efforts by planting several types of tree crops and/or other plants to maintain soil cover in order to bind soil grains more strongly. Some functions of vegetative methods are: 1. Protect against the destructive power of falling rain grains. 2. Protect against the destructive power of surface soil flow. 3. Improving soil infiltration capacity and water retention. 4. Improve porosity, aggregate stability, and soil chemical properties. 5. Increase the absorption capacity of the soil for water (Sarminah, 2018) (Figure 12).

Types of vegetation that can be applied to this method include trembesi trees and golden teak trees. These two types of trees also have roots that can accelerate the absorption of water on the ground surface to absorb into the soil so as to help maintain the availability of groundwater resources (Figure 13).

From these directions, sustainable groundwater management that can be applied in Sumberjaya Sub-district is an integrated concept in the form of a) preserving and saving groundwater through the concept of water harvesting and groundwater recharge wells; and b) preserving and protecting the environment using vegetative concepts. The concept can be seen in the following scheme (Figure 14).

Table 8. Calculation Results with Combined Concept

Months	Monthly Rainfall (mm)	Area (Ha)	Area (m^2)	Amount of Rainwater harvested (litres)	Amount of Rainwater harvested (m^3)
January	23.50	131.7	1,317,080	30,951,380	30,951.38
February	38.33	131.7	1,317,080	50,488,066.67	50,488.067
March	22.00	131.7	1,317,080	28,975,760	28,975.76
April	22.33	131.7	1,317,080	29,414,786.67	29,414.786
May	24.33	131.7	1,317,080	32,048,946.67	32,048.947
June	6.50	131.7	1,317,080	8,561,020	8,561,020
July	0.00	131.7	1,317,080	0	0
August	35.50	131.7	1,317,080	46,756,340	46,756.34
September	54.50	131.7	1,317,080	71,780,860	71,780.86
October	103.50	131.7	1,317,080	136,317,780	136,317.78
November	496.00	131.7	1,317,080	653,271,680	653,271.68
December	532.00	131.7	1,317,080	700,686,560	700,686.56
Total	**1,358.50**	**131.7**	**1,317,080**	**1,789,253,180**	**1,789,253**

Source: Analysis Results, 2022

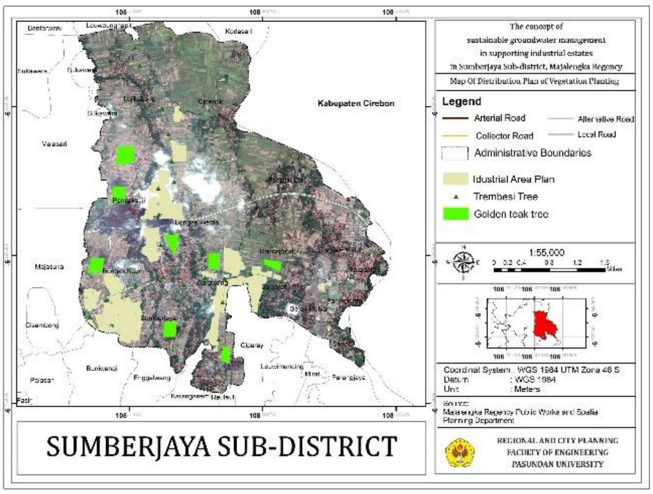

Figure 12. Distribution Plan of Vegetation Planting in Industrial Areas

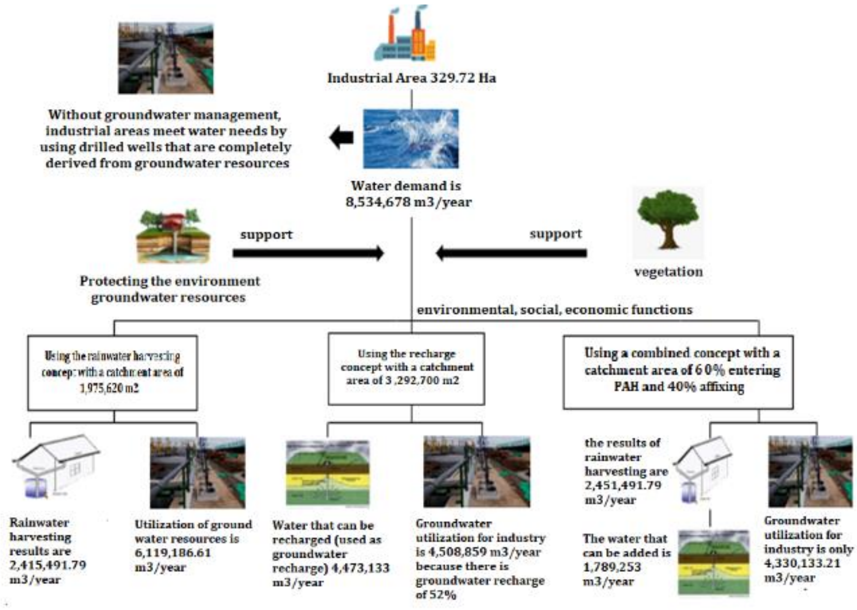

Figure 14. Groundwater Conservation Scheme for Industrial Estate in Sumberjaya Sub-district

Figure 13. Trembesi Tree or Kihujan Tree (left) and Jati Emas Tree (right)

This complements previous research studies that have been conducted where the previous studies approached 1 type of solution in groundwater conservation, such as recharge wells only or water harvesting only, as described in the introduction above.

4. CONCLUSION

The conclusion of this study reveals that the industrial sector in Sumberjaya Sub-district has a diverse distribution, including small, medium, and large industries. The utilization of groundwater resources for industrial needs is done through the construction of boreholes with depths reaching 100–300 meters. Nevertheless, the quality, quantity, and continuity of groundwater in this area are still quite good and available to fulfill the daily needs of industry and the community.

In relation to the groundwater management system, Sumberjaya Sub-district's potential includes major water catchment areas, local productive aquifers, and rainfall potential. Issues in Sumberjaya Sub-district include the designation as an Industrial Designation Area without a policy related to groundwater management, the absence of PDAM services, and the lack of responsiveness of industrial companies to the surrounding environment.

Groundwater management directives can support the Industrial Designation Area in Sumberjaya Sub-district. Implementing groundwater conservation measures, such as protecting the environment of groundwater sources, preserving and saving groundwater through rainwater harvesting, recharge wells, and combined methods, as well as preserving and protecting the environment, helps maintain the sustainability of groundwater resources and mitigate potential negative impacts from industrial activities in the area.

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