First International Symposium on Evaluation of Mechanisms Sustaining the Biodiversity in Lake Tonle Sap, Cambodia

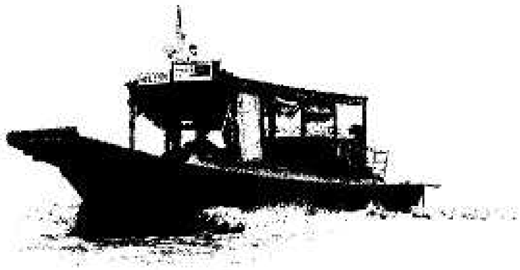
December 1 - 2, 2005

Seminar Room, Ministry of Industry,

Mines and Energy,

Phnom Penh, Cambodia

Abstracts



Teams EMSB and EMSB-u32

International Research Missions

Evaluation of Mechanisms Sustaining the Biodiversity in Lake Tonle Sap, Cambodia

First International Symposium on Evaluation of Mechanisms Sustaining the Biodiversity in Lake Tonle Sap, Cambodia

December 1 - 2, 2005

Seminar Room, Ministry of Industry, Mines and Energy,

Phnom Penh, Cambodia

The symposium is organized under the sponsorship of:

The EMSB and EMSB-u32 Teams

Department of Geology, General Department of Mineral Resources, Ministry of Industry, Mines and Energy, Kingdom of Cambodia

Department of Hydrology and River Works, Ministry of Meteorology and Water Resources, Kingdom of Cambodia

In collaboration with:

Kanazawa University, Japan

With the support of:

Japan Society for the Promotion of Science, Grant-in-Aid for International Scientific Research (15405004)

UNESCO MAB-IHP Joint Programme Ecological and Hydrological Research and Training for Young Scientist in Tonle Sap Biosphere Reserve, Cambodia: Research and Training for Young Scientists

Kanazawa University 21st Century COE Program

Hokkaido University 21st Century COE Program

Organizing and Scientific Committee

Dr. Shinji Tsukawaki (Kanazawa University, Japan)

Mr. Sotham Sieng (Department of Geology, GDMR, MIME, Cambodia)

Prof. Akifumi Ohtaka (Hirosaki University, Japan)

Mr. Hak Mao (Department of Hydrology and River Works, MMWR, Cambodia)

Prof. Yoshihiko Hirabuki (Tohoku Gakuin University, Japan)

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Mr. Yuji Araki

Graduate School of Environment and Information Sciences, Yokohama National University, Japan

Email: 02td002@ynu.ac.jp

Schedule and Programme

DAY 1 December 1, 2005

07:30 Registration

08:30 Opening Remarks (H. E. Mr. Suy Sem, Minister, Ministry of Industry, Mines and Energy, Kingdom of Cambodia)

08:45 Group Photo and Coffee Break

Ⅰ. Introduction & Ⅱ. Geology (Chair: Mr. Sieng Sotham)

09:15 Tsukawaki, S. and Members of EMSB and EMSB-u32 Teams: Introduction and Research activities of the EMSB and EMSB-u32 teams in Lake Tonle Sap, Cambodia in 2003-2005

09:30 Tsukawaki, S., Sotham, S. and Members of Tonle Sap 21 Programme: Formation of the present natural environment on Lake Tonle Sap and the lower courses of the Mekong River system in Cambodia: geological history of Cambodia during the last 20,000 years

09:45 Tsukawaki, S., Sotham, S., Sim, I., Takebayashi, H., Ooji, A., Bunnarin, B. and Sambath, T.: Lithological features of cored sediments from the southern part of Lake Tonle Sap and the Tonle Sap River

Ⅲ. Hydrology and Limnology (Chair: Prof. Akifumi Ohtaka)

10:00 Endoh, S., Fujita, K., Nakai, S., Okumura, Y., Oyagi, H., Fujii, T., Tsukawaki, S. and Monichoth, S. I.: Continuous measurement of water temperature in Lake Tonle Sap

10:15 Oyagi, H., Endoh, S., Okumura, Y., Monichoth, S. I., Tsukawaki, S., Ishikawa, T., Fujii, T., Fujita, K. and Mori, K.: Seasonal changes in water level and water quality in Lake Tonle Sap, Cambodia

10:30 Sarkkula, J., Koponen, J. and Kummu, M.: Flood pulsing and productivity factors in Tonle Sap system

10:45 Mohanti, M. and Murray, A. S.: Chilika Lake on the Bay of Bengal, Eastern India: towards a greater understanding of management of Asian lake system *Cancelled

Ⅳ. Plant Ecology (Chair: Prof. Shuichi Endoh)

11:00 Araki, Y., Powkhy, D., Hirabuki, Y., Rachna, C., Tsukawaki, S., Tomita, M. and Suzuki, K.: Floodplain vegetation under severe human impact: succession pattern and invasion of exotic mimosa in Lake Tonle Sap, Cambodia

11:15 Vanna, L.: Rice remains in the prehistoric pottery tempers of the shell midden site of Samrong Sen: implications for early rice cultivation in central Cambodia

11:30 3-minite Poster Presentation (8 posters, Chair: Prof. Shuichi Endoh)

*****************12:00 Lunch break*****************

13:30 Poster Session

Ⅴ. Civil Engineering (Chair: Prof. Yoshihiko Hirabuki)

14:30 Takebayashi, H., Luu, X. L., Egashira, S., Tsukawaki, S., Sim, I., Sambath, T., Sotham, S. and Ide, S.: Flow pattern and size distribution of bed material at Chaktomuk in Cambodia

Ⅵ. Zoology and Ichthyology (Chair: Prof. Yoshihiko Hirabuki)

14:45 Ishikawa, T., Oyagi, H., Ohtaka, A., Narita, T., Sim, I. and Tsukawaki, S.: Primary production in Lake Tonle Sap

15:00 Ohtaka, A., Katakura, H., Kamiya, T., Narita, T., Motomura, H., Ishikawa, T., Mukai, T., Kuwahara, Y., Tsukawaki, S., Sophorn, V., Rachna, C. and Vuthy, T.: Diversity of aquatic invertebrates in Lake Tonle Sap

15:15 Narita, T., Ohtaka, A., Motomura, H., Mukai, T., Ishikawa, T., Sophorn, V., Rachna, C. and Vuthy, T.: Food web structure study by natural stable isotope in Lake Tonle Sap, Cambodia - a preliminary report -

15:30 Sauth, E., Kannitha, L., Kanamori, M. and Murayama, T.: Study tour in EMSB and the research of rainfall at NIE

15:30 Coffee Break

Ⅶ. Atmospheric Sciences (Chair: Dr. Shinji Tsukawaki)

15:45 Furuuchi, M., Murase, T., Tsukawaki, S., Sotham, S. and Peou, H.: Air Pollution in Angkor Monuments Area in Cambodia

16:00 Okumura, Y., Endoh, S., Darith, E. and Oyagi, H.: Meteorological characteristics of Siem Reap City, Cambodia

16:15 Discussion (Chair: Dr. Shinji Tsukawaki)

16:45 Concluding Remarks (Dr. Shinji Tsukawaki: Head of the EMSB & EMSB-u32 Teams)

17:00 Closing Remarks (H. E. Mr. Chea Sieng Hong: Secretary of the State, Ministry of Industry, Mines and Energy, Kingdom of Cambodia)

POSTER

Le, X. T.: Tonle Sap - Mekong River and the similar systems in the Southern Vietnam

Hirabuki, Y., Araki, Y., Powkhy, D., Takehara, A., Tsukawaki, S., Suzuki, K., Sockrithy, I. and Rachna, C.: Herbaceous water-plant vegetation in flooding Lake Tonle Sap, Cambodia: distributional pattern and ecological implications

Watanabe, R., Ohtaka, A., Katakura, H., Kamiya, T., Narita, T., Motomura, H., Ishikawa, T., Mukai, T., Tsukawaki, S., Sophorn, V., Rachna, C. and Vuthy, T.: Seasonal changes of net-plankton communities in Lake Tonle Sap

Ohtaka, A. and Tsukawaki, S., Red Euglena (Euglenozoa, Euglenophyceae) in Cambodian waters.

