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INVESTIGATION OF RECENT $PM_{2.5}$ CHANGES IN CHONBURI PROVINCE USING EWMA CHARTS

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ABSTRACT

This work focuses on investigating the recent nature and changes of $PM_{2.5}$ concentrations in Chonburi Province to see whether the process shift is meeting set the daily Thailand's national air quality standard. The objective will be achieved by identifying the basic characteristics and then monitoring the process mean of $PM_{2.5}$ concentrations in 2020 with EWMA charts. The obtained results reveal the EWMA charts taken by 3 air quality monitoring stations across Chonburi Province have potential to rapidly to detect changing in the level of daily maximum $PM_{2.5}$ concentrations. The EWMA analysis suddenly illustrates a significant signal of daily maximum $PM_{2.5}$ concentration was sharply increasing most notably 4 months of 2020; January, February, March and December for each of monitoring stations.

KEY WORDS: $PM_{2.5}$, Process Mean Shift, EWMA Charts

INTRODUCTION

Chonburi is one of the eastern provinces located on the Gulf of Thailand coast. The region has a tropical climate which is influenced by the southeast monsoon during August to October and the northeast monsoon during November to February. It is thus clearly different 3 seasons; Summer (March to May), the Rainy season (August to October) and Winter (November to February) (Tourism and Sports Office, 2021). Moreover, Chonburi Province is part of the 3 eastern provinces; like Rayong and Chachoengsao, of the Eastern Economic Corridor (EEC) development which is an area-based development initiative, aiming to revitalize the well-known Eastern Seaboard where numerous business developers have experienced a rewarding investment journey and exceptional achievements (Eastern Economic Corridor (EEC), 2021). Therefore, Chonburi Province has continued to encounter urgent and rapid development with mega construction, various industries such as; oilrefinery, renewable energy, petrochemical including heavy shipping and transportation. All of these are resulting in an increase in chiefly of pollutants originating in human activity specifically fine particulate matter known as $PM_{2.5}$. The smaller $PM_{2.5}$ is seriously massive concern for human health because it can infiltrate deeply into the lungs, relating to extensive harm. It also runs up to the blood stream extending the risk of cancer and respiratory, cardiovascular and ischemic heart disease (Bener *et al.*, 2009; Li *et al.*, 2010; Hochstetler *et al.*, 2011). The World Health Organization (WHO) recommends the air quality standard of $PM_{2.5}$ set to 25 $\mu g/m^3$ for 24-hour mean while Thailand's standard is twice as high as the WHO's, 50.

The Pollution Control Department (PCD), Ministry of Natural Resource and Environment had recorded $PM_{2.5}$ concentrations for Chonburi monitoring stations in 2015 while other stations through Thailand was just completely monitored and provided in a few years ago. That's why all detailed information or knowledge of $PM_{2.5}$ made publicly available is inadequate. Nevertheless, Chonburi Province was one out of 12 mega cities in Thailand with high annual average concentrations of $PM_{2.5}$ exceeding the WHO standard during 2014 to 2016 (Greenpeace, 2021) also it tended to rising in subsequent years. The Thai government then announced the problem of $PM_{2.5}$ pollution as a national agenda so it might cause to the number of days which $PM_{2.5}$ concentrations above the Thai standard were decreasing in 2017 (The Pollution Control Department (PCD), 2021). The Air Quality Index (AQI) is a value for daily reporting how pure or polluted our air is which is calculated from concentrations of the 6 main air pollutants; $PM_{2.5}$, PM_{10}, O_3, CO, NO_2 and SO_2. The control chart is a particularly useful technique to identify sustained step changes in those concentrations by measurement of noise such meteorological variation obscured from other analysis tools. Some researchers have continually applied different control charts to remove seasonal effects also improve sensitivity and ability to evaluate the timing of changes in concentrations of $PM_{2.5}$ (London Air, 2005; Nasser *et al.*, 2018), PM_{10} (London Air, 2005; Norshahida *et al.*, 2014), O_3 (Muhammad, 2015), NO_2(London Air, 2005; William *et al.*, 1978), SO_2 (William *et al.*, 1978) and CO_2 (Philippe et al., 2014).

