

การประมาณค่าฝุ่น PM₁₀ จากฝุ่นละอองทั่วไป กรณีศึกษา: โรงงานยาสูบ กระทรวงการคลัง Estimation of PM₁₀ Levels from TSP: Case Study in Thailand Tobacco Monopoly

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บทคัดย่อ

งานวิจัยครั้งนี้มีวัตถุประสงค์เพื่อศึกษาปริมาณฝุ่นละอองที่มีขนาดไม่เกิน 10 ไมครอน (PM₁₀) และฝุ่นละอองแขวนลอยรวม (TSP) รวมถึงหาความสัมพันธ์ระหว่างฝุ่น TSP และฝุ่น PM₁₀ เพื่อใช้คาดการณ์ค่าความเข้มข้นของฝุ่น PM₁₀ จากฝุ่น TSP ในบรรยากาศการทำงานในพื้นที่การผลิต บริเวณกองการใบยา ของโรงงานผลิตยาสูบ 5 โรงงานยาสูบ กระทรวงการคลัง โดยเลือกเก็บตัวอย่างอากาศ 5 จุด ๆ ละ 12 ตัวอย่าง รวมจำนวนตัวอย่างของฝุ่น TSP เท่ากับ 60 ตัวอย่าง และฝุ่น PM₁₀ เท่ากับ 60 ตัวอย่าง ซึ่งมีระยะเวลาในการเก็บตัวอย่าง ตั้งแต่เดือนมกราคม – กุมภาพันธ์ 2551 ประยุกต์ใช้วิธีการเก็บตัวอย่างฝุ่นตามแนวทางชี้แนะของ NIOSH ผลการศึกษาพบว่า ปริมาณความเข้มข้นของฝุ่น TSP ทุกจุดตรวจวัดมีค่าแตกต่างกัน และมีรูปแบบการกระจายที่ไม่แน่นอน มีค่าอยู่ระหว่าง 0.4873 - 13.6512 mg/m³ ค่าเฉลี่ยเท่ากับ 4.238 mg/m³ ส่วนปริมาณความเข้มข้นของฝุ่น PM₁₀ มีค่าใกล้เคียงกันในแต่ละจุดตรวจวัด มีค่าอยู่ระหว่าง 0.0318 - 2.6901 mg/m³ ค่าเฉลี่ยเท่ากับ 0.374 mg/m³ การมีปริมาณฝุ่น TSP และฝุ่น PM₁₀ เพิ่มขึ้นหรือลดลงพบว่าไม่ขึ้นกับจำนวนชุดของใบยาที่เข้าสู่กระบวนการผลิตแต่ละวัน ปริมาณฝุ่น TSP มีแนวโน้มเพิ่มขึ้นในช่วงปลายสัปดาห์ ส่วนปริมาณฝุ่น PM₁₀ ไม่มีแนวโน้มเพิ่มขึ้นตามวันทำงาน และพบว่าวันที่วัดอุณหภูมิต่ำเป็นวันที่มีปริมาณฝุ่น TSP และฝุ่น PM₁₀ สูงกว่าวันอื่น ปริมาณความเข้มข้นของฝุ่น TSP และฝุ่น PM₁₀ มีความสัมพันธ์กันอย่างมีนัยสำคัญ (p<0.05) แต่ค่อนข้างต่ำมากจากค่า r² ที่จุดเก็บตัวอย่าง T₁ - T₅ เท่ากับ 0.3610, 0.0029, 0.1524, 0.2452 และ 0.6261 ตามลำดับ ความสัมพันธ์ของฝุ่น TSP และฝุ่น PM₁₀ รวมทุกจุดตรวจวัดมีค่า r² = 0.2119 ซึ่งต่ำมากเช่นกัน แสดงให้เห็นว่า ปริมาณความเข้มข้นของฝุ่น PM₁₀ ไม่สามารถประมาณได้จากฝุ่น TSP ในทุกจุดตรวจวัด เนื่องจากมีปัจจัยอื่นที่มีผลต่อการเปลี่ยนแปลงปริมาณความเข้มข้นของฝุ่นเข้ามาเกี่ยวข้อง ดังนั้นเพื่อเป็นการเฝ้าระวังสุขภาพอนามัยของพนักงานที่ปฏิบัติงาน โรงงานยาสูบควรมีการตรวจวัดปริมาณฝุ่น PM₁₀ เพิ่มเติมจากการตรวจวัดฝุ่น TSP

