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The Integration of Cleaner Production Indicators on the Environmental Performance Measurement System for the Indonesian Natural Rubber Industry

Sawarni Hasibuan[#], E. Gumbira-Sa'id[*], Eriyatno[*], Illah Saillah[*], Suharto Honggokusumo[*^], M. Romli[*]

[#] *Agroindustrial Technology Department, Bogor Djuanda University, PO Box 35 Ciawi, Bogor 16720, Indonesia*
E-mail: sawarni02@yahoo.com

* *Agroindustrial Technology Department, Bogor Agricultural University, PO Box 220 Bogor 16002, Indonesia*
E-mail: gumbira_said@yahoo.com; eriyatno@yahoo.com; isailah@yahoo.com; cdsapipb@indo.net.id

*^ *Senior Researcher at Makin Group, Jakarta, Indonesia*
E-mail: suharto.h@gmail.com

***Abstract*— This study aims to identify the priority of the cleaner production implementation and integrate it in the design of a comprehensive environmental performance measurement system for natural rubber industry in Indonesia. Prioritizing the cleaner production on the production process of natural rubber is based on the case of 10 Indonesian crumb rubber companies using the Analytical Hierarchy Process. The comprehensive environmental performance measurement system in natural rubber industry, i.e. in crumb rubber industry, starts from the selection of key environmental performance indicators (KEPI) using the fuzzy independent preference evaluation method. The environmental performance measurement model is developed to assist users in evaluating the comprehensive environmental performance and condition of the key indicators. The weighting for each of the KEPI is performed by means of the expert choice software. The environmental performance measurement model is designed in the form of a environmental scorecard with traffic light facilities which can provide recommendations based on the performance achievement status of each KEPI. From the results of the model verification in the case of crumb rubber industry, several indicator statuses were found "not good", i.e. on the index of raw materials, solid waste load, water conservation, energy conservation, and environmental innovation indicators. The environmental performance ranking model is designed to evaluate the comprehensive environmental performance in different companies or at different assessment periods.**

***Keywords*— Cleaner Production; Crumb Rubber Industry; Environmental Performance Measurement System; Environmental Scorecard.**

I. Introduction

Indonesia's role up to the present is still significant as the world's leading natural rubber producing country after Thailand. Indonesia's natural rubber production rate over the last 10 years is classified as high, i.e. 5.97% per year, exceeding Thailand (2.17%) and Malaysia (0.3%) [1]. Based on the International Rubber Study Group (IRGS)'s projection (2009), Thailand's position as the world's largest natural rubber producer will be replaced by Indonesia in the year 2020 with a production of 3.548 million tons, while Thailand's production is projected at 3.286 million tons [2]. Most (84.5%) of the Indonesian natural rubber production is intended for the export market. Indonesia's natural rubber export is dominated by crumb rubber, which is 95.63%; the rest is in the form of RSS (Ribbed Smoke Sheet), concentrated latex, and others [3,4]. Considering that Indonesia's natural rubber production is mostly intended for the export market, Indonesia needs to observe the various developments of global consumer demands, such as environmental requirements [5].

Up to the present, Indonesia's natural rubber processing industry is not fully efficient in its production process; the indication can be observed from the large volumes of liquid waste and solid waste generated. In addition, in the process of crumb rubber processing, odors that interfere with environmental comfort around the plant is also produced. All of this has a consequence on the amount of costs that should be allocated by the crumb rubber industry to minimize environmental contamination impacts of its production activities.

Departing from the above fact, the Indonesian crumb rubber processing industry, as one of the country's foreign exchange sources from the plantation sub-sector, needs to increase its efficiency while at the same time reducing the environmental impact of its production process. The cleaner production approach is believed to be a win-win solution in overcoming contamination problems because it harmonizes two interests, i.e. environmental and business interests [6,7]. Cleaner production is not merely a change of production materials and equipment, but should result in a sustainable production and consumption system.

In order that the implementation of cleaner production runs effectively and efficiently, the cleaner production indicators need to be integrated into the environmental performance measurement system of the Indonesian natural rubber processing industry [8]. The Integrated Environmental Performance Measuring System (IEPMS) approach will integrate cleaner production indicators in Key to Environmental Performance Indicator (KEPI) in the Indonesian crumb rubber processing industry [9,10]. The clean production indicators are based on production process benchmarks at 10 Indonesian crumb rubber companies4.

