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Research Article

Field Validation of a Public Health Particulate Matter (PHPM) Low-Cost $PM_{2.5}$ Monitor and Commercial Sensors with Light Scattering Technology

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Low-cost $PM_{2.5}$ sensors are the key to creating high-resolution monitoring networks for localized reporting and increased public awareness. A low-cost $PM_{2.5}$ sensor using light-scattering technology Public Health Particulate Matter (PHPM) was developed and validated against measurements from a commercial device that reports real-time aerosol concentration and also collects gravimetric samples (DustTrak DRX Aerosol Monitor 8533). Linear regression of measurements from a controlled indoor site and three ambient air sites found that the novel $PM_{2.5}$ sensor correlated well with the measured $PM_{2.5}$ concentrations ($r \geq 0.90$) at the three ambient air locations with $PM_{2.5}$ concentrations ranging from 48 to 602 $\mu g/m^3$ measured at 30-minute intervals. The correlation was lower ($r = 0.71$) at the chamber, which used incense as a particulate matter source. The PHPM data of $PM_{2.5}$ concentrations was using multiply with 2.33. The hope is that the PHPM device can provide an additional tool for participatory in community and increased public awareness about $PM_{2.5}$ in Thailand. This PHPM device is more suitable for ambient air than the chamber. The PHPM device is inexpensive, portable, and can be charged with a power bank.

1. Introduction

Particulate matter air pollution with an aerodynamic diameter less than 2.5 microns ($PM_{2.5}$) is recognized as a global health threat that requires prioritized research [1]. While efforts to monitor ambient air quality have increased substantially across the globe, significant gaps remain, with many parts of the world having no regular $PM_{2.5}$ monitoring [2]. Localized measurements of $PM_{2.5}$ are important due to the high variability in ground level air pollution caused by complex interactions of topography [3], air patterns [4], and emission sources [5]. Two major barriers, however, to widespread implementation of $PM_{2.5}$ monitoring are the cost and technical requirements of high-accuracy equipment that relies on filtration and gravimetric mass determination [6]. Furthermore, gravimetric methods typically generate data with 24-hour measurement periods, while higher temporal resolution is preferable for real-time monitoring,

(a) (b)

Figure 1: Particulate matter monitoring devices used. (a) Low-cost particle scattering $PM_{2.5}$ sensor (PHPM) and (b) DustTrak DRX Aerosol Monitor 8533.

Table 1: Characteristics of SI, SN, and SV type dust measuring instruments used in research.

Characteristics	Instrument type SI	SN	SV
Approximate price (US dollars)	66.6	50	50
Packaging size (mm)	78 × 84 × 52	75 × 75 × 46	60 × 60 × 26
Product weight (g)	251	93	86
Estimated PM_x concentration	$PM_{2.5}$	$PM_{2.5}$	$PM_{2.5}$
Measurement of $PM_{2.5}$ concentration			
(i) Measuring range ($\mu g/m^3$)	0-999	—	0-500
(ii) Resolution ($\mu g/m^3$)	1	—	1
(iii) Accuracy ($\mu g/m^3$)	±15%, 10	—	±10%@100 ~ 500 $\mu g/m^{3/}$ ± 10 $\mu g/m^3$@0 ~ 100 $\mu g/m^3$
Measurement method	Laser scattering	Laser scattering	PLANTOWER laser particulate matter sensor
Display	—	—	—
Limitation	(i) Cannot be used in environments with high concentrations of $PM_{2.5}$ or greater than 999 $\mu g/m^3$ (ii) Cannot be used in an environment with too high temperatures (iii) Cannot be used in a humid environment	(i) Uses medical grade low current laser transmitter (ii) Uses temperature and humidity compensation algorithm which ensures the accuracy of product testing (iii) Uses a special air duct design by air intake every 30 seconds is 283 mL (iv) Use heat dissipation design which ensures that the laser transmitter 3000 h (v) Cannot be used in an environment with excessive temperature	(i) Cannot be used in environments with high concentrations of $PM_{2.5}$ or greater than 500 $\mu g/m^3$ (ii) Cannot be used in an environment with too high temperatures (iii) Cannot be used in an environment with too high temperatures (iv) Cannot be used in a humid environment

Table 2: Characteristics of SC, CKDPM, and PHPM type dust measuring instruments used in research.

Characteristics	Instrument type SC	CKDPM	PHPM
Approximate price (US dollars)	23.3	66.6	23.0
Packaging size (mm)	$60.3 \times 21.4 \times 84.3$	$48 \times 37 \times 12$	$15 \times 10 \times 5$
Product weight (g)	86	180	150
Estimated PM_x concentration	$PM_{2.5}$	$PM_{2.5}$, PM_{10}, PM_1	$PM_{2.5}$
Measurement of $PM_{2.5}$ concentration			
(i) Measuring range ($\mu g/m^3$)	—	0-500	0-500
(ii) Resolution ($\mu g/m^3$)	—	1	1
(iii) Accuracy ($\mu g/m^3$)	—	±10%@100 ~ 500 $\mu g/m^3$/± 10 $\mu g/m^3$@0 ~ 100 $\mu g/m^3$	±10%@100 ~ 500 $\mu g/m^3$/± 10 $\mu g/m^3$@0 ~ 100 $\mu g/m^3$
Measurement method	—	Laser scattering	Laser scattering
Display	LED digital display	LED digital display	LED digital display
Limitation	(i) Cannot be used in an environment with too high temperatures (ii) Cannot be used in a humid environment	(i) Cannot be used in environments with high concentrations of $PM_{2.5}$ or greater than 500 $\mu g/m^3$ (ii) Cannot be used in an environment with too high temperature (iii) Cannot be used in a humid environment	(i) Cannot be used in environments with high concentrations of $PM_{2.5}$ or greater than 500 $\mu g/m^3$ (ii) Cannot be used in an environment with too high temperature (iii) Cannot be used in a humid environment

Note: CKDPM type dust detector is a dust meter supported by the Chronic Kidney Disease Prevention and Slowing Project in the Northeast (CKDNET) sampler.

highly sensitive for the detection of glucose concentrations in human bodies [7], and biosensor has been proposed for detection of uric acid (UA) in human serum with a highly sensitive and selective optical fiber-based enzymatic [8]. In response, light scattering techniques (e.g., Chowdhury et al. [9]) have been developed that build the concept of optical particle counters and Mie's theory [10]. These light-scattering sensors are inexpensive and easy to operate.

