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Driving Sustainability in Poultry Production: Technical and Economic Evaluation of Wastewater Recycling in a Commercial Poultry Hatchery

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Abstract

Substantial growth of poultry industry had raised concerns about its environmental impact, particularly in relation to groundwater depletion and pollution. One potential solution to mitigate these issues is the implementation of a wastewater recycling system (WRS) which is not widely adopted in poultry industry due to a limited information on its technical and economic feasibility. Therefore, this study aimed to investigate the application of WRS in a commercial poultry hatchery in Indonesia and how it can be adopted widely to drive sustainability in poultry production. The technical aspect of the WRS was examined by evaluating its performance in removing pollutants and capability of reducing groundwater intensity ratio (GIR). Furthermore, the economic feasibility was explored through a cost benefit analysis (CBA), using net present value (NPV) as sole indicator expressed in United States dollar (USD). The results showed that multistage wastewater treatment applied in WRS consist of physical, biological & chemical process, and the removal percentage of biological oxygen demant (BOD), chemical oxygen demand (COD), total suspended solids (TSS), fat oil and grease (FOG) pollutants ranged from 47.5 - 95.1%, 48.4 - 91.3%, 24.9 - 95.3% and 68.0 - 89.3%, respectively. Furthermore, all the recycled water managed meet Indonesia quality standards. The application of WRS reduce groundwater withdrawal through the reduction of GIR by 30.18%. This decreased the reliance on groundwater sources without affecting productivity. The cost benefit analysis conducted on the WRS has uncovered numerous economic benefits such as cost saving in water bills and avoidance of pollution-related expenses with estimated positive NPV at USD 30,742.54 which exhibits economic feasibility. The study concluded that WRS remains a viable option for widespread implementation in the poultry industry, addressing water crisis and promoting sustainable production.

Keywords: Commercial Poultry Hatchery; Wastewater recycling; Cost Benefit Analysis; Groundwater Intensity Ratio; Pollutant Removal

1. Introduction

Poultry industry is considered as major sector that plays a crucial role in meeting the worldwide demand for protein. In 2022, the consumption rate was about 14.8 kg/capita, and it is projected to make up 47% of the protein consumed from meat sources in 2031 (Organisation for Economic Co-operation and Development, 2022). However, the rapid growth of poultry production has raised concerns regarding its environmental impact due to the intensive use of resources and waste generated (Tsolakis *et al.,* 2018). With respect to water resource impact, it was estimated that every kilogram of poultry meat requires up to 111 litres of freshwater and prompt eutrophication potential of about 3.9 kg of PO_4^{2+} equivalent (Pelletier, 2008; Wiedemann *et al.,* 2017).

Poultry industry production chain consist of series of process such as feed production, breeding farm, hatchery, growing farm, and ultimately leading to slaughtering or processing plant to produce meat or other products (Shabudin, 2012). Commercial Poultry Hatchery (CPH) is a link in the industrialized poultry production that produces chick. Furthermore, its production processes utilizes significant amount of water and produces waste, including wastewater from cleaning activities (Carter and Carr, 1976; Glatz *et al.,* 2011).

Several approaches have been investigated to mitigate the risk of wastewater discharge in poultry industry. One commonly adopted solution in poultry slaughtering plant is application of wastewater treatment before discharging to the environment (Bustillo-Lecompte and Mehrvar, 2017). Furthermore, various technologies such as reverse osmosis, dissolved air flotation, and integrated fixed film activated sludge are used to treat poultry wastewater (Baker *et al.,* 2021).

Wastewater recycling currently gain its popularity as potential solution to poultry wastewater management. This is because of its ability to reduce the risk of environmental pollution while increasing water usage efficiency (Avula *et al.,* 2009). However, it is not very popular in poultry hatcheries since most studies on this topic were very limited to other production chain such as poultry farms, slaughterhouses, and meat processing plants. The lack of references on wastewater recycling on CPH highlights a gap in the discussion of sustainable water management in the poultry production chain.

This study aims to bridge the existing gap by thoroughly examining the current wastewater recycling practices employed by a poultry company in Indonesia. The specific focus is on determining how these practices can be adopted as a common and widespread approach in the poultry industry. The objectives of this study encompass an investigation into the technical and economic feasibility of WRS implementation, including an evaluation of the process, the effectiveness in pollutant removal, and reducing the groundwater intensity ratio (GIR). Furthermore, a comprehensive cost-benefit analysis (CBA) was conducted to investigate economic feasibility of WRS. Through these endeavours, this study aimed to provide valuable insights into the overall feasibility, thereby contributing to the ongoing discourse on sustainable water management practices within the poultry industry.

