CHAPTER 5
DISCUSSION

5.1 Lichen diversity and distribution

Although, the number of foliose lichen diversity of mango trees in Lampang city is low in comparison with crustose diversity. Saipunkaew *et al*. (in press) found that the analysis of macrolichen data can provide good separation of their study sites that correlates well with anthropogenic effects, which associated with increasing population. In this study, some of these macrolichen species are contributes in polluted area and well known for their tolerance to pollution, for example, *Hyperphyscia adgultinata*, *Pyxine cocoes* and *Dirinaria picta*. While the others, *Parmotrema praesorediosum, Physcia poncinsii* and *Hyperphyscia pandani* were found in the rural area. Moreover species of Physciaceae, including *Pyxine cocoes* and *Dirinaria picta,* being a characteristic condition of urban and agricultural lowlands in the tropics as well as tolerant of pollution in urban sites (Saipunkaew *et al*., 2005). There was no presence of other species of *Parmotrema* in this study area except *Parmotrema praesorediosum*. Rainfall is the factor that affects the distribution of theses lichens since the highest number of Parmotrema is found in the upland where the rainfall is higher than in lowland (Saipunkaew *et al*., in press).

5.2 Mapping lichen

The method for mapping lichen diversity was based on a standardized sampling protocol by Asta *et al.* (2002). The protocol was developed by a group of European researchers to provide a repeatable and objective strategy for mapping lichen diversity as an indicator of environmental change. Due to the lack of local evaluation scales of environmental alteration, the method for both creating the interpretation scales and mapping lichen in this study referred to the VDI guideline (VDI, 1995), which is used in temperate areas. However, this interpretation scales may not suitable in the tropical zones because there are the difference in climatic condition and lichen species. Since lichen communities are affected by different ecological variables, including macro and micro climatic variation. Therefore, in areas where natural conditions are available, the interpretation of lichen diversity in monitoring environmental pollution is better when based on the evaluation of deviations of the communities from normal or natural conditions as described by Asta *et al.* (2002); Loppi *et al.* (2002a); Castello and Skert (2005).

Air quality in the city center of Amphoe Mueang Lampang was evaluated based on lichen diversity value, which was calculated from the frequency counts of all lichen species within a particular sampling quadrate positioned on the tree trunks. The LDVs (Table 4.4) can be used as evaluation values for assessing air pollution, as well as indicators for the abundance of lichen and lichen species in the sampling unit. The lowest LDVs was found in the center of city, indicating that the abundance of lichen and lichen species was low. In the outer zone of the city, LDVs increased, which indicate that the abundance of lichen was higher than in the city center.

An air quality map was created based on the LDVs of each sampling unit. The results were shown in two different ways. First, each sampling unit was colored according to the LDVs (Figure 4.3). Secondly, to obtain a more detailed and general picture of air pollution zonation in the study area, isolines were drawn to represent the air quality class zones (Figure 4.4).

The air quality zones indicated by lichens were found to correspond with the land use type and the population density in the study area. In the center part of Lampang city the highest level of air pollution was indicated. This zone was a very densely developed area (Figure 3.5) with the highest population density (Na Ma, 2004). Furthermore, this area was the central commercial area of Lampang city, and includes government institutes, schools and colleges, markets, hotels, hospitals and densely populated residential areas. Therefore, the heavily polluted air occurring in this area was caused by the heavy traffic load particularly during the rush hours, since there were many schools and colleges located in this area. Moreover, in the urban area where development is very dense, the air pollutants are more likely to be trapped inside the area because the wind speed is reduced due to the frictional drag of buildings on the air moving around them (Saipunkeaw, 1994). The most polluted air, as indicated by LDVs was also found in the northeastern part of the city. This could be due to the increasing of development in this area as people have begun to migrate out of the city center to settle in this area (Na Ma, 2004). A high-polluted air zone was indicated in the southwestern part of Lampang city. This area was also the densely developed area, but the population density was lower than the city center. This area included a moderately residential area, dense residential area and a commercial area (Figure 3.5). Moreover, this area covered the main road and highway where a high volume of traffic was present. High-to-moderate polluted air was indicated in the southeastern part. This zone included the moderately dense residential area and agricultural area, which had more open area than in the city center.