Mukai, T., Motomura, H., Ishikawa, T., Oyagi, H., Araki, Y., Ohtaka, A., Narita, T., Tsukawaki, S., Sotham, S., Sambath, T., Bunnarin, B., Sim, I., Rachna, C. and Powkhy, D.: DNA Analysis of Fishes in Lake Tonle Sap

Motomura, H., Mukai, T., Ohtaka, A., Katakura, H., Kamiya, T., Narita, T., Ishikawa, T., Tsukawaki, S., Sotham, S., Sambath, T., Bunnarin, B., Sokhom, N., Rachna, C. and Powkhy D.: Fishes of Lake Tonle Sap and Tonle Sap River, Cambodia

Furuuchi, M., Murase, T., Tsukawaki, S., Sotham, S. and Yamashita, M.: Air Pollution in Phnom Penh: Concentration and Chemical Compositions of Ambient Particles

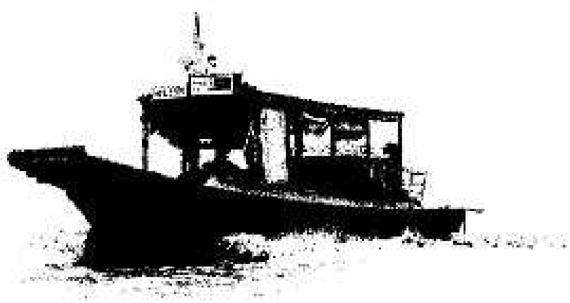
Furuuchi, M., Murase, T., Yamashita, M., Tsukawaki, S., Sotham, S., Jinno, T. and Sakai, K.: Ambient Air Temperature Distribution in Phnom Penh: Influences of Land Use and Mekong and Tonle Sap Rivers

DAY 2 December 2, 2005

Field Excursion to Southwest Coast of Cambodia

07:30 Departure at MIME
07:45 Departure at Diamond Hotel
09:30 Break
11:00 Visit Southwest Coast of Cambodia at Shihanuk Ville
12:00 Lunch
13:00 Visit Mangrove Forest
14:00 Visit a Quarry of Sandstone
15:00 Leave to Phnom Penh
16:30 Break
18:00 Arrival at Diamond Hotel
18:15 Arrival at MIME

Ⅰ. Introduction



Teams EMSB and EMSB-u32

International Research Missions

Evaluation of Mechanisms Sustaining the Biodiversity in Lake Tonle Sap, Cambodia

Introduction and Research Activities of the EMSB and EMSB-u32 Teams in Lake Tonle Sap, Cambodia: 2003-2005

Shinji Tsukawaki and Members of EMSB & EMSB-u32 Teams

Abstract

INTRODUCTION

Lake Tonle Sap, the largest lake in the Southeast Asia, is well-known that it has been closely associated with the lives and culture of the Cambodian people since the Khmer Dynastic periods. The lake is also famous as "the elastic water world" because its water area expands drastically in rainy seasons, and as "the heart of Cambodia" referring to various and multifarious freshwater organisms, edible fish in particular. Such settings hold out a promising prospect for investigations of unique freshwater eco-system in and around the lake under the control of dynamic seasonal fluctuations in water level due to alternating wet and dry seasons. However, no systematic and overall ecological researches had been made in the lake in spite of scientific and social importance of the lake has been strongly pointed out from various fields.

Two scientific programmes of "Tonle Sap 96 Project" in 1996 and "Tonle Sap 21 Programme" in 2000 - 2002 both lead by Shinji Tsukawaki of Kanazawa University cooperating with Department of Geology, General Department of Mineral Resources, Ministry of Industry, Mines and Energy, Kingdom of Cambodia were carried out to investigate the geological and environmental developments of the lake. As the result of both programmes, the history of the lake and related water system was concluded that the lake was born as small lakes in the central part of the Tonle Sap Basin at about 7,500 years B. P. and the present great lake was created by an environmental event which is a connexion of the lake with the Mekong River at around 5,500 years B. P by the rise and high-stand of global sea-level at the Holocene Optimum. Further, it is also pointed that the environment of the lake has been geologically and sedimentological stable since 5,500 years B.P. till the present time.

BACKGROUND OF EMSB TEAM

On the basis of the results of the Tonle Sap 96 and 21 programmes, and taking the results of the other related studies into account, the "Tonle Sap EMSB Programme: Evaluation of Mechanisms Sustaining the Biodiversity of Lake Tonle Sap, Cambodia" was planned and started in 2003 as a three-year cooperative research study between Cambodia and Japan supported financially by the Japan Society for the Promotion of Science, Grait-in-Aid for International Scientific Research (15405004). As for the overall surveys of the programme, field studies from

various scientific fields such as invertebrate zoology, plant ecology, physical and chemical limnology, geology and geomorphology were investigated in and around both northern and southern parts of the lake during both dry and wet seasons by regular and collaborating scientific members focusing on evaluation mechanisms sustaining the biodiversity of the lake.

In accordance with the chief aim of the EMSB Programme, zoological assemblages and their time-spatial changes of invertebrates and vertebrates fish in particular, botanical assemblages and their spatial distribution, both physical and chemical properties of lake water and their seasonal changes, and geological and geomorphological background of the lake were first investigated individually in both northern and southern parts of the lake in both dry and wet seasons to grasp peculiar characters of the lake in each field, then each second result would be referred reciprocally and summarised.

The EMSB programme is the first systematic and scientific research of Lake Tonle Sap concerning with the biodiversity of the lake. According to the expected result of the programme, mechanisms sustaining the great biodiversity of Lake Tonle Sap will be explicated, and the result will provide a certain information and knowledge to develop, preserve and maintain the natural environment of the lake.

BACKGROUND OF EMSB-U32 TEAM

The overall field surveys of the EMSB programme had been successfully accomplished in November 2003 and May 2004. However, since marked year-round change of the water environment and related seasonal fluctuations of ecosystem in the lake had been recognized afresh during the course of the surveys, countermeasures for them became a prompt subject of discussion within the team. Because the overall field surveys of the programme had been scheduled only in seasons of both lowest and highest water-level of the lake, execution of some additional surveys between the seasons were needed to detect the above-mentioned changes. Further, generally speaking it was necessary to carry out a number of years observations for all scientific researches, arrangements of long-term observations were urgently necessary for the lake to sustain its plentiful present environment, the great biodiversity in particular.

In spite of importance of Lake Tonle Sap in various meaning had been accepted as being beyond doubt and the EMSB programme which was the first systematic research of the lake concerning with the biodiversity of the lake had started already, there were two problems awaiting prompt solution as stated above. Judging from the present situations, encouragement of young scientists and/or technical experts such as graduate students and research associates of universities and/or institutions in both Japan and Cambodia in each scientific field should be the best means to settle the problems. They would be able to concentrate on the research of the lake, and would be able to carry out the long-term observation and monitoring of the lake.

Accordingly, a new research team "Tonle Sap EMSB-u32 Programme: UNESCO MAB-IHP Joint Programme Ecological and Hydrological Research and Training for Young Scientist in Tonle Sap Biosphere Reserve, Cambodia: Research and Training for Young Scientists" consisting of young researchers and technical experts as a supplement team of the EMSB team but the main body in future has set up. The u32 team worked tightly cooperating with the EMSB team during its first year activity under a guidance of the EMSB team to learn research techniques and to acquire experience to work in the lake. After the period, the team started their research in the lake as the occasion demands corresponding to delicate seasonal fluctuation of the lake for two years.

It was expected that the members of the u32 team would understand the importance of interdisciplinary research to elucidate the harmony between ecosystem and natural environment of the lake through the fieldwork in collaboration. The objectives and goal of the EMSB-u32 team should be encouragement and promotion of young researchers and technical experts to improve and continue interdisciplinary scientific research on the lake.

RESULTS OF THE EMSB AND EMSB-U32 TEAMS

In spite of some scientific descriptions and analyses have been under the examination, preliminary results of the EMSB and EMSB-u32 Teams will be presented in the symposium. The final results will be compiled and published in 2006.

APPENDICES

MEMBER OF EMSB AND EMSB-U32 TEAMS

Regular Members of the EMSB Team

Shinji Tsukawaki (Head of the Team, Kanazawa University: Geology)
Akifumi Ohtaka (Hirosaki University: Zoology)
Haruo Katakura (Hokkaido University: Zoology)
Takahiro Kamiya (Kanazawa University: Zoology)
Yoshihiko Hirabuki (Tohoku Gakuin University: Plant Ecology)
Shuichi Endoh (Shiga University: Hydrology)
Yasuaki Okumura (Osaka Electro-Communication University: Hydrology)
Sieng Sotham (Department of Geology, GDMR, MIME: Geology)
Ang Cheoulean (Royal University of Fine Arts: Cultural Anthropology)

Collaborating Members of the EMSB Team

Tetsuya Narita (Kyoto University)
Hiroyuki Motomura (Kagoshima University)
Kanichi Mita (Shiga Prefecture)

Cooperating Members of the EMSB and EMSB-u32 Teams

Masami Furuuchi (Kanazawa University)
Hiroshi Takebayashi (University of Tokushima)

Member of the EMSB-u32 Team

Yuji Araki (Yokohama National University: Plant Ecology)
Hideo Oyagi (Nihon University: Hydrology)
Toshiyuki Ishikawa (Hokkaido University: Zoology)
Takahiko Mukai (Gifu University: Zoology)
Sim Im (Department of Geology, General Department of Mineral Resources, Ministry of Industry, Mines and Energy: Regional Geology)
Monichoth So Im (Department of Hydrology and River Works, Ministry of Meteorology and Water Resources, Kingdom of Cambodia: Hydrology)
Rachna Chhay (Department of Monument and Archaeology, APSARA Authority: Archaeology)

RECORDS OF RESEARCH MISSIONS

First Research Mission of the EMSB Team in Siem Reap, October - November 2003

Zoology

Akifumi Ohtaka (Hirosaki University)
Haruo Katakura (Hokkaido University)
Tetsuya Narita (Kyoto University)
Kei Matsubayashi (Hokkaido University)
Takahiro Kamiya (Kanazawa University)
Im Sokrithy (Department of Culture and Research, APSARA)
Ven Sophorn (Department of Culture and Research, APSARA)