2. Materials and method

2.1 Description of study site

The company in this study located in Cipunagara subdictric, Subang, Indonesia just about 30 km south of Java sea, specifically located within coordinates 6°27’57.8”S 107°50’44.4”E as showed in Figure 1. The site was surrounded by vast rice field, as Subang considered as one of Indonesia largest rice producer. The company is part of major poultry production company in Indonesia and recognized as a large-scale CPH with a capacity of about 10 million days old chick (DOC) per year. Furthermore, the company implemented standardized production process which begins with receiving the hatching egg from the farm until the production of DOC after 21 days of incubation. Maintaining hygiene is crucial for maximizing productivity of CPH productivity by preventing poultry disease transmission. Therefore, the company implemented strict biosecurity measures for personnel, equipment, and egg-cleaning procedure for every production batch using various cleaning agents such as detergent, formaldehyde or $KMnO_4$.

2.2 Wastewater pollutants removal

The company provided wastewater quality data from influent and effluent of the WRS covering the period from January to December 2022. For this study, the data were compared against the Indonesia wastewater quality standard (PERMENLH 5/2014 appendix XLVII) specifically for parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and fat oil and grease (FOG). These were used to describe the wastewater characteristics and evaluate pollutant removal performance.

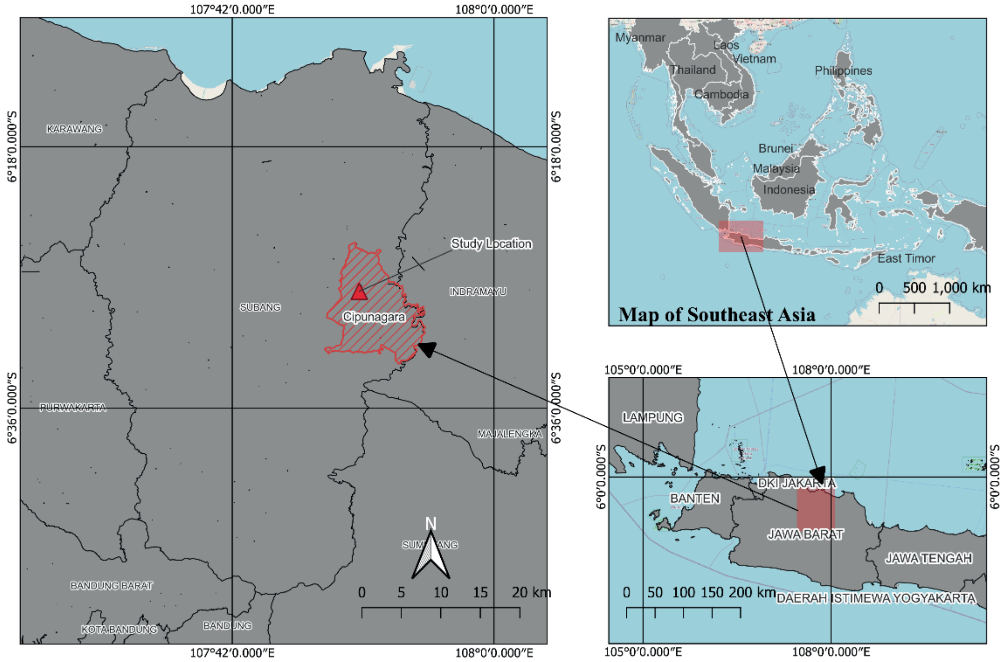

Figure 1. Map of study location

2.3 Groundwater intensity ratio

This study proposes groundwater intensity ratio (GIR) as indicator to evaluates the possibility of the WRS to decrease the environmental impact of CPH on groundwater withdrawal without jeopardizes production process. The GIR indicator serves as a valuable tool for assessing the feasibility of implementing the WRS. It measures the ratio between the volume of groundwater extracted and the production output of the CPH process. By analyzing this ratio, this study can determine the extent to which the WRS can effectively minimize the environmental consequences associated with groundwater withdrawal.

$$GIR = \frac{G_i}{P_i} \qquad \text{(Eq.1)}$$

GIR expressed in m^3/ton was estimated by comparing monthly groundwater withdrawal (G_i) with monthly output of production (Pi) as showed in Eq 1.

A downward trend after implementation of WRS indicates technological feasibility in term of mitigating the risk of excessive groundwater withdrawal in CPH.

2.4 Cost Benefit Analysis

In order to evaluate the economic viability of the water recycling system (WRS), a comprehensive cost benefit analysis (CBA) was undertaken. All costs and benefits were expressed in United States dollars (USD) to facilitate a standardized assessment. The exchange rate utilized for this study was set at USD 1 = 15,203 Indonesian rupiah (IDR), based on the prevailing exchange rate in February 2023. The total cost of WRS was examined by summarizing its entire construction and annual operational cost for the assumed timespan project of 20 years. The direct saving of the WRS was considered as the cost saving in water bill, which was estimated by comparing annual water bill before implementation and afterward. Furthermore, avoidable pollution charge (APC) was studied as one of indirect benefits. This was because untreated wastewater characteristic that exceed the quality standards limit mentioned in Table 3 was subject to a pollution fine according to the Indonesia ministry of environment (MOE) Regulation no. 4/2017. This fine was calculated based on the country's regulation for determining environmental loss (PermenLH 7/2014) using the following formula:

$$APC_i = \Sigma \frac{(Cmax_{\,i} - Cs_i)Q_{max}}{PU_i}\ 1.63 \quad \text{(Eq.2)}$$