Several low-cost particulate matter sensors have been developed and validated across the world [6, 9]. These sensors have become critical tools for providing localized air quality readings and raising awareness of particulate matter pollution [11]. Advances in computing power and power consumption have made low-cost sensing devices an important supplement to the granular network of regulatory stations established around the globe and help to engage local communities with air quality data [12]. Generally, these low-cost devices can quite accurately measure $PM_{2.5}$ concentrations under most conditions [13, 14]. However, the accuracy of such low-cost air sensors has been questioned, and the need for calibrating these devices is critical [15]. However, given the knowledge gaps, the aim of this study was to focus on estimating $PM_{2.5}$ concentrations using low-cost PHPM sensors in real-world situations. Therefore, calibrating and validating low-cost $PM_{2.5}$ sensors built on light-scattering technology is necessary before implementation in the community. This similarity metric can also guide the adoption of low-cost monitors and/or data selection in future field research as well as spatiotemporal [16]. While $PM_{2.5}$, which results from vehicle exhaust, biomass burning,

Figure 2: For example, sampling locations among Faculty of Public Health area with operated device.

and industrial emissions, has received substantial publicity and attention in Thailand [17], high-resolution monitoring of $PM_{2.5}$ is still limited in Thailand [18]. Widespread local data, however, is important. Attitudes, awareness, and risk perception affect the public's proenvironmental behaviors that influence $PM_{2.5}$ [19, 20].

Thus, increasing awareness and publicity of $PM_{2.5}$ concentrations at the local level is important. Accordingly, the objectives of this research were to develop a simple, low-cost device for real-time reporting of $PM_{2.5}$ concentrations in the ambient air and to calibrate the device by determining the relationship between the device's readings and a standardized commercial aerosol sensor. This device is intended for widespread implementation at local health centers to

Figure 3: The sensor used to measure dust up to 2.5 microns in size according to this invention.

raise awareness about $PM_{2.5}$ at the local level, as access to real-world $PM_{2.5}$ data is essential for more effective and safe assessment of people's health risks and self-protection.

2. Materials and Methods

2.1. Instruments. A low-cost $PM_{2.5}$ sensing device Public Health Particulate Matter (PHPM) was developed for use in monitoring ambient air $PM_{2.5}$ concentrations at local health stations or other local agencies (Figure 1(a)). The PHPM uses the light scattering technique to measure particles suspended in the air. A red laser illuminates through a cavity with active ventilation provided by a fan. A photodiode measures the scattered light to determine the mass of particles according to Mie's theory. These readings were then converted to $PM_{2.5}$ concentrations by researcher. The estimates from the PHPM device were compared against a standardized commercial product, the DustTrak DRX Aerosol Monitor 8533 (TSI International, Shore-view, Minnesota, USA) (Figure 1(b)). This device can provide real-time aerosol concentration data, while simultaneously measuring both mass and size fraction. While also using a light-scattering laser photometer, it also collects gravimetric samples. These DustTrak monitors have been used to validate or calibrate several low-cost devices for both indoor and outdoor aerosol measurement [21, 22]. The estimates from the PHPM device were compared with the commercial sensors with light scattering technology which include SI, SN, SV, SC, and CKDPM. All commercial devices are shown in Tables 1 and 2.

2.2. Sampling Locations. The two instruments were set up together at four locations from December 2020 to February. Considering human activities in each sampling area to represent each site for reporting measurement results to cover the most residential areas. The first location (chamber) was inside a control room, in which incense was burned to provide a source of aerosols. The second location (University campus) was located on the campus of Khon Kaen University (16.4706°, 102.8255°) (Figure 2). The third location (urban center) was in downtown Khon Kaen, located near high-traffic roads and markets (16.4287°, 102.8354°). The fourth location (rural industrial) was located in a primarily agricultural area but in the vicinity of a sugar cane factors. Data from each instrument was logged every 30 minutes.