คำสำคัญ : ฝุ่นละอองที่มีขนาดไม่เกิน 10 ไมครอน ฝุ่นละอองแขวนลอยรวม คุณภาพอากาศในอาคาร โรงงานยาสูบ กระทรวงการคลัง

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ABSTRACT

The purposes of this study are to investigate the levels of particulate matter which size is no larger than 10 micron (PM_{10}) and total suspended particles (TSP) in the workplace and to study the relationship between mass concentrations of TSP and PM_{10} , so as to estimate PM_{10} from TSP in the workplace of Blending and Cutting Sub-Division Factory No.5 of the Thailand Tobacco Monopoly. Data samples were collected at 5 sampling sites ($T_1 - T_5$), 12 samples per site. Hence, there were 60 samples of TSP and 60 samples of PM_{10} . All data samples were collected between January and February, 2008. The sampling procedure was applied by National Institute for Occupational Safety and Health (NIOSH) recommendation. The results revealed that levels of TSP at the sampling sites were varied and displayed no pattern while PM_{10} concentrations showed similarity at all sites. TSP concentrations were 0.4873 - 13.6512 mg/m^3 and the average was 4.238 mg/m^3 . Concentrations of PM_{10} were 0.0318 - 2.6901 mg/m^3 and the average was 0.374 mg/m^3 . Variations of TSP and PM_{10} concentrations did not depend on the amount of batches of tobacco leaves. The level of TSP showed accumulation continuously through to the end of the week. But PM_{10} did not show the same trend. It appeared that TSP and PM_{10} levels were highest on the day that raw materials were very parched. The ANOVA p - values showed significant relationship ($p < 0.05$) between TSP and PM_{10} at all sites. However, the relationships based on linear and non - linear regression equations were poor from Coefficient of Determinant (r^2) at $T_1 - T_5$ sites were 0.3610, 0.0029, 0.1524, 0.2452 and 0.6261 respectively and r^2 from all sites was 0.2119, which was weak together. Thus, PM_{10} at factory No.5 could not be estimated from TSP by using linear relationship, because there might be some other factors influencing a variation of particles. Therefore, regarding to employees' health, the measurement of PM_{10} should be included to TSP measurement.

Keywords : PM_{10} , TSP, Total dust, Indoor Air Quality, Thailand Tobacco Monopoly

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INTRODUCTION

There are many industries in Thailand, which rapidly expand and distribute in every regions of Thailand and that are main sources of air pollution. For air pollution problems from industrial process; especially, process which low efficiency for air pollution treatment, PM_{10} is one of most important air pollutant (นพภาพร, 2547). PM_{10} is respirable dust, size is no larger than 10 micron. Moreover, most of dust from combustion and industrial process are no larger than 10 micron which is important problem of health and environment (US EPA, 2006). This research aimed to study the processes of production in the Factory No.5 of Thailand Tobacco Monopoly (TTM), Ministry of Finance, which measured TSP concentration but did not measure PM_{10} concentration and found that some years (since 2003 - 2007) TSP had exceeded the standard in some processes. Moreover, the trend of TSP concentration in some

processes might exceed the standard. However, the measurement of TSP only may not represent for PM_{10} concentration because the measurement of TSP covers the extent of PM_{10} . Therefore, it is necessary to measure PM_{10} due to its adverse effect on human health especially workers, who work in places that the level of PM_{10} always violates the standard.

METHODS

1. The study area

The research was conducted in the area of the Production Department, Factory No.5 (Blending and Cutting Sub - Division) of TTM. The Factory No.5 was selected due to have the highest concentration of particulate matter, found in the workplace among three factories (No. 3, 4, and 5).