Where APCi is the avoided pollution charge of parameter i (in USD), Cmax_i is the maximum concentration of parameter i recorded (in mg/L), CSi is the concentration standards of parameter i (in mg/L), Q_{max} represent maximum untreated wastewater discharged in one year (mg/year). PUi represent Indonesia regulated pollution unit of parameter i described in Table 1. The pollution unit was estimated and multiplied by USD 1.63, which was the base rate per pollution unit in Indonesia.

The company location was surrounded by 19.6 Ha of rice field along its wastewater stream. The avoidable compensation cost was estimated under the assumption that untreated wastewater used for irrigation will lead to a decrease in production yield compensated by the company. Therefore, the presence of WRS impose indirect benefit as the company can avoid such cost. The degree of decrease in production yield was estimated using the assumption based from Konwar & Jha (2010) which suggest FOG contamination of rice fields potentially reduce the yield by 20%. The following formula used to estimate avoidable compensation cost.

$$\begin{aligned} ACC &= (PY\ x\ P) - (PY\ x\ 20\%)P \\ ACC &= \big((A\ x\ PR)x\ P\big) - ((A\ x\ PR))x\ 20\%)P \end{aligned} \quad \text{(Eq.3)}$$

The benefit of avoided compensation cost (ACC) was estimated by subtracting the initial income of farmer without environmental pollution. This was calculated by determining the production yield (PY) in Ton/year and multiplying it by the current base price of rice (P) of USD 473.59/ton. The initial income was then subtracted from the estimated value when there was 20% decrease in production yield due to environmental pollution. To estimate the production yield, the 19.6 hectares (Ha) area rice field (A) was multiplied by the rice productivity rate (PR) obtained from the regional statistic agency (ton/Ha/year).

NPV was used to measure performance of the WRS in terms of its economic value, and is defined as the difference between the total discount benefits and costs, as shown in Eq. 3. Where C_k and B_k are the costs and the benefits in year k, respectively, and r is the discount rate, while n is as follows;

$$NPV = \sum_{k=0}^{n} \frac{-C_k + B_k}{(1+r)^k} \quad \text{(Eq.4)}$$

When NPV ≥ 0, the implementation of the WRS is economically feasible. However, when it is < 0, the investment costs outweigh the benefits, implying that the project is not economically feasible and should be rejected or discontinued.

3. Results and discussion

3.1 Description of WRS

According to company data, the primary water source for the operation was groundwater, with an average monthly withdrawal of 2,546 m^3. To support the entire operation, recycled water was predominantly utilized, providing an average monthly yield of 1,894 m^3. Figure 2 illustrates that a significant portion of water usage in the CPH process was attributed to biosecurity measures, encompassing activities such as personnel showering & diving, laundry for employee uniforms, car dipping, and cleaning production equipment.

To ensure proper treatment and management of the wastewater generated from biosecurity activities, it undergoes processing at a wastewater treatment plant (WWTP). Following this initial treatment, the wastewater is further treated by the implemented water recycling system (WRS). This additional treatment step provided by the WRS ensures that the water is appropriately purified and can be effectively recycled for various purposes within the operation.

Table 1. Water Pollution unit

Parameter	Pollution unit (kg)
COD	50
TSS	50
FOG	3

Source: Indonesia MOE regulation no. 4/2017

Wastewater from the biosecurity process should also be subjected to several procedures in WWTP. Some of the processes in WWTP and WRS systems, include physical, biological, and chemical treatment, as shown in Figure 3.

The treated water subjected to the WRS system, as described in Table 2 was stored in 3 storage tanks with a total capacity of 60 m^3. Subsequently, it was reused for cleaning equipment such as egg trays and incubators.

