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Safety and Risk Evaluation using HIRARC Model at Palm Oil Mill

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The rapid development of industrial field giving a huge impact to the society or even in organizations however total number of accident is currently increase due to the lack awareness about the important of safety and health issue. This study focusing on safety and health issue and safety improvement at Palm Oil Mill at East Malaysia. The mill is produce two products which are crude oil and kernels. In order to identify the hazards in this mill, several methods had been used such as questionnaires distribution, interview session, observations, safety audit and body discomfort survey. Hazard Identification, Risk Assessment, and Risk Analysis (HIRARC) model were used in this study. The data collected and recorded for the risk and ergonomic assessments. Risk and ergonomic assessment is conducted after the hazards being identified in all 6 stations of Palm Oil Mill with total 33 activities were analyzed. Quantitative risk assessment was used by considering the likelihood and severity of the hazards. The values of risk were determined based on the table of likelihood and severity. All the hazards identified is sort into station and level of risk. The hazards with high value of risk is considered as the problem identification. Comprehensive discussion and analysis were done on the top three (3) high risk activities. The ergonomic assessments which are Rapid entire body assessment and body discomfort survey were used as a tools to support finding. HIRARC model has successful being used to analyze the hazard and risk exposure on the palm oil mill and action need to be taken on the high risk activities to prevent from an accident.

Keywords* : *Ergonomic, REBA, HIRARC, Palm Oil Mill

I. INTRODUCTION

The development of agriculture in Malaysian brought the increasing of performance in palm oil industry. Palm oil production is the among main sector in Malaysia and Malaysia also is one of the largest production in the world [1]. In Malaysia, there is more than 40% of oil palm plantation holds by the private company. In the year 2016, Malaysian Palm oil Board reported the oil palm planted in Malaysia up to 5.74 million which mean increased 1.7% from the 5.64 million hectares from the previous year. There have increasing of new oil palm plantation at Malaysia, especially in Sarawak where it shows the increase by 4.7% of planted oil palm. The biggest area of oil palm planted still in Sabah state with 1.55 million hectares followed by Sarawak 1.51 million hectares. However, in peninsular Malaysia had recorded 2.68 million hectares of oil palm planted in 11 states (MPOB, 2017). Table 1, shows the amount of palm oil production from the Malaysia compared with the others countries produce palm oil [2].

Table 1 : Top Palm Oil Producing Countries in The World [2]

Rank	Country	Production (in metric tons)
1	Indonesia	3,60,00,000
2	Malaysia	2,10,00,000
3	Thailand	22,00,000
4	Colombia	13,20,000
5	Nigeria	9,70,000
6	World	58,800,000

In the year 2016, dry weather due to the EL-Nino phenomena was cause the production of crude palm oil decreasing. CPO production drop 13% with 17.32 million tonnes compared with 19.96 million tonnes in previous year. However, due to the high quality of CPO production export value palm oil product in 2016 increase to RM64.58 billion from RM63.2 billion in 2015. One of the aspect to have high quality of product, comes from the high performance of Mill and refineries. MPOB recorded that in Malaysian, the total mills is about 454 with the capacity operations exceeded 111,966,200 tonnes per year. The high capacity of CPO production was come from Peninsular Malaysia with 57,178,000 followed by Sabah 33,679,200 and Sarawak with 21,109,000 tonnes of CPO production. The total refineries in Malaysia are 53 and the capacity exceeded 27,669,171 tonnes per year. The largest amount of product shows the high performance and technologies were implemented in the refinery makes the process more hygiene and produce high quality of product.

Malaysian Palm Oil Board, MPOB shows the result of number of fresh fruit bunch (FFB) mills at Sabah is 129 mills and the capacity in operations exceeded 33,679,200 tonnes per year.

