

## IMPROVEMENT SUGGESTION OF SOLAIR INCINERATOR WASTE ENTRY DOOR SIZE SPECIFICATION AND POSITION USING HIERARCHY OF CONTROL FRAMEWORK

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### Abstract

Awkward posture refers to positions of the body while performing work activities that deviate significantly from the neutral position and may pose risks such as damage traumatic work Musculoskeletal Disorders (MSDs). Solair incinerator controlled by one operator. The position of operator enter the waste indicates as awkward position. The existing work posture assessment score with RULA obtain 7. The value indicates that the working posture is necessary investigate and change immediately. Because the operator working with the hand(s) above the head, or the elbow(s) above the shoulders more than 2 hours total per day. This study focus on observation to work posture and the facility (entry door of incinerator) when operator enter the waste. The existing dimension of the entry door is L x W x H x D = 100 cm x 70 cm x 169 cm x 83 cm. The suggestion size is 80-101 cm for height. The waste container load 1-1.5kg with diameter 27 and height 40. And suggestion standard screw container is 9 inch. After analysis and get score 2 for the improvement size of incinerator entry door purpose to avoid the awkward position and reduce the risk of MSDs to the operator.

**Keywords:** awkward position, incinerator entry door, musculoskeletal disorders (MSDs), RULA

### 1. Introduction

Incinerator is one of the startup technology developed by Bandung Techno Park. Starts with many problems caused by garbage in big cities. In Figure 1 shows landfill waste data at several area around Bandung.



Figure 1. Landfill Waste Data in Bandung

Solair incinerator is an incinerator that uses water mixed with diesel as fuel. By using water that is split into hydrogen as an extra fuel makes the heat in the combustion process becomes high. Solair Incinerator use three times the treatment process to neutralize toxins and smoke combustion so that the burning of garbage only in the form of hot air that is not harmful to the environment [1].

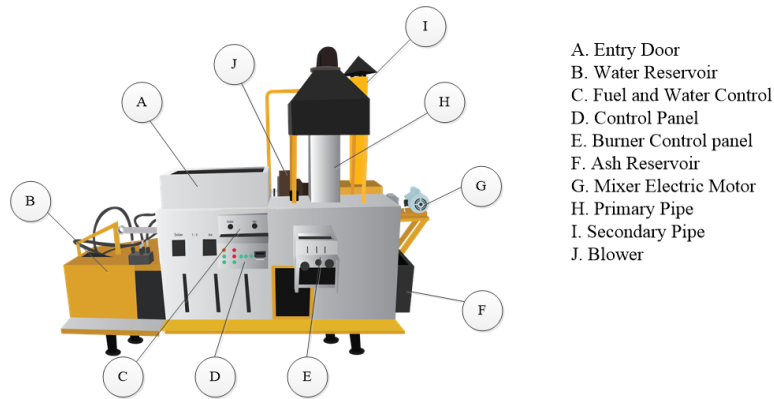


Figure 2. Incinerator BTP Parts

Solair incinerator controlled by one operator. To operate the incinerator, the first thing to do is turn on the machine by switch on the generator, compressor, and water-diesel fuel at the control panel as shows at figure I.a. The second is operator load the waste from the entry door shows at figure I.b and the last job of operator is operate the burner that shows as figure I.c.

