

Verification of FreshAir' Air Quality Measuring Device

TRANSITE24 PVT LTD

IN COLLABORATION WITH UNIVERSITY OF MORATUWA AND
INDUSTRIAL TECHNOLOGY INSTITUTE

‘FreshAir’ Air Quality Measuring Device

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Verification Methodology

Introduction

Considering the health concerns imposed by the exceedance of the limits set for Particulate Matter by the Central Environmental Authority (in accordance with the Sustainable Development Goals (SDGs) set by the United Nations, requiring limitation of the annual mean levels of fine particulate matter (e.g. PM_{2.5} and PM₁₀) in cities, measuring of Air Quality has become a crucial component of all construction related activities and a mandatory requirement in Environmental Impact Assessment – EIA reports of all construction projects of in Sri Lanka, especially in the Highway sector.

In the current context of Air Quality Measuring Devices of the country, all infrastructure projects utilize the services of the Industrial Technology Institute – Sri Lanka in order to measure the air quality parameters at desired locations by an Air Quality Measuring Vehicle housing devices facilitating the measurement of the levels of PM_{2.5} and PM₁₀ at an hourly interval.

The limitations of this process are the expensive nature of the operation (\$7,000 per session), lack of convenience in transportation of the devices to desired location (as the whole vehicle has to be moved) and the inability to obtain real time data on the air quality parameters within a certain designated hour.

When taking the availability of portable dust monitoring devices for purchase in to account, the following devices are available, but again with the limitations of cost and lack of accuracy of operations.

- Dust Monitor DustTrak DRX TSI 8533 - \$10,950.00
- TSI 8534 Handheld DustTrak DRX - \$9,350.00

FreshAir – Product Overview

It is within this background that FreshAir is being introduced, with the objective of addressing the drawbacks of the current mechanism of Air Quality Monitoring in Sri Lanka, in terms of Cost, Convenience and the Accuracy of Results.

The Basic Concept behind the device is real time data collection, and manipulation of the obtained data as per consumer requirements.

Methods of Air Quality Measurement

There are two methods of air quality measurement, Beta Attenuation Method and Infra-red particle sensing method, namely.

Beta Attenuation Method

In this method, the Air Quality (or the Dust Quality) is presented as an hourly average of cumulated values for dust particle content over a given hourly interval for the desired location.

This is the method utilized by the Air Quality Measuring Vehicle owned by the Industrial Technology Institute – Sri Lanka.

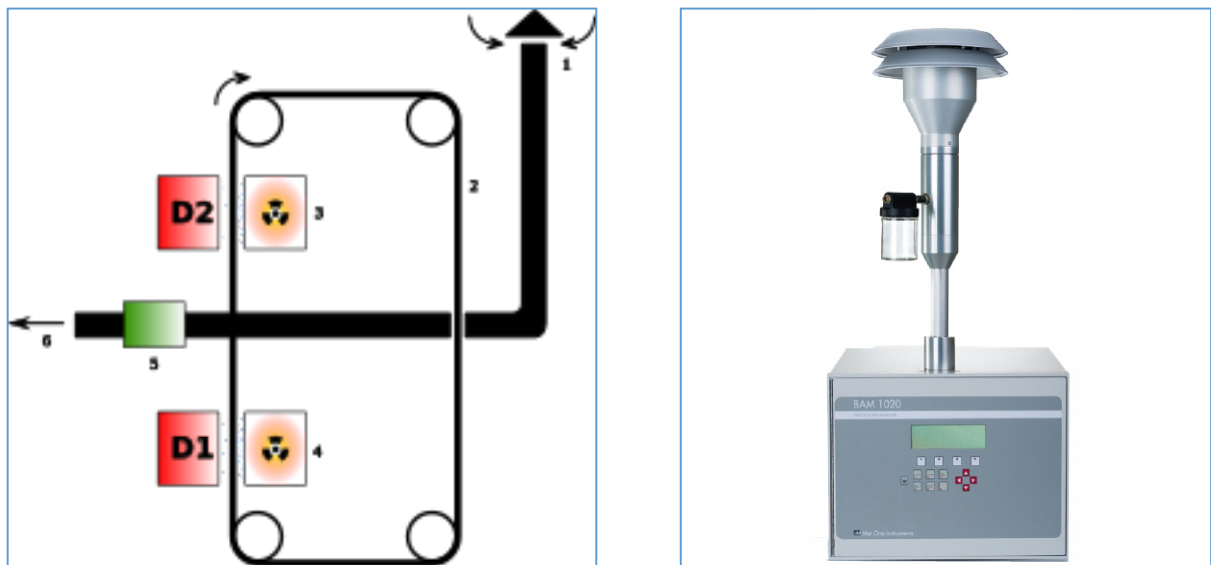


Figure 1 : Beta Attenuation Method of testing particulate matter

Infra-red Particle Sensing Method

In this method, the Air Quality (or the Dust Quality) is presented as a real time distribution of dust particle content for the desired location.