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This is the highest development and achievement of palm oil industry in Malaysia, but at the same time the accident which involved the fatal accident also increased and these problem may affecting the quality of operation in this sector. Ali et al, 2009 claimed the major of accident in workplace are poor of handling tools and machinery in industry [3]. Based on the data of SOCSO annual report, the total amount of workplace injuries in Malaysia was reported 114,134 cases in 1995 and it is the highest amount of accident and the cases was decreased to 85,926 cases in 2001. Sabah Department of Occupational Safety and Health (DOSH) reported that the number of accident increased from the previous year which is from 112 cases to 265 cases in 2013. The data shows that the accident in Malaysia is not consistent in other words constantly fluctuating.

The best way to improve the quality of operation while evading the likelihood accident is taking serious about the safety management. Although, the most risk and hazard can be preventing by using available method, accident still can occur due to the lack of awareness from the workers itself. In fact, the majority accident in the industry is come from the unsafe work and unsafe condition at the workplace.

This study focus on one of the palm oil mill in East Malaysia (Sabah) which produced crude palm oil. The mill have facilities on site capable of processing at range 75 metric tonne of fresh fruit bunch(FFB) per hour through sterilizer, auto-feeder, thresher, processing station, clarification station and others. Around 75% of FFB were obtained from the company's own plantation and the rest from outside suppliers. The mill can receive fresh fruit bunch for 400 metric tonnes per day and produced 20% of Oil Extraction Rate, OER. The capacity of production exceeded 80 metric tonnes per day. However, the area of production line like FFB ramp, sterilizer and other place have high tendency to face risk.

The HIRARC model will be used in this study to identify and solve the most crucial safety issue on the selected palm oil mill. HIRARC model methodology will start with identification of hazards, then assessment of risk and last the determination of control measures for the implementation of safety and health in the operations.

II. HIRARC MODEL

A. Observation

Observation is the one of the method to identify hazards at the workplace. For this study, observations were conducted at production line including FFB loading ramp, sterilizer station, press station, thresher, kernel station and boiler. A set of safety audit provided from the safety officer and it was completed during the observation in order to identified problem in selected areas. This process was conducted together with safety officer of the palm oil mill. From the observation, there is no accident case recorded at the production area. The hazard identified were the hole on the platform did not cover, certain belting also not had their case, certain places is too oil and need to be cleaned. During the observation also, some photos were captured as the method to identifying the hazard. All the data required such as tools, machinery, layout, and chemical used were recorded and the process of interviewing the safety officer conducted with purpose to get more details information about the safety management in the company.

B. HIRARC Analysis

The data recorded from the observation were analyzed into the table according to the sequential processes selected. From the risk management methodology, first procedure in HIRARC analysis was selecting the activities and hazard identification. The hazard from those activities and it is causes was determined and written in the table. Hazard impact rating and follows by propose the possible and reasonable solution to solve the problem. HIRARC is the popular tools that had many companies used to structure the hazard identification, risk assessment and risk control [4,5]

C. Analyze and Estimate Risk

Calculation of risk is determining by the likelihood and severity of the credible accident sequence in order to determine the priorities of identified hazards [6]. This method divides into three parts that is qualitative, quantitative or semi quantitative method. A qualitative analysis is use words to explain the likelihood and severity occurs and this method must the done by the peoples who have expert knowledge and experience on the field. In semi-quantitative analysis, it uses scale to describe the values. This scale is used to produce expanded ranking scale. Quantitative analysis uses the both value of likelihood and severity from various data which recorded past accident and scientific research. Table 2, shows the value of likelihood of an event occurring.