2.3. Sampling Method. The concentration of $PM_{2.5}$ samples were collected for 12 days, with data being recorded every

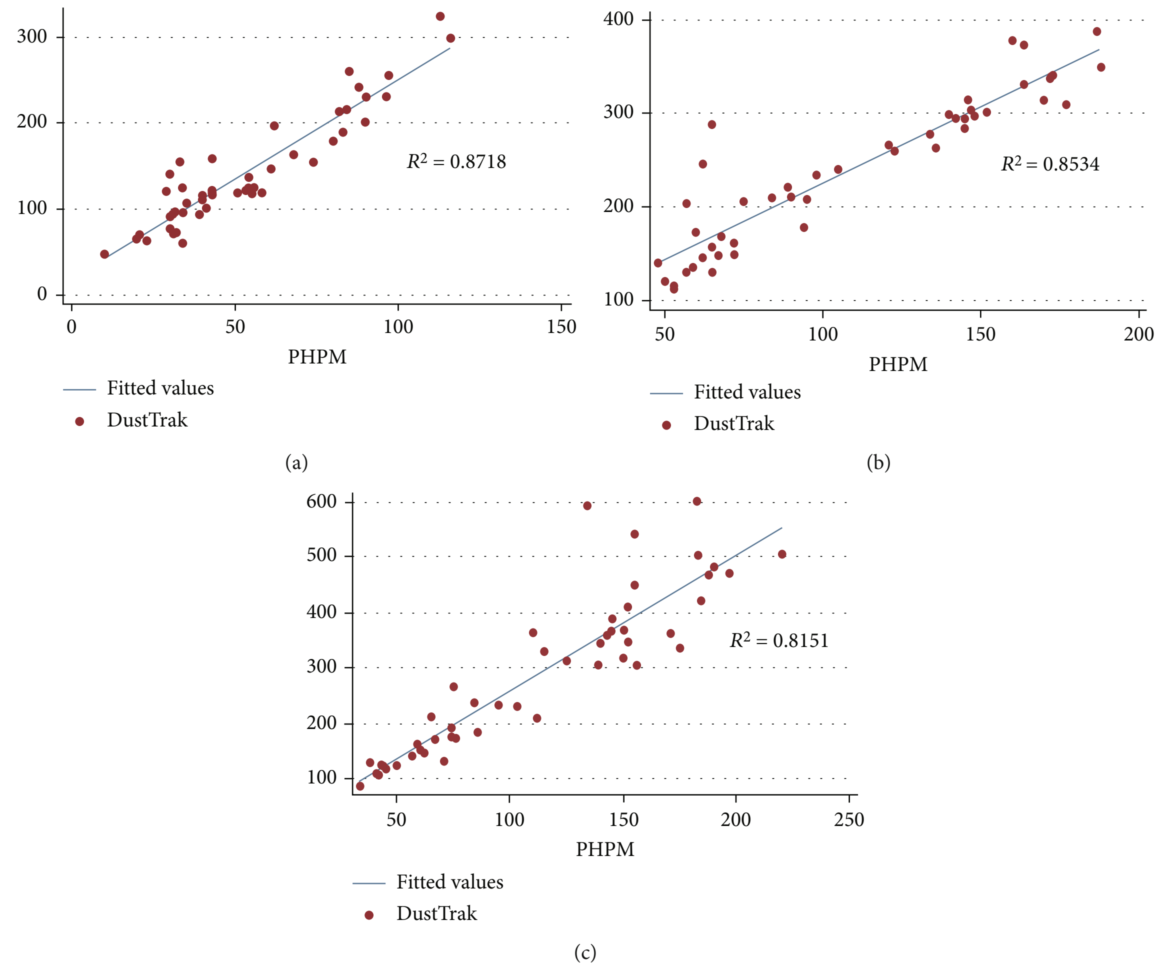

FIGURE 4: Observed $PM_{2.5}$ concentrations, as measured by the DustTrak Drx Aerosol Monitor 8533, on the y-axis compared to the estimate of $PM_{2.5}$ from the PHPM device, as measured at (a) a controlled indoor environment with incense (chamber); (b) the Khon Kaen University campus (University campus); and (c) at rural area near a sugar cane factory (rural industrial).

TABLE 3: Pearson's correlation coefficient, r, for each sampling location and summary statistics of measured $PM_{2.5}$ concentrations.

Site	Observed $PM_{2.5}$ in DustTrak 8533 ($\mu g/m^3$)†	Estimated $PM_{2.5}$ in PHPM ($\mu g/m^3$)†	Correlation, r
Chamber	241.8 (102-477)	139.3 (50-804)	0.71
University campus	143.2 (48-325)	53.6 (10-116)	0.93
Urban center	240.8 (112-388)	109.2 (48-188)	0.92
Rural industrial	292.6 (85-602)	113.9 (34-220)	0.90

†Average and range (in parentheses) are reported.

30 minutes from 8:00 a.m. to 8:00 a.m. the next day for 24 hours. Collect dust samples with a size of not more than 2.5 microns ($PM_{2.5}$) by installing a collector. Dust samples for both the High-Volume Air Sampler, 5 types of dust measuring instruments (commercially sold brands) and simple dust measuring instruments up to 2.5 μm that were developed from December 2020 to January 2021 for 24 hours from 8:00 a.m. to 8:00 a.m. of the next day for 24 days. Methods for collecting dust samples with a size not exceeding 2.5 μm ($PM_{2.5}$) by a High-Volume Air Sampler. Preparing filter paper, glass fiber filter is baked to remove moisture for 24 hours. After baking, put the filter paper in the dehumidifier cabinet for at least 24 hours. Then, put the filter paper in the filter head 1 sheet per time used sampling. When the sample collection is complete, the filter paper is placed in the dehumidifier for at least 24 hours and then weighed with a fine balance with 5 decimal places before and after the collected samples were to determine the weight of the dust particles on the filter paper. Method of collecting dust samples particulate matter up to 2.5 μm ($PM_{2.5}$) by DustTrak 8533, five types of dust measuring instruments (commercially sold brands), and a simple developed dust measuring device up to 2.5 μm. The method of collecting samples of these instruments is simple.

