การประเมินคุณภาพอากาศของสวนสาธารณะในกรุงเทพมหานครด้วยโลหะหนักที่สะสมในลำต้นปาล์มขวด และการแพร่กระจายของไลเคน

Assessing air quality of public parks in Bangkok by heavy metals accumulated in the barks of royal palm trees, and lichen distribution

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บทคัดย่อ: มลพิษทางอากาศพวกโลหะหนักจากการเพิ่มขึ้นของอุตสาหกรรมและชุมชนเมือง กลายเป็นปัญหาที่รุนแรงต่อระบบนิเวศและสุขภาพของมนุษย์ สวนสาธารณะเปรียบเสมือนปอดและพื้นที่พักผ่อนหย่อนใจที่อยู่ท่ามกลางเมือง ซึ่งโลหะหนักของสวนเหล่านี้โดยเฉพาะในประเทศกำลังพัฒนารวมถึงกรุงเทพ ฯ ยังไม่มีการตรวจสอบ การศึกษาในครั้งนี้เพื่อใช้เปลือกต้นปาล์มขวดและไลเคนที่เติบโตอยู่บนต้นไม้เหล่านั้น ประเมินคุณภาพอากาศซึ่งมีสาเหตุมาจากโลหะหนัก ในสวนสาธารณะ 5 แห่งในกรุงเทพ ฯ ตัวอย่างเปลือกไม้จากสวนพระนคร, สวนหลวงร.๙, จัตุจักร, ลุมพินีและธนบุรีรมย์ พร้อมกับเขาหินซ้อนซึ่งใช้เป็นพื้นที่ควบคุม นำไปวิเคราะห์โลหะหนัก pH และการเหนี่ยวนำไฟฟ้า ในขณะเดียวกัน บันทึกความถี่และความสมบูรณ์ของไลเคน *P. cocoes* พบว่า Pb มีปริมาณสูงกว่าในทุกสวนสาธารณะ ส่วนโลหะหนักชนิดอื่นมีความเข้มข้นเรียงลำดับได้ดังนี้ Fe, Zn, Co, Mn, Cu, Ni และ Cd ตามลำดับ อาจมีสาเหตุมาจากการใช้น้ำมันผสมตะกั่วในช่วงทศวรรษที่ผ่านมา พร้อมกับตะกั่วมีระยะเวลาการสลายตัวนาน พื้นที่ควบคุมมีความเข้มข้นของโลหะหนักน้อยกว่าบริเวณอื่น ๆ ยกเว้น Pb อาจเกิดจากได้รับสารตะกั่วจากโรงงานอุตสาหกรรมที่อยู่ใกล้เคียง pH ของเปลือกไม้มีค่าอยู่ระหว่าง 4.99-6.25 และแสดงความสัมพันธ์เชิงบวกกับความเข้มข้นของโลหะหนัก ยิ่งไปกว่านั้น ยังพบว่าความถี่และความสมบูรณ์ของไลเคนมีค่าสูงที่ช่วง pH 5.5-6.0 สามารถเรียงลำดับคุณภาพอากาศของพื้นที่ศึกษาจากดีที่สุดถึงแย่สุดได้ดังนี้ เขาหินซ้อนหรือสวนหลวง ร.๙, สวนพระนคร, สวนธนบุรีรมย์, สวนลุมพินีและสวนจัตุจักร

Abstract: Heavy metals air pollution from increasing industry and urbanization become severe problem of ecosystem and human health. Public parks are regarded as lung and recreation area of city dwellers. However, heavy metal air pollutant of the parks, especially in developing countries including Bangkok are not known. This study aimed at using barks of royal palm and epiphytic lichen that inhabited them to assess air quality caused by heavy metals of five public parks in Bangkok. Barks of royal-palm trees from Pranakorn, Rama 9, Jattujak, Lumpini and Thonburirom, as well as Khaohinsorn for control site, were analyzed for heavy metals, pH and electric conductivity. Frequency and abundance of the lichen *P. cocoes* inhabited the palm trees were recorded. The results showed that Pb presence in several orders of magnitude higher than other heavy metals in every parks. Other heavy

metals, Fe, Zn, Co, Mn, Cu, Ni and Cd, had subsequently lower concentration. It might have been the evidence of using leaded gasoline, which has long resident time, during the past decades. All heavy metals in the barks of the royal palms at the control site had lesser concentration than the polluted sites, except Pb. This evidence suggested that Khaohinsorn might receive Pb pollutant from nearby industries. Bark pH ranged 4.99-6.25, and showed positive correlation with concentration of heavy metals. In addition, high frequency and abundance of *P. cocoes* were measured from bark pH 5.5-6.0. Air quality of the study sites can be ranked from best to poorest as followed; Khaohinsorn or Rama 9, Pranakorn, Thonburirom, Lumpini and Jattujak.