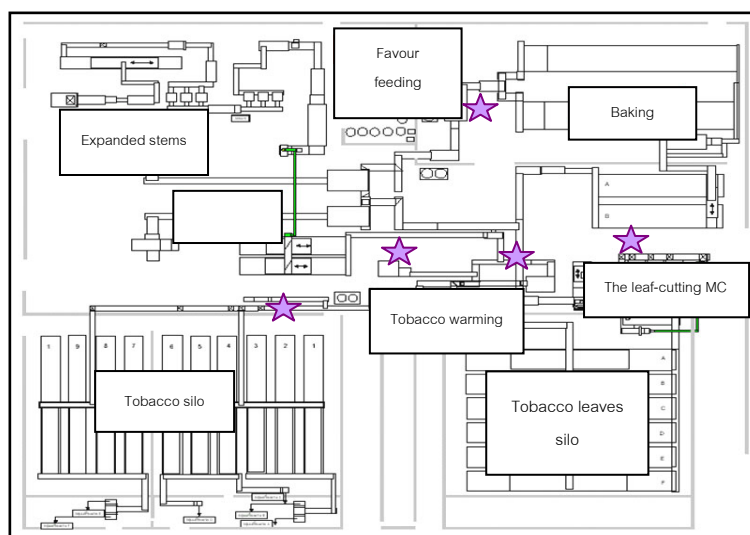


Figure 1: Sampling sites

T₁: The tip of cigarette-slitting machine

T₂: The vibratory conveyor before entering the drying cylinder

T₃: The leaf - cutting machine

T₄: The conveyor before entering proctor

T₅: The expanded tobacco - feeding machine

2. Equipment and tool

For TSP: Particulate matter was collected on Glass fiber filter (1.2 micron pore size) and put in a 37 -mm cassette and attached to a high - flow personal sampling pump, which set flow rate as 1.7 liter/minute (NIOSH 0500, 2003) (See in Figure 2).

For PM_{10} : Use the indoor particle sampling equipment with option to Glass fiber filter (1.2 micron pore size) and selected the small size of particle by cyclone and attached to a high - flow personal sampling pump, which set flow rate as 1.7 liter/minute (NIOSH 0600, 2003) (See in Figure 3).

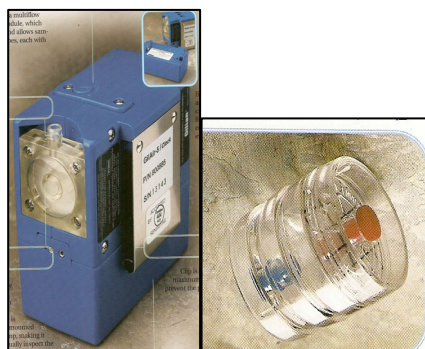


Figure 2 Personal sampling pump with filter

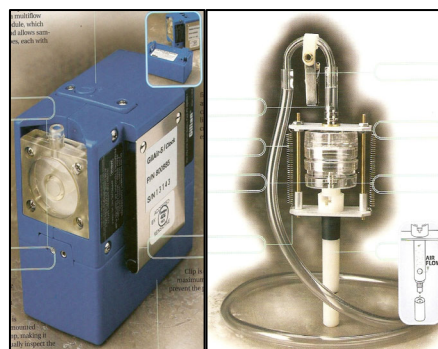


Figure 3 Personal sampling pump with cyclone

3. Sampling period

The samples were collected sample once a week from start feeding the leaves till stop in each day (time period of leaves feeding varies). However, sampling period might be changed. NIOSH recommended that sampling period should not less than 70% of working time (วันทนีย์, 2547). Collected sample by rotating the day from Monday to Friday in each sampling week. Collected samples are TSP 60 samples and PM₁₀ 60 samples. The total sample was 120 samples.

