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Evaluation of Potential Use of Multi-Level Sprayer and Electronic Controlling in Simple Wet Scrubber for CO2 Removal and Water Usage Efficiency Enhancement

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ABSTRACT

There are several strategies that can be used to reduce pollutants and carbon dioxide (CO_2) from smoke during combustion, and one of them is using a wet scrubber sprayer. A multi-level sprayer had been studied, but it was investigated without considering electronic control. Therefore, the work evaluates whether applying a multi-level sprayer with electronic control can reduce the value of CO_2. The study's objective is to assess the potential utilisation of multi-level sprayers and electronic control in determining the efficiency of a basic wet scrubber for removing CO_2 generated from burning garbage, particularly dry waste like paper, with the additional goal of minimising water usage. The system will be built in a small and simple wet scrubber with dimensions of 60 cm in height and about 40 cm in length and width. CO_2 value and water usage in the wet scrubber will be measured. The results from implementing the one-level, two-level, and three-level sprayer with electronic control were compared and benchmarked with the value without a sprayer and electronic control. The work showed that the design leads to an improved water usage efficiency of the wet scrubber and reduced CO_2 value.

1. Introduction

A vessel was designed for decreasing volume of waste and garbage. The burning waste in the vessel named incineration chamber (incinerator). For more clean fog and healthy upshot, a tunnel creates out of incinerator to the dust and smoke gathering (cyclone) in case to reduce amount of danger combustion upshot which is taken from previous study [1] which is used cyclone for control particulate. Residual of the cyclone would be cleaned in the other vessel (wet scrubber) by using sprayer of water. This method is known as Wet Scrubbing method. Dust or solid particle to this Wet Scrubber are sprayed by using water to fall down. From previous study [2], Hu used wet scrubber by experimental study to remove dust. According to [3], combustion on diesel adding with nano particles can increase number of CO2 about 17.03%. A technology named Multi level sprayer at wet scrubber

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can be controlled for the removal of Carbon Dioxide (CO2) as explained from previous study by Xinli Zhao *et al*., [4]. An increasing of Carbon dioxide at atmosphere can be directed to human health risk. Potential high risk will be indicated at CO2 value start to exist at 1000 ppm as describe by Jacobson [5]. Explained by Kapalo [6] that at the temperature range of the burning candle 0 – 50^{o}C, CO2 concentration is about 0 – 3000 ppm. Even some researchers have forecast the increasing of carbon emission. From 2019 Until 2030 it is noticed the increasing of carbon emission 63% according to noticed value from studied by Yong [7]. Many technologies can be used in purpose to removal Carbon Dioxide but some of the method cannot be applied for the reason of safety, high toxicity and corrosive, according to Kwong Ceng Lang [8]. Another method can be applied with pyrolysis process from previous studied [9] but still with existing of CO2 from next studied [10]. Particulate controlling by using microcontroller can decrease amount of water which is sprayed to wet scrubber about 59.8%. It was studied by Arif [11].

This research as approach as a problem solving to overcome pollutant caused by combustion process of paper dry waste (garbage). It aims to apply temperature sensor (DHT 11) based on Arduino (microcontroller) controlling pump of multi sprayer integrated with the timer relay to fill the water storage. Even variable Spray process can be controlled by using multi sensor as describe by Song [12].

After implementation, CO2 value will be measured by using CO2 meter in ppm (part per million). According to Buildera, one of a leading expert in carbon dioxide (CO2) measurements for property owners and facilities maintenance managers, level of hazard scale divided into 4 level as showed in Figure 1. From Figure 1 showed level of healthy CO2 value limited in uppers green colour with value number about 1000 ppm. Above this value which is start with yellow one is not noted as the health number of Carbon Dioxide value. Carbon Dioxide Hazard scale According to Buildera.com (one of a leading expert in carbon dioxide (CO2) measurements for property owners and facilities maintenance managers)