Introduction: Tree bark is continually exposed to the environment over a period of several years. Therefore, it can give precise information about changes that occur in the air conditions of ecosystem. This and other characteristics make tree bark a suitable material for the evaluation of air pollution.[5] It was frequently used in the analysis of heavy metals deposition.[7,9,10] Traffic emissions on roads and metallic industrials were main cause of heavy metals accumulation on the surrounding environment including vegetations.[8] The study of tree bark properties is a method that has been used by researchers to evaluate the impact of air pollution on extensive areas, industrial sites and large urban agglomerations.[5,7,8,9] Moreover, epiphytic lichens have been widely used for bioindicator of air pollution such as, *Pyxine cocoes*, which is a common species in urban areas,[1,2,3,4] . It showed high performance of PSII in moderately air pollution.[2] Therefore, abundant and frequency of this species, may indicate the level of air pollution. Bangkok has heavy traffic from motor vehicles, which emits heavy metals, NO_x, CO_2, CO, SO_2, fine dust particles, volatile organic compounds etc. Therefore, public parks which seem to be lung of the people in Bangkok could be impacted by air pollution and consequently affect health of the people who recreate in the parks. The aims of the present study were to investigate heavy metals accumulated in tree bark, bark pH and conductivity, as well as distribution of lichen in public parks in Bangkok in order to using tree barks and lichens as bioindicator to evaluate air quality.

Table 1. Character of 6 sites selected for collecting samples of tree bark in polluted and unpolluted areas.

Site	Location	Area (rai)	Description
Unpolluted			
Control (KRDSC)	Phanomsarakham district	1,895	Rural or cultivated area, less traffic
Polluted			
Pranakorn	Ladkrabang district	50	Suburb area, east of Bangkok, low traffic
Rama 9	Prawet district	500	Suburb area, south-east of Bangkok, medium traffic
Jattujak	Jattujak district	155	Urban area, north of Bangkok, high traffic vehicles
Lumpini	Prathumwan district	360	Urban area, in center of Bangkok, high traffic
Thonburirom	Thungkhru district	63	Urban area, south-west of Bangkok, medium traffic

Methodology:

Study area

Five public parks in Bangkok were used to evaluate level of air quality by analyzing heavy metals accumulated in barks of Royal palm, and lichens that inhabited the barks. The parks designated as polluted areas included, Pranakorn, Rama 9, Jattujak, Lumpini and Thonburirom (Table 1). They are different in size, density of traffic, anthropogenic activity, climate condition etc. The Khaohinsorn Royal Development Study Center (KRDSC) surrounded by cultivated area of Phanomsarakham District was used as a control site (unpolluted area). KRDSC is 132, 123 and 45 km far from Bangkok, Mabtaput industrial estate and Kabinburi industrial park respectively.

Bark sampling, pH and conductivity measurements and lichen distribution.

In June 2010, 5 royal-palm trees (*Roystonea regia* (Kunth) O.F. Cook) were randomly selected from each site. All of them had girths more than 100 cm. Barks of trees about 1 to 2 mm thick were chipped off at breast of height (1.3 m above the ground) by stainless in 4 aspects (N, S, W, E). Samples from the four aspects of the same tree were mixed in plastic bags and transferred to laboratory at Ramkhamhaeng University. Bark pH were measured in situ on the four aspects nearby bark collecting spots by using pH meter (pH-electrode, EUTECH CYBERNETICS). The lichen *Pyxine cocoes* Swartz was choose to assess air quality. This species is commonly grow in urban areas, but rarely found in clean areas.[1, 2, 3, 4] Frequency and abundant of the lichen were recorded by surrounding on trunks of palm trees at 80 to 180 above the ground. Number of thalli in each quadrate were count, and area determined by using AxioVision LE Rel. 4.1. The samples of tree bark at laboratory were dried in an oven at 100 ^{o}C and pulverized in mixer. Four gram of dried material was transferred into a 50 ml flask. Deionized water was added to bring the extract up to the total volume of the flask. The samples were shaken continuously for 48 hours and electric conductivity were measured by Waterproof ECScan Low (EUTECH INSTRUMENTS) using five samples per site.[5]