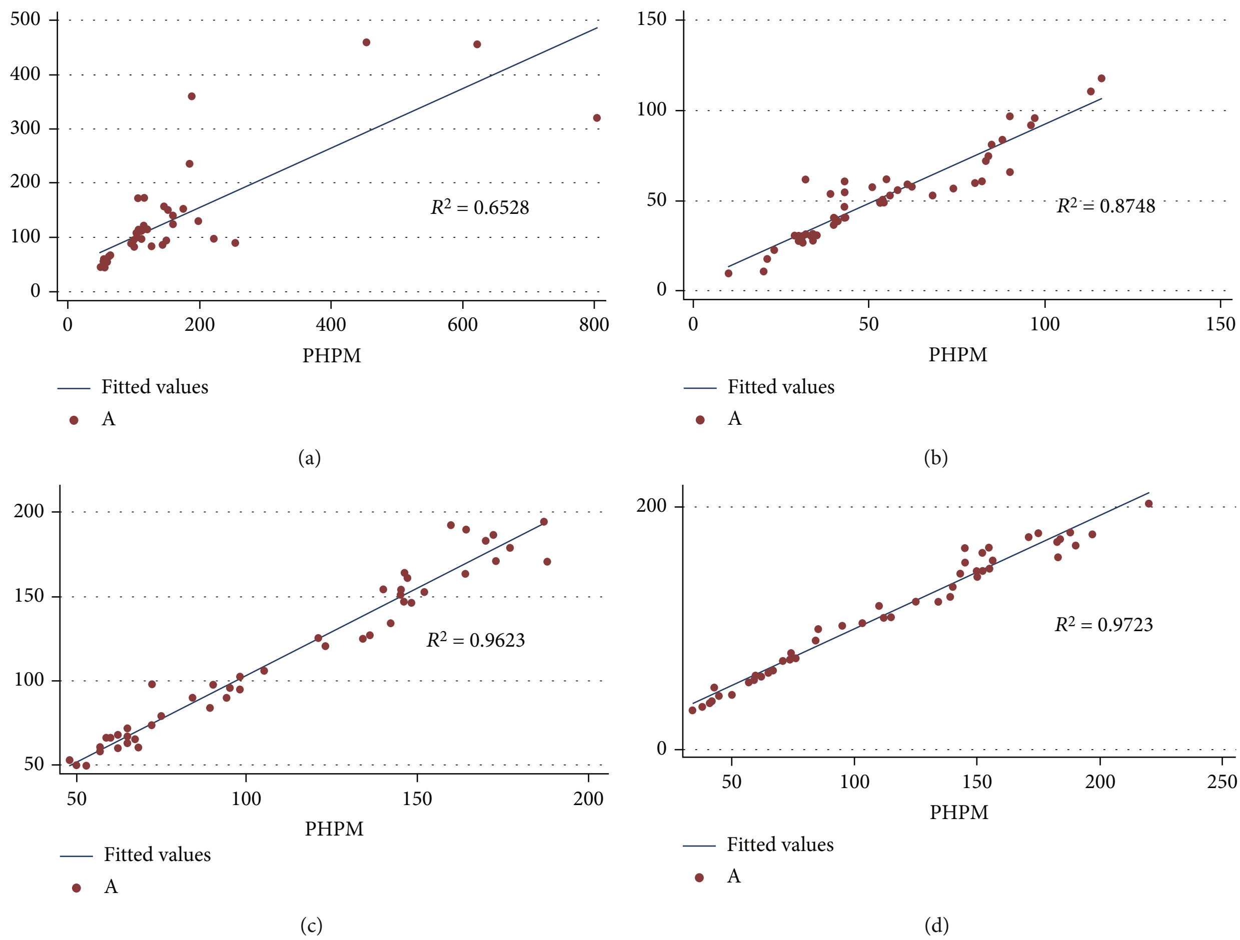

Figure 5: Observed $PM_{2.5}$ concentrations, as measured by the SI device, on the y-axis compared to the estimate of $PM_{2.5}$ from the PHPM device, as measured at (a) a controlled indoor environment with incense (chamber); (b) the Khon Kaen University campus (University Campus); (c) in downtown Khon Kaen (urban center); and (d) at rural area near a sugar cane factory (rural industrial).

The machine will suck air into the system and analyze the data and display results immediately on the display screen, which will take samples every 30 minutes from 8:00 a.m. to 8:00 a.m. of the following day from December 2020 to January 2021 and averaged by using standard 24 h. Analyzing fine particulate matter $PM_{2.5}$ by gravimetric method by weighing the dust filter paper with a size of not more than 2.5 μm ($PM_{2.5}$) before and after, samples were taken, and the weight difference was determined to calculate the concentration of fine particulate matter using the formula as follows:

$$\text{PM2.5}\left(\mu g/m^3\right) = \frac{\left(W_f - W_i\right) \times 10^6}{\text{Vstd}}, \quad (1)$$

where W_f = filter paper weight after sampling (g)

W_i = presampling paper weight (g)

Vstd = volume of air at standard conditions (cubic meter unit)

10^6 = convert grams to micrograms

Source: Office of Air Quality and Noise Management, Pollution Control Department, Thailand.

2.4. Data Analysis. Pearson's correlation coefficient, r, was computed to measure the association between the $PM_{2.5}$ estimates from the PHPM and measurements from the DustTrak 8533 for each sampling location independently. Linear regression was used to calibrate the readings of the PHPM to the DustTrak 8533 readings. All data analysis was completed in STATA version 15 (copyright of Khon Kaen University). Simple linear regression was used to describe the relationship between the two variables and to make predictions. By constructing an equation showing a linear relationship between two variables from the linear equation as follows: $yi = a + bxi$ or $yi = \beta_0 + \beta 1xi$, where y value is the concentration of $PM_{2.5}$ obtained from the $PM_{2.5}$ measuring device. A simple developed and x is the reference DustTrak 8530, where a or β_0 is the y-intercept constant and b or $\beta1$ is the slope or coefficient, where r^2 is 0 to 1, and approaching 1, the regression equation can explain a lot of the change. The data were analyzed from the sampling results of dust concentrations up to 2.5 microns by statistical methods, using Pearson correlation coefficient between the two variables. The estimation equation for Pearson correlation coefficient (r_{xy}) is given as follows:

$$r = \frac{\text{COV}(X, Y)}{S_x S_y}, \quad (2)$$

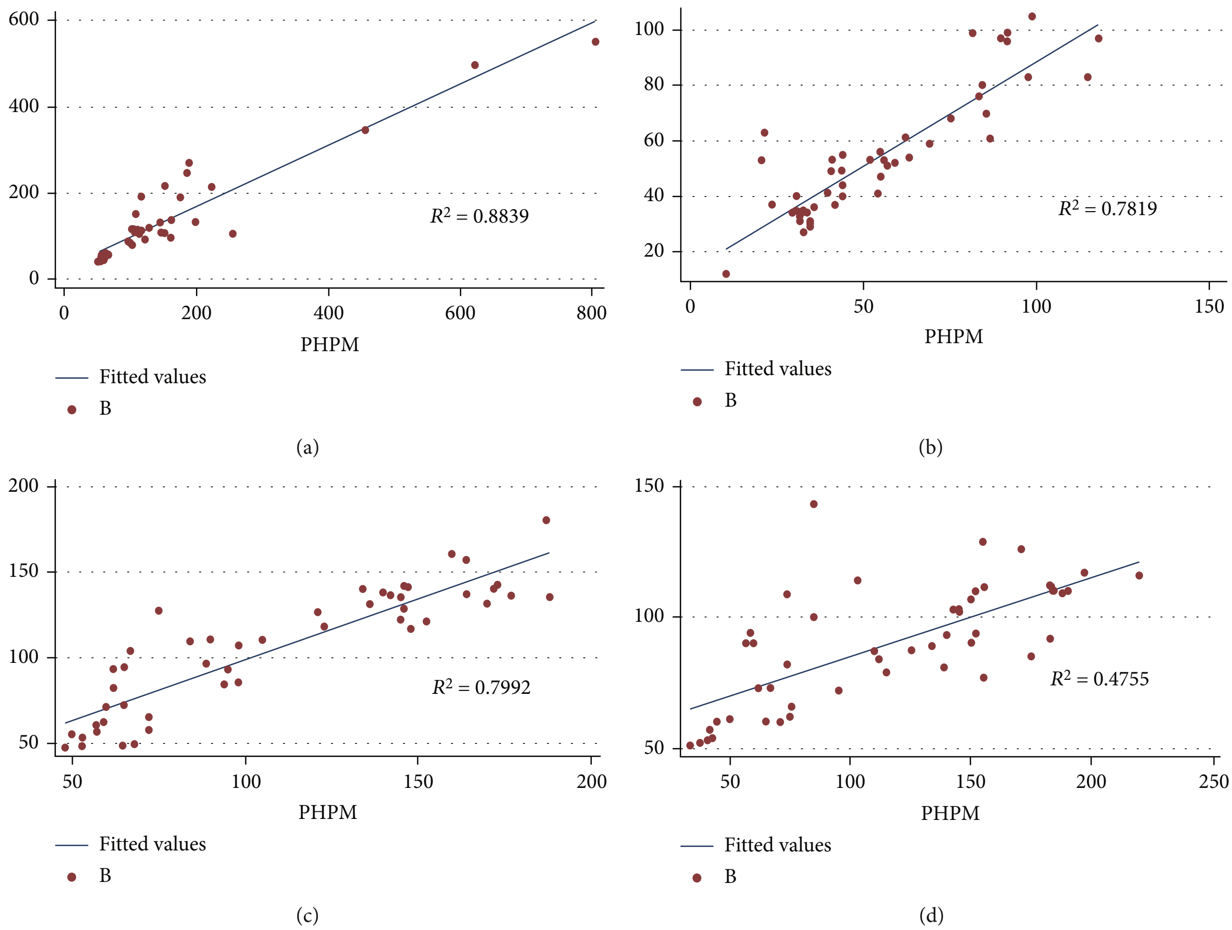

Figure 6: Observed $PM_{2.5}$ concentrations, as measured by the SN device, on the y-axis compared to the estimate of $PM_{2.5}$ from the PHPM device, as measured at (a) a controlled indoor environment with incense (chamber); (b) the Khon Kaen University campus (University campus); (c) in downtown Khon Kaen (urban center); and (d) at rural area near a sugar cane factory (rural industrial).

with

$$\mathrm{COV}(X, Y) = \sum_{i=1}^{n} \left(\frac{(xi - \bar{x})(yi - \bar{y})}{(n-1)} \right), \quad (3)$$

where $\mathrm{COV}(X, Y)$ is the sample covariance between two random variables X and Y that are normally distributed with means $\bar{x}$ and $\bar{y}$ standard deviations S_x and S_y, respectively.

3. Results

The graph shows the high correlation of the data with $r = 0.93$ and $R^2 = 0.87$, meaning that the resulting regression can easily account for the distribution of the results measured with a dust measuring instrument up to 2.5 μm, 87 percent. Concentration prediction obtained from a simple dust measuring device up to 2.5 microns in size using a simple regression equation was as follows: $y = 18.58 + 2.33X$. It was found that dust concentrations of no more than 2.5 microns were found, obtained from a simple dust measuring device that measures no more than 2.5 μm with an increase of 1 μg/m^3. As a result, the dust concentration of up to 2.5 μm obtained by the DustTrak 8533 was increased by 2.33 μg/m^3, where y is the predicted value of the particulate concentration equation of 2.5 μm obtained from simple dust measuring instruments up to 2.5 μm which are given as values from DustTrak 8533, and x is the concentrations of dusts up to 2.5 μm obtained from dust detectors. Size is not more than 2.5 μm easily. A PHPM instrument for monitoring $PM_{2.5}$ concentration is shown in Figure 3.

3.1. Observed and Estimated $PM_{2.5}$ Concentrations. Overall, a positive linear relationship was observed between the PHPM estimates and the $PM_{2.5}$ data from the DustTrak 8533 (Figure 4). The highest $PM_{2.5}$ concentrations were observed in the chamber (Figure 4(a)). Ambient air $PM_{2.5}$ concentrations at the three outdoor sites were similar. However, the $PM_{2.5}$ was lowest at the University campus site (Figure 4(b)) and highest at rural area near a sugar cane factory (rural industrial) (Figure 4(c)). Overall, the estimates from the PHPM were lower than the data from the DustTrak 8533 (Table 3).

3.2. Correlation of PHPM Data to DustTrak 8533 Data. Considering only the outdoor ambient air sites, the correlation between PHPM and DustTrak 8533 was high, with a Pearson's correlation coefficient values ($r = 0.90$) (Table 3). The