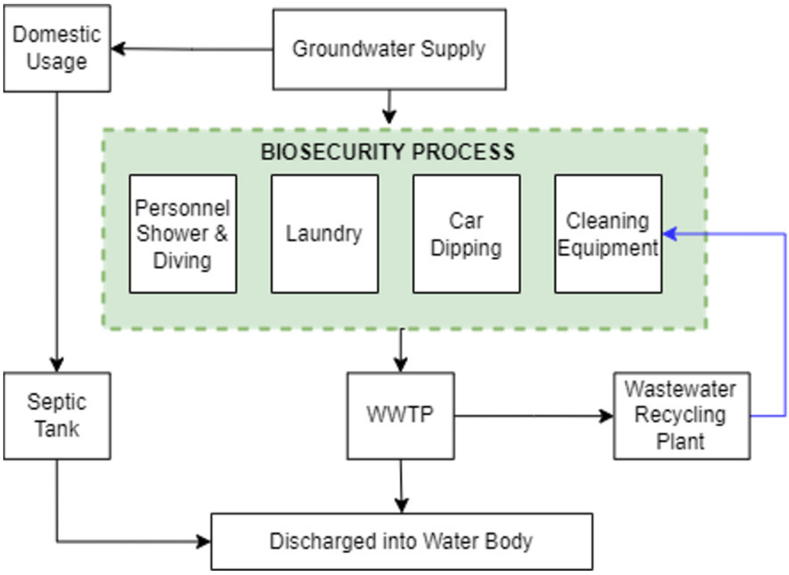

Figure 2. Water Utilization Scheme

Table 2. WWTP and WRS Process Description

Process	Description
Screening	Mesh placed before equalization to separate large particles such as egg shells, embryo parts etc.
Equalization	Collection of composite wastewaters in the single basin to homogenize wastewater characteristics and control the flow
Filtration 1	Simple filtration using a combination of silica and zeolite sand to remove suspended solids
Sedimentation	Control the flow and suspend some solids into the sediment
Biodigester	Utilizing bacteria to process wastewater in anaerobic conditions to dissolve organic matter
Filtration 2	Simple filtration using a combination of silica and zeolite sand to remove suspended solids
Aeration Pond	Blower combined with disk diffuser supplying air to increase dissolved oxygen in wastewater
Ultrafiltration	Consist of several filter media as follow 1. Silica sand 2. Manganese sand 3. Activated Carbon 4. Resin cation
Ultraviolet (UV)	Exposing wastewater to UV rays to kill the pathogen
Chlorination	Adding dose of chlorine to kill the pathogen

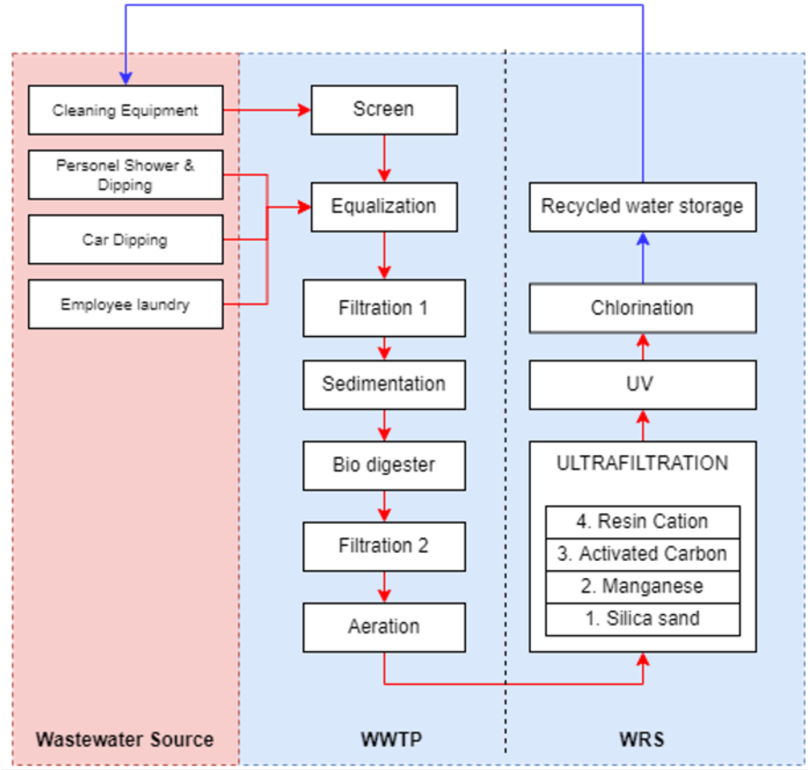

Figure 3. Wastewater Recycling Processes

The treatment of water starts with common process of primary treatment to remove large particles utilizing screen installed then equalization that serves purposes of sedimentation & homogenization of wastewater characteristics, then following by secondary treatment with the objectives to reduce the concentration of organic materials in the wastewater before it is discharged (Salgot and Folch, 2018). Furthermore, WRS unit depicted in Figure 3 consist of tertiary treatment processes including ultrafiltration, UV and chlorination. The addition of tertiary process in overall wastewater treatment potentially maximizes environmental benefits gained such as energy & water saving because the water can be reused (Awad *et al.,* 2019)

3.2 Wastewater characteristic

The untreated wastewater from CPH showed characteristics which exceeded the Indonesia quality standard, as shown in Table 3. The results indicated the potential of wastewater to pollute the environment. High content of BOD and TSS was discovered and they aligned with previous study conducted by Carter & Carr (1976). Furthermore, the significant concentration of these parameters resulting from cleaning of hatchery equipment. The cleaning process starts by pushing all debris from incubators with pressurized water into wastewater drainage. Therefore, the majority of cleaned debris consist of organic material, contributing to increased BOD and TSS at a certain level. Additionally, a high level of COD was detected in untreated wastewater, indicating the presence of oxidizable organic and inorganic materials. The frequent use of detergent and formaldehyde in CPH is suggested as one factor that can lower BOD removal. This is because the surfactant they contain potentially inhibits biofilm production (Lotfy and Rashed, 2002; Sirianuntapiboon and Srikattanaprom, 2003).