Table II. Value of likelihood [7]

Likelihood	Description	Rating
Most likely	The most likely result of the hazard	5
Possible	Has a good change of occurring and is not unusual	4
Conceivable	Might be occur at sometimes in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

Severity can be divided into 5 categories. The severity is measured based on the individual's health, the environment, or the property. Properly consideration need to be done before determine the rating value. The types of severity, description and rating for each category presented in Table 3. Risk analysis is used likelihood and severity value to presenting result in risk matrix. Risk can be calculated by using equation 1. Table 2.4 shows the risk matrix after likelihood times with severity values and table 5 shows the relative values for each risk.

$$\text{Risk} = L \times S \qquad (1)$$

Where ; L = Likelihood ; S = Severity

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Table 1. Indicates the severity values [7]

Severity	Description	Rating
Catastropic	Numerous fatalities, irrecoverable property damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realized	4
Serious	Non-fatal injury, permanent disability	3
Minor	Disabling but not permanent disability	2
Negligible	Minor abrasions, bruises, cut, first aid type injury	1

Table 4. Risk matrix [7]

Likelihood(L)	Severity(S) 1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Table 5. Relative values [7]

Details	Risk	Action
High	15-25	Requires immediately action to control the hazard as detail in HIRAC
Medium	5-12	Requires a planned approach to controlling the hazard and applies temporarily measured if required.
Low	1-4	Considered as acceptable further reduction may be not necessary. If the risk can be resolved quickly and efficiently, control measure should be implemented and recorded

III. Results and Discussion

33 activities were analyzed from 6 stations in the selected Palm Oil Mill. Among that activities, 22 from it were categorized as medium and high level of risks as shown in table 6. From the analysis FFB loading ramp known as F, sterilizer station as S, press station as C, thresher as T, kernel station as K and boiler as B. The number after alphabet is represent number of activities.

Table 6. Data analysis

Station	Risk	Activity	Hazard
F1	16	Lifting FFB to the lorry	Bad body posture
C1	15	Maintenance the press machine, change the screw	Lift the Screw press machine cause back pain
C6	15	Change the roller of King cracker machine	The hammer hit the hand
S1	9	Loading fresh fruit bunch in the spherical sterilizer	Falling from the floor to spherical tank
S3	9	Walking near the mouth of spherical sterilizer	Falling into spherical sterilizer
S4	12	Maintenance the automatic valve	Falling from the platform
K1	12	Turn on the machine when repairing the conveyor	Lack buddy system
B1	9	Climb to the high place use ladders	Falling from the high place
C2	12	Open the valve of steam supply and valve of crude oil	Hot steam and oil
K2	12	Turn on the machine when repairing the conveyor	Hit by the moving object
B3	12	Carry the fiber to the boiler's bunker	Bad body posture
B4	12	Repair conveyor	Touched with the moving object
F3	9	Pull out the door ramp	FFB fall to the worker
S2	9	Loading fresh fruit bunch in the spherical sterilizer	Hot steam
C3	9	Cleaning the waste oil on the floor of workplace	Slippery on the wet floor
K3	9	Repair the conveyor	Awkward body posture
B2	9	Carry the fiber to the boiler's bunker	High noise
F2	8	Grading and unloading FFB from the lorry	Fall from the high place and from the lorry
C4	8	Switch on the machin	Electric shock
C5	8	Repair the pipe	Touched with the hot pipe, water and crude oil.
T1	6	Operation of FFB in thresher machine	Touched with the moving screw
T2	6	Walking on the wet platform	Slippery and hit the casing machine

Pareto Chart in Figure 1 shows the ranking of the risk obtained from the HIRARC analysis. From the analysis, there have 3 level of risks in HIRAC which are higher and action need to be taken as soon as possible. That activities are i) lifting FFB to the lorry, ii) lifting press machine parts and iii) change the roller of SuperCracker machine.

