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GREY WATER FOOTPRINT ANALYSIS OF RICE-STRAW PULP TOWARD AN ADAPTIVE STRATEGY TO CLIMATE CHANGE

Miranti Ariyani[1], Chay Asdak[2] and Totok Herwanto[2]

[1] Department of Biology, STKIP, Garut, Indonesia
[2] Postgraduate Program of Environmental Studies, & Faculty of Agro-industrial Technology Universitas Padjadjaran, Bandung, Indonesia

ABSTRACT

Water crisis is one of the main problems due to climate change. This condition is deteriorated by pollution in receiving water body. Pulp and paper mill is known as industry that contributes to water pollution in receiving water body, because it generates large amount of waste water. Estimating pollutant in rice-straw pulp production process through grey water footprint calculation is very important to determine the adaptive strategy in order to minimize the impact that could occur due to fresh water scarcity caused by climate change. Grey water footprint is an indicator of the freshwater required to mix and dilute polutant and maintain water quality according to water quality standard. The objective of this research is to find out the grey water footprint value of rice-straw pulp production and to formulate some strategy in order to reduce the amount of pollutant. Quantitative-less dominant qualitative methods are used in this research. Data were collected through observations, direct measurement and semi-structured interviews at each step of production. The result shows that the grey water footprint value of rice straw pulp is 721.2 m"/ton, it means that in every ton pulp produced, 721.2 m3 of water is needed to assimilate the pollutant discharged to water bodies. The strategy to reduce the impact due to pollutant generated from rice straw pulp production is water efficiency at every step of production through application of cleaner production technology.

Keywords: *Cleaner production,* grey *water* ***footprint,*** *rice-straw pulp production, sustainable water resources*

INTRODUCTION

Rice-straw pulp as raw material for paper-making is an important program to reduce the dependency on wood. Increasing pulp production will contribute to the increasing of waste water discharged. The increasing of waste water will affect the water pollution in receiving water bodies. The limited amount of water resources coupled with pollution in receiving water bodies, will lead to unsustainable water resources utilization. There are several problems related to water resources, such as water scarcity and degradation water resources. Both are related to each other. Water scarcity occurs due to exploitation of water consumption , this condition is deterioted by water pollution at receiving water bodies. The amount of fresh water are limited, so it is necessary to use sustainable mechanisme i.e water recycling and zero waste to reduce the pollutant (Hoekstra, 2008)

The amount of pollution discharged by industry can be revealed if the overall amount of water consumed in the production process is known. One method that can be used as an indicator of water resources utilization is waterfootprint methods. Waterfootprint is the method that can provide information of the total volume of water consumed in producing good and services consumed by individual, business and state (Chapagain and Hoekstra, 2004).

There are three categories of water, i.e. green, blue and grey components. According to Hoekstra et al (2009), the blue component is an indicator of consumptive water use (fresh surface water and ground water). The green component refers to the precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. They explain further that grey water footprint is an indicator of the degree of freshwater pollution that can be associated with the process step. Grey water defined as the volume of freshwater that is required to assimilate the load of pollutant based on existing water quality standards. The objective of this study is to quantify the amount of grey water at pulp production as a references to determine the adaptive strategy of water resources management so the impact that might be occurs due to water pollution and fresh water scarcity could be minimized.

MATERIALS & METHODS

The object of this research is to quantify the amount of pollutant (grey water footprint) not only at the cultivation stage of paddy-rice but also at the industrial stage (pulp production). Besides the value of water footprint, this study also analyzes the impact that might occur due to pollutant and formulates the response. The sustainability of water resources can be analyzed from environmental as well as economic perspectives. Sustainability from environmental and economic perspectives refers to water use efficiency in terms of quantity and economic value so we can reduce the environmental impact without compromising the productivity. The data in this study are obtained through observations, direct measurement, semi structured interview and supported by literature. The data required in this study are grey water (degree of water pollution) is calculated through the assimilative capacity of water bodies to the amount of pollutant.