FOG was also highlighted because most of the influent data exceed the permitted concentration. The high content was suspected to originate from egg waste residues such as shells or yolk. This was understandable since egg yolk is a source of fat for poultry embryo development. Meanwhile, lipids account for

65% of the dry matter of egg yolk (Xiao *et al.,* 2020). Furthermore, the presence of FOG in water posed an environmental risk, as it was considered a water-insoluble pollutant and potentially harmful to animals and plants (Eljaiek-Urzola *et al.,* 2019).

3.3 Pollutant removal performance

WWTP and WRS operated sequentially, employing a series of processes to remove water pollutants, Figure 5 shows that the influent concentration of pollutants exceeded the quality standards at most periods. However, the existing processes in WWTP and WRS managed to lower the concentration to meet the expected quality standards.

The pollutant removal performance was contributed by series of processes in WRS that are sequentially arranged, as described in Figure 3. Each process serves specific purpose and are in line with the common stages of wastewater treatment which start from primary to tertiary (Lofrano and Brown, 2010).

The result suggests that average WRS pollutant removal performance for all parameters approximately over 70%. However, the data trend in Table 4 shows some deviation of the pollutant removal efficiency. Higher deviation indicates that there is significant variability or inconsistency in the WRS process over time that need to be closely monitored (Kosjek *et al.,* 2007). The variance pollutant removal performance could be affected by several factors including: wastewater characteristics, technology design, hydraulic retention times, and environmental factors such as seasonal changes. (Varma *et al.,* 2021). Standardizing process of wastewater treatment & monitoring could be immensely helpful to achieve consistent expected pollutant removal performance.

3.4 Groundwater Intensity Ratio

Figure 4 shows the trend of GIR for 36 months, spanning from January 2020 to December 2022 and in the range of 8.2 m^3/ton to 32 m^3/ton. The WRS construction finished in month 16 (April 2021), but the highest GIR was recorded in month 20 (August 2021). Upon further investigation, it was discovered that the tuning process of newly constructed WRS was the cause since the it required backwash of the system more frequently. However, the average GIR before WRS from January 2020 to March 2021 was estimated at 25.1 m^3/ton product. After using recycled water in April 2021, the it decreased to 17.52 m^3/ton at the end of 2022, accounting for a 30.18% improvement.

The downward trend of GIR indicated that WRS managed to reduce the groundwater withdrawal per output production indicating improvement in water efficiency. However, the system can be optimized further by implementing more aggressive & expansive

Table 3. Wastewater Characteristic

Parameters	Concentration (mg/L)				
	Quality standard	Min	Max	Average	Deviation
TSS	200	13	299	157.3	107.1
BOD_5	50	32.9	219.01	113.3	58.1
COD	100	64.6	429.4	229.4	108.0
FOG	10	1.6	16	9.8	5

Table 4. Pollutant removal performance

Parameter	Min	Max	Average	Deviation
TSS	29.4%	95.3%	79.6%	33.1%
BOD_5	47.5%	95.1%	78.2%	14.2%
COD	48.4%	91.3%	72.0%	14.3%
FOG	68.0%	89.3%	81.1%	27.8%

strategy such as increasing WRS capacity, expanding recycled water utilization for domestic usage & the combination with rainwater harvesting if appropriate (Tzanakakis *et al.,* 2020)

Nevertheless, the results suggest that having multiple water sources ensuring water security especially in water scarcity area, emphasizing the importance of diversifying water supply to achieve sustainability (Ribeiro *et al.,* 2022).

3.5 Cost of WRS

The Initial construction cost of WWTP & WRS was USD 66,829 with the annual operational & maintenance (O&M) cost was USD 10,285/year by incorporating the cost of personnel, equipment and wastewater quality monitoring with detail as follow:

Construction cost account as the biggest cost due to intensive use of material, construction equipment and labor. However, it just one time cost trough entire lifespan of WRS. Electricity cost considered as largest O&M cost account 34.5% of total O&M cost followed by labor and water quality monitoring respectively contributed 27.7% and 26.1 of total O&M cost. High electricity cost is justified due to numerous pumps installed since the WRS located in flat terrain so it requires constant pressure to channel the wastewater. Labor cost also considered substantial since it requires specific personnel competency to operates & monitor WRS with advanced technology. The cost of water

