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# Study of factors in reducing dust in the process of burning clay bricks using the repeated firing technique with an open kiln system

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## Abstract

This study focuses on reducing PM2.5 dust pollution in clay brick burning by using the technique of extracting smoke by installing a scrubber, studying the appropriate factors in adjusting the settings, including wind power and scrubber distance that affect the amount of PM2.5 dust, as well as checking the amount of gas after re-incineration. From the experiment, it was found that data were collected from incineration that did not use the smoke extraction technique with a scrubber for 24 hours. The data collection results from dust measurement with a sensor that measured PM2.5 dust values where the average amount reached 694.3 μg/m$^3$ in 24 hours, which is 13.87 times higher than the standard. When the Scrubber was installed and burned again, it was found that the amount of PM2.5 dust particles decreased to a minimum of 120 μg/m$^3$ from the analysis. P-Value found that both factors, Wind power and Scrubber distance, did not significantly affect the amount of PM2.5 dust. With a statistical confidence level R-Sq = 81.87 %

**Keyword :** bricks**,** repeated firing technique**,** open kiln system

## 1. Introduction

Reducing pollution in the combustion process is necessary for many reasons. It focuses on protecting human health, the environment, and sustainable development. Combustion, which involves burning fuel to produce energy [1], is a major source of various pollutants that can hurt the environment. Important reasons for reducing pollution in the combustion process are (1) for air quality and human health; This is because the combustion process releases pollutants such as nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), particulate matter (PM), volatile organic compounds ($VOC_s$), and carbon monoxide (CO) into the air. These pollutants can lead to gastrointestinal diseases. Breathe Heart and blood vessel problems and other human health problems, especially in communities with high levels of pollution [2] (2); to reduce climate change, the combustion of fossil fuels such as coal, oil, and natural gas releases carbon dioxide ($CO_2$) [3], which is an important greenhouse gas that contributes to climate change [4] (3). Reduce impact on the environment. Air pollution from combustion can cause acid rain. They are harmful to aquatic ecosystems, soil quality, and plants. These pollutants can also cause smog. Cause damage to the environment [5].

Currently, pollution from the combustion process in Thailand is a serious environmental and public health problem. This is especially true of burning fossil fuels such as coal, oil, and natural gas. In various industries, this process releases pollutants into the atmosphere. This leads to dust (PM 2.5), causing various health problems, including respiratory diseases (such as asthma and chronic lung disease) [6-8], cardiovascular problems, and even premature death. Vulnerable populations such as children, the elderly, and people with pre-existing health conditions are especially at risk. In the community, pollution from burning often comes from daily activities such as burning rice cobs, burning weeds, or even burning various types of biomasses, which are burned in the open. Household businesses are one of the factors that cause dust pollution, such as the production of red clay bricks, especially in the northeastern region of Thailand. In the areas of Roi Et, Kalasin, Maha Sarakham, Sakon Nakhon, Ubon Ratchathani, etc., it is estimated that more than 300 factories use rice husk as fuel for burning the rice husk system to burn bricks, approximately 30 tons/brick, 1.1-1.2 hundred thousand bricks/month. It is resulting in a lot of dust pollution.

Therefore, solving the pollution problem by developing reduction or elimination technologies is imperative. Smoke and dust from the long-term production process of clay bricks or red bricks. There are many reports about dust capture techniques, such as developing a dust capture system. Dust-trapping cyclones (Cyclone), Gravity Settler, and water droplet trapping in the commonly used Spray Tower Scrubber and Packed Bed Scrubber types cannot trap PM 2.5 dust. As for trapping water droplets, Tray or Plate Scrubbers and Venturi Scrubbers have moderate dust-trapping efficiency. It can trap dust with sizes starting at 1 micron. The bag filter and electrostatic dust collection systems (Electrostatic Precipitators: ESP) can trap PM 2.5 [9]. Study the dust removal efficiency with a wet air treatment system for a community rice mill." The results of the research concluded that the wet scrubber equipment is effective. Captures 91 percent of dust particles at a water pressure level of 0.30 bar. Dust collection efficiency will likely increase if the water pressure level increases. Therefore, the wet air treatment system helps the rice mill business co-exist sustainably with the community. [10] Study of a dust collection system that combines a cyclone with a static electricity dust collection system. (Electrostatic Precipitators: ESP to be able to capture both large dust particles with cyclones and dust traps) and small ones with an electrostatic dust collection system. From measuring the amount of dust, it is seen that dust collectors using cyclones and electrostatics can help reduce dust problems. The droplets can be removed, but the electrostatic dust capture system is complicated. Moreover, it must use electric current in the system [9]. Combining the advantages of the two systems will allow dust capture from burning both large particles, and smaller is even better. From the study developing a cyclone scrubber for a small solid waste incinerator, it was found that the particle removal efficiency of the cyclone scrubber is higher than that of a normal cyclone, which is 72 % [7-8]