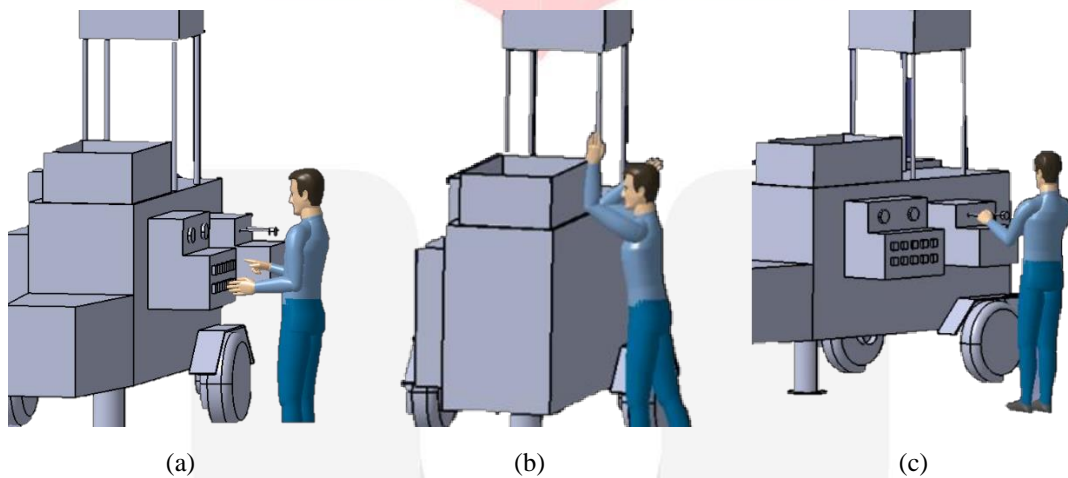


Figure 3. Incinerator Operator Jobs

Analyze with Caution Zone Checklist by WISHA (Washington State Department of Labor and Industries). From 3 main position of operator when operate the incinerator, second position as figure I.4 indicates operator posture is awkward position. Because the operator working with the hand(s) above the head, or the elbow(s) above the shoulders more than 2 hours total per day [2].

Awkward postures may pose risks such as damage traumatic work Musculoskeletal Disorders (MSDs) is disorders of the muscles, nerves, tendons, ligaments, joints, cartilage and spinal discs [3].

This leads for improvement / modifications to the waste entry door incinerator part which causes awkward position on the operator. Therefore, the need for redesign at the waste entry door incinerators can meet the criteria of ergonomics and also meet the needs of operators for load the waste process.