This method utilizes the concept of scatter of the input Infra-red light by the available particulate matter at any given time in order to determine the air quality at a certain location at that point in time, and thus provide results which are a step ahead from that provided by the Beta Attenuation method.

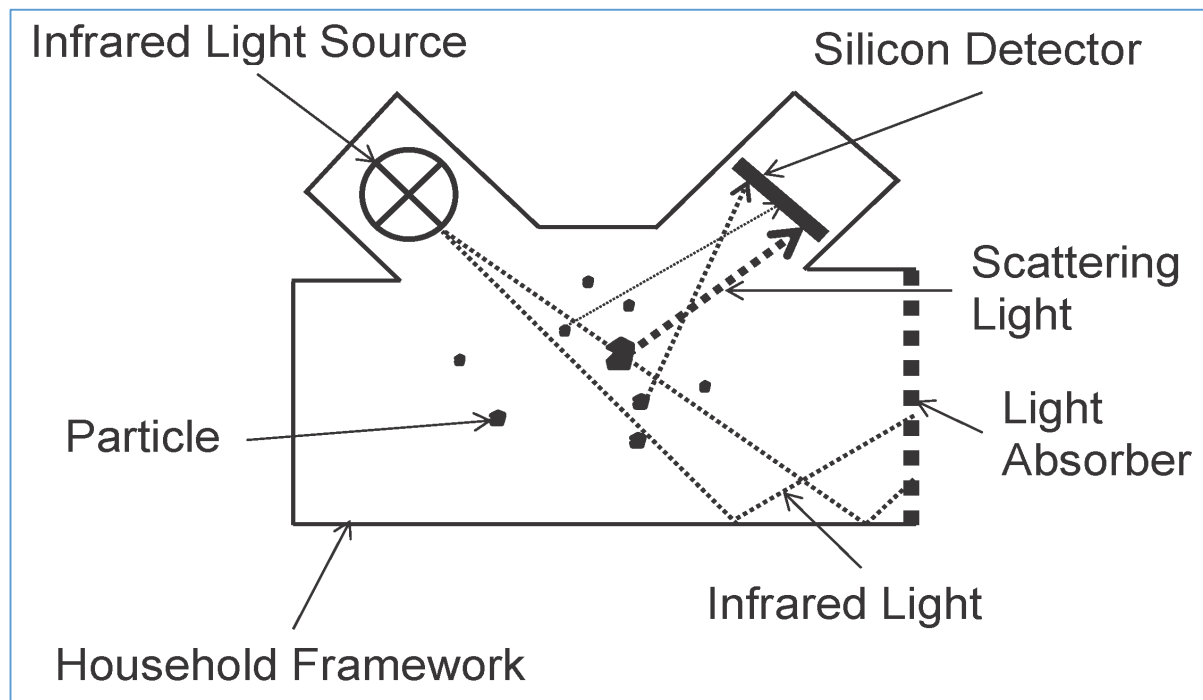


Figure 2: Infra-Red method of testing particulate matter

Verification of Results

Theory

FreshAir Air Quality Monitoring Device utilizes the infra-red Particle Sensing method for the purpose of determining the Dust Quality at a desired location as follows;

- At any given point of time, the Air Flow fans of the attached sensor to the device absorbs a constant rate of air from the surrounding into the sensor.
- An infra-red emitter is directed to the absorbed air via a channel through which the passage of the air is facilitated.
- The initial strength of the infra-red wave is a constant and a known value, and the strength of the infra-red wave received following the incidence on the absorbed air is measured.
- A voltage is generated based on the variation between the initial and final strengths of the Infra-red wave (between the receiver and emitter).
- This generated voltage depicts a linear variation along with the quality of the air passing through the air channel.
- Accordingly, the values of Particulate Matter ($PM_{2.5}$ and PM_{10}) which indicate the Air Quality are measured by the extent of the channel (of known dimensions) occupied by the dust present in absorbed air at a given time, using the strength variation of the infra-red wave.