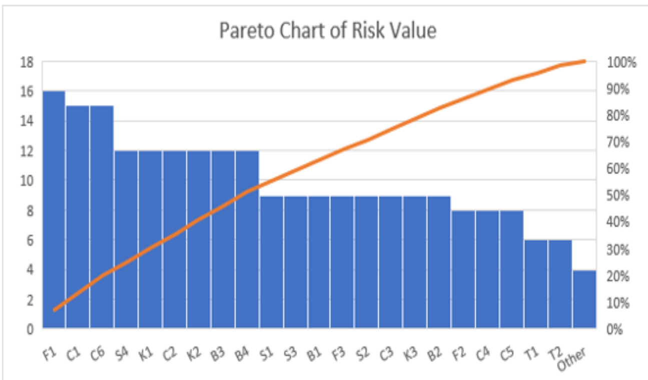

Figure 1. Pareto Chart of Risk value

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A. Grading and unloading FFB from the lorry

Figure 2. Lifting FFB

HIRARC analysis shows lifting FFB is the activity which contribute to the highest risk due to bad body posture. In this problem, the workers are required to lift fresh fruit bunch by using steel rod from the ground to lorry with the height of lorry at range 3 meter to 5 meter. The process take time mostly around 10 minutes for every lorry and repeated until done. The pain caused by the bad body posture when the worker does lifting the FFB activity. There are few steps to do this work, firstly the worker need to hook the FFB and then lift the FFB up to their shoulder and the push out the FFB to the lorry. Some workers said some FFB need two workers to lift it because the weight is too heavy and from that the worker feel their body getting pain. Besides, the worker also informed that the tendency the FFB fall over worker is too high because the FFB needed to push over their head. Currently, the safety officer giving some talk about the important of ergonomics as the way to reduce this problem. Rapid Entire Body Assessment (REBA) were done to confirm the scenario.

B. Rapid Entire Body Assessment (REBA)

This survey is used to identify which part of the body is most painful will experience by the worker after loading the fresh fruit to the lorry. There are 5 respondents were interviewed and all of them are in age 30 to 40 years. From the survey shows that the body parts that experienced highest pain is lower back. All the workers said they had experienced lower back pain so frequently. One worker was complained that he currently get the slip disc and he cannot to seat for a long periods time. His age in 40 years above and work for above 10 years at this company. Besides, the new employee also claimed that he experienced pain on his shoulder. This is because mostly the motion of work on lifting the FFB required the workers placed the rod in their shoulder before push the FFB to the lorry. So that is why the shoulder also contribute to the third higher pain than neck, knee, elbow, hand, and thigh.

Table 7. REBA action levels

Action level	REBA score	Risk level	Action (including further assessment)
0	1	Negligible	None necessary
1	2-3	Low	May be necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very high	Necessary NOW

Figure 3. Body posture

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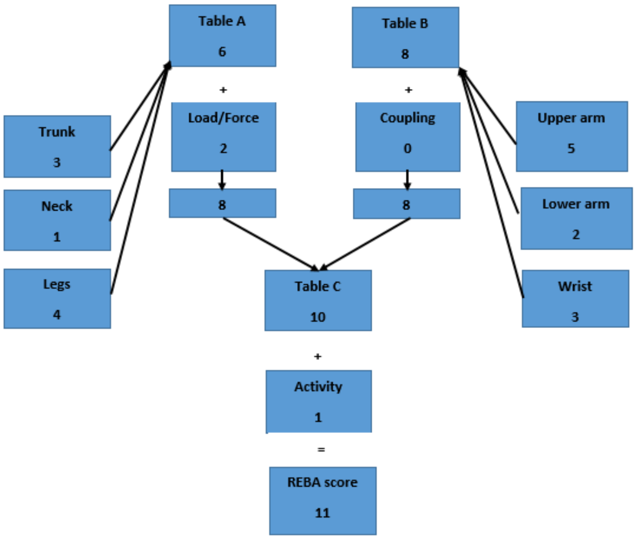