Heavy metals analysis

Five replicated per tree (25 samples/site) were employed ~~to~~ in the analysis of heavy metals, which included Cu^{2+}, Ni^{2+}, Zn^{2+}, Co^{2+}, Fe^{3+}, Pb^{2+}, Mn^{2+} and Cd^{2+}. Each replicate consisted of 0.2 g of bark sample was digested in muffle furnace for 3 hrs at 550 ^{o}C temperature. After digestion was completed, 4 ml of 6 M HNO_3 was added and the mixtures was then heated at about 150 ^{o}C to dryness. Subsequently 4 ml of 1 M HNO_3 was added and reheated, then allow to cool at room temperature. Afterward, 1 ml of 0.1 M HNO_3 and 5 ml of deionized water were added, and stir for 10 min. The samples were then transferred into 10 ml volumetric flask and diluted with deionized water. Thereafter, sample solutions were filtered through 0.45 and 0.2 µm nylon membrane filters, and kept in glass bottles at 4 ^{o}C for analysis.[6] Heavy metals were analyzed by Ion Chromatography (LC20 Chromatography enclosure, DIONEX), with AD20 Absorbance Detector, GP50 Gradient Pump, Ionpac CS5A (250 mm x 4 mm) analytical column.

Statistically analysis

Statistical analysis were performed by using SigmaPlot V.11. The relationship among groups were test with one-way analysis of variance (ANOVA), Turkey's pairwise comparisons at the significance level $p < 0.05$, 0.001, and Pearson correlation.

Results The royal palm had bark pH ranged from 4.99 – 6.25 (Fig. 1). The control site had the lowest value, but without significant difference from other polluted sites, except Pranakorn ($p < 0.05$). Electrical conductivity from the bark solutions ranged from 618 –

1,020 µS, and showed the same pattern with bark pH, but had the Thonburirom showed significant difference ($p < 0.05$). Total heavy metal concentrations ranged from 372.8 – 1,055.7 mg/kg (Table 2). Rama 9 had the lowest concentration, and significantly different ($p < 0.001$) from other sites. Lead had the highest concentration followed by Fe, Zn, Co, Mn, Cu, Ni and Cd. The lichen *P. cocoes* was absent from control and Jattujak areas. By contrast, Thonburirom and Lumpini had the highest frequency of 80%, and the highest abundance of 810 cm^2 was measured from the latter.

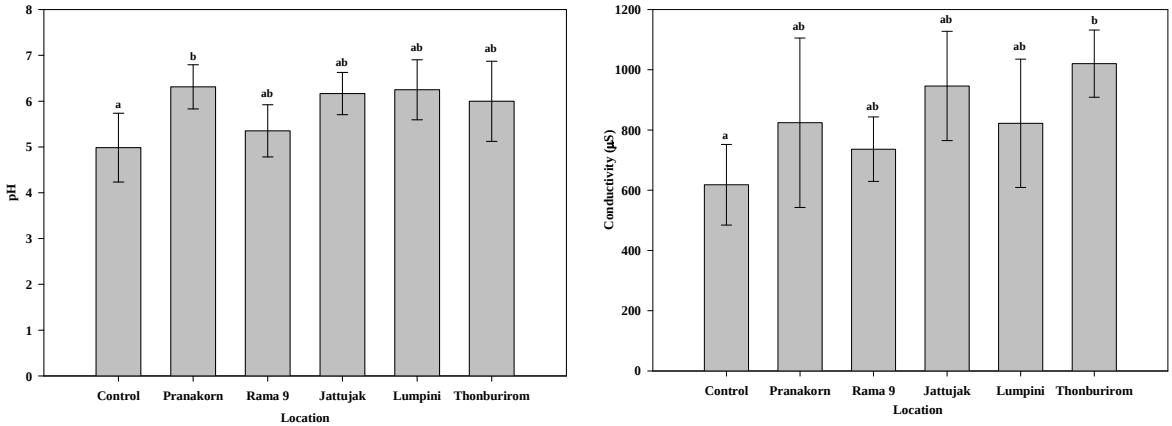

Figure 1. Bark pH and electrical conductivity from royal palm trees at the control (KRDSC) and polluted sites.