Figure 3: Developed device “FreshAir” to monitor air quality by Trancite24 PVT LTD

Verification of Particulate Matter Sensors

While the existing mechanism of measuring Air Quality in Sri Lanka (Air Quality Measuring Vehicle – Industrial Technology Institute - ITI) utilizes the Beta Attenuation method, FreshAir utilizes the Infra-red Particle Sensing method.

In the process of verifying the results obtained by FreshAir for a certain location at a given point in time, the mean value obtained for the particle distribution of hourly collected data from FreshAir was fitted to the hourly mean value obtained from the Air Quality Measuring Vehicle.

Accordingly, two locations were decided upon for the purpose of verification of results obtained from FreshAir in accordance with that obtained from ITI as follows;

- Industrial Technology Institute Premises (Non-industrial Environment)
- North Western Province Industrial Zone (Industrial Environment)

At each hourly interval, the results of both devices were compared and the mean value of the normal distribution obtained from FreshAir was multiplied by a linear factor to align the mean value with that obtained by the ITI device, for increased accuracy.

Results - Industrial Technology Institute Premises

The data collection at ITI was carried out on 4th January 2018. The data was collected to initially test the sensors and observe the long-term operation of the device for longer period. The data was collected for 4 hours and was analyzed using statistical methods. The verification of the sensor was fine tuned to fit the hourly average obtained by Infra-Red method to the cumulative average value produced by BAM.