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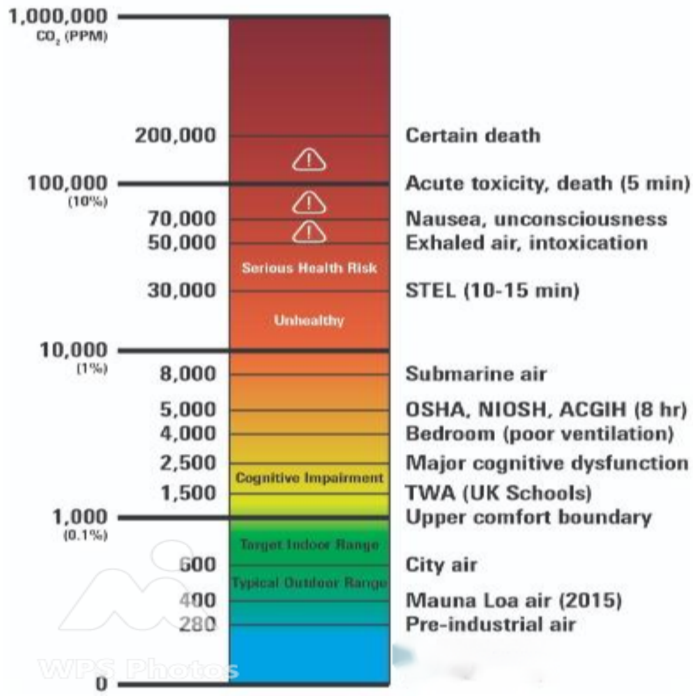

Fig. 1. Figure Level of Carbon Dioxide Hazard scale

2. Methodology
2.1 Scheme of System

This research was conducted in two steps, it was measurement and the other was application of a thermal sensor base controlled system integrated with timer relay and construction of multi-level sprayer (in this case, 3 (three) level sprayer). According to Shakri [13] the surface tension of the liquid can also be changed with the manipulation of the process parameters (e.g.; flow rates). Scheme of the application of sensor base controlled system integrated with timer relay and construction of multi-level sprayer (in this case, 3 (three) level sprayer) as showed in Figure 2. block diagram of the system. The system is started from combustion process in a vessel named incinerator. A temperature sensor read the value setting by a microcontroller. After it reached setting value, timer relay will be activated according to amount of water volume. At the same time, pump will be activated to turn on the multi-level sprayer. After the water tank empty, filled water pump will be in the "on" condition.

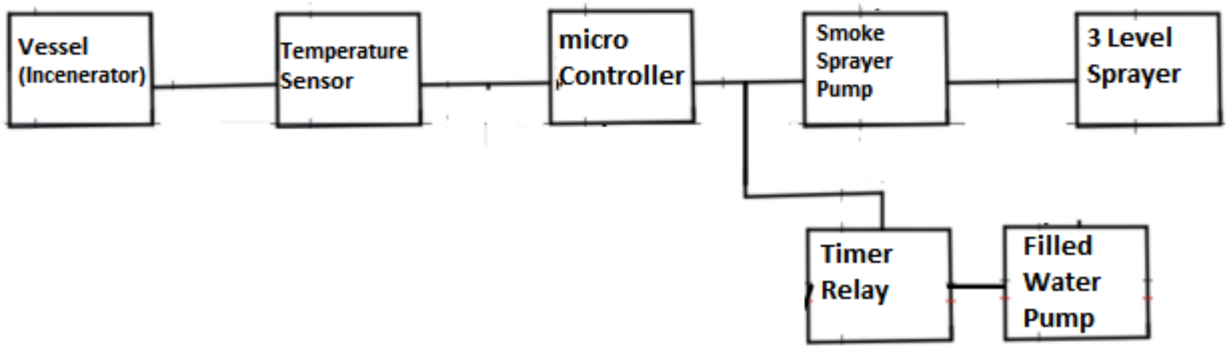

Fig. 2. Block Diagram of the system scheme

2.2 Measurement of Carbon Dioxide Value

Carbon Dioxide Value (CO_2) was measured by using CO_2 meter in ppm (part per million). It will analyse the value of reduction of CO_2 and its efficiency. Efficiency of CO_2 reduction as describe by Kordylewsk as the formula below [14]:

$$\eta CO2 = \left(1 - \frac{CO2_{wyl}}{CO2_{wlot}}\right).\ 100\% \quad (1)$$

Which is :
CO_2 = Efficiency of CO_2 reduction
$CO_{2,wyl}$ = input CO_2 value in ppm
$CO_{2,wlot}$= output CO_2 value in ppm