From the research report mentioned above, the author has proposed using scrubber dust collection technology to suck up smoke and pollutants that have passed through incomplete combustion. By taking the smoke and pollution from the Scrubber to re-incinerate it before releasing it into the atmosphere. This study examined factors in setting up scrubbers to capture dust and smoke, including the amount of suction air force (M/s) and the height of the Scrubber (Cm) that affect the amount of dust (PM 2.5) while burning Inmon with rice husks the researcher expects that this research will be beneficial to education and industrial communities for further use in real life in the future.

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## 2. Method of study

### 2.1 Equipment and materials for experiments

Investigation into the mitigation of dust emissions from the combustion of red clay bricks, employing rice husks, was conducted. The compositional analysis of rice husks is presented in Table 1, while Table 2 illustrates the composition of rice husk ash following combustion (expressed in weight percentages). The rice husks underwent incineration at a controlled temperature of 500 degrees Celsius within a furnace, equipped to maintain a constant temperature. In the process, three samples of rice husks sourced from distinct geographical regions were subjected to chemical analysis. A scrubber, capable of exerting suction forces ranging from 0 to 30 M/s, was employed to extract smoke and dust during the initial burning, prior to subsequent re-burning. The schematic representation of this process is illustrated in Figure 1. The vertical mobility of the scrubber, adaptable to desired distances, constitutes a significant variable in this study.For the quantification of smoke flow rate during re-burning, a wind measuring device (anemometer) was utilized. Dust levels during combustion were measured using Plantower's PMS7003 sensor. Additionally, the composition of smoke resulting from incineration was analyzed using the Gas Analyzer DP-28-BIO. This analyzer is proficient in measuring eight gases, namely CH4 (methane), CO2 (carbon dioxide), O2 (oxygen), H2S (hydrogen sulfide), NH3 (ammonia), CO (carbon monoxide), H2 (hydrogen), and N2O (nitrous oxide). The measurement ranges for each gas are specified, and measurements were taken at 30-minute intervals. The results of the smoke component analysis from the burning of rice husks are summarized in Table 3.

**Table 1** Chemical composition of rice husks

| **Composition** | **% Wt** | | |
|---|---|---|---|
| | **Sample 1** | **Sample 2** | **Sample 3** |
| $SiO_2$ | 72.44 | 74.06 | 71.06 |
| $MnO_2$ | 0.29 | 0.25 | 0.21 |
| $Fe_2O_3$ | 1.35 | 1.24 | 1.14 |
| CaO | 1.22 | 1.12 | 1.32 |
| MgO | 0.29 | 0.21 | 0.21 |
| $Al_2O_3$ | 1.24 | 1.1 | 1.34 |
| Organic matter and moisture | 23.17 | 22.02 | 24.72 |

**Table 2** Chemical Composition of rice husk after burning (Wt %)

| **Sample** | **Composition** (% Wt) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **$SiO_2$** | **$K_2O$** | **$NaO_2$** | **CaO** | **MgO** | **$Fe_2O_3$** | **$P_2O_5$** | **$SO_3$** |
| **1** | 96.5 | 1.00 | 0.4 | 0.25 | 0.25 | - | 0.30 | 1.0 |
| **2** | 93.96 | - | - | 0.88 | 0.76 | - | 2.85 | - |
| **3** | 94.50 | 1.21 | 0.42 | 0.75 | 0.32 | 0.12 | 1.75 | - |