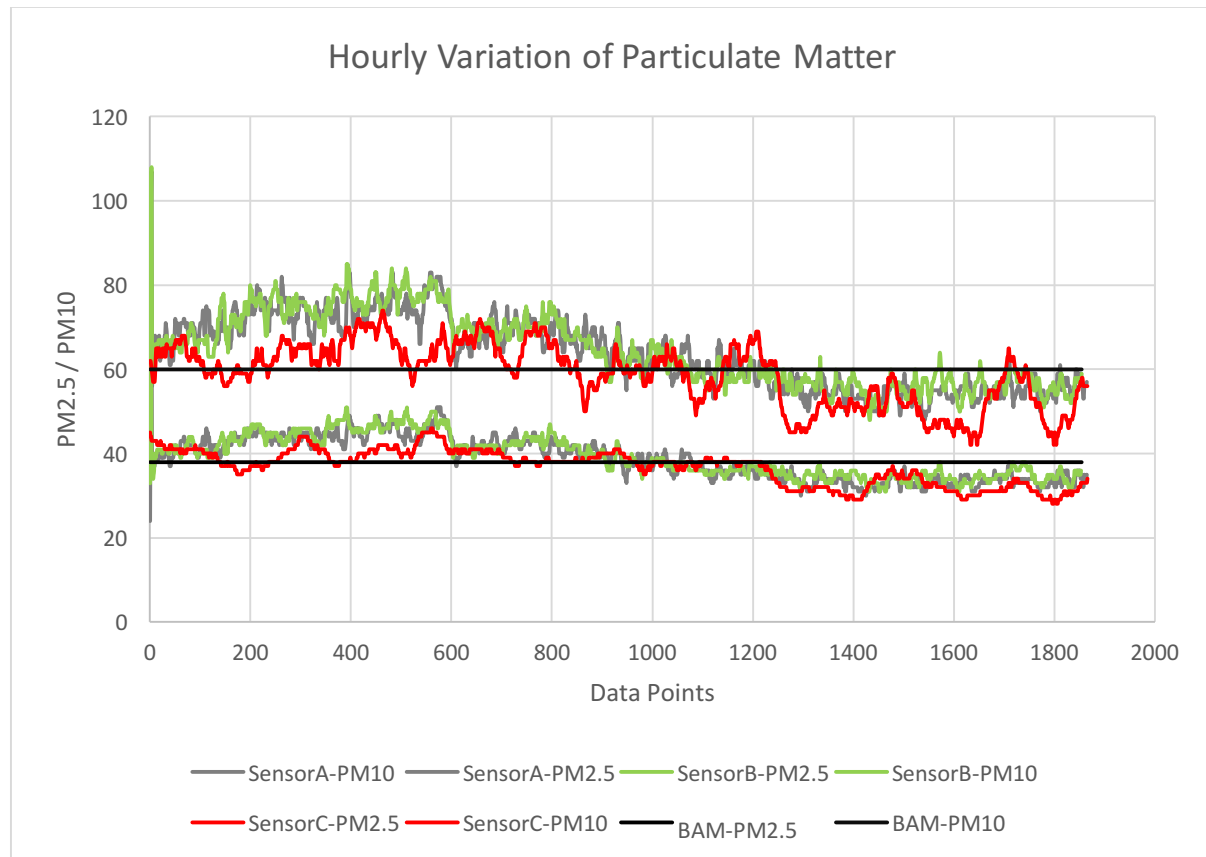


Figure 4 : Hourly Variation of Particulate matter

The Figure shows results given by Infra-red PM sensors and hourly average value obtained by BAM method. For verification purposes three sensor types (A,B and C) were used. During the four-hour period, first three-hour data was used to fit the distributions to the required level. The Figure 1 is the data collection during the fourth hour which shows the significantly high association between BAM method and infra-red method. The objective of fitting the distribution to match the average PM values given by BAM is a success.

When considered the sensor type sensor C performed well by giving lower variations when compared with both Sensor A and Sensor B. The results show that sensor type C is much reliable in obtaining results.

Device	A	B	C	A	B	C	BAM	BAM
	PM 2.5	PM 2.5	PM 2.5	PM 10	PM 10	PM 10	BAM 2.5	BAM 10
Average	38.77	39.37	36.78	63.95	64.68	58.85	38.00	60
Std. Dev	5.00	4.93	4.15	8.52	8.67	7.33	-	-
Max	69	64	46	107	108	74	-	-
Min	24	21	28	37	33	42	-	-
Range	45	33	18	70	60	32	-	-
Confidence Level (95%)	0.23	0.22	0.19	0.39	0.39	0.33	-	-

Table 1 : Data analysis of different types of sensors

When analyzed the statistics obtained from three sensors, the sensor C data has a closer approximation to the average value given by the BAM method. The standard deviation of the data is 4.15 for PM2.5 and 7.33 for PM10 which is the lowest from other sensors. Further sensor type C has the lowest confidence level (95%) from the data set. Therefore, the results given by the Sensor type C is much reliable and efficient as a point estimator.

In conclusion, it was identified that the results given by infra-red method and BAM could be verified by statistical methods and there exists a linear relationship between the sensed data. Thus, by referring to the BAM the infra-red sensors were fine tuned. The data collected for the initial verification was only lasted for four hours. Therefore, it is expected that the verification process being carried out for a longer time intervals in future.

Results - Industrial Environment

Although the performance of the device in sensing particulate matter at non-industrial premises is a success, it was a question how well the device will perform at industrial environment. Hence the second phase of verification process was extended to collect data at an industrial environment which has sudden changes in PM levels. The data collection was carried out for a period of three days starting from 19th to 21st January 2018. Data was collected for a period of 36 hours having 12 hours (7.00am – 7.00pm) on each day. Statistical hypothesis based on means was followed in verification process.

The hypothesis of the IR hourly average PM value is not equal to BAM average value was considered in the analysis. To illustrate the data, a linear regression model for PM2.5 and PM10 was used. In the data collection, the raw values given by the sensor was used without considering the initial verification factors to check whether there is an association between the environments.