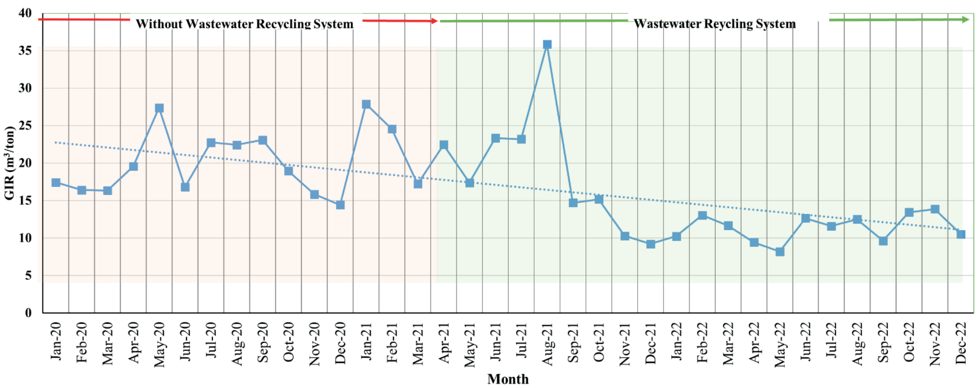

Figure 4. Groundwater Intensity Ratio

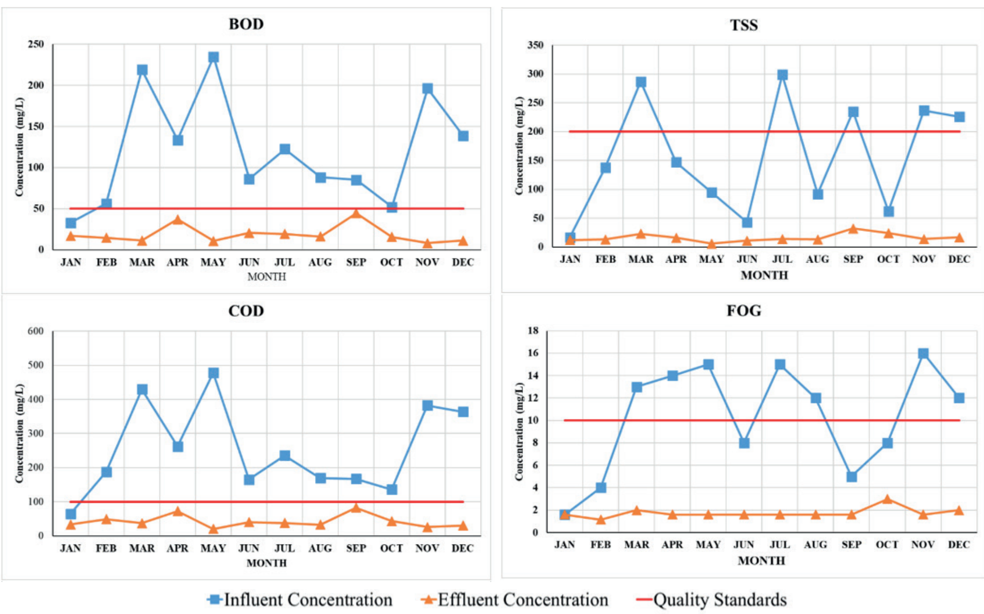

Figure 5. Pollutant removal trend

quality monitoring also contributes significant to overall expenses since it was required both by the company & mandated by Indonesia regulation. Therefore, the cost of wastewater treatment may vary and mostly site specific. Numerous studies suggest that wastewater treatment cost influenced by various factors such as scale, treatment capacity, technology used, regulatory compliance and site condition, Those factors can significantly impact the overall expenses involved (Ćetković *et al.,* 2022; Jagaba *et al.,* 2021).

With such amount of investment, the company expect the benefit produced would outweigh the cost. Implementation of WRS was examined and the result suggest that WRS provides several benefits including cost saving in water bill which considered as direct benefit since results can be obtained instantly. The indirect benefits also expressed consist of avoidance of pollution-related expenses such as pollution charge & compensation cost.

3.6 Benefit in cost saving water bill

The company is subject to a monthly regional tax on groundwater withdrawal or known as water bill. Prior to the implementation of the water recycling system (WRS), the entire operation relied solely on groundwater supply in 2020, leading to a total water bill of USD 13,058.22 for the year. However, after the WRS was implemented in April 2021, there was a gradual reduction in groundwater withdrawal, resulting in a significantly lower water bill, as depicted Figure 7.