2.3 Sprayer and Water Usage (Volume)

Defining distance and quantity of nozzle at 40 cm pipe. It's base on overlap condition of spraying according to Anam [15].

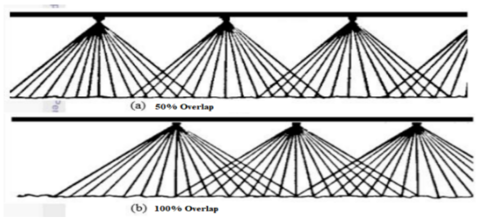

Fig. 3. Overlap condition of spraying

$$Quantity\ of\ nozzle\ =\ Length\ pipe/\ percentage\ overlap\ sprayer \tag{2}$$

$$Volume\ of\ water\ usage\ =\ \frac{debt\ \left(\frac{litre}{(seond)}\right)}{spraying\ time\ (\sec ond)} \tag{3}$$

2.4 Materials and Methods

Materials in this research are divided in 3 (three) types, which are:

i. Building the simple wet scrubber construction, (acrylic materials)
ii. Designing, wiring and applying the electronic controlling system
iii. Applying multi-level sprayer system and pumping

Methods: Defining parameter of spraying, which are : length of the pipe using, construction of nozzle (kind of overlap condition), quantity of nozzle. Applying these to simple wet scrubber system which is planned.

Wet scrubber which is used in this research is made of acrylic material thickness about 3 mm, beam shape 40 cm length, 40 cm width and 60 cm height. Equipped with dc water pump 12 Volt, 4 Ampere and multi-level sprayer as shown in Figure 4

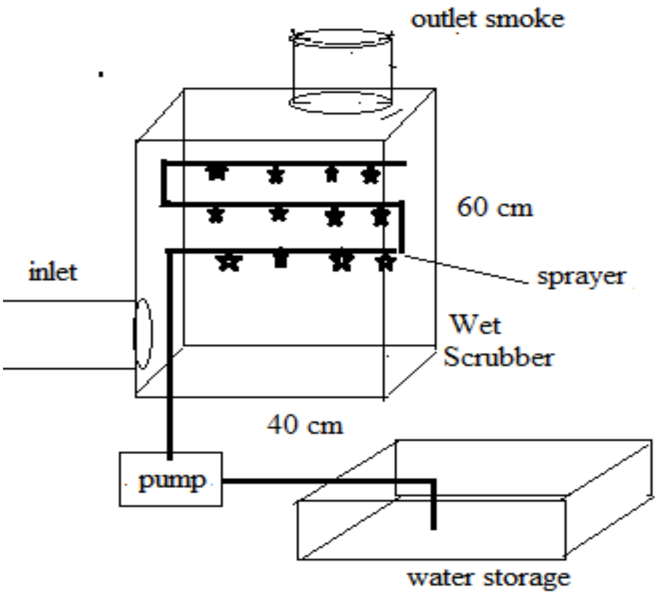

Fig. 4. Combustion system with simple wet scrubber

Designing electronic controlling, by defiling the block diagram system as showed in Figure 2. Steps of electronic controlling follow Figure 5 flow chart. Started from combustion temperature to activated pump of sprayer after temperature sensor reach 45°C. As long as pump is still in the "on" condition, a relay timer will counter the time until water storage empty then activate filling water pump.