Figure 0. REBA score

According to Figure 3 shows the score of REBA analysis. Since the neck position is only in position at between 10^{O} to 20^{O}, the trunk locate position at between 20 to 60^{O} yielding score 1 and 3. The legs located at range > 60^{O} and force load with >20lbs bring the total value of Table A with 8 values. Table B consists upper arm score, lower arm score wrist and coupling score. Refer to location of upper arm shows that the worker move their shoulder around 40 to 90^{O} gives the score with 5 score and the lower arm score with value 2. Based on the workers hand movement, their wrist location are in range 15^{O} above and 15^{O} below. These three score were combined with coupling score with 0 and then yielding to 8 score in Table B. Score A and score B are entered in Table C to generate a score. The activity entered is score 1 (repeated small range actions) is added with the value in Table C. Summary of REBA analysis is shown in figure 4. The final REBA score is 11. This score is categorised as a very high risk level and immediate action needed to control this risk.

C. Analysis of Low Back Problem

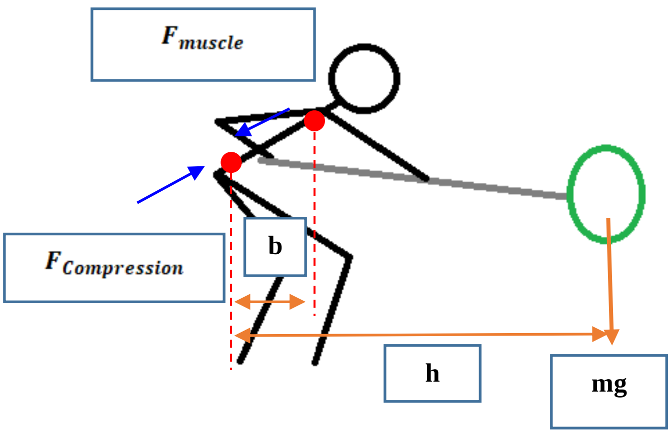

Figure 5. Lifting diagram of forces acting on the body

h: the horizontal distance from the load to the load to the L5/S1 disc

b: the horizontal distance from the center of mass of the torso to the L5/S1 disc

After doing some measurement,

the approximate value of b = 20cm and h = 100cm

and lift a load, $Wload$ = 25 kg (245 N) the person has torso weight, $Wtorso$=350 N

$$F_{muscle} = W_{load} \times \frac{h}{5} + W_{torso} \times \frac{b}{5} \quad (2)$$

$$= 245N \times \frac{100}{5} + 350N \times \frac{20}{5}$$

$= 6300\ N$

From the observation, we assume that the value of $\alpha = 50^{o}$

So, the force compression is

$$F_{Compression} = 245N \times \cos 50^{o} + 350N \times \cos 50^{o} + 6300N$$

$$= 6682.5N$$

The disc compression shows the high values and it may give hazardous to the workers if this task need to be perform repetitively and frequently.

D. Analysis of Lifting

NIOSH Lifting Equation is a valid tools for assessing risk of low back pain (LBP) due to manual lifting and it also being used to compare the lifting demands associated with different lifting task [8]. Waters (2011) stated that when the Lifting Index increase, the risk of LBP also increase [9].

Table 8. Lifting Index

Lifting Index (LI)	Comments
<1.0	Good Lifting
1.0 - 2.0	Likely to pose and increased risk for some workers
2.0 – 3.0	Higher low back pain prevalence in jobs
>3.0	Many or most workers are at high risk developing low back pain