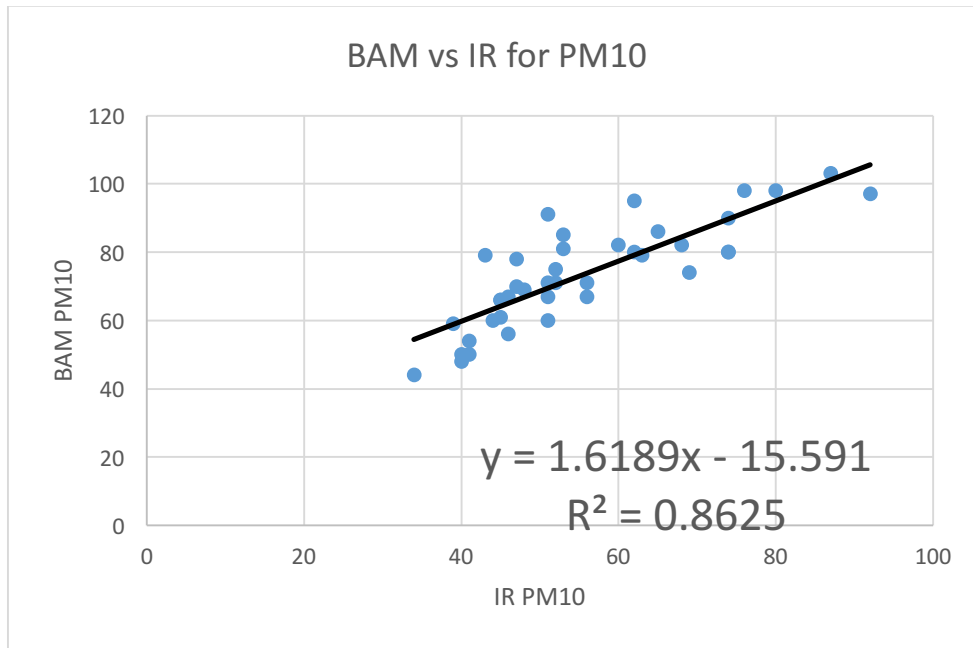


Figure 5 : Linear regression model of BAM and IR methods of PM10 monitoring

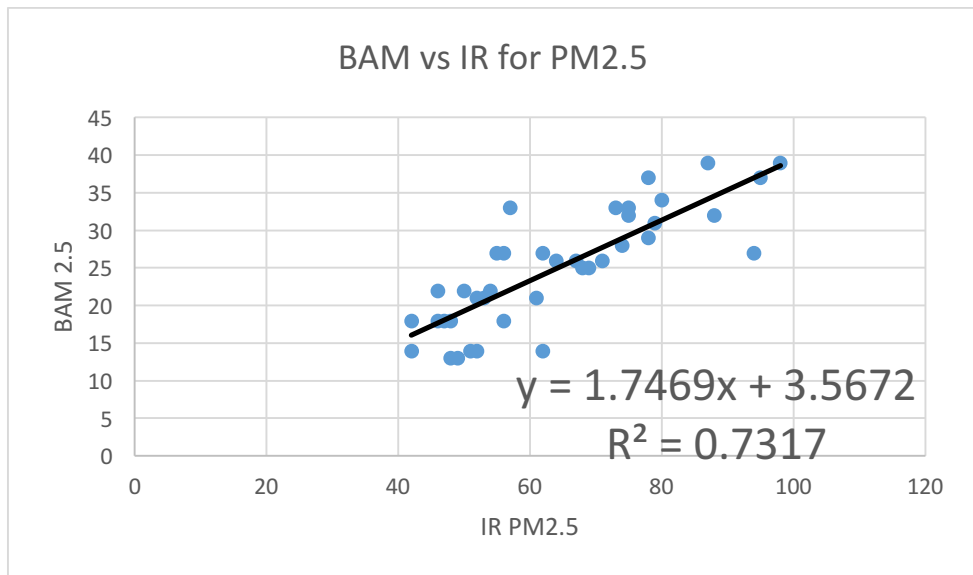


Figure 6 : Linear regression model of BAM and IR methods of P2.5 monitoring

The Figure 2 and Figure 3 give the linear variation of PM values within the range of 40 to 100 $\mu\text{g}/\text{m}^3$. The observed values were within extreme weather condition such as high temperature and high winds. The obtained results show that there is a very high co-relation between Bam and IR method by giving R^2 value of 0.86 for PM10 and 0.73 for PM2.5 respectively.

In order to test the hypothesis, the obtained model was used to factor raw data and follow up the statistical testing. The results of the analysis showed that the hypothesis is significant at 95% significant level to reject the null hypothesis.

One-Sample Test						
	Test Value = 18					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
PM2.5	-10.001	3514	.000	-.37148855	-.44431439	-.29866271

Table 2: Test results for hypothesis test on PM2.5 sample

One-Sample Test						
	Test Value = 39					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
PM10	-25.656	3514	.000	-1.5017382	-1.6165014	-1.3869750

Table 3: Test results for hypothesis test on PM10 sample

The Table2 and Table3 shows the test being tried on randomly selected one hour data sample. The null hypothesis of IR hourly average PM value is not equal to BAM average value was rejected at both hypothesis tests in PM10 and PM2.5. Which indicate that the alternative hypothesis of the average values obtained from both methods could be within the acceptable limits. It could be further illustrated from the distribution of PM10 and PM2.5.