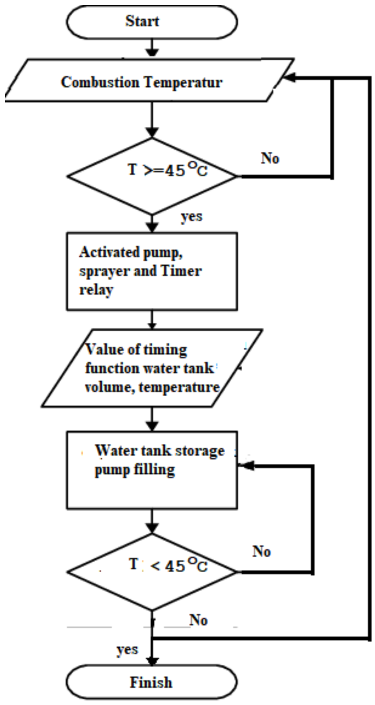

Fig. 5. Controlling Flow Chart

Wiring of the system is as shown in the Figure 6. The wiring consists of 3 sufficient blocks which are: Controller, timer relay and pumping. Applying multi-level sprayer system and pumping.

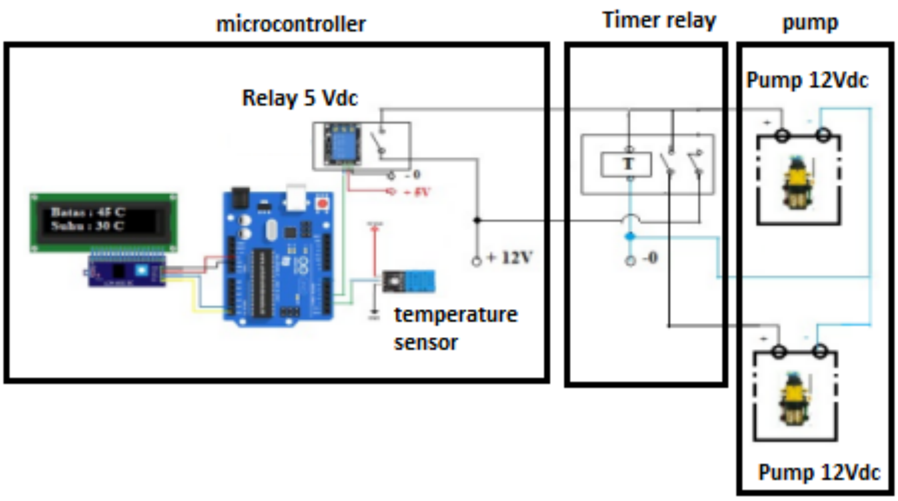

Fig. 6. Wiring of the system

Multi-level prayer (three level) was installed in the wet scrubber rectangle box as shown in the Figure 7.

Fig. 7. Sprayer multi-level (three level) system

3. Results

3.1 Multi Sprayer and Water Usage

Result of the Sprayer Length of pipe which is used is 40 cm length. Percentage overlap spray using is 100%. Base on Eq. (4) number/quantity of nozzle as shown below :

Quantity of Nozzle = length pile /spray percentage overlap (4)

By choosing overlap 100% with spray width 6 cm, then quantity of nozzle which will be mounted is:

Quantity of Nozzle = 40 cm / 6 cm = 6.6 pcs (5)

Then Nozzle quantity are about 6 pcs in every level.

Determining debt at every level sprayer:

Using measurement spraying time at every level, it can conclude that more level of sprayer causes bigger difference between the fluid and the solid surface and heat transfer decrease. Nur Hazilah *et al.*, [16] explained that when there is a temperature difference between the fluid and the solid surface exist, it impacts on the heat transfer characteristics. Result is shown in Table 1. For one level sprayer, it takes the longest time to spray 1 litre water but with lowest debt. The time needed to spray 1 litre water is shorter as increased of sprayer level. As shown at Table 1 where defined the water debt at 1 litre volume for every level sprayer.

Table 1
Water Debt at every level for 1 litre volume

Sprayer level	Spraying Duration (second)	Debt (litre/second)
1	44	0.0227
2	26	0.0392
3	19	0.0537

It can be figure out at curve diagram below. From curve in Figure 8, it is shown the level of sprayer as a function of debt (litre/second). Highest the water level sprayer, higher its water debt.

