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Research Article

DETERMINING CURRENT SITUATION OF FINE PARTICULATE MATTER IN CHACHOENGSAO PROVINCE

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ABSTRACT

This research principally pays attention on determining the current situation of fine particulate matter known as PM2.5 in Chachoengsao Province, situated in the east of Thailand, to check if the process change is encountering set the daily Thailand's national air quality standard. The aim will be succeeded by investigating the important characteristics of PM2.5 concentrations for a year (from November, 2020 to October, 2021) with descriptive statistic and cluster analysis. The process means of PM2.5 concentrations for 5 months (from November, 2021 to March, 2022) are later examined with the exponentially weighted moving average chart called EWMA chart. The results of cluster analysis expose that PM2.5 concentrations are affected by not only a season but also a time period during a day. The concentration of PM2.5 is highest in Winter particularly a day time but lowest in Rainy season specifically a night time. The EWMA chart taken by only one air quality monitoring station; Tungsadao Subdistrict Municipality, Wang YenSubdistrict, Plaeng Yao District, in Chachoengsao Province is acutely able to monitor changing in the level of daily maximum of PM2.5 concentrations. It can also point out the process means of PM2.5 concentrations are out of control state as indicating of a false alarm in December, January and February. Besides, the EWMA chart can plainly express some more days (53 days) as the warning days to pay attention because all values of those days outweigh Thailand's standard as such 18 days in January, 19 days in February and 16 days in March.

Keywords: Fine Particulate Matter; Process Mean; Chachoengsao Province.

INTRODUCTION

Chachoengsao is a small province with an area of 5,370.28 km^2 situated in eastern coast of Thailand. Its climate is influenced by the northeast and southwest monsoon which leads to distinct 3 seasons; Winter (mid-October to mid-February), Summer (mid-February to mid-May) and the Rainy season (mid-May to mid-October) (Chachoengsao Provincial Health Office, 2019). Chachoengsao Province is later set to be a part of the Eastern Economic Corridor or EEC same as Chonburi and Rayong Provinces so it is composed of both traditional and new industries such as automobile manufacturing, agricultural machinery and electrical appliances commerce. Owing to not only rapid expansion but also various developments, Chachoengsao Province has to face a problem of air pollution particularly the fine particulate matter called $PM_{2.5}$. $PM_{2.5}$mainly derived from the combustion of fuel in car engines, forest burning and fossil fuel industrial plants like coal, petrol and natural gas, etc. (Koplitz *et al.,* 2017; Narita *et al.,* 2019). Moreover, $PM_{2.5}$ is one of 6 crucial air pollutants; like PM_{10}, O_3, CO, NO_2 and SO_2, considered for the Air Quality Index or AQI, a daily reporting number how polluted our air is. The World Health Organization (WHO) reported $PM_{2.5}$ as a carcinogen specifically lung cancer (World Health Organization, 2013). The WHO also defined air quality standard of $PM_{2.5}$ for 24-hour mean valued 25 $\mu g/m^3$ which is much stricter than Thailand's standard, 50 $\mu g/m^3$. The knowledge and information of $PM_{2.5}$ for Chachoengsao Province is quite insufficient because the Pollution Control Department (PCD), Ministry of Natural Resource and Environment had just collected $PM_{2.5}$ concentrations for Chachoengsao monitoring station in 2019 as well other small provinces across Thailand were just fully supplied in a few years ago. Presently, the $PM_{2.5}$ concentrations for Chachoengsao Province were reported higher than both WHO and Thailand's standard in many days of Winter such as 83 $\mu g/m^3$ (AQI=182) in January 22, 2021. (Department of Disaster Prevention and Mitigation, Ministry of Interior Thailand, 2021). It is also more likely to increase in following years which in the long term can impact human health. Nowadays, the pollution problem of $PM_{2.5}$ is complementarily identified as a national agenda. Many researches are frequently applied various control charts as the powerful statistical tools for solving a problem of 6 main air pollutants for example; William *et al*., 1978 (NO_2 and SO_2); Environmental Research Group, King's College London, 2005 ($PM_{2.5}$, PM_{10} and NO_2); Norshahida *et al*., 2014 (PM_{10}); Philippe *et al.,* 2014 (CO_2); Muhammad, 2015 (O_3) and Nasser *et al*., 2018 ($PM_{2.5}$), etc.