The exponentially weighted moving average (EWMA) control chart is advantage on examining all magnitude shifts of process mean; small, medium and large, owing to the EWMA statistics is calculated based on a current observation and a data set of previous observations as well. In this work, the EWMA charts are then intended for identifying the presence and timing of distinct sustained step change in $PM_{2.5}$ concentration levels across the 3 different background sites of Chonburi Province; expanded urban (Thung Sukhla Subdistrict Region, Si Racha District), industrial area (Bo Win Subdistrict Region, Si Racha District) and residential community (Regional Environment Office 13, Ban Suan Subdistrict, Mueang District). Each of following EWMA charts were respectively presented in 2 phases. Based on a given period, the 2 key process parameters; mean and standard deviation of $PM_{2.5}$ concentrations, were estimated in Phase I. The notification of process status was later stated whether out of control by comparing to the reference values; the lower and upper control limits, in Phase II.

MATERIALS AND METHODS

The 3 air quality monitoring stations; Thung Sukhla Subdistrict Region, Si Racha District (32T), Bo Win Subdistrict Region, Si Racha District (33T), Regional Environment Office 13, Ban Suan Subdistrict, Mueang District (34T), were representatives to investigate the nature and timing changes of $PM_{2.5}$ concentrations in Chonburi Provinceas recorded by the Air Quality and Noise Management Bureau, Pollution Control Department. The steps of procedures were as follows.

1. To identify the basic characteristics of $PM_{2.5}$ concentrations, monthly mean $PM_{2.5}$ concentrations during 2017-2019 (The Air Quality and Noise Management Bureau, 2017) were explored with descriptive statistics.

2. To monitor the recent $PM_{2.5}$ change, daily maximum $PM_{2.5}$ concentrations in 2020 (The Air Quality and Noise Management Bureau, 2020) were analyzed with EWMA charts. The EWMA statistic at each time$t$ (z_t) is calculated as Equation 1.

$$z_t = \lambda x_t + (1-\lambda) z_{t-1} \qquad (1)$$

where λ be smoothing constant valued $0 < \lambda \leq 1$, x_t be daily maximum $PM_{2.5}$ concentration ($\mu g/m^3$) at time$t$ following normal distribution and the starting valuez_0 usually set to the in-control process mean. The control limits of EWMA chart, upper/lower control limits, are also computed as Equation 2.

$$UCL./LCL. = \mu_0 \pm L\sigma \sqrt{\left(\frac{\lambda}{2-\lambda}\right)\left[1-(1-\lambda)^{2t}\right]} \qquad (2)$$

where μ_0 and σ be the mean and standard deviation of in-control process and L determines the width of control limits. If $t \to \infty$, then the control limits reduce as a form of Equation 3.

$$UCL./.LCL = \mu_0 \pm L\sigma \sqrt{\frac{\lambda}{2-\lambda}} \qquad (3)$$

The z_t statistic against time$t$ is then plotted into the EWMA chart containing the previously mentioned control limits. If any z_t statistic goes beyond upper control limit(*UCL*) or lies below lower control limit (*LCL*), the process mean is notified as the out-of-control state. For this work, we particularly need to control the daily maximum $PM_{2.5}$ concentrations not to exceed the Thailand's national air quality standard therefore only the positive deviations which far away the *UCL* are criticized.

RESULTS AND DISCUSSION

The results of work are demonstrated in these following steps.

1. The line graph as well box plot of monthly mean $PM_{2.5}$ concentrationsof each of monitoring stations are accordingly pictured in Figure 1 and 2.

For Fig. 1, it can be said that station 33T depicts the highest value and station 32T pictures the lowest

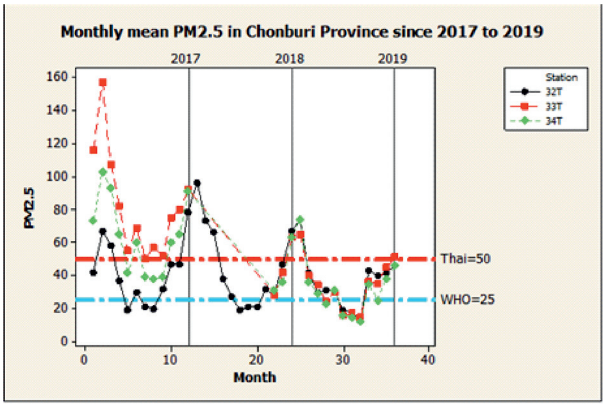

Fig. 1. Line graph of monthly mean $PM_{2.5}$ concentrations in Chonburi Province