Plant Ecology

Yoshihiko Hirabuki (Miyagi University of Education)

Akihide Takehara (Iwate University)
Drong Powkhy (Peace-in Tour, Siem Reap)

Hydrology and Limnology
Shuichi Endoh (Shiga University)
Yasuaki Okumura (Osaka Electro-Communication University)
Ea Darith (Department of Culture and Research, APSARA)

Geology and Archaelogy
Shinji Tsukawaki (Kanazawa University)
Sieng Sotham (Department of Geology, GDMR, MIME)
Akihito Ooji (Kanazawa University)
Ly Vanna (Kanazawa University)
Hidekazu Chino (Japan Broadcasting Corporation)
Midori Kato (Niigata University)

<u>Optional Research Mission of the EMSB Team in Siem Reap and Kompong Chhnang, January 2004</u>

Zoology
Tetsuya Narita (Kyoto University)
Hiroyuki Motomura (National Science Museum)
Drong Powkhy (Peace-in Tour, Siem Reap)

Geology
Shinji Tsukawaki (Kanazawa University)
Yasukuni Ookubo (Geological Survey, Japan)
Ben Bunnarin (Department of Geology, GDMR, MIME)

<u>Second Research Mission of the EMSB Team in Siem Reap, May 2004</u>

Zoology
Akifumi Ohtaka (Hirosaki University)
Tetsuya Narita (Kyoto University)
Ryusei Watanabe (Hirosaki University)
Im Sokrithy (Department of Culture and Research, APSARA)

Ven Sophorn (Department of Culture and Research, APSARA)

Botany and Plant Ecology

Yoshihiko Hirabuki (Miyagi University of Education)
Akihide Takehara (Iwate University)
Drong Powkhy (Peace-in Tour, Siem Reap)
Chhay Rachna (Department of Culture and Research, APSARA)

Hydrology and Limnology

Shuichi Endoh (Shiga University)
Yasuaki Okumura (Osaka Electro-Communication University)
Ea Darith (Department of Culture and Research, APSARA)
Kosuke Fujita (Shiga University)
Satoko Nakai (Shiga University)

Geology

Shinji Tsukawaki (Kanazawa University)
Sieng Sotham (Department of Geology, GDMR, MIME)
Yuko Ishikawa (Kanazawa University)

Kick-off Research Mission of the EMSB-u32 Team in Kompong Chhnang and Siem Reap, November 2004

Shinji Tsukawaki (Kanazawa University)
Yuji Araki (Yokohama National University)
Sieng Sotham (Department of Geology, GDMR, MIME)
Im Sim (Department of Geology, GDMR, MIME)

Joint Research Mission of the EMSB (3rd) and the EMSB-u32 (1st) Teams in Siem Reap and Kompong Chhnang, November- December 2004

Zoology

Akifumi Ohtaka (Hirosaki University)
Haruo Katakura (Hokkaido University)
Tetsuya Narita (Kyoto University)
Hiroyuki Motomura (National Science Museum)

Takahiko Mukai (Gifu University)
Toshiyuki Ishikawa (Hokkaido University)
Yasuo Mukai (Osaka Prefectural University)
Yasuhiro Kuwahara (Abashiri Fisheries Office)
Tan Vuthy (Department of Demography, APSARA)

Botany and Plant Ecology
Yoshihiko Hirabuki (Miyagi University of Education)
Yuji Araki (Yokohama National University)
Drong Powkhy (Peace-in Tour, Siem Reap)
Chhay Rachna (Department of Monument and Archaeology, APSARA)

Hydrology and Limnology
Shuichi Endoh (Shiga University)
Yasuaki Okumura (Osaka Electro-Communication University)
Hideo Oyagi (Nihon University)
Tomoyasu Fujii (Nara University of Education)
Ea Darith (Department of Culture and Research, APSARA)
So Im Monichoth (Department of Hydrology and River Works, MMH)
Kosuke Fujita (Shiga University)
Satoko Nakai (Shiga University)

Geology
Shinji Tsukawaki (Kanazawa University)
Sieng Sotham (Department of Geology, GDMR, MIME)
Im Sim (Department of Geology, GDMR, MIME)
Akihito Ooji (Kanazawa University)
Toshiko Shiozaki (Obirin University)

Optional Research Mission of the EMSB-u32 Team in Siem Reap and Kompong Chhnang, January 2005

Shinji Tsukawaki (Kanazawa University)
Yuji Araki (Yokohama National University)
Hideo Oyagi (Nihon University)
Ben Bunnarin (Department of Geology, GDMR, MIME)

Second Research Mission of the EMSB-u32 Team in Kompong Chhnang and Siem Reap, February - March 2005

Zoology

Takahiko Mukai (Gifu University)
Toshiyuki Ishikawa (Hokkaido University)

Botany and Plant Ecology

Yuji Araki (Yokohama National University)
Drong Powkhy (Peace-in Tour, Siem Reap)
Chhay Rachna (Department of Monument and Archaeology, APSARA)

Hydrology and Limnology

Hideo Oyagi (Nihon University)
So Im Monichoth (Department of Hydrology and River Works, MMH)

Geology and Civil Engineering

Shinji Tsukawaki (Kanazawa University)
Im Sim (Department of Geology, GDMR, MIME)
Ben Bunnarin (Department of Geology, GDMR, MIME)
Akihito Ooji (Kanazawa University)
Kenichi Sakai (Kanazawa University)
Hiroshi Takebayashi (University of Tokushima)
Luu Xuan Doc (Ritsumeikan University)
Touch Sambath (Department of Geology, GDMR, MIME)

Atmospheric Sciences

Masami Furuuchi (Kanazawa University)
Takeo Sakano (Kanazawa University)

Joint Research Mission of the EMSB (4th) and the EMSB-u32 (3rd) Teams in Siem Reap and Kompong Chhnang, May - June 2004

Zoology

Akifumi Ohtaka (Hirosaki University)

Tetsuya Narita (Kyoto University)
Hiroyuki Motomura (National Science Museum)
Takahiko Mukai (Gifu University)
Toshiyuki Ishikawa (Hokkaido University)
Ryusei Watanabe (Hirosaki University)
Takayuki Watanabe (University of Tokyo)

Botany and Plant Ecology
Yuji Araki (Yokohama National University)
Drong Powkhy (Peace-in Tour, Siem Reap)
Chhay Rachna (Department of Monument and Archaeology, APSARA)

Hydrology and Limnology
Yasuaki Okumura (Osaka Electro-Communication University)
Hideo Oyagi (Nihon University)
Tomoyasu Fujii (Nara University of Education)
Ea Darith (Department of Culture and Research, APSARA)
So Im Monichoth (Department of Hydrology and River Works, MMH)
Kosuke Fujita (Shiga University)

Geology and Civil Engineering
Shinji Tsukawaki (Kanazawa University)
Ben Bunnarin (Department of Geology, GDMR, MIME)
Im Sim (Department of Geology, GDMR, MIME)
Hiroshi Takebayashi (University of Tokushima)

Atmospheric Sciences
Masami Furuuchi (Kanazawa University)
Takeo Sakano (Kanazawa University)
Takahiro Murase (Kanazawa University)
Mika Komori (Kanazawa University)
Touch Sambath (Department of Geology, GDMR, MIME)

Fourth Research Mission of the EMSB-u32 Team in Kompong Chhnang and Siem Reap, July - August 2005

Zoology

Takahiko Mukai (Gifu University)
Toshiyuki Ishikawa (Hokkaido University)
Hiroyuki Motomura (Australian Museum)
Ben Bunnarin (Department of Geology, GDMR, MIME)

Botany and Plant Ecology

Yuji Araki (Yokohama National University)
Yoshihiko Hirabuki (Tohoku Gakuin University)
Mizuki Tomita (Yokohama National University)
Drong Powkhy (Peace-in Tour, Siem Reap)
Chhay Rachna (Department of Monument and Archaeology, APSARA)

Hydrology and Limnology

Hideo Oyagi (Nihon University)
So Im Monichoth (Department of Hydrology and River Works, MMH)

Geology and Civil Engineering

Shinji Tsukawaki (Kanazawa University)
Im Sim (Department of Geology, GDMR, MIME)
Kenichi Sakai (Kanazawa University)
Yukimi Takeshita (Kanazawa University)
Hiroshi Takebayashi (University of Tokushima)
Touch Sambath (Department of Geology, GDMR, MIME)

Atmospheric Sciences

Masami Furuuchi (Kanazawa University)
Takahiro Murase (Kanazawa University)
Tsuyoshi Jinno (Kanazawa University)
Touch Sambath (Department of Geology, GDMR, MIME)

Ⅱ. Geology

Sand from the Tonle Sap River

Cored sediment from Lake Tonle Sap

Formation of the Present Natural Environment on Lake Tonle Sap and the Lower Course of the Mekong River System in Cambodia
- Geological History of Cambodia during the Last 20,000 years-

Shinji Tsukawaki[1], Sieng Sotham[2] and Members of Tonle Sap 21 Programme[3]

Abstract

Introduction

During the course of the programme “Tonle Sap 21”, twelve short and six long cores were recovered from the northern part of Lake Tonle Sap to reconstruct environmental history of the lake and its environs. On the other hand, about 100 surface sediment samples were obtained to grasp compositional features of microorganisms and surface sediments, and their spatial distribution in the present lake floor and adjacent fluvial systems such as the Tonle Sap, Mongkul Borey and Mekong rivers.