The research objective is to design an integrated environmental performance measurement system in the Indonesian crumb rubber industry through the stages of: 1) identification of cleaner production indicators in the Indonesian crumb rubber industry, 2) determination of key to environmental performance (KEPI) measurements in the Indonesian crumb rubber industry, 3) designing environmental scorecards with the traffic light system facility in the Indonesian crumb rubber industry.

The presence of the integrated environmental performance measuring system is expected to more motivate crumb rubber companies in Indonesia in adopting a sustainable production system that results in improved competitiveness of the Indonesian crumb rubber industry in the global market.

II. RESEARCH METHOD

A. Framework

One of the approaches to environmental management of the production process that takes place is by carrying out an approach to environmental performance measurements of potential impacts that can be caused by each process that takes place by using the KEPI (Key to Environmental Performance Indicator) approach [11]. With the KEPI approach, an identification of potential impacts that may arise from each stage of the process is carried out, thus companies can take corrective actions or preventive measures against the production process stages that have a risk of environmental impact [12,13,14]. With the KEPI approach, companies can determine the indicators relevant to the level of environmental performance viewed from the perspective of the production process.

B. Stages of Research

The research began by identifying the needs of stakeholders on environmental performace measuring systems and clean production priority based on the cases of 10 crumb rubber companies using the Analytical Hierarchy Process (AHP) method [15,16,17,1]. The KEPI design was built based on a number of measurements, aspects, and purposes. Environmental aspects of the production process activities that causes quite a large impact is considered as the key to environmental performance indicator (KEPI). The KEPI validation was performed using the Fuzzy Independent Preference Evaluation (FIPE) method [19,20,21]. Each KEPI indicator was given a score with the help of the Expert Choice software. Some adjustment processes were performed by considering real conditions in the field and the ease of implementation [13,18,22].

The environmental performance measurement design developed was presented in the form of environmental scorecards equipped with a traffic light system facility that functions as a feedback for existing performance achievements.This document is a template. An electronic copy can be downloaded from the conference website. For questions on paper guidelines, please contact the conference publications committee as indicated on the conference website. Information about final paper submission is available from the conference website.

III. RESULT AND DISCUSSION

A. Identification of Cleaner Production Indicators of the Crumb Rubber Industry

With regard to the flowchart of input and output as well as the condition of the crumb rubber production process existing in the field, various alternatives on application opportunities for cleaner production can be evaluated. Activities that provide important environmental impacts on crumb rubber processing are 1) high water consumption, 2) discharge into a body of water, 3) high energy consumption, 4) emissions into the air, and 5) public opinion particularly related to odor pollution that quite interferes with environmental comfort.

Based on expert evaluation, cleaner production priority comes from quality improvement of ***rubber material*** with a weight of 0.224. The next potential for cleaner production are the ***conservation of energy and water resources*** with a weight of 0.181 and 0.138 respectively. The average consumption of electrical energy in SIR 20 crumb rubber agroindustry is 0.924 MJ/kg of rubber and for diesel fuel, the average is 1.9003 MJ/kg of rubber. Based on the cleaner production priority, indicators of cleaner production in crumb rubber industry is further elaborated. The benchmark refers to conditions that can best be achieved by the crumb rubber industry in Indonesia. As an illustration, for the consumption of water, a "Very Good" condition falls at a level of water consumption of less than 20 m3/ton of products.

B. Designing of a Comprehensive Environmenta Performance Measurement System

The planning of a comprehensive environmental performance measurement system of the crumb rubber industry was developed from the results of discussions with experts, literature study, existing conditions and the needs for implementation of cleaner production in the crumb rubber industry [23,24,25]. The exploration of early key to

TABLE I
MATRIX ILUSTRATION OF THE KEPI INDICATOR DEVELOPMENT DESIGN OF CRUMB RUBBER INDUSTRY

Environmental Measurement	Environmental Aspects	Purpose	KEPI	KEPI Number	Standard
Raw Material	Raw material selection	Meet the SNI of raw materials	Dirt content	1	Max 5%
			Coagulant used	2	Coagulant recommended
			Coagulant thickness	3	< 150 mm
			Contaminant type	4	No heavy contaminant
Efficiency	Water consumption	Resource efficiency	Water consumption/ton of rubber	5	Max 35 m^3/ton
			Water recycle	6	Min 15%
	Energy consumption	Energy conservation	Energy source	7	Environmentally friendly
			Electricity consumption	8	Max 400 KVA/ton of product
			Fuel consumption	9	Max 35 l/ton of product
			Energy to transport	10	Max 0.057 J/ton of product
	Pre-drying	Increasing Po	Length of pre-drying	11	Max14 days
	Production	Increasing productivity	Wet production	12	Min 3 tons/hour
			Dry production	13	Min 3 tons/hour
Product	Customer satisfaction	Satisfying customers	Level of customer satisfaction	14	> 90%
	Rubber product quality	Meet the SNI of SIR products	Dirt content	15	Max 0.2%
			Ash content	16	Max 1%
			PRI	17	Min 50
			Po	18	Min 30
Pollution Responsibility	Liquid waste	Meet the quality standard of liquid waste	BOD_5 concentration	19	Max 60 ppm
			COD concentration	20	Max 200 ppm
			TSS concentration	21	Max 100 ppm
			pH	22	6-9
			$N\text{-}NH_3$concentration	23	Max 5 ppm
			Ammonia concentration	24	Max 10 ppm