## 2. Research Methodology

### 2.1 Conceptual Model

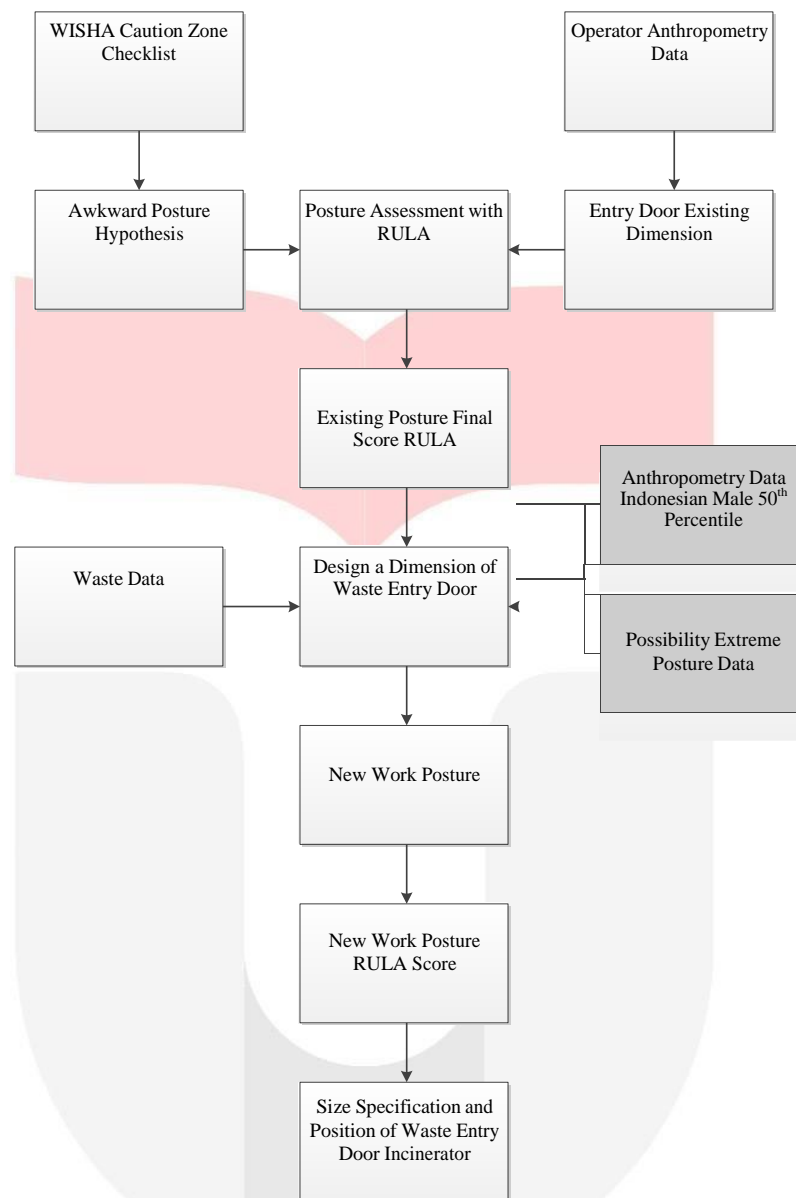


Figure 4. Conceptual Model

This research aims to avoid operator from awkward posture that may cause Musculoskeletal Disorder (MSDs) risk when enter the waste into incinerator with suggestion the size specification anposition. The observation begin from the jobs of operator operate the incinerator. From WISHA caution zone checklist discovered that while operator enter the waste into incinerator indicates as an awkward position. The existing work posture RULA score indicates need a further investigation.

To be able to design technical specifications suggestion waste entry door, it is necessary to note the parameters - the parameters as follows:

1. Work posture of operator
2. Anthropometric data will be used in the design, the anthropometric data of Indonesian men 50th percentile.
3. Range size of the waste to be processed.

Designing waste entry door incinerator work done to repair the existing system work postures incinerator particular user. Final output of this research is suggestion of size specification and position incinerator entry door. Based on RULA score that obtain the improvement suggestion size categorized as acceptable.

3. Discussion

3.1 Data Collecting

The operational hour of Solair Incinerator is about 15 hour per day. Solair Incinerator burner can combust 112L dry waste per day. Solair Incinerator has some type of waste that can combust and can't combust.