The exponentially weighted moving average chart known as EWMA chart is highly efficient and widely used control chart for detecting changes of process mean specifically small and medium mean shifts since EWMA concept is simultaneously focused a current observation and a data set of previous observations. The only one monitoring site of Chachoengsao Province, Tungsadao Subdistrict Municipality, Wang Yen Subdistrict, Plaeng Yao District, therefore supplied the $PM_{2.5}$ concentrations for investigating varying sizes of sustained shifts. Generally, the EWMA chart is conducted over two Phases. Phase I is presented for estimating 2 in-control process parameters; mean and standard deviation, based on a historical data set. Phase II is then exhibited for monitoring the future observations to check the on-going stability of the process mean by comparing with the lower and upper control limits (LCL./UCL.).

MATERIALS AND METHODS

Tungsadao Subdistrict Municipality, Wang YenSubdistrict, Plaeng Yao District (60T) is the only one representative of air quality

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monitoring stations in Chachoengsao Province to determine the current situation of fine particulate matter considered in term of $PM_{2.5}$ concentrations $(\mu g/m^3)$ from November, 2020 to March, 2022 as furnished by the Air Quality and Noise Management Bureau, Pollution Control Department (2020). The details of procedure steps were as follows.

1. To display the important characteristics of $PM_{2.5}$ situations, daily maximum of $PM_{2.5}$ concentrations for a year (from November, 2020 to October, 2021) were considered with descriptive statistics and cluster analysis.
2. To investigate the current $PM_{2.5}$ change, daily maximum of $PM_{2.5}$ concentrations for 5 months (from November, 2021 to March, 2022) were monitored with the EWMA chart which the statistic at each time i, z_i, is computed as Equation 1.

$$z_i = \lambda x_i + (1-\lambda) z_{i-1} \quad (1)$$

where λ be smoothing parameter $(0 < \lambda \leq 1)$, x_i be daily maximum of $PM_{2.5}$ concentration $(\mu g/m^3)$ at time i following normal distribution and z_0 be starting value commonly set to the in-control process mean. At each time i, both control limits of EWMA chart are also respectively calculated.

The upper control limit is defined as Equation 2.

$$UCL_i = \mu_0 + L\sigma\sqrt{\left(\frac{\lambda}{2-\lambda}\right)\left[1-(1-\lambda)^{2i}\right]} \quad (2)$$

The lower control limit is also defined as Equation 3.

$$LCL_i = \mu_0 - L\sigma\sqrt{\left(\frac{\lambda}{2-\lambda}\right)\left[1-(1-\lambda)^{2i}\right]} \quad (3)$$

where μ_0, σ be successively mean and standard deviation of in-control process and L be constant value stand for the width parameter of EWMA control limit.

After wards the z_i statistic is plotted against time i into the EWMA chart concluding both control limits mentioned previously. Ifany z_i statistic lies above the upper control limit (UCL_i) or below the lower control limit (LCL_i), the process mean is informed as the out-of-control status. Moreover, we only focused on the positive deviations which far away the upper control limit because we particularly need to direct the daily maximum $PM_{2.5}$ concentrations not to exceed the Thailand's national air quality standard.

RESULTS AND DISCUSSION

The results of finding are following demonstrated.

1. Descriptive statistics for daily maximum of $PM_{2.5}$ concentrations for a year is shown in Table 1. The mean of daily maximum of $PM_{2.5}$ concentrations are higher than both of the Thai and WHO limits in January and February but lower than the Thai limit in July, August and September as well only 5 days in August and 7 days in September below the WHO limit. The daily maximum of $PM_{2.5}$ for overall ranges in concentrations from 7 to 216 $\mu g/m^3$ with the mean and standard deviation as 37.82 and 26.9 $\mu g/m^3$, respectively.

Table 1: Descriptive statistics for daily maximum of $PM_{2.5}$ concentrations

Month	Maximum	Mean	Minimum	SD.
Nov	68	30.10	14	11.56
Dec	88	39.68	7	19.84
Jan	216	72.32	21	49.44
Feb	133	79.25	40	24.41
Mar	79	47.10	28	13.04
Apr	54	33.37	16	8.42
May	63	31.26	11	14.03
Jun	35	25.77	18	4.64
Jul	38	21.77	10	6.23
Aug	34	22.77	13	5.23
Sep	44	22.83	11	8.17
Oct	106	30.35	13	18.11
Overall	216	37.82	7	26.90

The scatter plot of daily maximum of $PM_{2.5}$ concentrations is also drawn in Figure 1. It presents many days in December, January and February are higher than both of the Thai and WHO limits. That is accordingly with the raw data. There are severally 10, 18 and 25 days above the Thai limit while almost a month in December (22 days), January (29 days) and February (28 days) beyond the WHO limit. Contrarily, the daily maximum of $PM_{2.5}$ concentrations are not over the Thai limit in June, July, August and September also there are less than 10 days over the WHO limit in July, August and September.