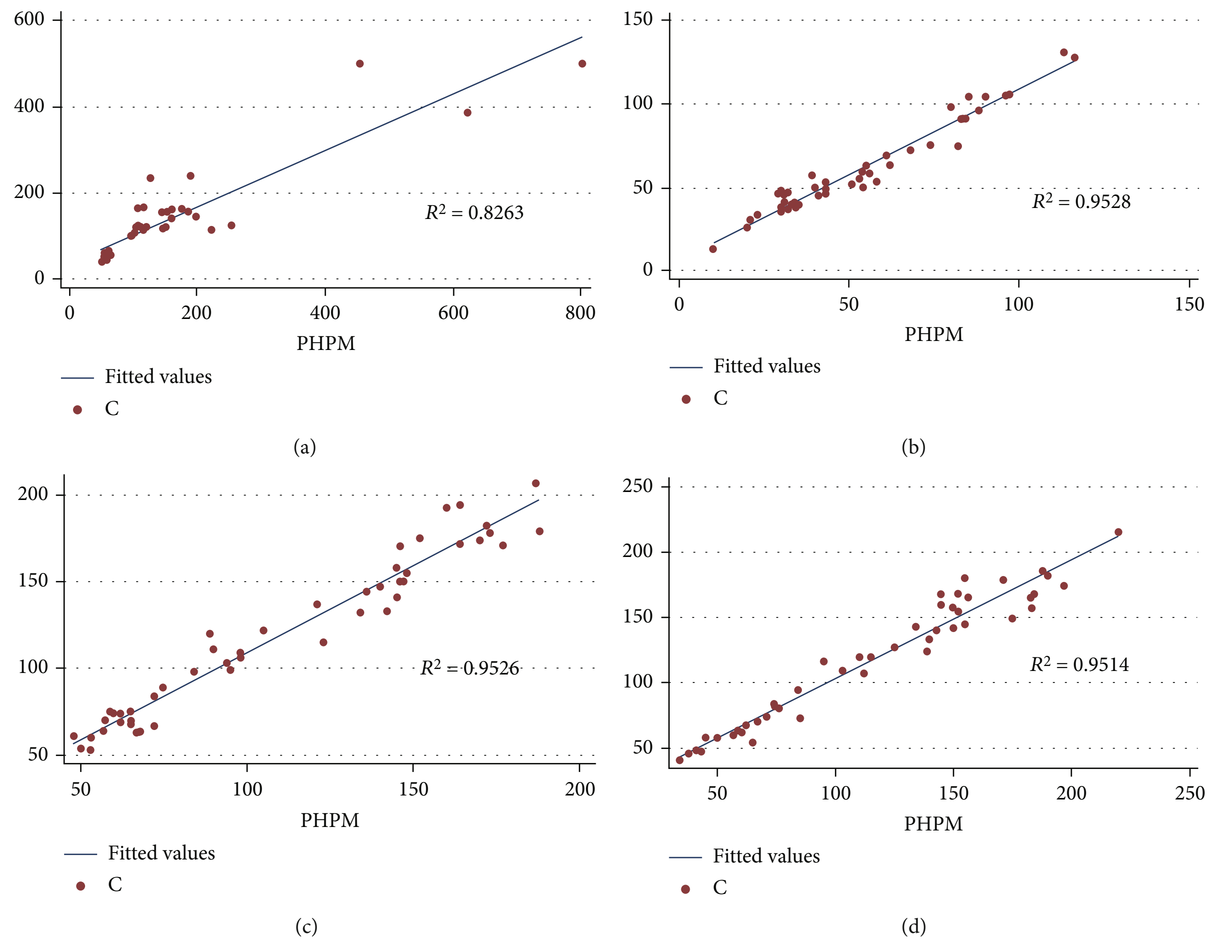

Figure 7: Observed $PM_{2.5}$ concentrations, as measured by the SV device, on the y-axis compared to the estimate of $PM_{2.5}$ from the PHPM device, as measured at (a) a controlled indoor environment with incense (chamber); (b) the Khon Kaen University campus (University campus); (c) in downtown Khon Kaen (urban center); and (d) at rural area near a sugar cane factory (rural industrial).

chamber data, however, show nonlinear relationship and lower correlation. In general, the values reported by the PHPM system were lower than the DustTrak 8533 estimates, indicating the PHPM device was underestimating $PM_{2.5}$. Nevertheless, the PHPM system performed well with high correlation with $PM_{2.5}$ concentrations in its targeted environment of ambient air. Linear regression determined the relationship of $PM_{2.5}$ from the PHPM device to be

$$\mathrm{PM2.5}\left(\mu\mathrm{g}/m^3\right) = 18.6 + 2.33 \times \mathrm{PHPM} \tag{4}$$

The data suggests that this linear relationship can be used to correct the PHPM data for 30-minute $PM_{2.5}$ concentrations using a correction factor of 2.33 and is applicable for use in ambient air with $PM_{2.5}$ concentrations in the range of 50 to 600 μg/m^3. The results of the study of the relationship of the data in the study method are shown in Figures 5–9.

4. Discussion

This research found that the correlation between the low-cost light-scattering sensor and the higher accuracy DustTrak device was relatively high ($R^2 > 0.80$) across all observed $PM_{2.5}$ concentrations in the three outdoor ambient air test sites. However, the lowest observed $PM_{2.5}$ concentration was 48 μg/m^3 according to the DustTrak device. Testing of multiple commercial low-cost $PM_{2.5}$ sensors has demonstrated that the correlation between such low-cost devices and the DustTrak device can have poor correlation at concentrations less than 50 μg/m^3 [23]. Therefore, it is possible that the PHPM device may be inaccurate at concentrations less than 50 μg/m^3. However, the targeted application of the device is to increase awareness of $PM_{2.5}$ concentrations during $PM_{2.5}$ pollution events (generally higher than 50 μg/m^3). Therefore, inaccuracy at this range does not substantially impact the intended use.

A limitation of the device is that substantial variations in conditions may affect the correction factor determined from this research. While air quality data from low-cost sensors is extremely valuable for both research and public health usage, it should be carefully evaluated, especially under unusual atmospheric or genesis conditions. In addition, the sensors will automatically alarm when the dust concentration is detected over the standard. In the dust season, people were alarmed, and they felt panic; thus, we decided to turn off the alarm. The sensors need to be used with Internet