Cored Sediments

Important information was obtained from short corings of the first survey. Most short cores from the marginal parts of northern Lake Tonle Sap lack the lower compact mud layer recognised during the "Tonlesap 96 Project" as the lake sediments deposited before the connection with the Mekong River. However, because semi-consolidated clayey sand or sandy clay, interpreted as basement strata of the present lacustrine sediments, was recovered in all cores, it is inferred that Lake Tonle Sap was considerably smaller before the connection with the Mekong River at about 5.5 Ka than at the present time.

A 340 cm thick sedimentary section, including basement strata, was recovered by long coring in the central part of northern Lake Tonle Sap during the second survey. Radiocarbon dating of the longest core revealed that the sediments continuously covered the period from 7.6 Ka to 5.5 Ka. Micropalaeontological analysis using diatoms and palynology from the cored sediments clearly indicated that, in spite of the recognition of some fluctuations in the diatom

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[3] Dallas C. Mildenhall (Geological and Nuclear Science, New Zealand), Motoyoshi Oda (Tohoku University, Japan), Fumio Akiba (JAPEX, Japan), Takahiro Kamiya (Kanazawa University, Japan), Masafumi Okawara (Iwate University, Japan), Michio Kato (Kanazawa University, Japan), Sambath Touch (GDMR, Cambodia), Ben Bunnarin (GDMR, Cambodia), Sim Im (GDMR, Cambodia)

flora, the lake has been a freshwater lake through its history, and no major vegetational differences were detected over the past 7.6 Ka years.

Surface Sediments

On the other hand, surface sediments obtained from the whole area of the lake revealed the spatial distribution of recent ostracods. Further, composition and provenance of clay minerals of the present lake were investigated using the surface sediments of the lake and those from adjacent water areas.

Discussion

Although some studies are still under investigation, the environmental changes and geological development of Lake Tonle Sap and the lower course of the Mekong River during the last 10,000 years can be summarized. Lake "Palaeo-Tonle Sap" appeared at about 7.6 Ka, and it existed for a period from 7.6 to 5.5 Ka. The lake was a considerably smaller freshwater lake or lakes, rather than the large lake of the present time, situated in the central axis area of the modern Lake Tonle Sap. At that time the palaeo-lake(s) was isolated from the major fluvial system in the Indochina Peninsula such as the Mekong River and muddy sediments derived mainly from alluvial plains around the lake were filling up the lake(s). Because of the connection of the lake with the Mekong River, probably caused by the rapid rise of sea-level after the Last Glacial Maximum and its high-stand at the Holocene Climatic Optimum, the present environment of Lake Tonle Sap appeared at 5.5 Ka and the environment has existed continuously till the present day.

Conclusion and Open Subjects

The exact shape and topography of Lake Palaeo-Tonle Sap still remains in question. Thus, shallow water seismic surveys should be carried out in the whole area of the lake to reveal palaeogeography of the lake during the period from 7.6 to 5.5 Ka. Further, since the basement strata in the long coring sites can be interpreted sedimentologically as sub-aqueous deposits, a long drilling programme in the central part of the lake should be made in order to develop the multiple history of the lake.

Keywords: Lake Tonle Sap, palaeoenvironment, environmental history, Cambodia, sediment core

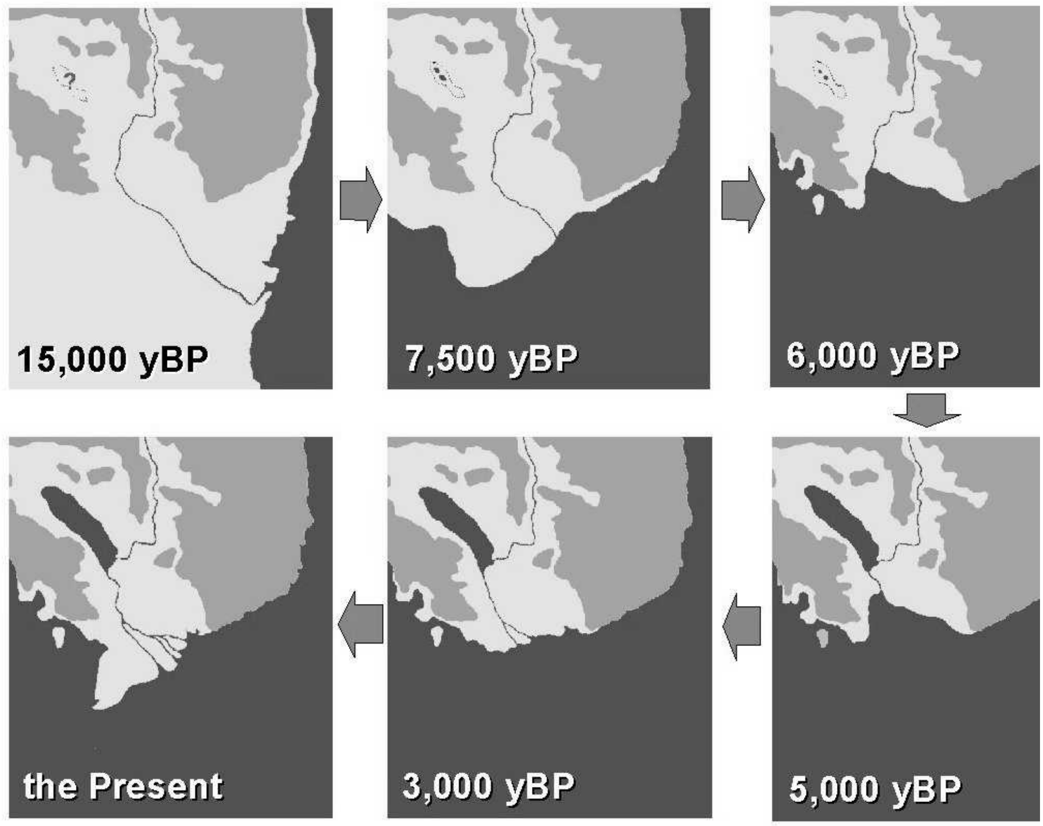

Fig. Environmental change of Lake Tonle Sap, Cambodia during the last 15,000 years.

Lithological Features of Cored Sediments from the Southern Part of Lake Tonle Sap and the Tonle Sap River, Cambodia

Shinji Tsukawaki[2], Sieng Sotham[2], Im Sim[2], Hiroshi Takebayashi[3], Akihito Ooji[4],
Ben Bunnarin[2] and Touch Sambath[2]

Abstract

Introduction

In spite of the lithological features of the bottom sediment of the northern part of Lake Tonle Sap have been already known and reported by the Tonle Sap 21 Team in 2002, they of the southern part and the Tonle Sap River have been left pending. Thus, an 160-cm-long Phleger type gravity corer with an about 16 kg weight was utilized to obtain cored sediments from these areas to grasp lithological features of these areas. Nine and ten cores were successfully recovered from the southern part of the lake and the lower courses of the Tonle Sap River, respectively (Tables 1 and 2).

Southern Part of Lake Tonle Sap

The cores EMSB3-TS1, -TS2, and –TS3 from the central part of the southern part of the lake are composed of upper soft homogeneous olive grey sandy mud with thin intercalations of molluscan shell layer and lower compact greenish grey mud with biogenic disturbance. A charcoal concentration layer is recognized on and above the boundary between them. The upper 20 cms of the upper sandy mud is soupy. The core EMSB-TS4 consists of upper soft homogeneous olive grey sandy mud with thin intercalations of molluscan shell layer, middle compact greenish grey mud with biogenic disturbance, and lower bluish grey hard clay. On the other hand, the cores EMSB-TS5, -TS6, and TS-7 from the eastern marginal part of the area are composed of upper soft homogeneous olive grey sandy mud with thin intercalations of molluscan shell layer and lower bluish grey hard clay. Only the soft homogeneous olive grey sandy mud with intercalating layers of molluscan shell and charcoal is recognizable in the core EMSB-TS8. The core EMSB-TS9 from the delta area of the southeastern marginal part of the lake consists of reddish brown semi-consolidated clay with biogenic disturbance.

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Lower Courses of the Tonle Sap River

The cores EMSB4-TSR-1', -TSR2, -TSR3, -TSR4 from the middle reach of the sampling area are composed mainly of soft homogeneous brownish grey sandy mud with thin, about 1 cm thick, intercalations of fine-grained sand. Molluscan shell layers and plant debris layers are intercalated in these cores. The cores EMSB4-TSR5, -TSR6 from the lower reach of the area consist mainly of soft homogeneous brownish grey sandy mud with 1 – 4 cms thick, intercalations of fine- to medium-grained sand. A normal grading is recognized in thick sand layers, and the basal planes of them are erosional. The core EMSB4-TSR7 obtained from the lowermost reach of the area closed to the junction with the Mekong River is composed of very irregular or mottled layers of fine- to medium-grained sand, coarse-grained sand, and homogeneous soft greyish brown mud. On the other hand, the cores EMSB4-TSR10, and -TSR9 recovered from the upper reach of the area are composed of soft homogeneous brownish grey slightly sandy mud with very thin intercalations of very fine-grained sand and plant debris. However, no sand layers are recognizable in the core EMSB4-TSR8 obtained from the uppermost reach. Consolidated sandstone is detected on the surface of the site EMSB4-TSR1 and about 42 cms deep from the bottom surface of the site EMSB4-TSR9.