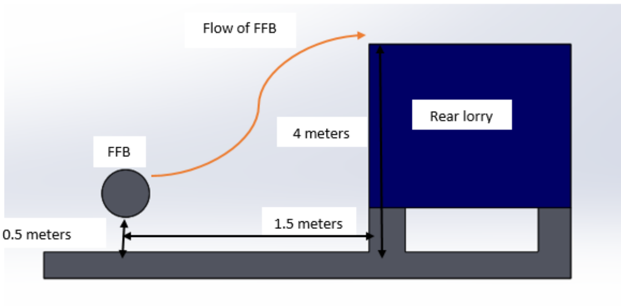

Figure 6. Lifting activity

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The parameters involved in this calculation is:
H = Horizontal of location of the object relative to the body
V = Vertical location of the object relative to the body
D = Distance is moved vertically
F = Duration of lifting
A = Asymmetry angle
C = Good coupling (Quality of the worker grip on the object)
The value of that parameters is
H = 150cm, V = 50cm, D = 350cm, F = 3 lifts/min, A = 30^o, C = 1
Job duration = 8 hours
Weight lifted = 25 kilogram
LC (Load constant) = 51 lbs = 23.1 kg
HM (horizontal multiplier) = 25/H = 25/150 = 0.17
VM (vertical multiplier) = (1-0.003 |V-75|) = (1-0.003 |50-75|) = 0.93
DM (distance multiplier) = 0.82 + 4.5/D = 0.82 + 4.5/350 = 0.83
AM (asymmetric multiplier) =1-0.0032A = 1- 0.0032(30) = 0.90
FM (frequency multiplier) = 0.55 (From Appendix B, Table 11-2, 3 lifts/min, 8 hours, V<75cm)
CM (coupling multiplier) = 1.0 (Good coupling) (Refer Table 11.3)
Therefore,
RWL= LC x HM x VM x DM x AM x FM x CM
= 23.1kg x 0.17 x 0.93 x 0.83 x 0.90 x 0.55 x 1.0
= 1.5kg

LI (lifting index) = Weight of FFB / RWL = 25/1.5 = 16.66 > 1.0 (high)
The result of this analysis shows that the workers highly tendency to get risk of back injury because the lifting index of 16.67 is higher than 1.0. As the prevention, employer must apply job rotation in this area or use mechanical assistant to perform this job.

E. Lifting Press Machine Parts

Figure 7. Lifting screw

Figure 7 shows, the situation where the screw press with the weight 180 kilogram lifted by a worker by using a chain block. This tool only uses manual handling where the worker need to pull chain of chain block to lifting the screw, casing and shaft of press machine. This work is impractical because take too long time to complete it. This work also fully used strength from the worker and caused the fatigue for human body. Impractical work will give effect on the body posture because the work doing repetitively. From the interview, the worker felt pain on their shoulder after pull the chain with longer time. Automated tool such as crane need to be used in order to reduce the risk of hazard.

F. Change the shaft and roller SuperCraker machine

Figure 9. Change the shaft

This process involved the material handling where the worker use hammer and a puncher to push out the shaft from the casing as shown in figure 9. The holder of the puncher just located on the bottom of shaft and it was not fixed and easily to move. Then the worker need to punch the shaft one by one using the puncher. During performing the task, the worker tends to use high strength to hit the shaft and the holder also may move since the hammer hit the puncher. Inadequate training may also bring the accident to the worker which hammer has high tendency to hit the finger or hand. From the interview, worker said they had experienced hit their hand because miss hit the puncher. Although the gloves were provided, but hitting from the hammer still can cause injury to the worker's finger and hand.

IV. CONCLUSION

From the study, it is very important to have a well-established maintenance and supervision program in order to ensure the safety and health in palm oil mill. Modern and automation systems can replace manual work and it will lower the risk of hazard. It is may be necessary to improve the system to ensure effectiveness and productivity while reduce the risk which exposed on the worker. HIRARC model has successful being used to analyze the hazard and risk exposure on the palm oil mill. Risk and ergonomic assessment was conducted after the hazards being identified in all 6 stations of Palm Oil Mill with total 33 activities were analyzed. Quantitative risk assessment was used by considering the likelihood and severity of the hazards. The values of risk were determined based on the table of likelihood and severity. From the analysis, there have 3 activities with high risk value which are i) lifting FFB to the lorry, ii) lifting press machine parts and iii) change the roller of SuperCracker machine. HIRARC need to be reviewed and action need to be taken especially on the high risk activities to prevent from an accident. HIRARC also need to be update annually to ensure the effectiveness of the Occupational Safety and Health management system.

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