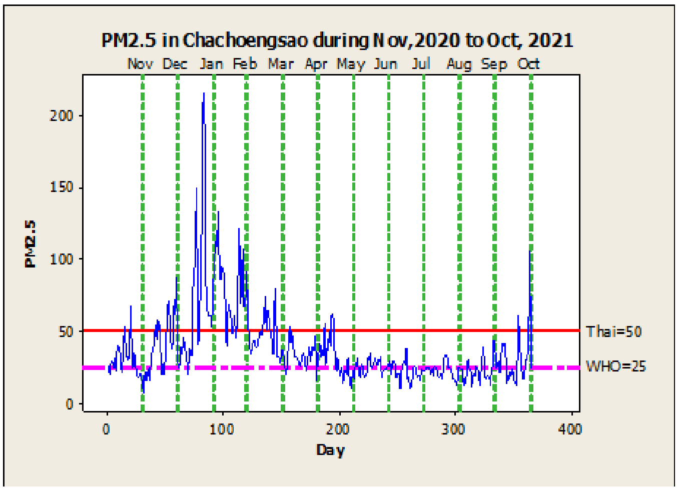

Figure 1: Scatter plot of daily maximum of $PM_{2.5}$ concentrations for a year

As previous results of Table 1 and Figure 1, cluster analysis is therefore applied to examine a seasonal effect of $PM_{2.5}$ concentrations. The cluster analysis for combining months was pictured as the dendogram in Figure 2.

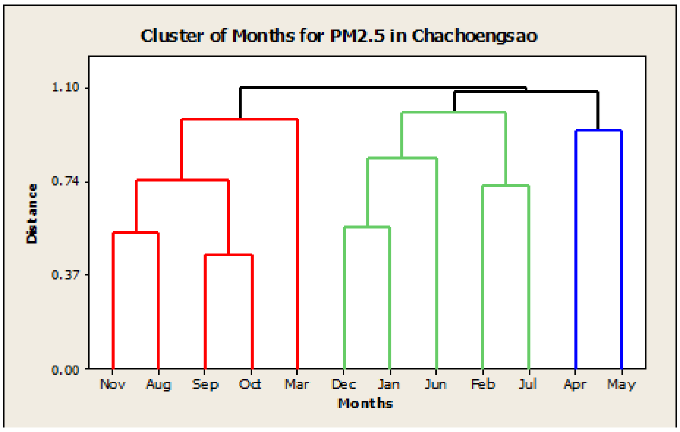

Figure 2: Dendogram of clustering the months

It clearly reveals there are three clusters relating to a season. Cluster 1concludes5 months; March, August, September, October and November, which their values are mainly in Rainy season (August, September and October) then drift to the beginning of Winter in November. It denotes the low of $PM_{2.5}$ concentrations. Cluster 2 contains 5 months; June, July, December, January and February, which their values are in Rainy season (June and July) then drift to winter (December, January and February). It stands for the high of $PM_{2.5}$ concentrations. Cluster 3 includes only 2 months; April and May, which are in Summer. It presents for the medium of $PM_{2.5}$ concentrations. Then, only the days having $PM_{2.5}$ concentrations exceeding the Thai limit are extracted to explain more whether there is a time period during a day impact on $PM_{2.5}$ concentrations by considering dendogram in Figure 3.

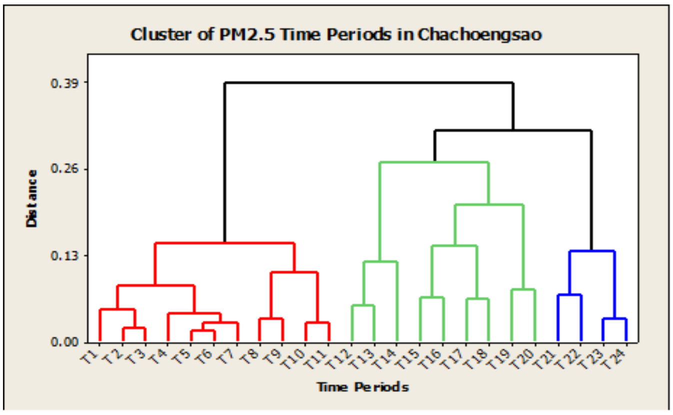

Figure 3: Dendogram of clustering the time periods

It exposes that there are three distinct groups in accordance with time period during a day. Cluster 1 is the day time ranged from the beginning of a day (12 am.)until11 am. (T1-T11). It denotes for the high of $PM_{2.5}$ concentrations. Cluster 2 presents from at 11 am. to 8 pm. (T12-T20). It stands the low of $PM_{2.5}$ concentrations. Cluster 3 is the night time ranged from 8 pm. to midnight (T21-T24). It presents for the medium of $PM_{2.5}$ concentrations.