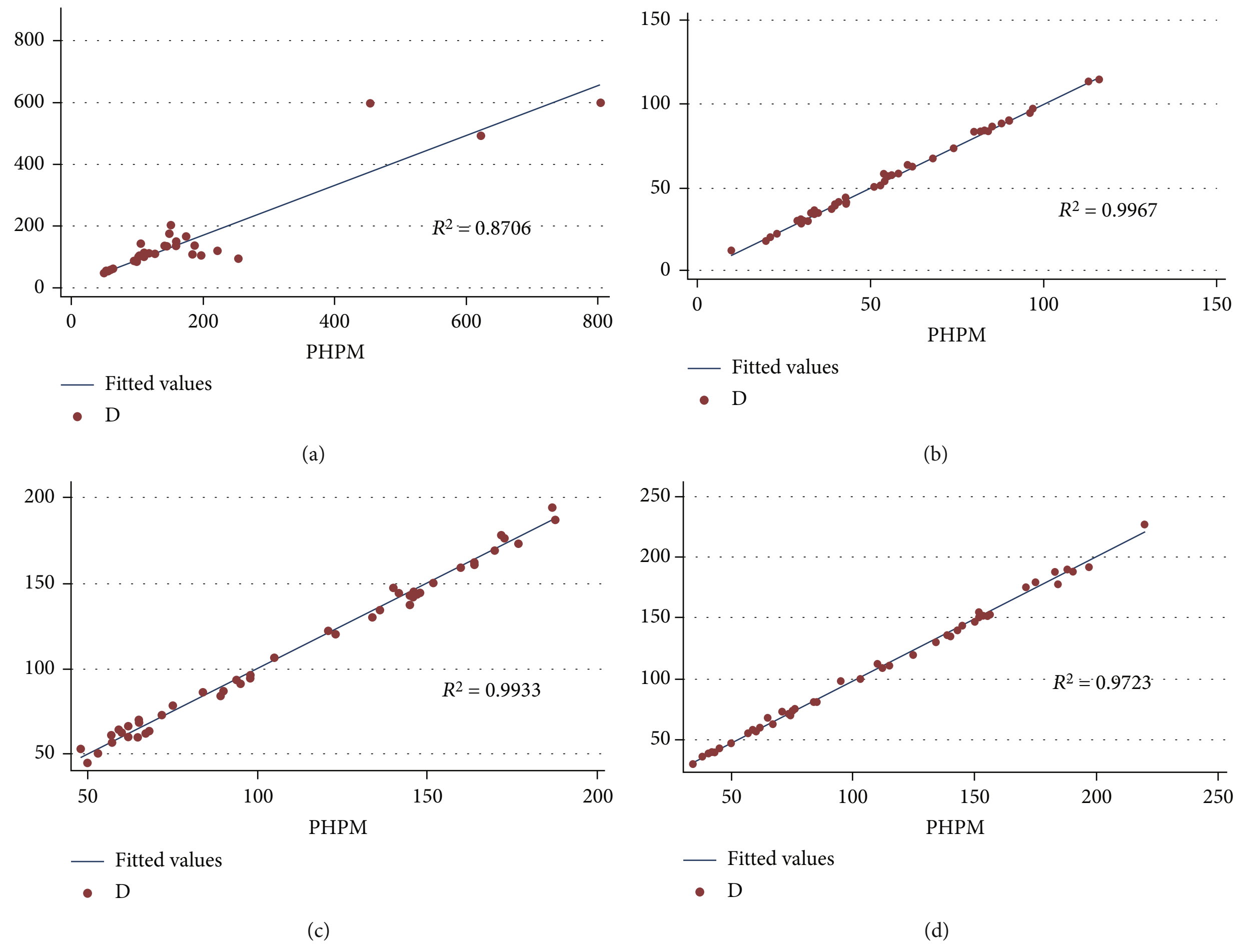

Figure 8: Observed $PM_{2.5}$ concentrations, as measured by the SC device, on the y-axis compared to the estimate of $PM_{2.5}$ from the PHPM device, as measured at (a) a controlled indoor environment with incense (chamber); (b) the Khon Kaen University campus (University campus); (c) in downtown Khon Kaen (urban center); and (d) at rural area near a sugar cane factory (rural industrial).

signal and also need a cloud storage for the application in order to link between dust quantity and health; anyway in some area, there is no Internet available, so the receivers needs to be installed and also a cloud storage. First, the performance of low-cost $PM_{2.5}$ sensors, such as optical particle counters, can be impacted by weather conditions. High relative humidity has been shown to cause optical particle counters to overestimate $PM_{2.5}$ concentrations [24]. Under high humidity conditions, hygroscopic growth of particles and reduced molecular mass of water result in an overestimation of particle mass [25]. Secondly, the varying size and composition of particles can also substantially affect the performance of low-cost $PM_{2.5}$ sensors [26, 27]. The effect of differing particle composition was observed in this study, too. While the sensors performed well ($r > 0.90$) in the ambient outdoor environments, the correlation was low in the chamber test using incense ($r = 0.71$). For this study, this PHPM device is more suitable for ambient air than the chamber. Thirdly, variations in the composition of atmospheric dust or meteorological conditions may also require adjustments in the computation methods for $PM_{2.5}$ estimation or the use of short time periods (e.g., one hour) [24]. Thus, caution should be applied in using the PHPM sensor outside of the tested conditions. If changes in the composition or size of the $PM_{2.5}$ particles, relative humidity, or desired temporal resolution occur, additional validation will be needed.

Another potential solution to the need for revised correction factors under varying conditions is to incorporate these confounding factors into the regression. While linear regression was used in this study, the accuracy of the low-cost device could be improved with multivariate regression that accounts for effects of confounding factors such as relative humidity or site-specific composition of the particulate matter [6] or nonlinear regression to account for nonlinear associations [28]. The widespread adoption of a low-cost $PM_{2.5}$ sensor will help increase public awareness of current $PM_{2.5}$ concentrations. The goal of increased awareness is to encourage coping activities, such as wearing a mask, [20] and pollution mitigation actions, such as using public transport [29]. Low-cost sensors can also facilitate an environment of citizen science, in which nonscientists actively participate in generating and sharing air quality data [30]. Such low-cost sensors have been used in open-source platforms to create a network of thousands of $PM_{2.5}$ monitoring