Data Collection for Grey Water on Cultivation Stages

Grey water footprint (m³/ton) in cultivation stage refers to the amount of water required to assimilate the pollutant that contaminated ground and surface water (Mekonnen and Hoekstra, 2010). The pollutant generally consist of fertilizers (nitrogen, phosphorus etc), pesticides and insecticides. Grey water value is calculated as the chemical application rate per hectare (kg/ha) times the leaching fraction divided by the maximum acceptable concentration (kg/m³) minus the natura concentration in the receiving water body (kg/m') and dividing all by crop yield (ton/ha) (Hoekstra et al., 2009). Grey water value are calculated using formulation (Hoekstra et al., 2009):

$$WF_{proc,gray} = \frac{(\propto \times AR)/(C_{max} - C_{nat})}{Y}$$

α is the percentage of nitrate leached (leaching fraction), AR is the amount of fertilizer used per hectare (kg/ha), C_{max} is the ambient water quality standard of nitrat in water body (kg/m³), C_{nat} is natural

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Corresponding Author.
E-mail: miranti.ariyani@yahoo.com

concentration of nitrat in receiving water body (kg/m") dan Y is yield (ton/ha).

Data Collection for Grey Water on Industrial Stages

Grey water on industrial stage is an indicator that refers to the pollution of receiving water bodies due to production of goods. *Grey water* value can be obtained by calculating the amount and consentration of pollutant which generated from every step production. The data are obtained through analysis of wastewater quality such as BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solid) and the degree of acidity (pH) based on The Decree of West Java Governor No. 6, 1999. Grey water value are calculated using formulation (Hoekstra e/ af., 2011) :

$$WF_{proc,gray} = \frac{Effl\ (C_{effl} - C_{nat})/Cmax - Cnat}{Y}$$

Effl is the pollutant load (volume/time), C_{effl} is pollutant concentration in effluent (kg/L), C_{max} the ambient water quality standard for that pollutant (kg/L) and Conf is natural concentration of pollutant in receiving water body (kg/m'). The value that used to calculate grey water value are the largest component among BOD, COD and TSS.

RESULTS AND DISCUSSION

Grey Waterfootprint Componen on Cultivation Stages

Generally, pollutant elements that were included in calculation of grey water in cultivation stage is nitrogen and pesticide (Hoekstra *et al.,* 2009), but in this study, pesticide were excluded from the calculation. Based on observation and interview, the amount of synthetic fertilizer (NPK) is 175-210 kg/hectare.

Grey water j!ootprint value which is derived from nitrogen fertilizers (NO °) in the rice cultivation is 29,1 m^3/ton. This value indicate that if the water containing nitrate discharged into receiving water body, it takes at least 29,1 m^3 water to assimilate pollutant which come from fertilizer used to produce one ton of straw. The result of calculation are presented at Table 1.

Table 1. Grey water footprint value of local paddy-rice

No	Parameter	A	AR (kg/ha/time)	C max (mg/L)	C max (kg/m³)	C nat (mg/L)	C nat (kg/m³)	$WF_{process}$ *grey* (m³/ton)
1	NO_3^-	0,05	63	20	0,02	0,69	0,00 069	29,1

Grey Waterfootprint Componen on Industrial Stages

The calculation shows that the amount of waste water generated from all stage of production is 421,96 m^3/ton (Table 4.2). This value is greater than the maximum limit of waste water according to The Decree of West Java Governor No. 6, 1999 , which is 100 m°/ton. The Quantity of waste water and concentration of pollutant are the main factors which contributed to grey water value.

According to the calculation, the largest grey water footprint value is come from washing process, which is 115,12 m^3/ton (Table 3). The high value of grey water at this step, is due to the higher load of contaminants that were identified from BOD value, which is 641 mg/L or equivalent with 267,07 kg/day (Table 4).