Discussion and Conclusion

On the basis of lithology and sedimentological analysis of the cores from the northern part of Lake Tonle Sap, Tsukawaki et al. (2002) reported that two small lakes "Palaeo-Tonle Sap" were situated in the area before the connexion of the lake with the Mekong River at about 5,300 years B.P. Lithological feature of the lower parts of the cores EMSB3-TS1, -TS2 and –TS3, and the middle part of the core EMSB3-TS4 are same with that of the cores from the northern part. Accordingly, it is inferred that a small lake was also situated in the southern part of the lake.

The cores from the lower courses of the Tonle Sap River are composed mostly of soft homogeneous brownish grey sandy mud with intercalations of thin sand layers with exception of the core from the lowermost reach which consists of irregular alternation of sand and mud. Thickness of the sand layers and average grain size of them have tendencies to thin and fine in accordance with distance from the junction with the Mekong River.

Table 1. List of cored sediments from the southern part of Lake Tonle Sap.

Site No (South Lake)	Date	Time	Latitude (N)	Longitude (E)	Depth (m)	Core Length (cms)	Remarks
EMSB3-TS1	07/12/2004	09:54	12 35 01.2	104 20 03.3	4.9	89	upper 60 cms soft olive grey sandy mud, lower greenish grey compact mud
EMSB3-TS2		10:44	12 37 31.2	104 20 04.3	5.1	87	upper 42 cms soft olive grey sandy mud, lower greenish grey compact mud
EMSB3-TS3		11:27	12 40 02.0	104 20 05.3	5.0	78	upper 35 cms soft olive grey sandy mud, lower greenish grey compact mud
EMSB3-TS4		12:06	12 42 30.8	104 20 03.6	5.1	83	upper 30 cms soft olive grey sandy mud, middle 42 cms greenish grey compact mud, lower bluish grey clay
EMSB3-TS5		13:30	12 42 29.7	104 25 03.1	5.0	62	upper 34 cms soft olive grey sandy mud, lower bluish grey clay
EMSB3-TS6	08/12/2004	10:17	12 40 02.0	104 25 01.6	5.2	49	upper 35 cms soft olive grey sandy mud, lower bluish grey clay
EMSB3-TS7		11:22	12 37 29.4	104 24 21.2	4.8	66	upper 50 cms soft olive grey sandy mud, lower bluish grey clay
EMSB3-TS8		12:06	12 34 59.1	104 24 57.0	4.5	82	sof olive grey sandy mud with intercalations of shell layer
EMSB3-TS9		13:16	12 32 33.7	104 22 28.4	4.5	30	reddish brown compact clay with biogenic disturbance

Table 2. List of cored sediments form the lower courses of the Tonle Sap River.

Site No (South Lake)	Date	Time	Latitude (N)	Longitude (E)	Depth (m)	Core Length (cms)	Remarks
EMSB4-TSR1	30/05/2005	10:57	11 42 59.6	104 50 36.2	11.9	1	consolidated sandstone
EMSB4-TSR1'		11:09	11 43 00.2	104 50 39.0	8.4	69	brownish grey sandy mud with thin intercalations of f. sand and shell fragments
EMSB4-TSR2		11:48	11 40 20.9	104 51 40.9	11.1	57	brownish grey sandy mud with thin intercalations of f. sand and shell fragments
EMSB4-TSR3		12:35	11 38 15.6	104 53 43.4	11.1	78	brownish grey sandy mud with intercalations of f. sand
EMSB4-TSR4		13:00	11 37 20.1	104 55 04.7	15.5	65	brownish grey sandy mud with thin intercalations of f. sand
EMSB4-TSR5		13:25	11 36 00.9	104 55 30.0	10.5	53	upper 34 cms brownish grey sandy mud, lower brownish grey muddy sand
EMSB4-TSR6		13:45	11 34 42.1	104 55 50.2	9.7	42	upper 15 cms and lower 10 cms brownish grey muddy sand, middle sandy mud
EMSB4-TSR7		14:05	11 33 40.8	104 56 29.6	15.4	30	irregular alternating layers of f.- m. sand and soft greyish brown mud
EMSB4-TSR8	01/06/2005	09:02	11 50 51.9	104 48 18.7	10.9	73	homogeneous brownish grey slightly sandy mud with plant debris
EMSB4-TSR9		09:35	11 48 12.9	104 49 01.5	9.3	43	homogeneous brownish grey slightly sandy mud, base consolidated sandstone
EMSB4-TSR10		10:05	11 45 33.7	104 50 00.2	9.2	69	homogeneous brownish grey sandy mud with an intercalation of m. sand

Ⅲ. Hydrology and Limnology

On the Way

Continuous Measurement of Water Temperature in Lake Tonle Sap

Shuichi Endoh[3], Kosuke Fujita[1], Satoko Nakai[1], Yasuaki Okumura[2], Hideo Oyagi[3], Tomoyasu Fujii[4], Shinji Tsukawaki[5] and So Im Monichoth[6]

Abstract

Water temperature has been continuously measured off Siem Reap and Kampong Chhnang for more than one year since May 2004. Two kinds of thermometers were used, that is, the Compact CT Meter produced by Alec Electronics, Japan, and Hobo Water Temp Pro produced by Onset Computer, USA. Data were sampled every 10 or 20 minutes and stored in the loggers attached by thermometers.

Daily mean value of water temperature has its maximum of 33 degrees in centigrade in May, and has a minimum of 25 degrees in January. Water temperature changes mainly related to air temperature change. For example, water temperature suddenly decreased from 30 to 25 degrees on 5th March 2005 due to air temperature drops. Daily change of water temperature is about 1 degree in rainy season and 3-5 degrees in dry season. This is due to the change of heat content of water volume caused by water depth change. Thermal stratification is generally weak up to 1 degree.

Clear inferior mirage was observed on highly turbid water in May, 2004. This mirage is considered to be created by the increase of surface water temperature caused by intense sunshine, calm wind and suspended dense soil in the water.

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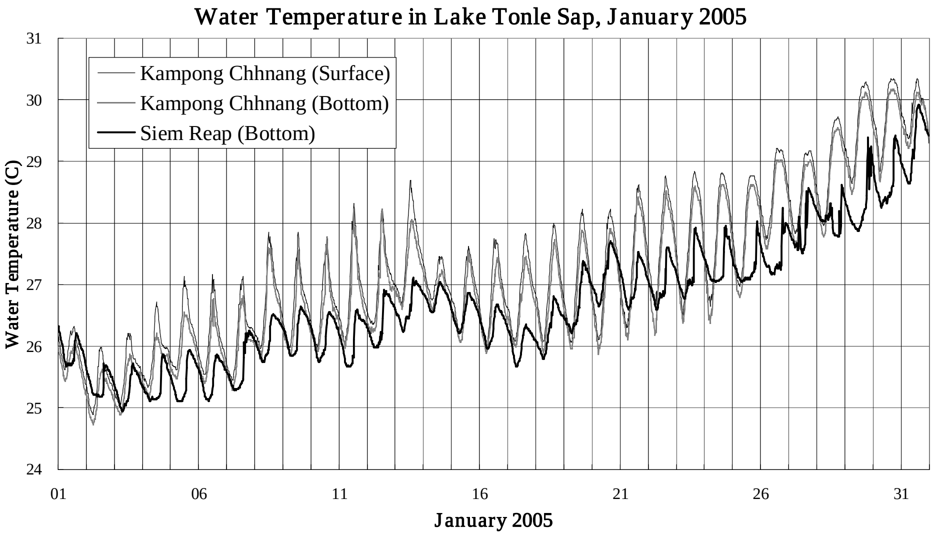

Water Temperature in Lake Tonle Sap, January 2005
Kampong Chhnang (Surface)
Kampong Chhnang (Bottom)
Siem Reap (Bottom)
Water Temperature (C)
31
30
29
28
27
26
25
24
01
06
11
16
21
26
31
January 2005

Inferior mirage of Phunun Kraom, Siem Reap (May 8, 2004)

Seasonal changes in water level and water quality in Lake Tonle Sap, Cambodia

Hideo Oyagi[4], Shuichi Endoh[2], Yasuaki Okumura[3], So Im Monichoth[4], Shinji Tsukawaki[5], Toshiyuki Ishikawa[6], Tomoyasu Fujii[7], Kosuke Fujita[2] and Kazuki Mori[1]

Abstract

A large-scale regional development including Lake Tonle Sap and the Mekong River basin has been recently planned in Southeast Asian. In addition, tropical lowland is a fragile area where global climatic change has a great effect on its physical environment. From such point of view, fundamental data on physical as well as human conditions should be collected and scientifically analyzed. The purpose of the present study is to evaluate the changes in water level and physicochemical properties of Lake Tonle Sap as affected by both seasonal differences in precipitation and human activity. It is important to make clear the hydrological characteristics and their factor in Lake Tonle Sap as a basic study in order to advance the environmental preservation in the Mekong River basin.