Table 1 Period of sampling

Month	Day	Monday	Tuesday	Wednesday	Thursday	Friday
January, 2008			1	2	3	4
		7	8	9	10	11
		14	15	16	17	18
		21	22	23	24	25
		28	29	30	31	
February, 2008						1
		4	5	6	7	8
		11	12	13	14	15
		18	19	20	21	22
		25	26	27	28	29



Sampling day

4. Data analysis

4.1 Calculation of mass concentration

- Volume of air sample (l) = Flow rate (l/min) x Time (min)
- Volume of air sample (m³) =
$$\frac{\text{Flow rate (l/min)} \times \text{Time (min)}}{1,000}$$
- Mass concentration (mg/m³) =
$$\frac{\text{Dust weight (g)} \times 1,000}{\text{Volume of air sample (m}^3\text{)}}$$

4.2 Analyzing for TSP and PM₁₀ relationship

One – way ANOVA (single factor) was used for analyze the variation of TSP and PM₁₀ concentration with the F- test at 95% confidence interval on p – value. Analyze the relationship using statistical method base on the linear regression formula as shown below:

$$y = ax + b$$

When y = concentration of PM₁₀ (mg/m³)

x = concentration of TSP (mg/m³)

a = slope of the linear graph

b = intercept

After that, analyze the relationship by statistical method to predict occurring TSP and PM₁₀ quantity by using non – linear regression formula.

RESULTS AND DISCUSSIONS

1. Comparisons between concentrations of TSP and PM₁₀Table 2 Comparisons between concentration of TSP and PM₁₀

Site	T ₁		T ₂		T ₃		T ₄		T ₅	
Date	TSP (mg/m ³)	PM ₁₀ (mg/m ³)	TSP (mg/m ³)	PM ₁₀ (mg/m ³)	TSP (mg/m ³)	PM ₁₀ (mg/m ³)	TSP (mg/m ³)	PM ₁₀ (mg/m ³)	TSP (mg/m ³)	PM ₁₀ (mg/m ³)
3 Jan 08	10.44726	0.26691	1.01953	0.16310	1.97466	1.83318	3.61526	0.32545	3.61526	0.28061
9 Jan 08	12.82499	0.53660	1.17165	0.64983	7.98173	0.48773	1.08152	0.22826	2.12585	0.21046
14 Jan 08	1.85815	0.20064	1.19913	0.11362	1.19913	0.11362	0.82139	0.11662	2.04886	0.35357
22 Jan 08	4.53294	0.26998	2.52414	0.89134	2.52414	0.58203	1.32072	0.23144	2.49055	0.27685
25 Jan 08	5.49509	0.32029	7.08509	0.25302	10.95072	0.69084	0.99060	0.11756	9.03639	0.43259
30 Jan 08	4.22179	0.37349	1.78540	0.24755	2.70691	0.54798	8.12648	0.29888	2.04533	0.17215
7 Feb 08	5.79857	0.30498	0.94804	0.04717	10.96491	0.43626	0.85149	0.03183	1.34559	0.09771
11 Feb 08	4.70728	0.24002	0.69540	0.25705	5.27123	0.65341	0.59847	0.34460	1.63221	0.25312
15 Feb 08	10.07862	0.26793	1.61662	0.40804	13.48436	0.72559	1.18805	0.11988	5.40293	0.33428
20 Feb 08	9.88485	0.25109	1.61704	0.14878	13.65115	2.69031	1.51145	0.15447	5.29754	0.32907
22 Feb 08	10.74483	0.28272	2.19555	0.25251	12.70758	1.19954	1.40781	0.21175	2.74160	0.23305
26 Feb 08	1.31932	0.04898	2.88166	0.12205	3.21933	0.14802	0.48727	0.04699	1.21259	0.18920

The levels of TSP were between 0.4873 - 13.6512 mg/m³ and average were 4.238 mg/m³. The highest level was observed at T₃ and the lowest level was observed at T₄. The levels of PM₁₀ were between 0.0318 - 2.6903 mg/m³ and average was 0.374 mg/m³, the area of the highest level was T₃ and

the area of the lowest level was T_4 . The highest level of PM_{10} was measured on February 20, 2008 that the same day and the same place as of TSP, which tobacco leaves were very parched.