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**Table 3** Chemical Composition of smoke from rice husk burning

| Sample | Composition | | | | | |
|---|---|---|---|---|---|---|
| | **$CO_2$** | **$O_2$** | **$CH_4$** | **$H_2$** | **CO** | **$N_2$** |
| **1** | 12.51 | 3.98 | 2.88 | 8.37 | 17.62 | 54.64 |
| **2** | 13.67 | 4.83 | 3.22 | 6.73 | 15.43 | 56.12 |
| **3** | 11.54 | 5.20 | 2.60 | 7.05 | 18.20 | 55.41 |

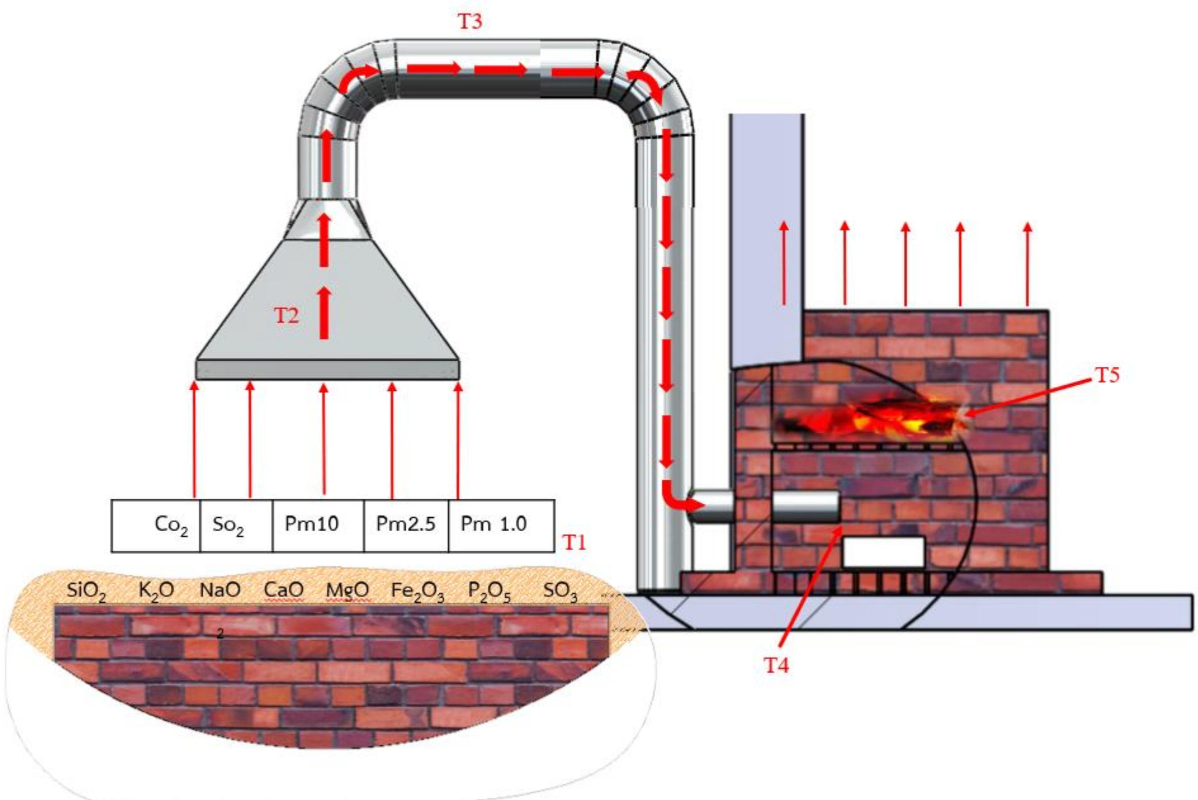


**Figure 1** shows a diagram of the experimental combustion process.

### 2.2 Experimental design

The factors considered in the experiment are delineated in Table 4. The experimental design methodology was employed for this investigation. Employing the Taguchi L9 method, the identification of statistically significant factors was conducted through the Analysis of Variance (ANOVA) test, utilizing the Minitab-19 program for experimental sequencing. The objective was to discern optimal factors by assessing the Signal-to-Noise (S/N) ratio associated with PM2.5

smoke emissions subjected to the heat extraction and removal process within a system engineered to minimize output. The pertinent value within the process was ascertained in accordance with Equation 1 [9].