Tonle Sap is the largest lake in area in Southeast Asia with remarkable characteristics of seasonal changes in water level extending about 10 m. Furthermore, this lake is known for diverse biota and has a close relation to the society, culture and a life of people in Cambodia. In addition, Lake Tonle Sap has a function of flood prevention as natural retarding basin by connecting the Mekong River to Tonle Sap River.

Two transverse surveys stations on N-S and NW-SE directions were established for both northern and southern parts of Lake Tonle Sap. A measurement on vertical profile of water temperature, dissolved oxygen, pH, chlorophyll-a, turbidly and electric conductivity of lake water was conduct. Water samples were collected in the lake and the major fluvial systems including Tonle Sap River and some tributaries. Self recording system for water level and temperature was installed from November 2004 at the observation towers in both northern and southern parts of the lake.

Changes in water level from November 2004 to May 2005 for season show no big difference between northern and southern parts of the lake. The maximum depth of the lake was

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about 5.5 m in November 2004, and about 0.5 m in May 2005, respectively. The average rate of lowering of water level from November 2004 to March 2005 was 5.1 cm/day, and this value decreased to 0.7 cm/day from March to May 2005. The maximum water depth in 2004 is calculated as 6.5 m showing much smaller value compared with that in normal year.

Electrical conductivity of water ranges 80 – 100μS/cm for Lake Tonle Sap, 10 – 80μS/cm for inflowing rivers, and 200μS/cm for Mekong River, respectively. Water quality is characterized as bicarbonate-calcium for both Lake Tonle Sap and the Mekong River. Therefore, it is considered that inflowing river water has an effect of dilution for lake water. Water quality of inflowing rivers has a different composition as compared with that of Lake Tonle Sap. By comparing water quality from January to May under the low water level conditions with that in November, difference is mainly recognized in the northern parts of the lake. In addition, such a tendency is typical at the northern observation tower. It is pointed out that the increase in the ratio of chloride and sodium in dry season is caused by anthropogenic contamination.

The primary source of water supply to lake water in dry season derives from inflowing tributaries including Siem Reap River. It is concluded that changes in water quality in dry season is induced by the increase of discharge from inflowing tributaries attendant with lowering of lake water level.

Flood pulsing and productivity factors in Tonle Sap system

Sarkkula, J[5]., J. Koponen[2] and M. Kummu[3]

Abstract

The Tonle Sap Lake with its floodplain is an integral part of the Mekong River system (Figure 1) and among the most productive ecosystems in the world (e.g. Bonheur, 2001; Lamberts, 2001; van Zalinge et al., 2003). For many of the Mekong fish species, the floodplain of the lake, and particularly the riparian flooded forest and shrublands, offers ideal conditions for feeding, breeding and rearing their young (Poulsen et al., 2002). The lake also operates as a natural flood water reservoir for the lower Mekong Basin, offering flood protection and assuring the dry season flow to the Mekong Delta.

The monsoon floods of the Mekong River are a key driver of the Tonle Sap Lake ecosystem. This pulsing system together with large floodplain, rich biodiversity, and high annual sediment and nutrient fluxes from Mekong makes the lake one of the most productive freshwater ecosystems in the world (Kummu et al., 2006). The main productivity factors in the lake are:

- Flooding
- Phytoplankton
- Plant ecosystem, flooded forest, decomposition
- Role of aquatic and terrestrial production
- Sediment / nutrient supply from Mekong and Tonle Sap tributaries, sedimentation

The fish catches have been recently used to measure the productivity of the Tonle Sap system. However, according to Lamberts (2006) the fish catches are not suitable indicator for the ecosystem productivity as those depend on so many factors. Lamberts (2006) concludes that "Quantifying and monitoring the basic processes that maintain ecosystem productivity is probably the only meaningful thing to do, taking into consideration the practical limitations mentioned." The factors that determine the production potential of flood pulsed ecosystems are known from the Amazon River Basin (Junk, 1997; Junk et al., 1989). According to Lamberts (2006) an integrated ecosystem productivity indicator should be developed based on existing data and knowledge that could easily be continued and updated:

- hydrodynamic characteristics of the flood pulse (timing, modality, speed, height,

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duration),

- sedimentation,
- flooded vegetation cover and composition
- fish migration obstacles.

During the WUP-FIN project (WUP-FIN, 2003) the mathematical flow models have been applied to the Tonle Sap Lake. The models are a three dimensional (3D) EIA Flow Model for the detailed hydrodynamic studies, and 3D EIA Water Quality Model for calculating the transport and concentrations of a selected water quality parameters and hazardous materials (Koponen et al., 1992; 2004; 2003). Model outputs for both real and hypothetical scenarios include e.g.

- tributary inflows
- 3D flow speed and direction
- flooding characteristics as flood arrival date, flood duration and flood depth
- dissolved oxygen concentrations
- suspended sediment concentrations and net sedimentation
- larvae and juvenile fish drift
- pollution dispersion, e.g. from floating villages

The model results can be used to support the productivity estimations of the Tonle Sap Lake and to predict the possible changes in it due to the local and Mekong upstream development.

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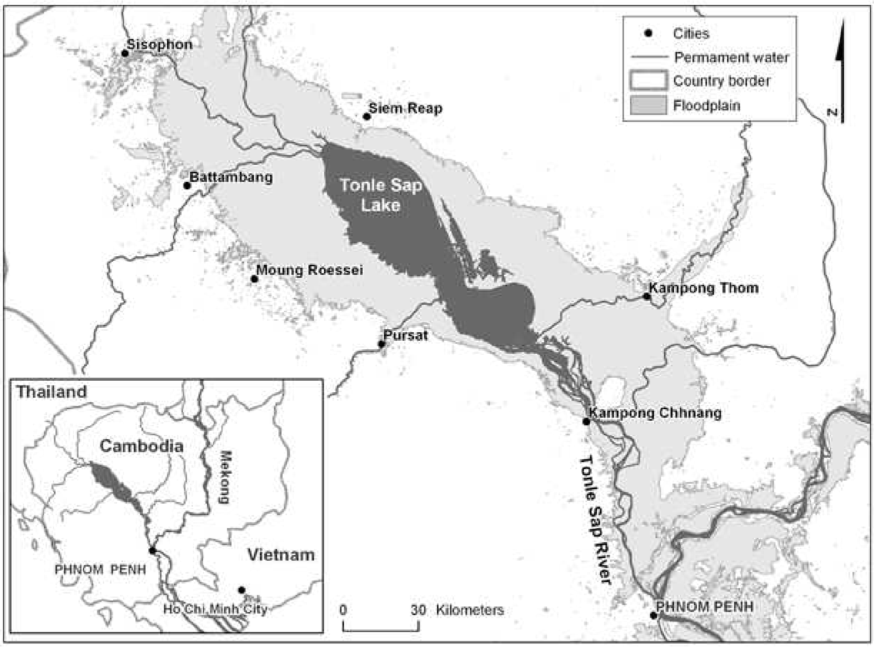

Figure 1. Tonle Sap Lake and its floodplain (Lamberts, 2006).

CANCELLED

Chilika lake on the Bay of Bengal, eastern India: Towoards a greater understanding of management of Asian lake system

M. Mohanti[6] and A.S. Murray[2]

Abstract

Chilika lagoonal lake on the Bay of Bengal, east coast of India (Orissa State) is the largest brackish water wetland – complex of Asia, being noted as a Ramsar site of national and International importance. This lagoon is separated from the Bay of Bengal by a sandy barrier-spit system ca. 60km long and ca. 150m wide associated with backshore sand dunes. An inlet / mouth in the barrier in the northeastern part facilitates semi-diurnal tidal exchange with the lake. The lake is fed by the fresh water of few rivers and streams on the north western part. Temporal and spatial changes have occurred in the location of the inlet / mouth in the barrier. Opening of the mouth and its shifting are associated with episodic events like storms / cyclones and longshore drift of sands along the coast. Migration of the inlet / mouth northeastwards have lengthened the deeper outer channel in the lake connecting the lake mouth with the lake interior and this is ca. 35 km in length. While the length of the lake is ca. 64 km, its maximum breadth is ca. 20 km. The lagoon presently covers an water expanse of ca. 1000 sq. km during he monsoon (mid. June to mid. October) and shrinks to ca. 750 sq. km in the summer months.

The evolution of this lake has been largely accomplished during the Holocene. 14C and OSL datings attest to several stages in the geomorphological evolution. palynological analysis in conjunction with 14C dating of core samples throw light on the floral succession in which mangrove vegetation is well marked (Asha Khandelwal: written communication) suggesting swampy sea marginal environment and sea-level oscillations during the Holocene. Several stages of barrier evolution narrowing and separating the lake from the sea have been thought from Optically stimulated luminescence datings (OSL). Older barrier systems have developed between 1000 years to 3500 years ago. The present barrier-spit that now separates the lake from the Bay of Bengal developed around 300 years ago.