environmental performance indicators was adopted from evaluation elements of ISO 14031 environmental performance [9,12,14]. The planning of an environmental performance measuring system for the crumb rubber industry also refers to the IEPMS model with a Plan-Do-Check-Act system that takes notice of two measurement categories, namely quantitative (operational) and qualitative (managerial). The designing of key to environmental performance indicators also need to be associated to environmental aspects and impacts on the overall activities that occur in the crumb rubber agroindustry. Validation results of the key to environmental performance indicators resulted in 50 KEPI. A comprehensive environmental performance was built based on a number of measurements, aspects, and purposes as illustrated in Table I. The weighting of each key environmental performance indicator (KEPI) was performed with the help of the *Expert Choice software*.

C. Environmental Scorecard^{CR} Measurement Model

Results of the environmental performance measurement of the crumb rubber industry that was developed was displayed in the form of a scoring board. For the consideration of efficiency and effectiveness without reducing the substance of evaluation, some KEPIs were simplified so that there were only 20 KEPIs on the scoring board. The scoring board contains the weight of each KEPI, the KEPI achieved score, the KEPI target score, and the calculation of the target achievement of each KEPI. The target score determination strategy on the environmental scorecard^{CR} was based on the results of primary data and secondary data acquisition.

Determination of the performance status of each selected KEPI was carried out by processing the achieved result and target into one particular score. The score was then evaluated based on several logical considerations so that its achieved performance status can be determined. The status score refers to three evaluation orders, i.e. 'higher is better', 'lower is better', or 'must be zero'. For the 'higher is better' evaluation system, the performance status was evaluated as 'Good' for a scorecard^{CR} value of > 75%; for scorecard^{CR} value between 50% and 75 %, the performance status was evaluated as 'Fair'; and for a scorecardCR value of < 50%, the performance status was evaluated as 'Poor'. On the other hand, for the 'lower is better' evaluation system, the performance status was 'Good' if the scorecardCR value was < 25%; the performance status 'Fair' for a scorecard^{CR} value between 50% and 75 %; and the performance status 'Poor' if the scorecardCR value was > 75%.

D. Traffic light system

On the environmental scorecardCR status, three colors were visualized, which indicated environmental performance conditions; red for a Bad/Poor environmental performance, yellow for a Moderate/Fair environmental working condition, and green for a Good/Satisfactory environmental working condition. Determination of the environmental performance status refers to numerical limitations explained in the previous section. This mechanism was designed to facilitate users to obtain recommendations for further action at the environmental performance condition achieved.

E. Environmental Performance Rating Model

Unlike in the environmental scorecard model where the status of each KEPI was expressed in three possibilities, i.e. 'higher is better', 'lower is better', or 'must be zero', in the composite index method, it is necessary to make a conversion in order that the research direction be the same. Therefore, the evaluation scores in the crumb rubber environmental performance rating model used 10 scales; the lowest score was 1, which indicated the worst condition, and the highest score was 10, as the best condition based on the scoring guide developed. This mechanism was designed to provide benchmark information (the highest score), the worst condition (the lowest score), and the average on each KEPI indicator. The performance rating model will perform an overall environmental performance aggregation and determine the inter-company or inter-period environmental performance rating status measured. The performance aggregation was obtained by multiplying the weight of each KEPI with its obtained score.

F. Model Verification and Validation

The model validation was performed using the face validity technique *[21]*. The development of models in this environmental performance measuring system was mostly done based on expert knowledge through acquisitions and in-depth interviews. In systems, a study such as this is categorized as a soft system which is relatively unstructured. In models with a soft system methodology approach, validation cannot be fully done mathematically, instead a testing is adequate to obtain an intellectual recognition that can be done through the expert judgment approach [19,24].