1.1 Comparison of TSP and PM_{10} against standards

The levels of TSP did not exceed standard regulated under the Thai standard (Declaration of Ministry of Interior on safety in the workplace regarding environment (chemical), 1977) and U.S. Department of Labor Occupational Safety & Health Administration (OSHA) for threshold limit values (TLVs) as 15 mg/m^3 (OSHA, 2003). However, when compared against American of Governmental Industrial Hygienists (ACGIH), TSP levels observed in some places violated the ACGIH standard of 10 mg/m^3 (ACGIH, 2002). Therefore, TSP concentrations in the workplace might cause adverse impact on worker health. The levels of PM_{10} at all sites did not exceed standard of Thai and OSHA, which regulated standard of respirable dust as 5 mg/m^3 . Moreover all samples did not violate the standard of 3 mg/m^3 which was regulated by ACGIH.

1.2 Comparison between concentrations and amount of batches of tobacco leaves (1 batch = 10,000 kg.)

The relationship between amount of batch of tobacco leaves and TSP, PM_{10} concentrations were very poor. However, PM_{10} concentrations at T_4 site had a trend to increase when amount of batch increase more than the others site which linear regression equations as;

Table 3 Linear regression equations between amount of batch and TSP, PM_{10} concentrations

Sampling site	Linear regression equation of TSP	r^2	Linear regression equation of PM_{10}	r^2
T_1	$y = 1.0842x + 0.8629$	$r^2 = 0.1851$	$y = 0.0352x + 0.0842$	$r^2 = 0.2206$
T_2	$y = -0.842x + 6.6927$	$r^2 = 0.5481$	$y = -0.0045x + 0.3210$	$r^2 = 0.0008$
T_3	$y = -0.3991x + 9.4149$	$r^2 = 0.0150$	$y = 0.1304x + 0.1252$	$r^2 = 0.0702$
T_4	$y = 0.6035x - 1.4859$	$r^2 = 0.1809$	$y = 0.0444x - 0.0588$	$r^2 = 0.4121$
T_5	$y = -0.436x + 5.6474$	$r^2 = 0.0822$	$y = 0.1748x + 0.0664$	$r^2 = 0.1145$

In conclusion, most of TSP and PM_{10} concentrations in the workplace did not depend on amount of batch, which input the process. It might be the result from the different humidity of tobacco leaves and the difference of process production and average of each batch were divided by brands of cigarettes, types of tobacco leaves and grades of tobacco leaves. Grades of tobacco leaves can be split by tobacco root, tobacco mature and tobacco immature. The difference of raw materials did not repeat in each day. Moreover, in each day had difference of humidity in atmosphere including process production are open, therefore, they reflected to TSP and PM_{10} concentrations and tobacco leaves input in each day had no the relationship.

1.3 Comparison between concentrations and working day

The comparison between TSP concentrations and working day rotating from Monday to Friday in each sampling week was done. It was found that TSP concentrations at all sites gave a trend to increase on Wednesday, Thursday and Friday revealing that TSP concentrations accumulated continuously to the end of the week. However, PM₁₀ concentrations did not relate with working day. Result from other factors affected to PM₁₀ concentrations.

2. Relationships between concentrations of TSP and PM₁₀

The results of the statistical analyses for relationship between TSP and PM₁₀ concentrations (ANOVA p – value) at T₁ – T₅ showed significant relationship (p<0.05) were shown as;

Table 4 The statistical analyses (ANOVA p – value) at T₁ - T₅

Sampling site	T ₁	T ₂	T ₃	T ₄	T ₅
P-value (sig.)	5.3E-06	0.00188	0.00017	0.0002	0.01415

However, the relationship based on linear regression equations and non - linear regression equations were poor with Coefficient of Determinant (r²) as seen in table 4.