value of monthly mean $PM_{2.5}$ concentrations in 2017 while all stations show approximately the same monthly mean $PM_{2.5}$ concentrations in both 2018 and 2019. Most monthly mean $PM_{2.5}$ concentrations of station 32T draws within the Thai limit while station 33T and 34T, most of them are below the Thai limit only in 2019, between the WHO and Thai limit in 2018 and above the Thai limit in 2017 as seen in Fig. 2. The mean and standard deviation of monthly $PM_{2.5}$ concentrations in Chonburi Province during 2017 to 2019 are also respectively obtained as 27.37 and 15.3 $\mu g/m^3$.

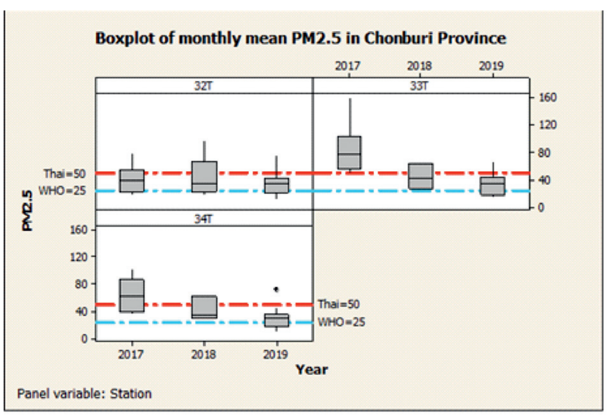

Fig. 2. Box plot of monthly mean $PM_{2.5}$ concentrationsin Chonburi Province

Fig. 2. Chonburi Province was just supported $PM_{2.5}$ data in the past few years so the in-control mean and standard deviation of $PM_{2.5}$ concentrations were not known from a pilot study or for a reference period. The in-control mean(μ_0) and standard deviation(σ) of $PM_{2.5}$ concentrations are then considered from the monthly mean $PM_{2.5}$ concentrations during 2017 to 2019. In addition, the 2 parameters, λ and L, of EWMA chart are estimated from simulation study corresponding to the in-control average run length (ARL_0). Since the change of $PM_{2.5}$ concentrations are evaluated as small process shift, λ and L are severally chosen as 0.05 and 2.492 according to recommendation of (Borror et al., 1999). The upper and lower control limits of a long run series are then computed as Equation 3 which get UCL=33.48 and LCL=21.26. Once thez_t statistics were plotted, the EWMA charts of daily maximum $PM_{2.5}$ concentrations of stations 32T, 33T and 34T were successively pictured in Fig. 3, 4 and 5.

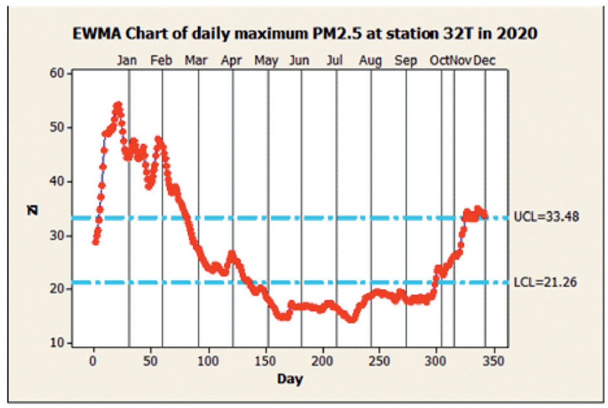

Fig. 3. EWMA chart of daily maximum $PM_{2.5}$ concentrations at station 32T

At station 32T shown in Figure 3, 90 out of 342 points of z_t statistics containing in 4 months of January (27 points), February (29 points), March (20 points) and December (14 points) fall outside the UCL, therefore the process mean can be notified as out-of-control state.