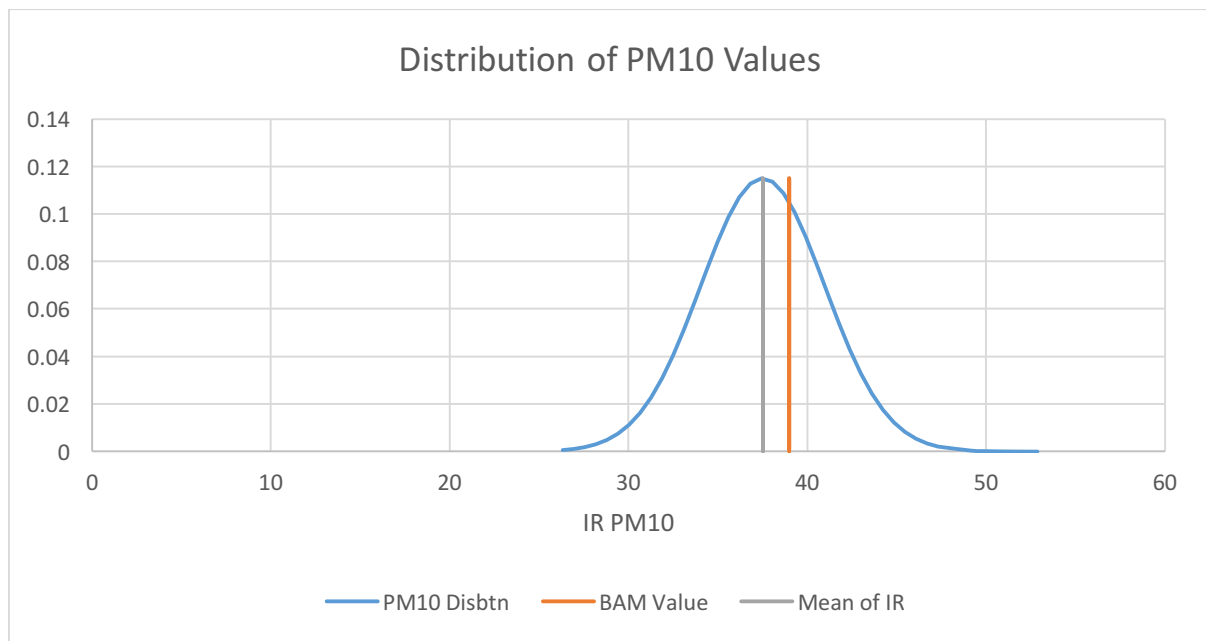


Figure 7 : Distribution of PM10 values within an hour

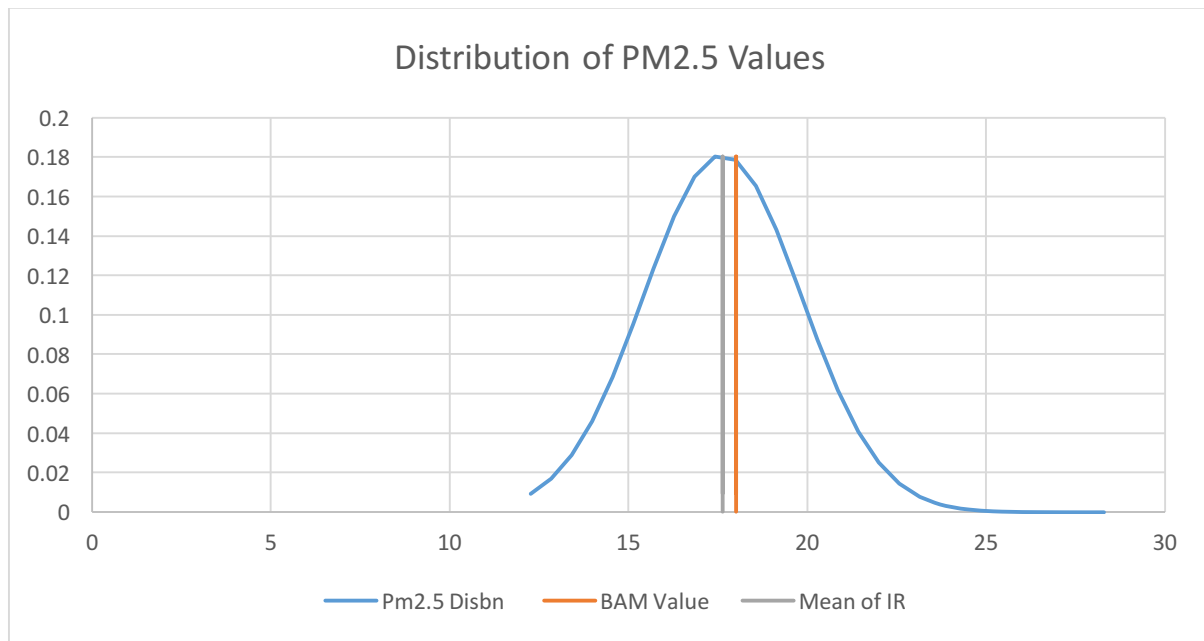


Figure 8 Distribution of PM2.5 values within an hour

From Figure 5 and Figure 6 it could be observed that the distribution of PM values within an hour could be easily fitted to the average value given by BAM. Therefore, it could be utilized in industrial environments with a verification method based on linear regression.

Summary of Verification Process

The verification process was conducted in two environments such as industrial and non-industrial. In both environments, a sound verification was carried out and results indicate the ability to use the device for air quality monitoring after following the verification method. The results indicate that the hourly average values obtained from Beta Attenuation method and Infra-Red Dust Sensors has a linear relationship in which sensor devices could be fine-tuned to give significantly acceptable estimates of dust levels. In future research, it is advised to carry out the verification process by incorporating weather factors such as temperature wind speed, relative humidity.

It could be concluded that after running the verification process the device is possible to use in both industrial and non-industrial environments to monitor atmospheric dust levels.

Appendix A

A	A	B	B	C	C	BAM	BAM
PM 2.5 S	PM 10 S	PM 2.5 S	PM 10 S	PM 2.5 S	PM 10 S	BAM 2.5	BAM 10
		21	33	45	62	38	60
24	37	45	73	44	62	38	60
51	79	61	105	44	61	38	60
65	101	64	108	43	60	38	60
69	107	35	57	43	59	38	60
35	56	35	59	43	58	38	60
36	62	36	60	43	57	38	60
36	61	34	57	43	57	38	60
37	61	35	58	43	57	38	60