Fig. 8. Water debt at 1 litre in every level sprayer

Using of three level sprayers result the highest value of water usage as increasing the duration of spraying. Lowest water usage in volume is in the smallest level sprayer and shortest duration of spraying. It can be seen in the Table 2.

Table 2
Water usage at every level with uniform spraying duration each level

Spraying duration (second)	Volume water usage (litre)		
	1^{st} level	2^{nd} level	3^{rd} level
220	5	5	8.6
	11.8		
132	3	5.18	7.1
88	2	3.5	4.7

Figure 9 describes that increasing duration of spraying can cause increasing of volume water usage also. Comparison between one level, 2 level and 3 level that is 3 level reach the highest volume water usage. Comparison between one level, 2 level and 3 level that is 3 level reached the highest volume water usage. According to Hu, Y *et al.*, [17] that in practical applications, when the blower speed and spray angle both increases, the collection volume is higher in the upper part of the tree crown. It means that increasing in speed, increasing in time and increasing volume in the upper part.

No appearances of electronic controlling because it takes more duration for spraying. Trend of this situation shown in Figure 10. It describes that increasing duration of spraying can cause increasing of volume water usage also.

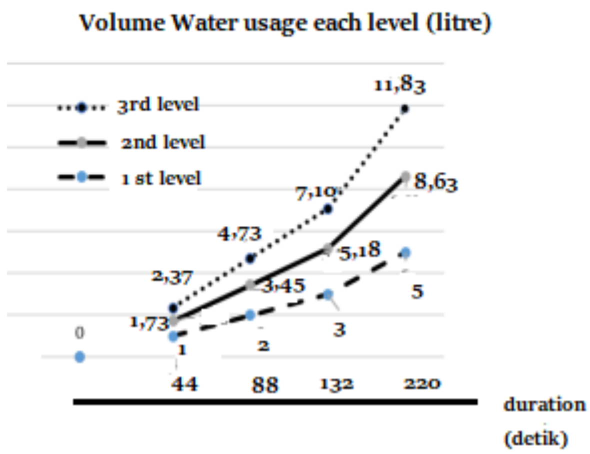

Fig. 9. Water debt at 1 litre in every level sprayer

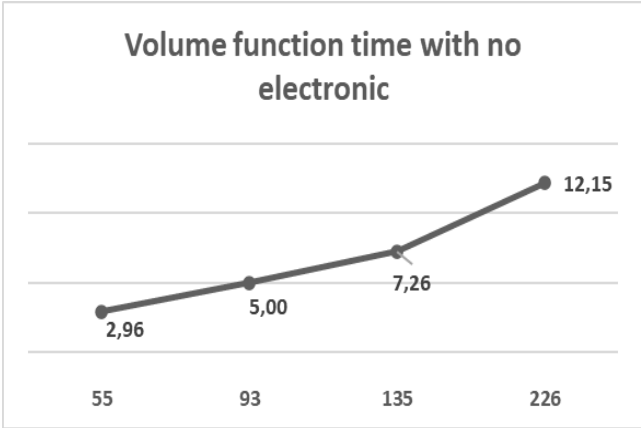

Fig. 10. Water volume function time with no electronic

Electronic controlling devices are installed in the system shown in the Figure 11. They are in the panel box which are consist of controller circuit and timer relay.

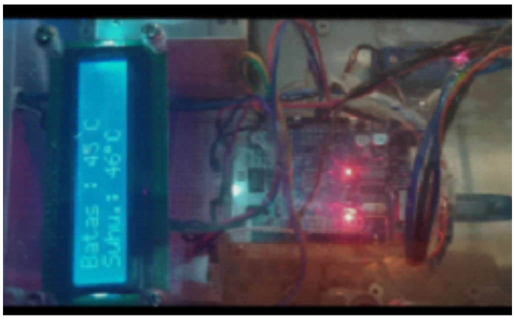

Fig. 11. Electronic controlling device

3.2 Measurement of Carbon Dioxide Value (PPM/Part Per Million)

Although the value of Carbon Dioxide can be monitored by using Internet of Thing [18] and by using LVAS (Low Volume Air Sampler) or Dust Detector [19] with efficiency 54.297%, in this research, upshot smoke and fog caused by combustion process is measured by using Carbon Dioxide Value meter. From Table 3, it can be described that decreasing of amount of Carbon Dioxide Value is when the system applied in the three-level sprayer with electronic controlling.