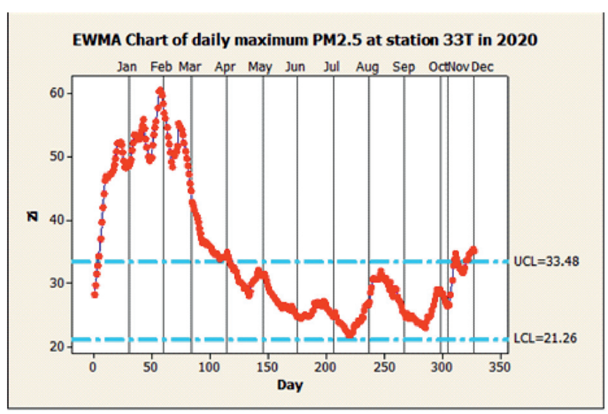

Fig. 4. EWMA chart of daily maximum $PM_{2.5}$ concentrations at station 33T

At station 33T shown in Figure 4, 124 out of 327 points of z_t statistics containing in 6 months of January (27 points), February (29 points), March (24

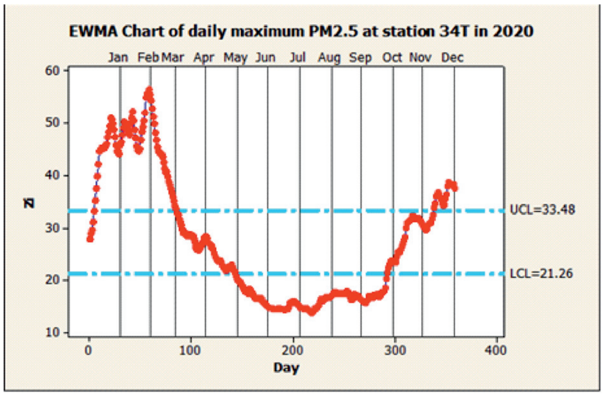

Fig. 5. EWMA chart of daily maximum $PM_{2.5}$ concentration at station 34T

points), April (30), May (3) and December (11 points) fall outside the*UCL*, therefore the process mean can be notified as out-of-control

At station 34T shown in Figure 5, 101 out of 358 points of z_t statistics containing in 5 months of January (26 points), February (29 points), March (24 points), April (1) and December (21 points) fall outside the*UCL*, therefore the process mean can be notified as out-of-control state.

CONCLUSION

The recent $PM_{2.5}$ changes in Chonburi Province are following concluded and discussed.

1. The $PM_{2.5}$ concentrations were high in 2017 and decreased in both of 2018 and 2019. Additionally, it may have a seasonal effect on $PM_{2.5}$ concentrations as indicating of most of high values over the daily Thailand's national air quality standard since December to March (Winter) but not more than the Thai limit during April to November (Summer and the Rainy season).

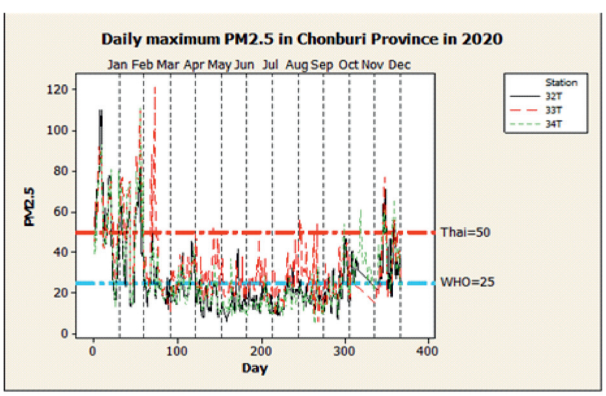

Fig. 6. Line graph of daily maximum $PM_{2.5}$ concentrations in Chonburi Province

2. Daily maximum $PM_{2.5}$ concentrations in 2020 is pictured as Fig. 6. It reports the number of days exceeding the Thai limit at each station are respectively: 38 out of 342 days (32T), 56 out of 327 days (33T) and 40 out of 358 days (34T).
   The resulting of obtained EWMA charts therefore are superiorly as the potential utilized tool for detecting small persistent changes of the recent $PM_{2.5}$ concentrations because the EWMA chart at every station can excellently point out some more days as the warning days to caution whether all those days are met the Thai daily standard as seeing of 90 out of 342 days (32T), 124 out of 327 days (33T) and 101 out of 358days (34T).
3. The one who authorize may utilize these findings as a guideline to manage, control and maintain level of $PM_{2.5}$ concentrations corresponding to the daily Thailand's national air quality standard by directing the number of days exceeding the Thai limit not higher or lessening them to lower than 2020 for the next later years.

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