The lagoon is generally shallow, the depth in large part of the lake being less than 2m, varying from 1.5m to 3.9m. The lake is brackish. Where the rivers debouch into the lake in the

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northwestern side, the lake is covered by freshwater. In the brackish regime, salinity varies from about 8-12 0/00. Salinity may exceed 30 0/00 in the outer channel during the summer. During the monsoonal rainy season, the salinity in large part of the lake is close to freshwater. Sediment loadings / siltation through the rivers cause shallowing of the lake and choking of the mouth occurs by sand influx from the seaward side reducing the tidal flux of saline water into the lake. The lake thus, tends more towards a freshwater regime when salinity is reduced. Eutrophication and increasing weed growth is well marked. Aquaculture ponds are expanding in the lake margin. Prawn aquaculture feed and agricultural fertilizers washed away from crop fields and anthropogenic activities pollute the lake.

Chilika lake has a well marked biodiversity. The lagoon ecosystem is characterized by high nutrient concentrations brought by riverine input and their effective recycling between sediments and water column. Both phytoplankton and macrophytes are important primary producers in the Chilika lake. Presently the grass-like submerged pondweed Potamogeton pectinatus dominates the macrophyte flora. This is followed by the emergent macrophyte Scripus articulatus. Water hyacinth is well marked in the northern side the lake. Fishes, prawn and crabs are valuable edible resources. Birds glorify the scenic beauty of the lake in winter. Hundred thousands of migratory birds come from Siberia, China, Iraq, Iran, Caspian Sea, Himalayas and other countries to spend the winter months in the Chilika lake because of less severe cold and availability of plentiful food. This year “bird flu” is apprehended and precautionary steps have been taken. Dolphins are other elements in the biodiversity of Chilika lake and are great attraction for the tourists, forming a part of the ecotourism project in coastal Orissa State. Government of Orissa is planning to fix up propeller guards in power boats plying in the lake for safety of the Dolphins.

The lake is showing signs of environmental degradation. Gradual shallowing of the lake due to siltation / sediment loadings through rivers entering into the lake, choking of the lake inlet / mouth by sand influx due to strong littoral drift of sands, eutrophication and increasing weed growth, rampant development of aquaculture ponds in the lake area, detrimental anthropogenic activities and pollution pose as major threats to the healthy maintenance of the lake. The coast is prone to natural hazards like heavy river floods during the monsoon and storms / cyclones in pre and post-monsoonal months. Impact of Supercyclone during October 1999 and Tsunami during December 2004 have also been experienced. These hazards can give a death blow to the ecosystem of the lake as well as the communities living on the lake margin.

Conservation of the lake and sustainable development of its resources require appropriate management strategies which need regular monitoring of physical, hydrological, limnological and biological aspects of the lake. Anthropogenic activities ruining the lake should be curbed by strong administrative and legal measures. In 2000, a new mouth has been opened in the middle of the barrier-spit to allow marine waters into the lake through tidal flux in order to enhance salinity level in the lake which has been diminishing. However, both sides of the mouth in the sand barrier are getting eroded, as a result the mouth has widened. If this widens further and there are incidences of natural hazards like a Supercyclone with storm surge rising upto ca. 12m, then the lake environment and people living around the lake will sustain irreparable loss and human miseries and death toll will be indescribable. Before opening this new mouth, more experimental studies, modelling, planning and field studies should have been conducted. There should have been other alternatives as well, if increasing salinity was the principal objective of opening the new mouth. Community involvement is deemed necessary in framing the management strategies apart from Government and NGOs co-operation. Disaster mitigation measures should also be incorporated in management schedule. Chilika Lake situation may impart stimulus and boost up understanding in management of Asian Lake System like that of Lake Tonle Sap in Cambodia.

Tonle Sap – Mekong River and the similar systems in the Southern Vietnam

Le Xuan Thuyen[7]

Abstract

Lake Tonle Sap is well known as a great natural reservoir regulating the water regime of the Mekong River. In fact, they are a joint specific hydro-geomorphologic feature in the monsoon region and the objectives essentially of many studies.

This poster is presented with emphasis on the presence of the similar systems existing other where in the Mekong River basin and in the adjacent basin of the Saigon-Dongnai River in the Southern Vietnam. Up to now, they remain to be poorly studied. One of them is the lake Lak and the Serepok River which drains also into the Mekong River, and the another one is the lake Bienlac joining the Saigon-Dongnai River.

The preliminary results of the study carried out around the lake Bienlac suggest that the lake originated in the early Holocene in consequences of the exogenous factors (debris flow coupled with gread flood) following the modification of the accommodation and slope occurred probably after the Pleistocene basalt effusion in the basin.

The continual research in these small systems is necessary and that should allow to enrich our understanding the origin and the function of the river –lake systems and their management.

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IV. Plant Ecology

Barringtonia acutangula

Mimosa pigra

Floodplain vegetation under severe human impact: succession pattern and invasion of exotic mimosa in Lake Tonle Sap, Cambodia

Yuji Araki[8], Dorng Powkhy[2], Yoshihiko Hirabuki[3], Chay Rachna[4],
Shinji Tsukawaki[5], Mizuki Tomita[1] and Kunio Suzuki[1]

Abstract

Introduction

Lake Tonle Sap, the largest inland water body in Southeast Asia, contains unique wildlife and ecosystems adapting to its large seasonal fluctuations of water level. In the highest-water season (October – November), waterlogged area expands four times as large as that in the lowest-water season (April – May) and the maximum depth reaches more than eight meters. In the present investigation, we studied (1) the vegetation structure of the middle area of floodplain where short-trees and shrubs dominated in the low water season, and (2) the characteristics and invasion of Mimosa pigra, a prickly exotic shrub from tropical America and the worst environmental weed in many tropical wetlands (Lonsdale, 1992).

Site and Methods

The study area is situated in the southern part of Siem Reap City (Fig. 1). The remnant stunted swamp forest (McDonald et al., 1997) dominated by Barringtonia acutangula scarcely distributes along the coastal part of the floodplain.

Quantitative data of phytosociological evaluation were collected in 40 quadrats (10 m × 10 m) arranged on the middle area of floodplain (ca. 3 km in distance). Sampling plots were classified by TWINSPAN (Hill, 1979), and ordinated by DCA (Hill and Gauch, 1980). We also interviewed with local people how they have been concerned with floodplain vegetation; i.e., history of logging, burning, reclamation and cultivation.

Results and Discussion

Five vegetation community types were recognized based on the TWINSPAN and DCA results (Fig. 2). The First is “Paddy field”, which located in the comparatively high elevation area of the floodplain, was cultivated farmland by the local people. The second is “Fallow field”,

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which was a vegetation type abandoned from “Paddy field” for 2-3 years. In this vegetation type, a lot of shrubs and seedlings of B. acutangula were found out. The third and the fourth are “Shrub” and “Short-tree forest”, which have been characterized by dominance of B. acutangula, and shrub species such as Phyllanthus reticulatus, Vitex holoadenon, Gmelina asiatica and Dalbergia entadioides, although vegetation height and dominance of each species were different between the two types. The fifth type is “Cutover forest”, which was received severe human impact due to gather firewood and reclamation. Our investigation found that the human behavior caused retrogressive succession on the floodplain against vigorous regeneration ability of B. acutangula and some shrub species mentioned above.

On the other hand, it was observed that alien species M. pigra which can grow aggressively, reduce or replace native vegetation, was distributed on all over the floodplain. It was also found that this species has characteristics as below: (1) flowers and seeds are produced through the year, and the main period of seed fall is from March to August, (2) above-ground organs of the plant cannot survive during submerged, but reproduce from root fragments in the next dry season.

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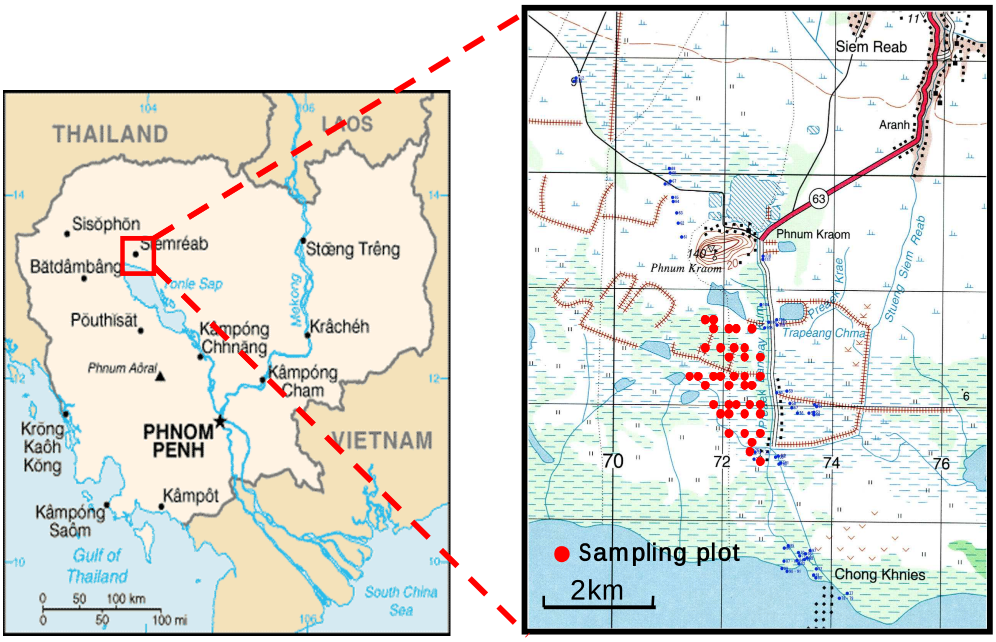

Fig. 1. Location of the research area and 40 sampling plots for phytosociological evaluation.