Table 5. Cost of WRS

No	Cost	Ammount (USD)	%
1	WWTP Construction	47,359	70.90%
2	WRS Construction	19,470	29.10%
Total Construction Cost (USD)		**66,829**	**100.00%**
1	Water quality monitoring	2,689	26.10%
2	Electricity	3,552	34.50%
3	Activated carbon filter	329	3.20%
4	Silica filter	164	1.60%
5	Resin cation filter	164	1.60%
6	Manganese filter	164	1.60%
7	UV lamp	33	0.30%
8	Chlorine	335	3.30%
9	Labor	2,853	27.70%
Total O&M Cost (USD/Year)		**10,285**	**100.00%**

Note: USD 1 = IDR 15,203 (Exchange rate in February 2023)

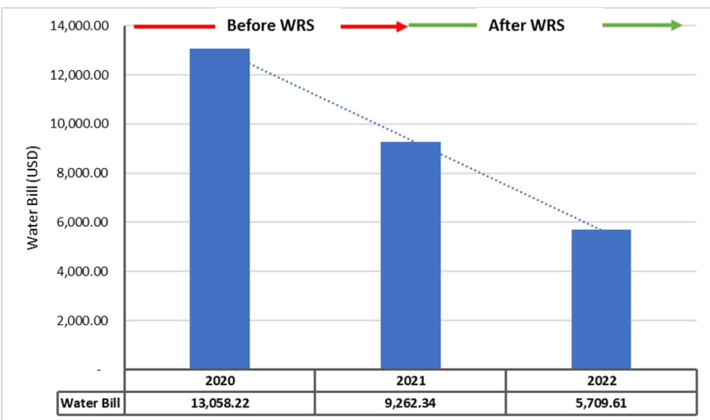

Figure 7. Trend of Water Bill

Through a comparison of the water bills in 2020 and 2022, it was determined that the implementation of the water recycling system (WRS) resulted in a remarkable 56.3% reduction in the water bill. This outcome serves as compelling evidence of the direct benefits that the WRS offers in terms of significant cost savings in operational expenses. The substantial decrease in the water bill clearly demonstrates the financial advantages of incorporating the WRS into the company's operations. Previous study argued that one of main objective of WRS implementation mostly financially motivated with objective to lower the water-related cost such as water bill (Beler Baykal, 2019). Cost saving saving was achieved by transforming the economy onto a resource-efficient path that eventually increased business competitiveness and provide resource for further growth (Di Maio and Rem, 2015)

3.7 Avoidable pollution charge

The untreated wastewater characteristic of CPH, as shown in Table 3, indicated that some data exceeded permissible concentration, making it an object of pollution charge according to Indonesia regulation. This study reported that potential pollution charge of USD 473.49/year can be avoided by the Company by implementing WRS as estimated in Table 6. The WRS manage to lower the risk of pollution charge by enabling the use of wastewater for other purpose, resulting in lower discharge.

The result only shows pollution charges that can be avoided limited to the condition in this study. The APC might differ under different wastewater condition because it is progressively estimated based on the degree & duration of pollution occurred. Moreover, it is crucial to consider the potential risks associated with pollution charges, as they not only impact costs but also have implications for a company's reputation. A recent study has demonstrated that implementing stringent environmental policies can adversely affect the stock returns of heavily polluting companies. (Guo *et al.,* 2020)

3.8 Avoidable compensation cost

The advantages of avoiding compensation costs in this study estimated based on the assumption made by Konwar *et al.* (2010). According to their study, the discharge of untreated wastewater into rice fields is projected to result in a 20% decrease in rice grain weight. This decrease in weight would subsequently lead to a decline in farmers' income when compared to unpolluted rice fields.

Table 6. Avoidable Pollution charge

Parameter	CS_i (mg/L)	$Cmax_i$ (mg/L)	$Cmax_i - Cs_i$ (mg/L)	Qmax (m^3)	$\frac{(Cmax_i - Cs_i)Q_{max}}{PU_i}$	APC_i (USD/Year)
TSS	200	299	99	25,247.16	50.0	81.38
COD	100	477	377	25,247.16	190.4	309.91
FOG	10	16	6	25,247.16	50.5	82.20
Avoidable Pollution charge (APC)						473.49

Note: 1 USD = IDR 15,203 following exchange rate in February 2023

Table 7. Avoidable Compensation Cost

Data	Unit	Value
**Rice field productivity (PR)	ton/ha/year	6
*Rice field area (A)	ha	19.6
Production yield (PY)	ton/year	117.6
*Rice base price (P)	USD/ton	473.59
Farmer's income without pollution (PY x P)	USD/Year	55,694.27
Farmer's income with pollution (PY x 20%)P	USD/Year	44,555.42
Avoidable compensation cost (ACC)	USD/Year	11,138.85

Note: 1 USD = IDR 15,203 following exchange rate in February 2023
*Site observation
** Harvested area and production of paddy in Cipunagara Disctrict (BPS Subang, 2013)

According to the regional statistical agency of Subang (BPS Subang), Indonesia, the rice productivity in the surrounding area was 6 tons per hectare per year, with a market price of USD 473.59 per ton. Under optimal conditions, it was projected that the 19.6-hectare field around the company could yield 117.6 tons of rice, valued at USD 55,694.27 per year. However, if untreated wastewater were to flow into the field without a wastewater recycling system (WRS), it was estimated that the production would decrease by 20%, resulting in a loss of USD 11,138.85 in annual income for the farmers.