37	60	36	60	43	57	38	60
37	62	40	66	43	59	38	60
40	68	40	66	43	62	38	60
38	66	39	63	43	65	38	60
38	65	40	64	43	65	38	60
38	65	40	66	42	65	38	60
38	66	41	66	42	63	38	60
38	65	41	66	42	65	38	60
39	65	41	67	42	65	38	60
39	65	41	67	42	65	38	60
40	68	41	67	42	63	38	60
39	64	41	67	42	63	38	60
39	62	41	67	43	63	38	60
39	63	41	67	42	63	38	60
39	63	41	67	42	63	38	60
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40	67	41	66	42	65	38	60
39	65	41	66	41	63	38	60
40	68	41	66	41	63	38	60
41	68	41	67	41	63	38	60
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38	62	42	67	41	63	38	60
39	63	42	67	41	65	38	60
39	62	42	68	41	65	38	60
39	62	41	67	41	65	38	60
39	62	42	67	41	65	38	60
40	65	42	67	41	65	38	60
40	67	41	66	41	66	38	60
41	69	40	65	41	66	38	60
42	72	40	65	41	67	38	60
41	71	42	67	41	67	38	60
41	71	42	67	41	67	38	60
41	71	42	67	41	67	38	60
41	71	41	66	41	67	38	60
40	70	41	66	41	67	38	60
40	69	40	65	41	67	38	60
40	68	40	65	41	66	38	60
40	68	40	64	41	66	38	60
40	68	40	64	40	66	38	60
42	70	39	64	41	67	38	60
43	71	39	64	41	67	38	60
43	71	39	64	41	68	38	60
43	71	40	67	41	68	38	60
43	71	40	66	41	68	38	60
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Appendix B

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	4	11	18	47	40	50
	5	12	14	42	34	44
	6	13	18	46	40	48
	7	14	21	52	46	56
	8	16	22	46	41	50
	9	17	22	50	41	54
	10	18	21	53	39	59
	11	9	18	48	47	78
	12	10	18	42	47	70
	13	11	14	62	46	67
	14	12	18	56	44	60
	15	13	27	56	45	61
	16	14	27	55	51	60
	17	15	27	62	51	67
	18	16	26	64	48	69
	19	17	25	68	53	81
	20	18	25	69	53	85
	21	19	26	71	43	79
	22	12	13	48	51	91
	23	13	13	49	51	71
	24	14	14	52	45	66
	25	15	14	51	56	67
	26	16	21	61	63	79
	27	17	28	74	87	103