Nitrogen dioxide concentration and health risk assessment at schools: Case study Tha sala District, Nakhon Si Thammarat province

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Abstract. A Traffic congestion around schools always problem for many schools. The biggest cause of the problem is the parent’s vehicles which they are dropping off and picking up their children from school. Other vehicle belongs to student and teacher in the school. Therefore, high air pollutant level usually found around school. Nitrogen dioxide (NO₂) is one of pollutant which associated with traffic density because it was emitted from internal combustion of vehicle. This gas causes inflammation of respiratory system and is a precursor of ground level ozone and particulate matter, which are associated with adverse health effects. It is also a source of acid rain which damage an ecological system. This study aims to measure concentration of NO₂ from three schools which have different traffic volume and building density in Tha sala district, Nakhon Si Thammarat Province, after that, the concentration was applied to evaluate health risk of exposure to NO₂ for residents who is living around schools including children and adult. The samples were collected by using passive samplers for 24 Hrs on the working day during February to May 2019. The results shown that the concentration of NO₂ at schools in semester start were ranged 48.6 - 78.1 µg/m³ which were 1.5 time over that in semester break period. Pollutant concentration was relative with traffic volume in the area. Even though, the NO₂ level from all schools were accepted by the 24-hours standard of nitrogen dioxide in ambient air (<113 µg/m³) but the toxicological risk assessment distinguished that the resident living around schools in Tha Sala district exposed to NO₂ above the recommended limits to human health

1. Introduction
Traffic congestion at school zones is frequently concerned for all schools. The overcrowding and blocking of streets on or near school property are usually found in the morning, and evening. This problem is typically associated with car transportation of children to and from school. Using of cars by the parents to drop off and pick up students and riding of motorcycle to school by the students have risen considerably in urban areas. It inconveniences parents, students, school authorities, school bus drivers, police and the resident neighborhood. Moreover, the traffic congestion increases vehicle emissions and degrades ambient air quality. Many traffic-related pollutants including carbon monoxide (CO), particulate matter (PM), volatile organic compounds (VOCs) and particularly nitrogen dioxides
(NO$_2$) are related to traffic volume [1,2]. NO$_2$ is generated from the reaction between nitrogen gas and oxygen gas under high temperature during combustion process to form nitric oxide (NO), then it is rapidly converted to NO$_2$. In urban area, therefore NO$_2$ is predominantly air pollutant emitted from vehicle source. NO$_2$ also present an association with cardiovascular disease and haemorrhagic stroke, and it is the strongest association between NO$_2$ concentrations and number of hospital admissions is observed [3]. Moreover, it is procurer of tropospheric ozone and nitric acid (acid rain) which cause of ecological deterioration [4,5].

Tha sala district is one of rapid growth area in Nakhon Si Thammarat Province because many schools and university are located in this area. Traffic congestion is becoming a serious problem in the district due to many schools are normally located at a community area of the district. Consequently, amount of traffic emitted pollutants particularly NO$_2$ should be extreme high. Unfortunately, information of NO$_2$ level in this area is still limited then this study aims to measure the concentration of NO$_2$ at schools in Tha sala district by comparing between semester start and semester break period. Then the concentration is applied to evaluate health risk of people who live near road side from NO$_2$ exposure. The result is very helpful for the authorities, and people in environmental management to reduce health risks and improve quality of life.

2. Material and Method

2.1. Study area

Study area is located in Tha sala district, Nakhon Si Thammart Province. Nakhon Si Thammarat located along the Gulf of Thailand about 780 km in the south of Bangkok. It is second largest province in southern of Thailand. The meteorological condition in this area is influenced by prevailing winds (southwesterly and northeasterly wind) then this province is normally had only the summer and rainy season for 5 and 8 months, respectively. The annual temperature and rainfall are around 27°C and 2500 mm, respectively. The sampling sites were selected from 3 schools in Tha sala district (Figure 1).

The 1st school is 100 m far from main road in Tha sala district. This area has medium density of building, and traffic volume. The 2nd school located in downtown of the district and near intersection. Therefore, this area has the highest traffic volume comparing with other studying areas. The 3rd school is the lowest density of both building, and traffic volume.

2.2. Sampling of nitrogen dioxide

NO$_2$ in ambient air was collected by using passive samplers 3 day per week on working day in summer season. The sampling was separated by semester periods including 3 weeks for semester start (February – March 2019) and 3 weeks for semester break (March – May 2019).