Table 5 The linear and non - linear regression equations with r²

Sampling site	Linear regression equation	(r ²)	Non - linear regression equation	(r ²)
T ₁	y = 0.0178x + 0.1588	r ² = 0.361	y = 0.092x ^{0.5817}	r ² = 0.5319
T ₂	y = 0.0078x + 0.2802	r ² = 0.0029	y = -0.0227x ² + 0.186x + 0.0702	r ² = 0.0852
T ₃	y = 0.059x + 0.4165	r ² = 0.1524	y = 0.0233x ² + 0.2906x + 1.2123	r ² = 0.3172
T ₄	y = 0.0242x + 0.1414	r ² = 0.2452	y = -0.008x ² + 0.0925x + 0.0763	r ² = 0.3321
T ₅	y = 0.0315x + 0.1612	r ² = 0.6261	y = 0.1213Ln(x) + 0.143	r ² = 0.6539

When all data measured were integrated, ANOVA p - value showed significant relationship between TSP and PM₁₀ (p<0.05), but they were weak as seen in Figure 4 (r² = 0.2119) and Figure 5 (r² = 0.349).

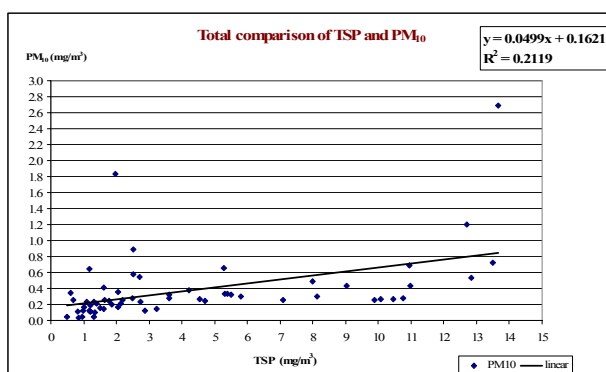


Figure 4 Linear regression at all sites

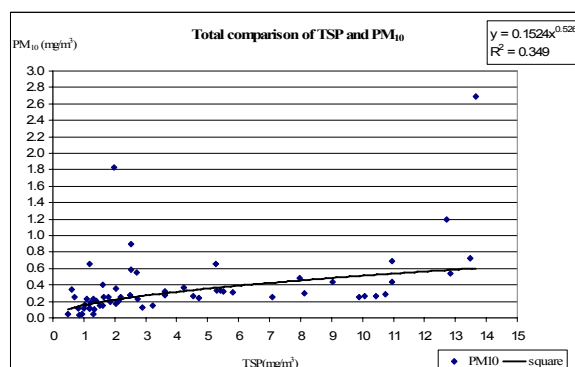


Figure 5 Non – linear regression at all sites

CONCLUSIONS

1. Comparisons between concentrations of TSP and PM₁₀

1) The levels of TSP at all sampling sites were varied and displayed no pattern, while the levels of PM₁₀ were similar.

2) The results of TSP concentrations in the workplace were not exceed of Thai and OSHA standards regulate for TLVs, when TSP was compared with ACGIH, TSP levels observed in the some places violated the ACGIH standard. Therefore, TSP concentrations in the workplace of Blending and Cutting Sub - Division of Factory No.5 of TTM might cause adverse impact on workers' health, while PM₁₀ concentrations were not exceed of Thai and OSHA standard levels, which regulated as 5 mg/m³ and standard of ACGIH as 3 mg/m³.

3) The relationship between amount of batch of tobacco leaves input into process with TSP and PM₁₀ concentrations were very poor except PM₁₀ concentrations at T₄ sampling site.

4) TSP levels at all sites gave a trend to increase on Wednesday, Thursday and Friday revealing that the levels of TSP accumulated continuously to the end of the week but the levels of PM₁₀ did not show a trend of accumulation.

2. Relationships between concentrations of TSP and PM₁₀

1) The linear relationships between TSP and PM₁₀ at T₁ - T₅ sites were very poor, therefore, the measurement of TSP concentrations in Factory No.5 could not be used for prediction of PM₁₀ concentrations in the factory because low value of r² indicates that there were some unknown factors affecting the linear relationships between TSP and PM₁₀ in Factory No.5 of TTM.

2) The relationship of TSP and PM₁₀ from all samples reveals that higher TSP gave a trend of higher PM₁₀. The linear relationships were as $y = 0.0490x + 0.1621$ and its regression (r²) was 0.2119.

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