The air quality was slightly better in the outer part of city where the volume of traffic and the population density were low. Most of the study area was determined as a moderate air pollution zone. This zone is scattered throughout the outer part of Lampang city, which was mostly the rice paddies. The area had more open area and better air can flow. Therefore, the trapped air pollutants were not found in this area. The low and very low air pollution zones were located in the outer part of Lampang city where was also open area and included rural village areas with the lowest population density. The best air quality was determined in the southeast of the city, where there were the rice paddies and small rural villages areas.

Besides the land use type and population density, the result of lichen mapping, also corresponded with the atmospheric pollutants measured by the passive sampling. The correlation test showed no significant correlation between LDVs and SO_2 (Figure 4.8) while a moderately significant correlation was found between LDVs and NO_2 (Figure 4.7). Since the NO_2 is a traffic related pollutant, the emissions are generally high in urban area rather than rural areas (Spiro and Stigliani, 1996). Moreover, the comparison of annual mean concentrations of NO_2 and SO_2 in Lampang city, in 2003 showed that the concentrations the concentrations of SO_2 are in range of 0.2-0.9 ppb. While the concentrations of NO_2 are in the range 7.0 – 36.5 ppb. Therefore, the frequency in lichen species and their occurrence were related to NO_2 concentrations rather than SO_2 concentrations, which are low in this study area.

5.3 Bark pH

Although the results from ANOVA implied that there was no significantly difference in average bark pH between each air quality class, the bark pH value was observed to decrease toward the better range of air quality. The bark pH in urban area was higher than those in suburban area (Table 4.5). These results contrast with the findings of the previous studies (Saipunkeaw, 1994; Subsri, 2002; Subsri and Saipunkaew, 2002) who reported that the bark pH of Mango tree is lower in the urban area than in the suburban area of Chiang Mai city. In this study, there was no significant correlation between bark pH and SO_2 (Table 4.8). Therefore, acidification due to anthropogenic SO_2 was not a major factor influencing bark acidity. However, besides the presence of pollutants, bark acidity is influenced by many factors including dust accumulation, which can reduces bark acidity (Hutchinson *et al.*, 1996). Moreover the widespread occurrence species of physciaceae, including *Dirinaria* and *Pyxine*, in the urban area in Lampang city may also associated with dust fallout (Loppi and Pirintsos, 2000). The Pollution Control Department (2004) reported that PM_{10} is a major air pollution problem in Thailand, and Lampang city is one of the areas that often exceeds the standard level concentration of PM_{10} (120 µg / m^3). Although the constitution of PM_{10} has not been investigated, the study in Hanoi, Northern Vietnam by Hiena *et al.* (2004) showed that high contributions made by Ca^{2+}, NH_4^+ and SO_4^{2-} in PM_{10}. This could explain the higher bark pH in urban area, where a higher concentration of PM_{10} was observed due to transportation combustion. Beside dust accumulation, the eutrophication from high concentration of NH_3 and high percent deposition of Ca^{2+}, NH_4^+ were determined in the city (Chirasathaworn, 2005). Theses may also affect high bark pH as well as the distribution of *Hyperphyscia adgultinata,* which was mostly presence in the urban area, is the group that associates with nutrient enriched bark (Purvis *et al*., 1992). In addition, the using of concrete as the main source material of buildings could lead to the high bark pH in urban area. Since the method for measuring pH of bark is the old technique. The other techniques that can measure the pH of bark surface accurately are recommended. Therefore, the further work on measuring other bark properties such as electrical conductivity, NH_4^+, SO_4^{2-} and NO_3^- is necessary in better understanding of the relationship between substrate properties, atmospheric pollutants and lichen distribution.

5.4 Passive sampling

The optimized condition for preparing and installing diffusion tubes referred to those obtained by Khaodee (in press) and Shakya (2004). TEA was used as the absorbent due to its ability to collect both SO_2 and NO_2 (Krupa and Legge, 2000).

Under the field conditions, passive samplers may provide under or over estimations in comparison to the corresponding data from active samplers because of the effects of wind velocity (turbulence), radiation, temperature and relative humidity, which affect adsorbent performance and sampling rate (Krupa, 2001).