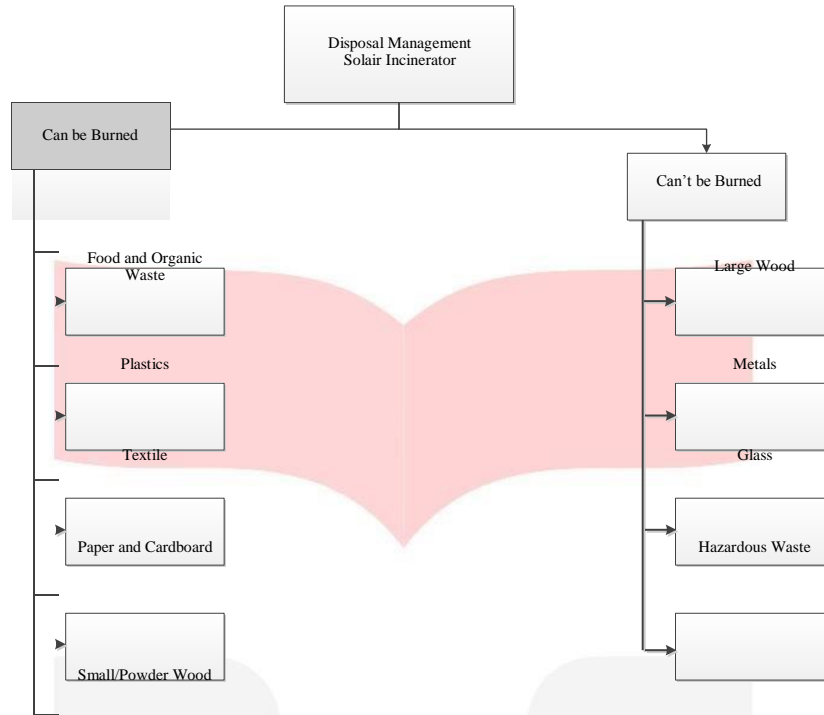


Figure 5 Disposal Management of Solair Incinerator

The data used in this research are the existing incinerator size, operator data anthropometry, operator work posture existing, and information about incinerator from the company. The dimension of existing entry door is LxWxHxD 90x60x169x28 cm for the upper part and for the under Part is LxWxHxD 100x70x141x55 cm. The anthropometry of operator is using anthropometry male percentile 50<sup>th</sup> Indonesian data approach. Because the incinerator still in develop phase and in in the future will produced more. The existing operator data still falls in the range of anthropometry male percentile 50<sup>th</sup> Indonesian data.

The observation work posture of operator with capture with camera 30 times of operator work posture while operates the incinerator. The purpose of this observation is to know the extreme posture of the operator while using this facilities. All the data assess with RULA, then the most extreme posture will be analyze further to know best dimension of facilities to provide it.

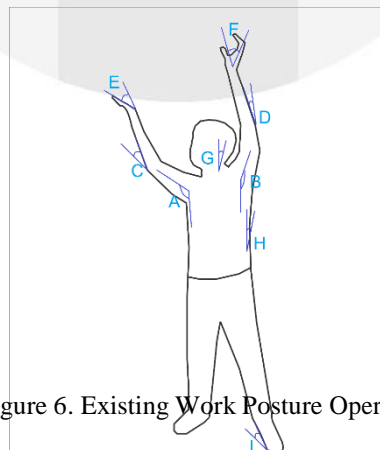


Figure 6. Existing Work Posture Operator

The angle that form from the posture shown in Table 1 then assess using RULA assessment in CATIA. The work posture in RULA divided into two groups, right and left body part.

Table 1 Angle Data of Existing Work Posture Operator

GROUP	A						B			
	ARM		FOREARM		WRIST		NECK	TRUNK	LEG	
Notation	A	B	C	D	E	F	G	H	I	
No.	R	L	R	L	R	L			R	L
25	149.323	151.899	42.476	18.872	29.545	18.872	7	7.94	0	19.35

The existing waste basket has diameter 52 cm to 59 cm and has the height is 82 cm. the volume of the basket is 80L may contain waste about 4.5 Kg dry waste.

### 3.2 Data Processing

After data collection process, in this stage is process the data. To identify where the most extreme posture occur every body part from the angle form with RULA assessment. The calculation and simulation use 50th percentile Indonesian anthropometric data to homogenize the data.

Table 2 RULA Score Existing Work Posture

Group	Body Part	Score		Final Score
		Right Side	Left Side	
A	Upper Arm	5	4	7
	Forearm	3	3	
	Wrist	3	3	
	Wrist Twist	1	1	
B	Neck	5	5	7
	Trunk	2	2	
	Leg	1	1	

The final score of RULA assessment right and left side got 7, which means work posture need further investigate and change immediately to reduce MSDs risk happens to the operator. Next is analyze the work posture to improve work posture operator based on the result of data processing especially for using waste entry door facility.

### 3.3 Analysis

Table 3 Movement Analysis of RULA Score Right Side

Group	Body Part	Score	Movement Estimate	Score
A	Upper Arm	5	Upper arm position indicates above 90 degrees	7
	Forearm	3	Lower arm position not above 90 degrees and arm outside of the body	
	Wrist	3	Wrist position is above 15 degrees to back	
	Wrist Twist	1	Wrist is twisted in mid-range	
B	Neck	5	Neck bending to back	7
	Trunk	2	The body is standing and bending to back	
	Leg	1	Leg and foot supported and balance	
Final Score				7

Table 4 Movement Analysis of RULA Score Left Side

Group	Body Part	Score	Movement Estimate	Score
A	Upper Arm	4	Upper arm position indicates above 90 degrees	5
	Forearm	3	Lower arm position not above 90 degrees and arm outside of the body	
	Wrist	3	Wrist position is above 15 degrees to back	
	Wrist Twist	1	Wrist is twisted in mid-range	
B	Neck	5	Neck bending to back	7
	Trunk	2	The body is standing and bending to back	
	Leg	1	Leg and foot supported and balance	
Final Score				7

From the simulation work posture existing data, RULA used to analyze and asses work posture of the operator. RULA assessment divided into two side part of every body part, right and left side. The score of RULA right side shown at table 3 and the left side score at table 4.