**Table 4.** Factors used in the experiment.

| Experimental factor | Experimental level | | | Responses |
|---|---|---|---|---|
| | (-1) | (0) | (+1) | |
| Wind power (m/s) | 10 | 20 | 30 | Amount of dust Pm 2.5 |
| Scrubber distance (cm) | 60 | 70 | 80 | |

$$S/N_s = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right) \quad (1)$$

## 3. Experimental results

### 3.1 Results of statistical data analysis using Taguchi method

Study of dust reduction from burning clay bricks plant rice husks using an open system using a scrubber to absorb smoke. Before taking the smoke from incomplete combustion back and re-burning it to achieve complete combustion before releasing it into the atmosphere. The objective is to reduce air pollution and reduce toxic dust from burning. By collecting data from incineration that did not use the scrubber extraction technique for 24 hours, the data collected from measuring dust with a sensor that measured PM2.5 dust had an average amount of 694.3. $\mu g/m^3$ in 24 hours is 13.87 times higher than the standard. Then, install a scrubber to absorb the smoke, re-incinerate it with heat, and measure the PM2.5 dust value by checking the parameters in Adjusting the scrubber settings, including wind power and scrubber distance that affect the reduction of PM2.5 dust. The design of the adjustment uses a design technique experimented with Taguchi L9. The experiments and inspection results are shown in Table 5, an analysis of appropriate factors or parameters for the PM2.5 dust reduction process in the red clay brick firing process. Use the average of the reduction in PM2.5 dust values as the response value. The results of the analysis of the main effects of the factors on the signal ratio of the PM2.5 dust amount are shown in Figure 2. In contrast, the results of the response to the signal ratio of the PM2.5 dust amount are shown in Table 6 and Analysis of variance (ANOVA) to find statistically significant factors regarding process parameters that affect the signal-to-noise ratio response of PM2.5 dust levels by setting the statistical significance level at Confidence level 0.05. Results of analysis of variance on signal-to-noise ratio values are shown in Table 7.

**Table 5** Experimental of orthogonal array-L9, S/N ratio of PM 2.5 quantity $\mu g/m^3$

| No. | Wind power (m/s) | Scrubber distance (cm) | PM2.5 | SN-Ratio | MEAN |
|---|---|---|---|---|---|
| 1 | 10 | 60 | 132 | -42.4115 | 132 |
| **2** | **10** | **70** | **198** | **-45.9333** | **198** |
| 3 | 10 | 80 | 184 | -45.2964 | 184 |
| 4 | 20 | 60 | 138 | -42.7976 | 138 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | 20 | 70 | 157 | -43.918 | 157 |
| 6 | 20 | 80 | 165 | -44.3497 | 165 |
| **7** | **30** | **60** | **120** | **-41.5836** | **120** |
| 8 | 30 | 70 | 122 | -41.7272 | 122 |
| 9 | 30 | 80 | 151 | -43.5795 | 151 |

Figure 2 shows the analysis of the main factors affecting the signal-to-noise ratio of PM2.5 dust levels. The lowest level of each factor was obtained as follows: The level of suction wind force at level 3 is 30 m/s. The height of the Scrubber is 60 cm.