The environmental-scorecard model verification was performed on three crumb rubber plant respondents, with the data of each KEPI indicator as presented in Table II. Based on the score acquisition percentage compared with the target, and the status determination scheme of each KEPI indicator, the conversion of the KEPI achievement percentage was transformed in the performance status of each KEPI using the traffic light system. Results of examination on result compatibility for environmental performance indicators are shown in Table II. The results showed that the environmental-scorecard model developed has met the objectives so that it can be recommended as an environmental performance measurement model of the crumb rubber plant that is part of a comprehensive environmental performance measurement system model of the crumb rubber industry.

TABLE II
DATA ON THE ENVIRONMENTAL PERFORMANCE OF THREE CRUMB RUBBER PLANTS

Environmental Measurement	KEPI	Scoring	Unit	Target	PT_B		PT_G		PT_D	
					Score	%	Score	%	Score	%
Strategic Planning	1 Leadership	Higher	-	7	5	71	6.5	93	6	86
	2 Strategic planning	Higher	-	5	3	60	4	80	4	80
	3 Environmental Innovation	Higher	-	4	2	50	2	50	3	75
Environmental Resource	4 Human resource training	Higher	%	20	12	60	15	75	17	85
	5 Environmental budget	Higher	%	5	2	40	4	80	4	80
	6 Management Participation	Higher	%	80	60	75	75	94	75	94
	7 Community relation	Higher	%	7	6	86	6	86	6	86
Raw Material	8 Raw Material Index	Higher	%	90	45	50	45	50	45	50
Process Efficiency	9 Water conservation	Lower	m3	30	35	117	18	60	19	63
	10 Energy conservation	Lower	1	30	45	150	25	83	24	80
	11 Internal productivity	Higher	%	90	75	83	53	59	71	79
Product	12 Customer satisfaction	Higher	%	90	80	89	90	100	90	100
	13 Product quality index	Higher	-	1.33	1.01	76	1.02	77	1.11	83
Contamination Load	14 Liquid waste load	Lower	%	50	50	100	25	50	25	50
	15 Gas emission load	Lower	%	70	60	86	70	100	70	100
	16 Solid waste load	Lower	%	3	5	167	4.5	150	4.4	147
	17 Toxic waste index	Higher	-	7	8	114	8	114	8	114
Emergency respond	18 Accident index	Lower	-	0	0	0	0	0	0	0
	19 Job safety facility index	Higher	-	7	5	71	5	71	5	71
Legal compliance	20 Legal Compliance Level	Higher	%	100	70	70	80	80	80	80

Environmental-scorecard results can only capture conditions at a particular time for a company. To determine the development of performance over time or inter-company, an environmental performance rating model was prepared for the purpose. The environmental performance rating tries to sort the total environmental performance score obtained, or in essence determines the priority of environmental performance rating by considering the weight on each KEPI. At the early stages, a normalization of the KEPI score is previously done to obtain a uniform grading scale in order to allow for a comparison. Results of verification on three crumb rubber plants are presented in Table III. The results showed that the model corresponds with the purpose of designing the environmental performance rating model for the crumb rubber industry.

TABLE III
RESULT OF EXIMINATION ON ENVIRONMENTAL PERFORMANCE RATING AT THREE CRUMB RUBBER PLANTS

PLANT	TOTAL PERFORMANCE	STATUS	RATING	CONFORMITY
PT_J	5.2	FAIR	2	√
PT_A	4.5	FAIR	3	√
PT_D	5.1	FAIR	1	√

IV. CONCLUSIONS AND SUGGESTION

A. Conclusions

1) Critical stages of process that have a significant impact on the environment in the crumb rubber processing industry are at the stages of raw material reception, blending, and drying. Cleaner production intervention alternatives in the crumb rubber industry are raw material quality improvement, water recycle, energy conservation, good housekeeping, SIR product quality scheme improvement, and management system application.

2) The environmental performance measurement model was designed in the form of a scoring board with facilities that can provide recommendation on the status of achieved performance of each key to performance indicator (KEPI) equipped with the traffic light system. Results of model verification in the crumb rubber agroindustry shows that there are still environmental performance indicators with a 'Poor' status, especially for raw material, solid waste, water conservation, energy conservation, and environmental innovation.

B. Suggestions

1) The implementation of cleaner production in the crumb rubber agro-industry needs to be improved through the socialization of cleaner production economic benefits for all actors, involving farmers' associations and companies as well as the regional government.

2) Successful implementation of a comprehensive environmental performance measuring system in the crumb rubber industry requires the support of an integrated management information system in order that the data actuality and information, both on cleaner production benchmark and environmental innovations, be reliable and well socialized. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

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