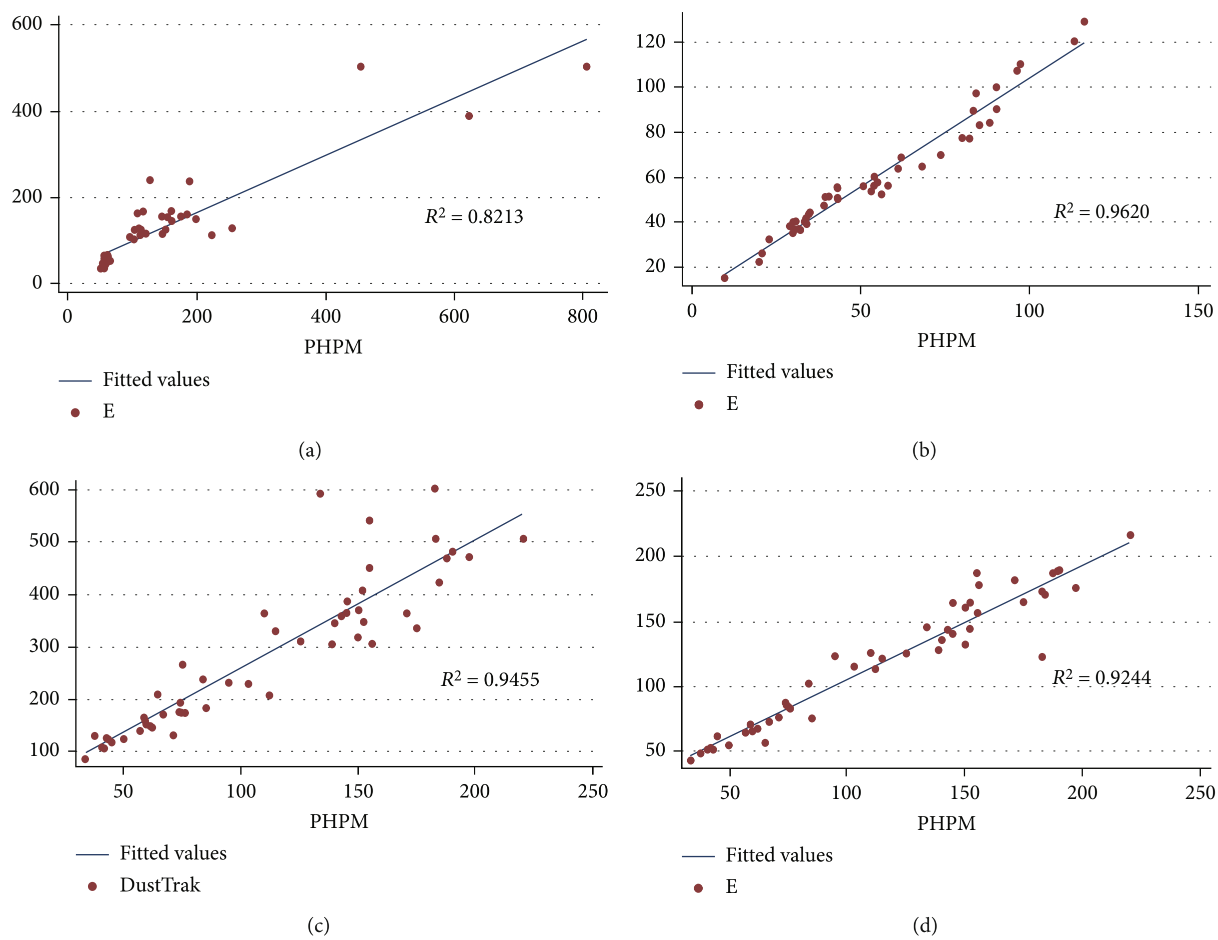

Figure 9: Observed $PM_{2.5}$ concentrations, as measured by the CKDPM device, on the y-axis compared to the estimate of $PM_{2.5}$ from the PHPM device, as measured at (a) a controlled indoor environment with incense (chamber); (b) the Khon Kaen University campus (University campus); (c) in downtown Khon Kaen (urban center); and (d) at rural area near a sugar cane factory (rural industrial).

devices [31], in networks of community air monitoring stations [32], and to measure other pollutants besides just $PM_{2.5}$ [33]. In addition, depending on the sensing capabilities of the developed and maintenance sensor probe, working on the method is to be specific and accurate for detection [7, 8].

5. Conclusion

A novel low-cost $PM_{2.5}$ sensor using light-scattering technology, PHPM, was developed and validated under both the chamber and field ambient air conditions. The PHPM has a large LED display screen, to be easy to see when installing in public areas where people can be aware of the amount of dust in the area where they live. In addition, the tool can be used outdoors due to its heat-resistant metal body. The instrument is working; it will suck the air through the air intake in the sensor. There will be a laser light source acting as part of the beam to strike particles of various sizes that enters the machine by a dust measuring device that does not exceed 2.5 microns in size.

Validation against a DRX Aerosol Monitor 8533 found that the average concentration of $PM_{2.5}$ for the PHPM device was using multiply with 2.33, according to linear regression. Under ambient air conditions with $PM_{2.5} > 50\,\mu g/m^3$, the PHPM device correlated well with the DustTrak device ($r > 0.90$). However, the correlation was weaker under indoor ambient air conditions with incense as a particle source. The hope is that the PHPM device can provide an additional tool for participatory citizen science and increased public awareness about $PM_{2.5}$ in Thailand. The PHPM device is inexpensive, portable, and can be charged with a power bank. Additionally, a simple measuring device for dust of less than 2.5 μm with a unique characteristic body made of heat-resistant metal can be used outdoors. The front has a large digital display of the amount of dust particles up to 2.5 μm. In the front part, there is a dust level display, no more than 2.5 μm, red, yellow, and green lights on the top, and there is a ventilation hole. The internal sensor used to read the amount of dust, the size of not more than 2.5 μm, is PMS 7003. There are components, which are composed of a heat-resistant metal body, an invention that has never been done before. (1) The front has a digital display of the amount of dust particles up to 2.5 μm. (2) In the front part, there is the level display of particulate matter up to 2.5 μm in red, yellow, and green lights is a new invention (3) with dust levels in the range of ≥50 μg/m^3 red indicator light. When the dust concentration is higher than the standard value, it affects health, and there will be an alert sound immediately. The level of dust is in the range of 0-25 μg/m^3 green indicator light. When the dust is concentrated, there is no health effect, and the level of dust is in the range of 26-49 μg/m^3 yellow indicator light, when the dust concentration is starting to affect health. The sensor is a processor that controls the status light. A heat-resistant metal measuring instrument is built into the unit with a PMS 7003 sensor. The sensor has an air intake port attached to the PMS 7003 sensor unit. The top of the measuring instrument has several air intake holes to allow the sensor to absorb a lot of air. This is a new invention. (4) It allows the sensor to read the amount of dust particles up to 2.5 μm. (5) The sensor's characteristics are a one-time response time of less than 1 second, integrated response time of less than or equal to 10 s charging 5 V, less than or equal to 100 mA working environment -10~+60°C, humidity 0~99% measuring range 0-500 μg/m^3, and resolution 1 μg/m^3 meter accuracy ±10% @$100 \sim 500 \pm 10$ μg/m^3, @0~100 μg/m^3. The limitation is that it cannot be used in environments with a dust concentration of 2.5 μm or more 500 μg/m^3 and cannot be used in environments with excessive humidity and temperature.

Data Availability

The data used during the current study are available from the authors upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Authors' Contributions

P.S., P.K., and S.S., are responsible for the conceptualization; P.S., P.K., W.L., and R.S. for methodology; W.L. for software; P.S., P.K., W.L., R.S., N.M., and J.R. for validation; P.K., W.L., and R.S. for formal analysis; W.L., R.S., and C.J. for resources; P.S. and S.S. for writing—original draft preparation; P.S. and S.S. for writing—review and editing; P.K. for visualization; and P.S. for funding acquisition. All authors have read and agreed to the published version of the manuscript.

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