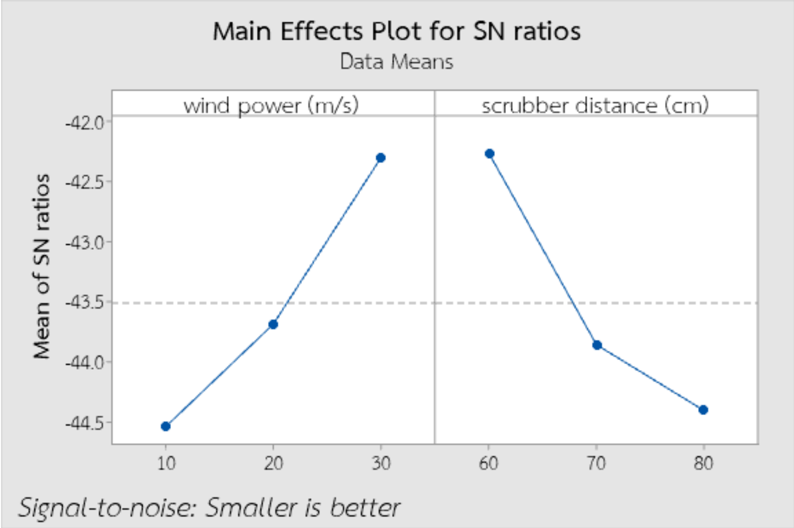


**Figure 2** Effects of two factors on S/N-ratios of PM 2.5 $\mu$g/m$^3$.

Table 6 shows the response values of the signal-to-noise ratio of the PM2.5 dust amount of each factor level. The analysis found that the suction air force's highest level 3 response is -42.30. The 1st level response of the scrubber height is -42.26.

**Table 6** Analysis of Variance for SN Ratios

| Level | wind power (m/s) | Scrubber distance (cm) |
|---|---|---|
| 1 | -44.55 | -42.26 |
| 2 | -43.69 | -43.86 |
| 3 | -42.30 | -44.41 |
| Delta | 2.25 | 2.14 |
| Rank | 1 | 2 |

Table 7 shows the analysis of variance (ANOVA) of the signal-to-noise ratio of the PM2.5 dust amount. The P-Value analysis found that there was no factor with a P-Value less than 0.05. Both the two factors, Wind power, and Scrubber distance, have a P-Value of 0.092 and 0.097, respectively, meaning that both factors do not affect the amount of PM2.5 dust with statistical significance at the 0.05 level, with a level of confidence in the Statistics R-Sq = 81.87 %

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**Table 7** Analysis of Variance for SN Ratios

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| Wind power (m/s) | 2 | 7.738 | 7.738 | 3.8688 | 4.6 | 0.092 |
| Scrubber distance (cm) | 2 | 7.444 | 7.444 | 3.7222 | 4.43 | 0.097 |
| Residual Error | 4 | 3.362 | 3.362 | 0.8404 | | |
| Total | 8 | 18.543 | | | | |

S = 0.9167, R-Sq = 81.87 % , R-Sq(adj) = 63.74 %

From the analysis of appropriate factors for reducing PM2.5 dust, it was found that Wind power at 30 m/s and Scrubber distance at 60 Cm had the lowest amount of PM2.5 dust at 120 $\mu g/m^3$. Results of regression equation analysis for Predicting the amount of PM2.5 dust as shown in Equation 2 and substitute the appropriate parameters in Equation (2) to predict the amount of PM2.5 dust. From the prediction using the regression equation, the value is equal to 113.37. $\mu g/m^3$, which has a value close to the actual experiment. Moreover, from the Taguchi method prediction, the amount of PM2.5 dust is equal to 120 $\mu g/m^3$.

$$PM2.5 = 63.9 - 2.017\ (\text{wind power}) + 1.833\ (\text{scrubber distance}) \quad (2)$$

substitute value

$$PM2.5 = 63.9 - 2.017\ (30) + 1.833\ (60) = 113.37\ \mu g/m^3$$

**Table 8** Composition of smoke from repeated burning

| Sample | Composition | | | | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $O_2$ | $CH_4$ | $H_2$ | CO | $N_2$ |
| **1** | 50.51 | 6.01 | 1.22 | 4.32 | 3.42 | 34.52 |
| **2** | 43.53 | 7.75 | 0.76 | 3.35 | 2.13 | 42.48 |
| **3** | 50.95 | 8.42 | 1.12 | 3.05 | 1.24 | 35.22 |
| **average** | **48.33** | **7.39** | **1.03** | **3.57** | **2.26** | **37.41** |

### 3.2 Measuring the amount of gas after re-combustion

Measure the amount of gas after repeated burning by measuring from the mouth of the furnace with a Gas Analyzer according to section 2.1. The results of measuring the amount of gas after repeated burning, repeating the measurement 3 times, found that the amount of $CH_4$ and CO were reduced to 1.03 and 2.26, respectively. As for the amount of $CO_2$, the average value increased to 48.33, as shown in Table 8—data for measuring the amount of gas after re-combustion.