Several studies have examined the performance of the diffusion tube in comparison with the active measurement method. The overestimation in measured concentration of NO_2 was found (Gair *et al.*, 1991; Gair and Penkett, 1995; Heal and Cape, 1997; Ayers *et al.*, 1998; Glasius *et al.*, 1999; Heal *et al.*, 1999; Bush *et al.*, 2001; Hansen *et al.*, 2001; Ukpebor *et al.*, 2004). This study found overestimate of NO_2 only in sampling site no. 23. The others sites found underestimate of NO_2 concentration when compared to the values obtained by chemiluminescence monitor (Figure 4.9), while the measurements of SO_2 concentration were overestimated to those of active monitoring (Figure 4.10). The underestimation which mostly determined could be related to the photo degradation of NO_2-TEA in the diffusion tube because the transparent polyethylene diffusion tube were exposed to the sun, as described by Shakya (2004). The author found a 54.13% underestimation of NO_2 measured from the polystyrene diffusion tube and a 15.39% underestimation was found from the polyethylene diffusion tube in comparison with the data obtained by chemiluminescence monitor. Heal *et al.* (2000) explained that a small flux of UV reaching the adsorbent, either by a small transmission through the tube walls or by internal reflections from the entrance of tube, would be sufficient to cause the exposure dependent loss of NO_2, through degradation of bound nitrite at TEA absorbent. Another explanation includes biodegradation of adsorb nitrite.

Santis *et al.* (2000) also related the underestimation of NO_2 measurements by diffusion tubes with overheating and photo degradation of the NO_2-TEA adduct during exposure of tubes to sun at the sampling sites. They recommend the careful extraction procedure, use of stainless mesh at the entrance of the tube, and use of non-transparent plastic tube to reduce error. Kasper-Giebl and Puxbaum (1999) found the average concentration of NO_2 determined by the diffusion samplers were 50% lower than results from chemiluminescence monitor. They suggested that this underestimation could be corrected by placing two grids into the diffusion tube. Krochmal and Kalina (1997b) recommend the use of non-transparent plastic as they found 50% lower NO_2 measurements in the transparent plastic badge type compared to non-transparent plastic badge type.

Subsequently, to eliminate the underestimation error in this study, which was caused by transmission of lights, it is recommended that a non-transparent diffusion tube or a diffusion tube wrapped in aluminum foil be used for these measurements.

Although the underestimation was found, but a significant correlation between the results from passive sampling, using a polyethylene diffusion tube, and the results from chemiluminescence monitor was reported (Shakya, 2004; Khaodee, inpress). Therefore, passive sampling represents a cost-effective tool for NO_2 and SO_2 monitoring and can be a substitute method for air pollution monitoring.

Saipunkaew *et al*. (in press) referred to a recent work using modeling of atmospheric sulfur at a 50 km scale during wet and dry seasons of the year in Thailand shows that, the level of SO_2 in Lampang is high level within winter (10-15 ppb). As Engardt and Leong (2001) suggest that SO_2 is rapidly converted to SO_4^{2-} in a tropical environment where it is deposited as particulate matter rather than as wet acid (Hien *et al*., 2004). Since species of *Hyperphyscia adgultinata* was also found in the urban area. Therefore, acidification is not the main factor affecting urban lichen communities. In the contrary, the temperate zone, the distribution of pollution tolerant and sensitive lichens has been associated with decreasing bark pH in the case of acidification from industrial SO_2 (Johnsen and Søchting, 1976)

From the results of this study the species that can be used as indicators of ueban pollution in Thailand are *Hyperphyscia*, *Pyxine*, *Lecanora* and *Rinodina*. However this study is the preliminary research for using lichen diversity to assess air quality. The lichens data were evaluated with the measured pollutants. Since the high numbers of sterile crustose are found in the urban area. These may affect the using of lichen diversity the urban area in Thailand. Moreover, the LDV method used in this study is the new approach and lacking of the evaluation scale. Therefore, further work on crating an evaluation scale for this mapping method for tropical zones is necessary.