The NO$_2$ passive sampler is using diffusion tube to collect NO$_2$, it is one of the most widespread methods for NO$_2$ measurement because this method is very simple and inexpensive. The passive sampler in this study was developed by Environmental Chemistry Research Laboratory (ECRL), Chiang Mai University. The detail of the sampler and chemical preparation was described by Bootdee et al. [6]. The diffusion tube contained Whatman glass fiber filter (GF/A) paper coating with 50 µL of 20% triethanolamine (TEA). A set of the sampler consisted of 5 sampling tube and 3 blank tube which kept in a shelter to prevent metrological effects. The sampler was hung at 1.5 – 2.0 m above ground level. After 24 Hrs exposure, the samples were extracted with 2 mL Deionized water (DI water). Then one mL the extracted solution was filtrated with 45 µm nylon filter and mixed with 2 mL Saltzman reagent which was a mixture sulfanilamide reagent (21.5 g of sulfanilamide + 56 mL concentrated ortho-phosphoric acid diluted to 1,000 ml with DI water) and one tenth part of N-(1Naphthyl) ethylenediamine dihydrochloride (NEDA) reagent (0.152 g of NEDA in 100 mL DI water). The purple solution (purple azodye complex) was developed after 15 minutes mixes. The solution was then measured for absorbance at 540 nm by spectrophotometer.
Figure 1. Study areas in Tha sala district, Nakhon Si Thammarat province.

2.3. Health risk assessment
Risk analysis focused on chronic exposure of NO\textsubscript{2} via inhalation intake for 2 residents (resident adult and resident child) living near the study site. This study was assumed that the receptors were exposed to the long-term averaged NO\textsubscript{2} concentration which was computed from pollutant concentration in semester start (C\textsubscript{ST}) and semester break (C\textsubscript{SB}) periods and number of weeks in both semester periods (equation (1)). Additionally, the concentration in indoor was equal to that of outdoor. The daily intake of both residents was calculated as equation (2) and the exposure factors are described in Table 1:

\[ C = \frac{(C_{ST} \times 13 \text{ week}) \times (C_{SB} \times 7 \text{ week})}{20} \quad (1) \]

\[ CDI = \frac{C \times IR \times ED \times EF}{BW} \times \frac{1}{AT} \quad (2) \]

The potential for non-carcinogenic effects of a chemical is evaluated by comparing the exposure level with a reference dose (RfD) which RfD of NO\textsubscript{2} is 1.1x10\textsuperscript{-2} mg/kg-day [7]. If the ratio of exposure to toxicity (hazard quotient; HQ) is less than 1, it means that no adverse health effects occur.

\[ HQ = \frac{CDI}{RfD} \quad (3) \]
Table 1. Exposure factors of NO\(_2\) for resident adult and resident child.

| Exposure factors | Symbol | Unit  | Child\(^1\) | Child\(^2\) | Adult\(^3\) | References |
|-----------------|--------|-------|-------------|-------------|-------------|------------|
| NO\(_2\) concentration | \(C_1\) | \(\mu g/m^3\) | 37.84 | 37.84 | 37.84 | This study |
| NO\(_2\) concentration | \(C_2\) | \(\mu g/m^3\) | 66.09 | 66.09 | 66.09 | This study |
| NO\(_2\) concentration | \(C_3\) | \(\mu g/m^3\) | 43.94 | 43.94 | 43.94 | This study |
| Body weight | BW | Kg | 26 | 26 | 55 | [8] |
| Average exposure time | AT | Day/Year | ED | ED | ED | [9] |
| Exposure duration | ED | Day/Year | 100 | 100 | 100 | |
| Exposure frequency | EF | Hr/Day | 14 | 24 | 24 | |
| Inhalation rate | IR | \(m^3/hr\) | 0.46 | 0.46 | 0.83 | [10] |

Remark:
1. Resident child who study at school outside study areas, exposure frequency was calculated from 24 hrs minus 10 hrs which the child stayed at school.
2. Adult is person who has the age over 12 year (USEPA, 1989 from [8]).
3. Exposure duration calculated only working day during summer period (Mid-February to June).

2.4. Assessment of air mass movement
Air mass movement during sampling period (February to May 2019) was used to assess risk area from NO\(_2\) exposure. 24 Hrs forward trajectory was calculated by using TrajStat program developed by Yaqiang Wang in 2008 [11]. This program is using the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model as an external process to calculate trajectories. The meteorological input for the trajectory model was the GDAS (Global Data Assimilation System) and meteorological data (1° x 1°). In this study, the trajectories from study schools were calculated 2 times per day (start point) at 07:00 am and 05:00 pm local time with 10 m above ground level. Moreover, cluster analysis in the program was used for group the main direction of air mass from study areas.