Table 2. The Amount of Wastewater from pulp production (m'/ton)

No	Process at *pufper machines*	The Amount of waste water/day (liter)	The Amount of waste water/ton pulp (m'/ton)
l	*Cooking*	23.294	236,67
2	*Hydrapulper*	0	
3	*Johnson screen*	0	
4	*Washing vacuum*	419.934	
5	*Cowan screen*	0	
6	*Valveless Filter*	71.760	
7	*Bleaching Hollander*	0	
	Total	**514.988**	
No	**Process at Paper Machines**	**The Amount of** waste **water/day (liter)**	**The Amount of** waste **water/ton pulp (m'/ton)**
1	*Wire Part*	1.080.000	185,29
2	*Press Part*	432.000	
Total		**i.512.000**	
Total waste water debit (m'/ton)			421,96

Sources: Primary data analysis, 2011

Table 3. Grey water footprint value on the processing straw into pulp

Parameter	WF t„„„ *grey* **(m'/ton)**		
	Cooking	**Washing**	**Pulp- sheet making**
COD	14,64	92,14	34,96
BOD^5	21,03	115,12	33,89
TSS	4,27	5,41	43,18

Sources : Primary data analysis, 2011

Table 4. Losd of Contaminant on the processing straw into pulp

Parameter	Load of Contaminant					
	Cooking		**Washing**		**Pulp-** sheet **making**	
	mg/L	**kg/day**	**mg/L**	**kg/day**	**mg/L**	**kg/day**
COD	3449, 6	80, 17	1209, 31	504,57	482,6	717,97
BOD^5	2100	48,8	641	267,07	200	294,84
TSS	584	13,58	42	17,21	342	515,59

Sources : Primary data analysis, 2011

From environmental perspective, washing process is an important procedure to separated the fiber from black liquor which still containing anorganic chemical and dissolved organic compounds derived by raw material. This process is also contribute to pollution in receiving water bodies, because its generate the largest volume of waste water (Anh, 1996).

Grey waterfootprint of Rice- Straw Pulp

In order to get the value of grey water footprint throughout all production process, it is required additional data such as *product fraction* (f_p) dan *value fraction* (f_v) as listed at Table 5. Table 6 shows that grey water footprint value of rice- straw pulp is 721,2 m^3/ton. it means that in every ton pulp produced, it is required 721.2 m^3 water to assimilate the amount of pollutant that were discharged to water bodies. *Grey water footprint* value shows shows the higher levels of pollution in water bodies and the natural capacity of water bodies to assimilate these pollutant.

Table 5. Product fraction dan value fraction of Paddy-Rice and its by Product

No.	Primary Product	Average weight (gram)	By Product	Average weight (gram)	Average price/ kg (Rp)	*Product fraction (f_p)*	*Value fraction (f_v)*
1	Paddy	64,71	Straw	8,09	750	0,125	0,032
2			Filled grain (GKP)	51,76	3500	0,8	0,97
3			Empty grain	1,62	0	0,025	0
4			Empty Panicle	3,24	0	0,05	0

Sources : Primary data analysis, 2011

Table 6. Grey water footprint value of paddy-rice and its derived product (m^3/ton)

Product			Grey		
			WF (i)	WF process	WF (p)
Paddy*	1	1	0	29,1	**29,1**
Straw	0,125	0,032	29,1	0	7,5
Pulp	0,17	1	7,5	115,1	721,2

Sources : Primary data analysis, 2011

Cleaner production is the key that can be applied to reduce the amount of waste water generated from rice-straw pulp production. According to Visvanathan *et al.* (2000) in Chapagain et *al.* (2006), application of cleaner production in production of cotton positively contributed to reduce chemical used up tp 30% and COD levels up to 60%.