From the posture analysis, from group A the highest score that need immediately improvement is upper arm part that got RULA score 4 for left side and 5 for right side because the shoulder rise and upper arm form angle above 90 degrees. And from group B neck got the highest score. The score is 5 because the head is in extension, the neck is twisted to right and the neck is side bending. Form both body part analysis, it happens because the operator lift the waste basket and the height of waste entry door is 169 cm that above the operator's shoulder height.

### 3.4 Improvement

By understanding and using the hierarchy of controls, researcher can prevent or minimize exposure to occupational hazards. It is critical to strive for the most effective measure possible and when selecting control measures, use a combination of methods. From those counter measure above, eliminate the hazard and substitute is not practicable. Because the entry door is cannot be separate from the burner. The channel is attach to the burner. The practicable method are engineer (redesign), administrate and personal protective equipment.

Table 5 Alternative Suggestion

Practicable Method	Examples
Engineering (redesign)	<ul style="list-style-type: none"> <li>• Add stairs or steps to raise the operator</li> <li>• Redesign the height of waste entry door</li> <li>• Redesign mechanism enter the waste</li> <li>• Redesign the entry door, so that operator not close to the burner</li> </ul>
Administrate	<ul style="list-style-type: none"> <li>• Providing training on the use of equipment or work practices</li> </ul>
Personal Protective Equipment (PPE)	<ul style="list-style-type: none"> <li>• Providing gloves etc to prevent exposure to operator</li> </ul>

This research only focus on Engineering or redesign to prevent operator from hazard and avoid the operator from awkward posture that may risk MSDs. Because the improvement is about the operator not to raise the hand above the shoulder.

Working with the arm raise above the head or the elbows above the shoulders more than 2 hours per day is indicates awkward position. To make the facilities safe, there are some alternatives to reduce awkward position based on Ergonomic Principle by Washington State Department of Labor and Industries:

1. Raise the worker:
  - Use height-adjustable work platform
  - Use step stools or rolling stairs
2. Lower the work
  - Store frequently used things below shoulder height
  - Bring work down and turn it on its side for better access
  - Lower sections of overhead conveyors for loading and unloading
3. Use tools with longer handles
  - Use telescoping or extension handles for non-power tools
  - Use extendable or adjustable fixtures for power tools
4. Design for the shortest workers
  - Keep things that are used frequently below 48 inches
  - Limit reach distance to 26 inches

From those suggestions aforementioned, the possibility is to redesign the facility. Alternatives that applicable to redesign the facility are raise the worker using step or lower the work, those will reduce the risk of fatigue and pain at hand and neck part of operator. With the height that suit and ergonomics with operator, the operator will avoid from MSDs risk.

### 3.4.1 Ergonomic Side Improvement

The improvement of waste entry door size has two consideration. The first is for the ergonomic side and the second is needs side. From the ergonomic side, based on RULA assessment the problem is the height of the facility. Classify of height for standing workers as three, there are precision work, light assembly work and heavy work [4]. In this case, enter the waste to entry door classified as heavy work and the operator of the incinerator is male. Because operator need to lift a basket full of waste into entry door of incinerator. The suggestion of facility height improvement is about 85-101 cm because there is another consideration for the improvement size, it is needs side improvement.

The size of other facility that related to the incinerator waste entry door is the waste basket. Tools used for enter the waste. The diameter of the basket not more than width of the shoulder 425 mm and the height is not more than the length of elbow to tip of finger 439 mm. There is a standard basket with the dimension diameter is 27 cm and the height is 40 cm. The basket may contain waste amount 1 - 1,5 kg.