It is important to note that these figures are estimates and do not account for the farmers' willingness to accept (WTA) compensation. The risk of compensation costs should be carefully considered, as the actual compensation amount may differ significantly from the estimated value. Various factors such as the characteristics of the subjects, their knowledge, perception, and awareness can influence the actual compensation costs (Sun *et al.,* 2019). Nevertheless, WRS provides the benefit of waste reduction, by minimizing the volume of wastewater released into the environment, the company can avoid potential environmental liabilities (Tayebi-Khorami *et al.,* 2019). In many jurisdictions, businesses are required to compensate for the environmental damage caused by their wastewater discharges. This can involve fines, penalties, or mandatory cleanup measures. However, with an effective wastewater recycling system in place, companies can lower their risk of environmental pollution and subsequently reduce the need for compensatory actions

3.9 Cost Benefit Analysis of WRS

Despite being one time expense, construction cost account as the highest cost of WRS because it consists of labor, material, construction equipment, and construction supervision. After commissioning, the total operational cost was estimated at USD 10,285.08/ year.

Table 8 shows that benefit from avoidable pollution charge was considered the smallest, primarily due to the relatively cheap base rate per pollution unit. Since 2011, Indonesia has applied a base rate of USD 1.63/pollution unit, which has remained unchanged. Recent study shows that the cost of pollution abatement rises gradually due to deteriorating environmental condition that make it more expensive to manage (Cao *et al.,* 2019). This condition implies that benefit of avoidable pollution charge might be higher than estimated value, when the rate is adjusted by various factors including environmental condition and inflation.

The CBA carried out in this study by estimating Net present value using formula in Eq. 4. Assuming that the discount rate (r) was equal to 5,75% following Indonesia central bank interest rate in February 2022. Based on the evaluated costs and benefits over 20 years assumed project, it was discovered that the total NPV was larger than 0, amounting to USD 30,742.54. Therefore, the WRS was considered as economically feasible because of the positive value of NPV indicating that the benefit outweighs the cost (Verlicchi *et al.,* 2012).

Table 8. Summary of cost & benefit of WRS

A. Cost	Unit	Value
Construction cost	USD	66,829
Operational cost	USD/year	10,285.08
B. Benefit		
Cost saving in water bill	USD/year	7,348.61
Avoidable pollution charge	USD/year	473.49
Avoidable compensation cost	USD/year	11,138.85
Total Benefit	USD/year	18,960.96

Note: 1 USD = IDR 15,203 following exchange rate in February 2023

Beyond the value of NPV, WRS in general might offers more substantial economic benefit to drive environmental sustainability by ensuring lower risk of pollution. Polluted area is known to have worse income distribution caused by high health expenditures and declining labour productivity (Zhou and Li, 2021). Therefore, by implementing pollution abatement technology such as WRS, adverse cost would be avoided and much better environmental condition can be obtained resulting in economic growth (Danish and Ulucak, 2020)

4. Conclusion

This study briefly described the wastewater recycling practice in a CPH company in Indonesia and assessed its techno-economic feasibility. The biosecurity practices implemented in CPH contribute significantly to the water usage and wastewater generated. The untreated wastewater characteristics potentially exceed permissible concertation, posing an environmental risk in terms of pollution. To address this issue, WRS was implemented, employing multi-stage physical, biological, and chemical processes with varying pollutant removal performance over different periods, but overally, it meets the required quality standards for reuse. The results showed a remarkable 30.18% improvement in GIR indicating a reduced risk of groundwater depletion caused by CPH activities. Furthermore, an assessment of the economic feasibility of the WRS highlighted that while the initial construction cost was significant compared to operational expenses, the project offers numerous economic benefits including costs saving in water bill and the avoidance of pollution-related expenses. CBA evaluation showed positive NPV affirming the economic feasibility.

In conclusion, this study suggested that WRS remains as viable option to be adopted widely in poultry production. WRS implementation offers economic & social co-benefits that support sustainable development goals (SDGs) number 12: Responsible consumption & production. The WRS contributed to the goal by driving sustainable management and efficient use of natural resources, as well as the substantial reduction of waste through prevention, and recycling. However, a policy framework of WRS need to be developed such as intensive-based policy and simplified permitting process that would encourage other poultry business owners to adopt the environmentally sound technology.

Furthermore, this study can be beneficial to other researchers & professionals by providing a research framework that incorporate local context in evaluating the feasibility of environmentally sound technology. This study suggests that in depth assessment of environmental impact, cost, benefit and local regulation must be must be taken into consideration to minimise research bias and produce robust result of feasibility analysis that helps in decision making.

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