2. There are insufficient information of $PM_{2.5}$ concentrations in Chachoengsao Province because they were just collected in the past few years. The two parameters of in-control process; mean (μ_0) and standard deviation (σ) of PM2.5 concentrations, are then estimated from November, 2020 to October, 2021 while the z_i statistics were calculated base on data from November, 2021 to March, 2022. For the two parameters of EWMA chart; λ and L ,are evaluated from simulation study in accordance with the in-control average run length (ARL_0).Borror *et al.,* (1999) recommended to consecutively use λ and L with 0.05 and 2.2492 for a small process shift. Once the z_i statistics against time i are plotted, the EWMA chart concluding both upper and lower control limit sat each time i is displayed in Figure 4.

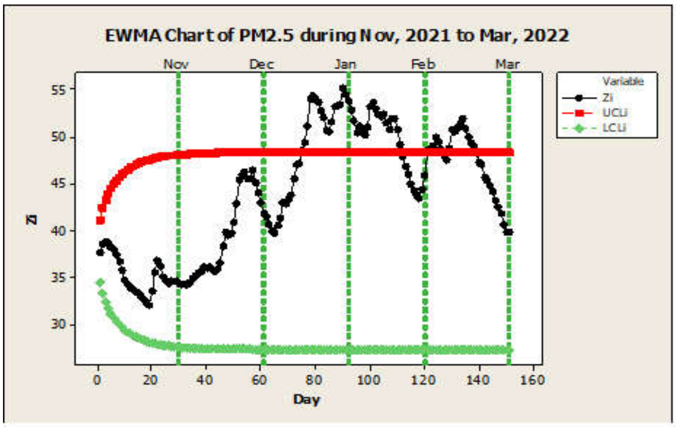

Figure 4: EWMA chart of daily maximum of $PM_{2.5}$ concentrations

There are 53 out of 151 points of z_t statistics contained in 3 months of January (18 points), February (19 points) and March (14 points) above the UCL. Therefore, the process mean can be notified as out-of-control state.

CONCLUSION AND DISCUSSION

The current situation of $PM_{2.5}$in Chachoengsao Province is successively concluded and discussed.

1. The daily maximum of $PM_{2.5}$ concentrations is high in December, January and February then gradually drift to medium in April and May and finally shift to low in August, September and October. Cluster analysis of months is also a confirmation of seasonal impact which $PM_{2.5}$ concentrations are high in Winter (December, January and February), medium in Summer (April and May) and low in Rainy season (August, September and October). Furthermore, cluster analysis of time periods during a day is even more presented $PM_{2.5}$ concentrations are high in day time (12 am. To 11 am.), medium in night time (8 pm. to midnight) and low from11 am. to 8 pm.
2. The scatter plot of daily maximum of $PM_{2.5}$ concentrations for 5 months is sketched in Figure 5. It displays there are totally 47 days exceeding the Thai limit;4 days (November), 9 days (December), 17 days (January), 9 days (February), and 8 days (March).

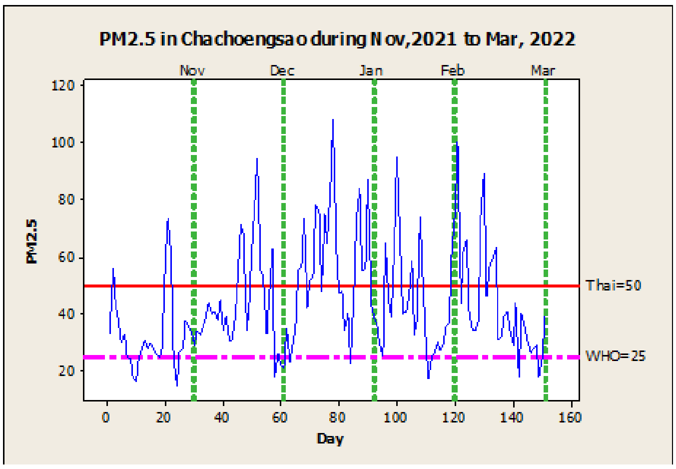

Figure 5: Scatter plot of daily maximum of $PM_{2.5}$ concentrations for 5 months

Therefore, the derived EWMA chart clearly performs as a potential method for detecting small actively changes of $PM_{2.5}$ current situation because it can superiorly indicate some more days (53 days) as the warning days to warn if all those days are met the Thai daily standard as seeing of 18 days in January, 19 days in February and 16 days in March.

3. The authorizer may employ these useful results as a supplementary for managing, planning and maintaining a level of $PM_{2.5}$ concentrations beneath daily Thailand's national air quality standard by controlling the number of days above the Thai limit not higher than the previous year even though reducing the number of days above the Thai limit for the consecutively following years.

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