The first mechanism that can be applied by the company to reduce waste in the pulp production is separation of NaOH from black liquor after cooking processing. Reuse of NaOH is able to reduce the production cost and negative impact of sodium to the environment. Research conducted by Rousu *et al.* (2002) on *Sustainable pulp production from agricultural waste,* state that separation process of NaOH from black liquor is very difficult process because the presence of silica in the black liquor. In addition, this technology is very expensive, (Oinonen and Koskovirta, 1999; Rangan and Rangamannar 1997), so that the separation process of silica will increasing the cost of production.

Formic acid can replacing the function of NaOH as chemical cooking and it is alternative way to reduce grey waterfooprint value. Utilisation of formic acid as a solvent cooking also known as *chempolis* process (Rousu *et al.,* 2002). This process involves several intensive testing, so that, this method are suitable from environmental perspective as well as economic perspective. By using this method, cooking solution (black liquor) could be recovered perfectly through recycling and recovery process.

The second mechanism that can be applied to reduce grey waterfootprint value are treat the waste water by appropriate mechanism so that the concentration of pollutant is equivalent with ambient water quality standard ($C_{eff} = C_{max}$)• When $C_{eff} = C_{max}$„ the grey water footprint value is equal to effluent value (Hoekstra *et al.,* 2011). According to Hoekstra et al. (2011), this happened because some of the capacity to assimilate pollutant has been consumed. Due to the effluent, the concentration of the chemical in the receiving water body has moved from C_{nat} (natural concentration of pollutant in receiving water bodies) in the direction of C_{max} (ambient water quality standard).

According to observation and interview process, it is known that before discharging the waste water into the receiving water bodies, it is firstly processed at waste water treatment plant. But, it is limited to primary processing (physics processing). According to Ali and Sreekrishnan (2001), the type of treatment that appropriate for wastes containing high organic material such as pulp and paper waste water is physical, chemical and biological treatment which consisting aerobic and anaerobic process. The result of the study conducted by Thompson *et al.* (2001) shows that the application of physical and biological treatment using anerobic mechanism effectively reducing the levels of BOD and COD up to 80- 90%.

Economic activities such as pulp and paper industry

can produce economic benefits, known as profit. According to Fauzi (2004) as well as Reksohadiprodjo and Brodjonegoro (1992), the economic benefit derived from economic activities without considering the impact of pollution, does not actual benefit, but categorize as marjinal benefit. One way to estimate the real benefit is internalizing the impact that would be occurs with considering the cost of waste water treatment process as component production.

Increasing rice-straw pulp production will increase the amount of pollutant discharged. In the end, this condition will affect the cost of waste water treatment, which includes development of waste water treatment plant, operational cost and monitoring cost. Because of the development of rice-straw pulp is the program of the government, government must be provides the subsidiaries in the from of waste water treatment plant as suggested by Rogers (1998).

The cultivation steps which produces rice-straw is also contribute to the pollution in receiving water bodies. The pollution which is derived from agricultural activities is categorized as non point source and it is very difficult to rehabilitate. Pollutant that come from fertilizers are a major source of pollution in receiving water bodies. (Galloway *ct al.,* 2003; Laegreid *et al.,* 1999 in Pathak *et al.,* 2006). SRI method is alternative way that can be applied to reduce the amount of pollutant leached. This method are not allowing the utilization any kind of chemical fertilizers, so that the value of grey water are 0 (zero) (Pratiwi, 2010). If it is difficult to achieved, another way to reduced pollutant is the optimalization of fertilizers usage according to appropriate management of fertilizer application. (Soepartini and Kasno, 1993 in Abdulrachman et al., 2009).

CONCLUSION

The result shows that the grey water footprint value of rice-straw pulp is 721.2 m^3/ton. The strategy can be carried out to reduce the impact due to pollutant generated from rice- straw pulp production is water efficiency at every production step of rice-straw pulp, e.g. through the application of SRI methods at cultivation step, cleaner production at production step and internalization of environmental impact through economic instruments.

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