Table 2. Frequency and abundance of the lichen *Pyxine cocoes*, and heavy metals in the barks of royal palm trees at the control and the polluted sites. (different letters mean significant difference at $p < 0.001$)

	Location					
Parameters	Control	Pranakorn	Rama 9	Jattujak	Lumpini	Thonburirom
Frequency (%)	0	60	20	0	80	80
Abundance (cm^2)	0	151	353	0	233	810
Heavy metals (mg/kg)						
Pb^{2+}	**612.6**	**538**	**248.2**	**650.1**	**703.3**	**770.6**
Fe^{3+}	19.7	159.2	57.4	218.9	131.4	53.5
Zn^{2+}	17.4	23.4	26.7	128.5	88.5	49.6
Co^{2+}	6.5	69.2	17.1	27.3	2.3	0
Mn^{2+}	18.6	37.2	12	9.6	20.7	24.3
Cu^{2+}	5.4	5.6	5.7	12.1	6.8	7.6
Ni^{2+}	0.8	4.4	1.1	7.3	8.1	20.8
Cd^{2+}	2	0	4.7	1.9	0	0
Total	**683b**	**837.1bc**	**372.8a**	**1055.7d**	**961.1cd**	**926.5cd**

Discussion:

Relationship of heavy metals and bark pH

Total concentration of heavy metals in all polluted sites were higher than the control site, except Rama 9 which had remarkable low concentration. It indicated that most sites in Bangkok were polluted with heavy metals. Motor vehicles, industries and anthropogenic

activities should be the causes of emissions.[5,8,9,10] . The highest concentration of Pb (612.6 mg/kg) at the control site, whilst other heavy metals had the lowest concentration, was the

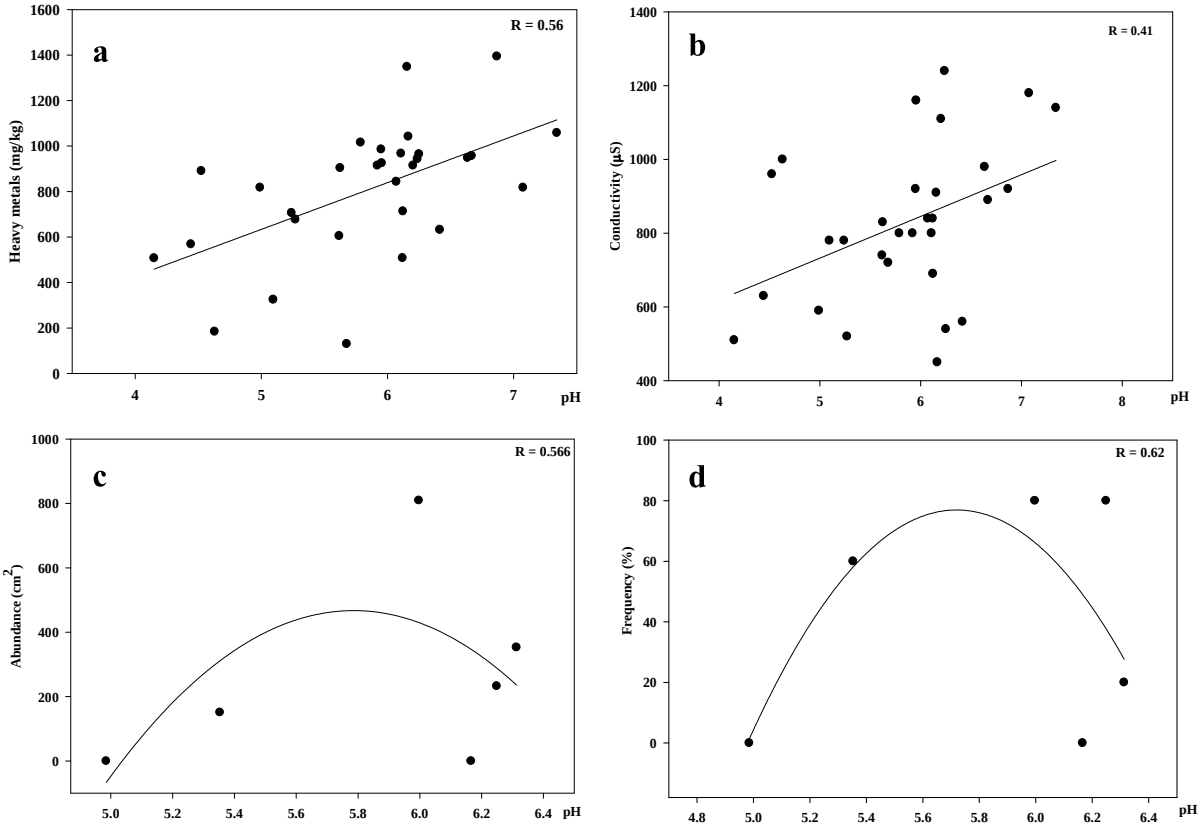

Figure 2. Relationship of a) heavy metals and bark pH, b) conductivity and bark pH, c,d) abundance and frequency of the lichen *P. cocoes* and bark pH.