3. Result and discussion

3.1. Nitrogen dioxide concentration
The result of this study shows that concentration of NO\(_2\) at schools in Tha sala district during semester start were 48.6 ± 2.3, 78.1 ± 11.5 and 51.6 ± 2.9 \(\mu g/m^3\) for the 1\(^{st}\), 2\(^{nd}\), and 3\(^{rd}\) school, respectively while, the concentration in semester break were 17.9 ± 0.3, 43.8 ± 3.9 and 29.7 ± 2.3 \(\mu g/m^3\), respectively (Figure 2). Concentration of NO\(_2\) in semester start were about 1.5 – 2.5 time higher than that in semester break period. Moreover, the 2\(^{nd}\) School presented the highest of NO\(_2\) concentration both periods and follow by the 3\(^{rd}\) school and 1\(^{st}\) school. The pollutant concentration was related with the traffic volume at schools (Figure 3). Traffic volume during semester start was about 1.5 time of that during semester break. Comparison of traffic volume on the road at schools, it was shown that the 2\(^{nd}\) school found the highest number of vehicles on the road. It might be due to the 2\(^{nd}\) school located near main road in downtown of Tha Sala and the government office, while the road near other schools were small and narrow road or bypass road from the main road. Although, vehicle volume at the 3\(^{rd}\) school during semester break was lower than that 1\(^{st}\) school the concentration of NO\(_2\) were opposite result due to the pollutants level at the 3\(^{rd}\) school could be influenced from the main road which located around 100 m from the sampling area.
Remark: Difference capital and small letter represented significance difference at 95% confidential for semester period and schools (each semester period) respectively

**Figure 2.** Comparison of NO$_2$ concentration among schools in Tha sala district.

**Figure 3.** Traffic volume and vehicle type at schools (7:00 am – 5:00 pm) in Tha sala district.

Even though the traffic volume in this study was lower than that in other study the NO$_2$ concentration in this study was comparable with the concentration found on the road in Chiang Mai Province (11 – 85 µg/m$^3$) [6] but it was higher than that from the study in city road highway of Montréal, Canada (20 - 53 µg/m$^3$) [12]. It might be due to road characteristic in Tha Sala district was 2-lane road which is narrow and less air ventilation comparing with the wilder road in Chiang Mai, Thailand and Canada. However, the concentration from all schools were accepted with 24 Hrs the environmental standard for NO$_2$ in Japan (113 µg/m$^3$).

### 3.2. Health risk assessment

According to NO$_2$ concentration was measured only on working day in summer period which it may reduce in rainy season due to meteorological conditions then health risk assessment was estimated only study period. The mean NO$_2$ concentration calculated by equation (1) were applied for assessment (37.8, 66.1 and 43.9 µg/m$^3$ for 1st, 2nd and 3rd school, respectively). Since the study areas selected in this study were community area, therefore the resident adult and child (Child 2) who study at school in the
study area should use exposure frequency for 24 Hrs. Whereas the resident child who study at school outside the study area (Child 1) should go to school during 7:00 am – 5:00 pm (10 Hrs) and stay at home after school for 14 Hr. The Figure 4 present the HQ value of residents living near schools in Thasala district. The HQ value of child1 residents were found lower than 1 because this resident group had short time stayed in the area (only 14 Hr). However, the excepted was found child 1 at the 2nd school, it might be due to the concentration of NO\textsubscript{2} in the area was the highest level.

![Figure 4](image)

Remark: HQ value less than or equal to 1 (red dashed line) refers to negligible hazard (noncancer disease) from exposure to the pollutant

**Figure 4.** Hazard quotient value of residents at schools in Thasala district.

In case of resident who had stayed in the area for whole day presented the HQ value greater than 1 means that they could have adverse effects from NO\textsubscript{2} exposure. Moreover, child2 (1.46 - 2.55) had the higher risk than that of adult resident (1.25 - 2.18) because a respiration rate per bodyweight of child was higher than adult. The results corroborated with the result from Diaz and Dominguez [10] who estimated health risk from heavy metal bound PM\textsubscript{2.5} in urban area of Mexico. They found that the HQ value of 2-6 (1.72) and 6-12 years old (1.81) was higher than that value of adult (1.15) because of high respiration rate. Moreover, the study of De Oliveira [9] indicated the children (< 8 years) shown the risk from PM\textsubscript{2.5} exposure about 12% greater than that of teenager (12–14 years).

### 3.3. The risk area from exposure to nitrogen dioxide

Air mass movement was important for pollutant distribution from source to acceptor area. The direction of the movement can be used to indicate the receptor area from pollutant distribution. Figure 5 present the grouping (Cluster) of direction and path of air mass movement (Trajectory) from study schools. The clustered results of all schools were similar because of identical of the close distance between schools. The trajectories shown that 80% of air mass (cluster 1 and 3) in summer season were mainly move to northwest direction. This result might be influence from sea breeze because the sea is located about 2 km in the east. The result was distinguished that the community area in northwest direction from schools should aware health effect from NO\textsubscript{2} exposure.
4. Conclusion

The study measured NO$_2$ concentration in traffic areas of schools in Tha sala district, Nakhon Si Thammarat Province during summer season for both semester start and semester break period. The concentrations in semester start period were around 1.5 time of that in semester break period. Moreover, the pollutants concentration was related with traffic volume in the area. Additionally, toxicity assessment from NO$_2$ exposure distinguished that NO$_2$ level might cause adverse health for resident living around schools, especially in northwest direction. The authority should urgently manage on traffic volume at schools in Tha sala, Nakhon Si Thammarat.

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