Table 3
Value of CO_2 out of wet scrubber

Sprayer level	Electronic controlling	Early value CO_2 PPM	Last value CO_2 PPM
1	No (manual visually)	3690	2722
2	No	3457	1886
3	N	2734	613
1	Yes	2785	1955
2	Yes	2496	1384
3	Yes	916	453

3.3 Reduction of Carbon Dioxide and Efficiency

Reduction value of Carbon Dioxide after spraying shown at Figure 12. There are four lines which are named for Carbon Dioxide value before spraying no electronic controlling, value after spraying no electronic controlling, value before spraying with electronic controlling, value after spraying with electronic controlling. According to Wang Z [20], the direct injection nozzle distribution covers a large area, which provides a large gas–liquid contact area. Therefore, a higher CO2 absorption.

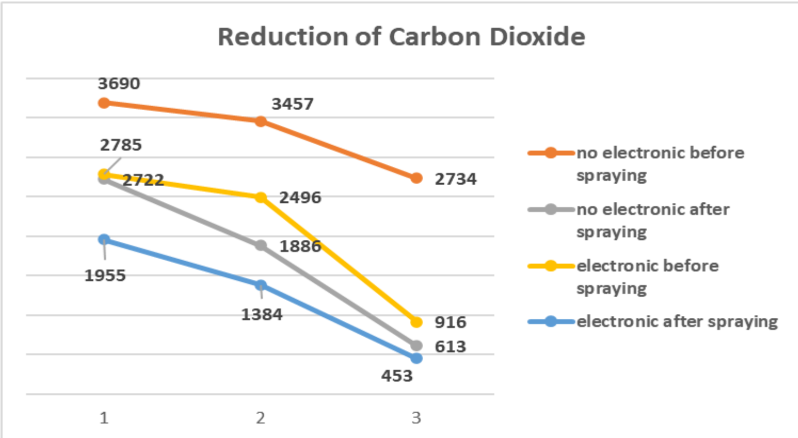

Fig. 12. Value of Carbon Dioxide

Reduction Value follows the formula as:

Reduction (no electronic controlling) at max.value = value before spraying - value after spraying
= 3690 - 2722 ppm
= 968 ppm

Reduction (with electronic controlling) at max.value = value before spraying - value after spraying
= 2785 - 1955 ppm
= 830 ppm

Researched by Firdaus [21] found that efficiency of 2-unit wet scrubber is 67%.

Average Efficiency value of the wet scrubber for no electronic controlling and with electronic controlling are calculated by using initial value same with no. electronic value:

Average efficiency of no electronic controlling

$$= 1 - \frac{Average\ reduction\ of\ no\ electronic}{Average\ of\ initial\ value} = \frac{1553.333}{3293.677} = 47.2\ \%$$

Average efficiency with electronic

$$= 1 - \frac{Average\ reduction\ with\ electronic}{Average\ of\ initial\ value} = \frac{2029.667}{3293.677} = 61.6\ \%$$

4. Conclusions

It can conclude from collecting measurement value and calculation result that, average efficiency of simple wet scrubber to remove Carbon Dioxide value with electronic controlling is equal to 61.6%. Meanwhile with no electronic controlling is equal to 47.2%.

Volume of water usage by spraying without electronic controlling takes more time then with electronic controlling. For 3 level sprayer which taking highest value of water volume usage, comparison between no electronic controlling and with electronic controlling bring out 12.15 litre max.value for no.electronic and 11.83 litre for with electronic controlling.

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