### 3.4.2 Needs Side Improvement

The channel incinerator size is needs to consider about the size of screw is used, based on the waste data that can burn in incinerator and the capability of burner in an hour. The burner can combust 16L waste in 20 minutes. For the waste channel or waste place before transferred to the burner in an hour process needs 48L.

The screw conveyor that needs for the waste entry door to transport waste from channel to burner based on the waste data, fits using screw conveyor with diameter 9 inch pipe size diameter is 2.5 inch as a standard. Using screw conveyor has a consideration, it is best fit with a closed channel.

### 3.5 Result Comparison

The simulation use the data specification that has been analysis based on the specification size recommendation. Besides change the height of incinerator entry door, the simulation use the recommendation size of waste basket. A good work posture is close to a ideal work posture, the work posture recommendation shown as figure 7.

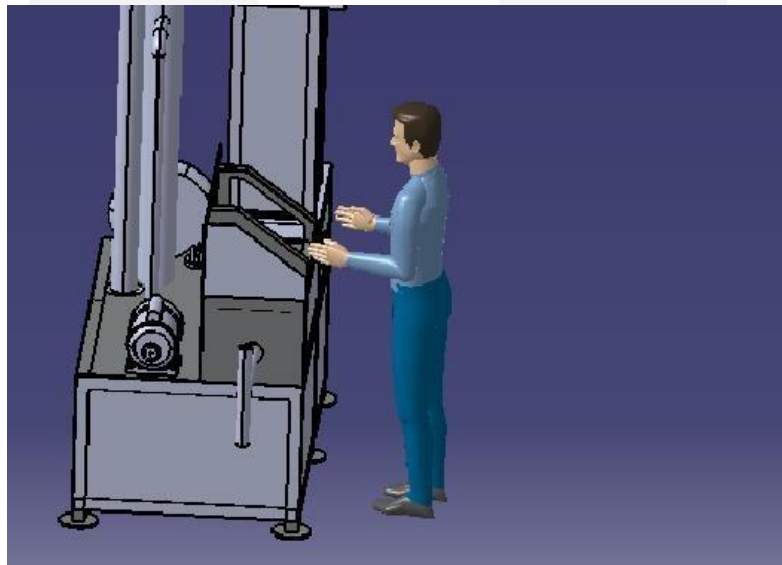


Figure 7 Work Posture Improvement Simulation

The simulation of the improvement size of incinerator entry door got RULA score is 2 which means is acceptable. The previous size of facilities is 7. The improvement is on the height from 169cm to 101cm and the weight of lift from 3kg to 1.5kg.



Table 6 RULA Score Comparison Right Side

Group	Body Part	Existing Score	Improvement Score
A	Upper Arm	5	1
	Forearm	3	1
	Wrist	3	1
	Wrist Twist	1	1
B	Neck	5	1
	Trunk	2	1
	Leg	1	1
Total Score		7	2

Table 7 RULA Score Comparison Right Side

Group	Body Part	Existing Score	Improvement Score
A	Upper Arm	4	1
	Forearm	3	1
	Wrist	3	1
	Wrist Twist	1	1
B	Neck	5	1
	Trunk	2	1
	Leg	1	1
Total Score		7	2

To lose the gap between 7 into 2 is because there are no upper arm position above the shoulders and neck not bending to back.

Based on the result of comparison the existing and improvement, use the improvement suggestion specification may avoid the operator from awkward posture that risk MSDs. The score of improvement is better because the improvement size of incinerator form a work posture approach ideal posture.\

#### 4. Conclusion and Suggestion

The recommendation size is 80-101 cm for height. The waste container load 1-1.5kg with diameter 27 and height 40. And suggestion standard screw container is 9 inch. After analysis and get score 2 for the improvement size of incinerator entry door purpose to avoid the awkward position and reduce the risk of MSDs to the operator from score the previous score is 7. The score of improvement is better because the improvement size of incinerator form a work posture approach ideal posture.

Suggestion for further research are the research should design the incinerator waste entry door with mechanism consideration and more detail interaction analysis with other component.

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