main caused for totally high concentration of heavy metals in this area. This evidence suggested that sources of Pb emission were presented in the control area. They were probably leaded fuel used in the Kabinburi industrial area, which is only 45 km away or other industries that emit Pb. Anyhow, the exact cause needs to be elucidated. However, bark pH and conductivity from bark solution showed that the control site had the lowest value, which mean that this site had the smallest amount of ions. This information indicated that the control site had the lowest level of pollutants. Higher conductivities of bark solution from other sites suggested that other pollutants, possibly ions from acidic or basic compounds may be the contributing factors. In contrast, Rama 9 had the lowest concentration of heavy metals compared with all sites. This site is relatively far from traffic and, high density of trees.[11] The highest concentration of Pb at every sites, compared with other heavy metals. Agreement with obvious studies from other counties.[8,12] Although leaded gasoline was banned from motor vehicles about a decade ago. Nevertheless, it used during the past may accumulated in barks of trees because it has greater affinity, strongly attached binding sites and long resident time.[19, 20, 21, 22] Fe, Zn and Cu are often high in metropolitan areas,[8,9,10] which mainly contributed by traffic, and anthropogenic activity.8 These elements are component of the main structure of cars, as well as building, which are dense in metropolitan areas[9,10]. Mn and Ni might be from fuel additives, as well as Pb, especially in diesel fuel used in factories, and automobiles. These two metals had the highest concentration at Thonburirom, which is close

to Phrapradaeng industrial area.[9,13] Co and Cd were usually less occurred, however, motor vehicles can be source of emission such as, tire, brake plate etc.[9,13] Moreover, bark pH

had positive correlation with total heavy metals concentration and conductivity (R=0.57, 0.41 p<0.001 respectively; Figure 2a and 2b). The data indicated that increasing concentration of heavy metals correlated with high bark pH, which probable influenced epiphyte such as lichens.

Lichen distribution and bark pH

The lichen *P. cocoes*, belong to family Physciaceae, this generally benefits from high concentration of nitrogen, which often observed in urban areas.[14] Figure 2c, d demonstrated that pH 5.5-6.0 favored high abundance and frequency of this lichen.[1,2,14] Some heavy metals are essential minor nutrient, which plants and lichens require in very small quantity. High concentration obviously damages their metabolism. The study did not observe NO_x which is obviously know as major pollutant in the area that use gasoline in engines.[15,16,17,18] Lowest acidity of the royal palm bark at the control site without *P. cocoes* suggested that other pollutants, beside NO_X, could be the cause. Alternatively, higher pH of the royal palm bark at the polluted sites caused by alkaline ions or buffering capacity of the bark.

Evaluation of air quality of public parks in Bangkok

Based on the information of lichen distribution, heavy metals concentration, conductivity, bark pH as well as relatively density of traffic vehicles. Air quality of the five public parks in Bangkok could be ranked form good to poor quality in this order. Rama 9 had the best air quality because of the lowest concentration of heavy metals, bark pH and conductivity. The second was Pranakorn, which supported by the same parameters. Although this site situated in suburb area, which rather far from center of Bangkok more than Rama 9, but it has small area (80 km^2) and close to road. The third was Thonburirom, which probability exposed to Phrapradaeng industry. The pollutants, Mn and Ni, were high although traffic was low. Lumpini, situated in center of Bangkok, showed the fourth order. This park exposed to intense anthropogenic activity. Although it has large area with high density of trees, but air pollutant did not reduced. The last order showed was the Jattujak, which had the highest values of the parameters measured.

Conclusion:

Bark of the royal-palm trees and lichen were efficient bioindicator of air quality. Barks from six sites accumulated heavy metals in different quantity, which could be consequences of air quality or soil chemistry. However, the distribution of *P. cocoes* that inhabited the barks supported the conclusion of air quality among these sites. Therefore, the best to the poorest air quality were Khaohinsorn Royal Development Study Center or Rama 9, Pranakorn, Thonburirom, Lumpini and Jattujak.

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Keywords: Heavy metals, Bioindicator, Bark pH, Lichen abundant, Public parks