## 4. Discussion of experimental results

This study focuses on reducing PM2.5 dust pollution at the household industry level, such as producing red clay bricks. The researcher's field visit found that burning red clay bricks causes pollution in the burning process, especially the diffusion of smoke and small dust particles. Therefore, it is the origin of the study of reducing pollution and dust by using smoke extraction techniques by installing a scrubber to suck smoke and dust. Then, the smoke obtained from the suction is re-incinerated to reduce pollution before being released into the atmosphere. The investigation studied factors in extracting smoke with a scrubber, along with measuring the smoke composition from rice husk burning both before and after repeated burning. The work results found that from examining the composition of rice husks and rice husk vines, they mainly contained $SiO_2$, organic substances, and moisture, which were consistent with the research report of Armesto et al. [10] and the composition of smoke from rice husks burning. The investigation also found high levels of $CH_4$ and CO, which are not beneficial when released into the atmosphere because $CH_4$ is a gas that can trap heat in the Earth's atmosphere. When released into the atmosphere, $CH_4$ absorbs infrared radiation and prevents some of the heat from escaping into space, causing global temperatures to increase to the point of global warming [11].

Similarly, CO gas does not have an effect. To directly causes global warming but also causes harm to the atmosphere due to its role in causing air pollution and direct health effects on humans [12]. Therefore, this experiment has used smoke from Burning comes to be burned again. From the experiment, when the smoke from burning red clay bricks with rice husks was used, it was found that the amount of $CH_4$ and CO decreased, as shown in Table 8.

Next, to analyze the appropriate factors of the exhaust extraction technique with Scrubber, for adjusting the factors using the Taguchi L9 technique to analyze the level of factors for exhausting smoke and dust, which includes Wind power at 10 - 30. m/s and Scrubber distance at 60 - 80 Cm. Results of the experiment are shown in Figure 5 from checking to find appropriate factors. It was found that the seventh experimental level, namely the factor level of Wind power at 30 m/s and Scrubber distance at 60 Cm, had the lowest amount of PM2.5 dust at 120 $\mu g/m^3$, 8 times lower than before. Install a scrubber or from an amount of 694.3 $\mu g/m^3$ in 24 hours, reduced to 120 $\mu g/m^3$ in 24 hours, but still exceeding the standard set by the Pollution Control Department of Thailand, which specifies that the amount of PM 2.5 should not exceed 50 micrograms per cubic meter, in 24 hours [13]. However, this research only presents a preliminary PM 2.5 dust removal technique, which is expected to be a guideline for further study and application in industry.

## 5. Summary

The study's results reduced the amount of PM2.5 dust for burning red clay bricks at the household level using the Scrubber technique by studying appropriate factors in adjusting the settings and checking the amount of gas after repeated burning. The results of operations can be summarized as follows.

1. Collecting data from incineration that did not use the scrubber extraction technique for 24 hours. The results of collecting data from measuring dust with a sensor that can measure PM2.5 dust has an average amount of 694.3 $\mu g/m^3$ in 24 hours, which is 13.87 times higher than the standard.

2. The P-Value analysis found that there was no factor with a P-Value less than 0.05. The two factors between Wind power and Scrubber distance had a P-Value equal to 0.092 and 0.097, respectively, meaning that both factors Do not affect the amount of PM2.5 dust with statistical significance at the 0.05 level, with a statistical confidence level of R-Sq = 81.87 %.

3. The analysis of appropriate factors for reducing PM2.5 dust found that Wind power at 30 m/s and Scrubber distance at 60 Cm had the lowest amount of PM2.5 dust at 120 $\mu g/m^3$.

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