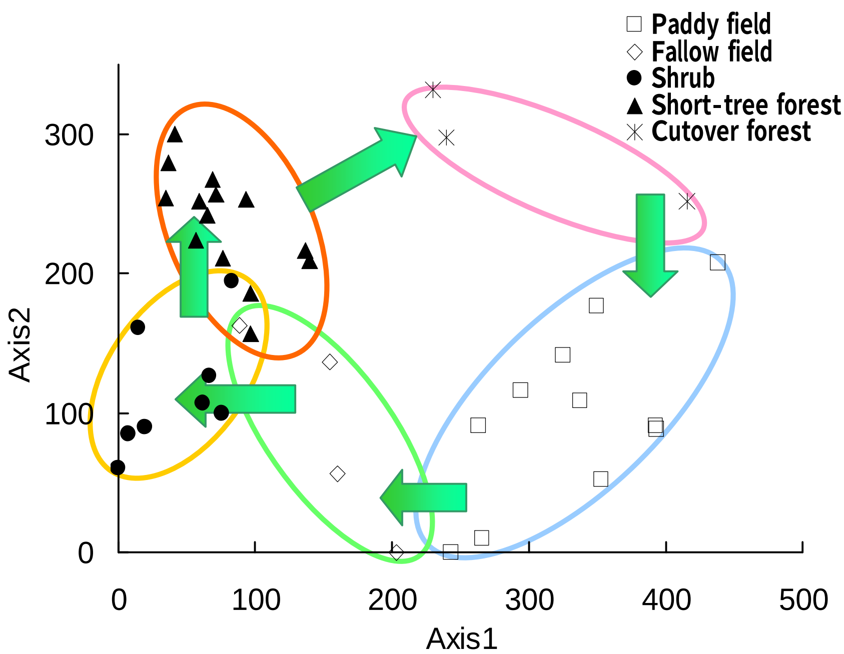

Fig. 2. DCA-ordination of 40 stands with species cover data. The stands dividing each vegetation group by TWINSPAN are encircled. The expected succession of vegetation is indicated by arrows.

Rice Remains in the Prehistoric Pottery Tempers of the Shell Midden Site of Samrong Sen: Implications for Early Rice Cultivation in Central Cambodia

Ly Vanna[9]

Abstract

It is not to be wondered at that the history of rice cultivation in Cambodia has not been well understood so far. Rice might well have been cultivated and domesticated in the central floodplains of Cambodia, since prehistoric times. Recent archaeological excavations conducted by the author at the shell midden site of Samrong Sen, which is located in the flooded area of the Tonle Sap River in central Cambodia, revealed that rice husks had been used to temper pottery with other agricultural by-products. They could have been dated to not later than 3,600 BP. More than 60 samples of complete rice were morphologically recorded for the first time, from a few hundred shards unearthed from the site. Judging from the morphological attributes of each specimen, we observed that there were some grains exhibiting the morphological patterns of the sub-species of Oryza indica, and of other varieties of Oryza sativa. The purpose of this article is to present some observations concerning the research of prehistoric rice in the flooded area of the Tonle Sap River. The paper will present the results of the examination of early rice remains at Samrong Sen, discuss the history of rice appearance in the flooded area of the Tonle Sap, and propose further research themes concerning prehistoric rice in Cambodia.

Keywords: Rice, Morphological attribute, Shell midden site, Samrong Sen, and Tonle Sap River, Oryza sativa indica, Oryza rufipogon, Oryza nivara.

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Herbaceous Water-plant Vegetation in Flooding Lake Tonle Sap, Cambodia: Distributional pattern and Ecological Implications

Yoshihiko Hirabuki[10], Yuji Araki[2], Dorng Powkhy[3], Akihide Takehara[4], Shinji Tsukawaki[5], Kunio Suzuki[2], Im Sockrithy[6] and Chay Rachna[6]

Abstract

Lake Tonle Sap is the largest inland water body in Southeast Asia, and is also characterized by drastic change of water-level between the highest- and lowest-water seasons (ca. 8 m); as a natural reservoir mediating downstream of the Mekong River, the whole waterlogged area reaches ca. 9000-14000 km^2 at the peak period of flooding, which is approximately four times as large as that in the lowest-water season (CNMC/NEDECO, 1998a, b). In the present study, we paid attention to the distribution of herbaceous water-plants in the most flooding period. Herbaceous water-plants which were chosen as an indicator of ecological evaluation seem to be a key element of lake ecosystem, because in many cases (1) they provide aquatic animals such as food, habitat and oxygen and (2) they are sensitive to change of physicochemical condition (e.g., Riemer, 1984; Sakurai, 1989).

The study area is located in the southern part of Siem Reap City, on the northwestern margin of Lake Tonle Sap. From 2003 to 2005, floristic and vegetational surveys were carried out, and, in the most flooding period (November), we performed phytosociological investigations at fifty quadrats (5 m × 5 m) arranging over various types of water-plant communities which had been physiognomically distinguished. Water depth and location of quadrat were also measured by LCD digital depth sounder and GPS, respectively.

The herbaceous water-plant vegetation (total number of species emerged ＝ 24) gradually changed in the following pattern from the area of ‘permanent lake’ to the upper reaches of ‘floodplain’ (ca. 8 km in distance) in the most flooding period: open water area with no herbaceous water-plants → free-floating plants (e.g., Eichhornia crassipes, Salvinia cucullata and Pistia stratiotes) → free-floating plants and floating-emergent plants (e.g., Polygonum barbatum, Ludwigia adscendens and Ipomoea aquatica), or submerged plants (e.g., Utricularia aurea, Hydrilla verticillata, Najas minor and Ceratophyllum demersum) → submerged plants and floating-leaf plants (e.g., Nymphoides indica, Trapa sp. and Nymphaea nouchali) →

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emergent plants (e.g., Nelumbo nucifera and Cyperus cephalotes). Additionally, these vegetational assemblages occasionally developed into the dense floating-mat or submerged-crowd.

Consequently, habitats of all herbaceous water-plants were restricted within ‘floodplain’ and showed zonal distribution containing patches of flourishing populations. Remnant Barringtonia-dominant swamp forest (tree height = ca. 7-15 m) and shrubland which also existed only in the ‘floodplain’ might weaken waves, currents and turbidity, and water depth, duration of flooding and the human impact of reclamation might affect such distributional pattern.

Keywords: distributional pattern, floodplain, growth form, herbaceous water-plants, Lake Tonle Sap, seasonal change of water-level.

Ⅴ. Civil Engineering

Bank Erosion

Chaktomuk in 1992

Flow pattern and size distribution of bed material at Chaktomuk in Cambodia

Hiroshi Takebayashi[11], Luu Xian Loc[2], Shinji Egashira[2], Shinji Tsukawaki[3], Im Sim[4], Touch Sambath[4], Sieng Sotham[4] and Suguru Ide[2]

Abstract

Chaktomuk is located in the north part of the Mekong Delta as shown in Figure 1. The Mekong River changes its flow from west to east at Phnom Penh, where the two rivers, the Tonle Sap River and the Bassac River, diverge. There is the Tonle Sap Lake at the north boundary of Tonle Sap River. The Great Lake is the largest freshwater storage in the Southeast Asia, which covers an area of about 13,000 km^2 (H. Hori, 2000). Tonle Sap system is well known because of its unique hydrological regime and its contribution to both the economy and the ecosystem of both Cambodia and South Vietnam. A unique hydrological system of the river is the inverse flow that takes place from June to September. In June, the water in the Mekong River starts to flow to the Tonle Sap River because of the flood in the Mekong River. Thus, the river flow begins to enter the lake and the Great Lake behaves as a very effective flood detention basin. On the other hand, from October to May, the flow direction in the Tonle Sap River is from the lake to the Mekong River because of the decreasing of the water surface elevation in the Mekong River. In this stage, the lake plays as a water supplier to the downstream area of the Mekong River. Such channel form and flow pattern is infrequent all over the world and produces very complicated phenomena.

Both bed and bank deformation at Chaktomuk has been occurred with the complex flow. The morphological deformation can change the flow characteristics at Chaktomuk and must be assessed on both the channel form and the flow characteristics for the economy and the ecosystem of both Cambodia and South Vietnam. K. W. Olsen and S. Tjerry (2002) performed the two dimensional bed deformation analysis of Chaktomuk area and suggested the river regulation works to suppress bank erosions. This study must be a great job and give us much information. But the deficiency of size distribution data of bed and bank material makes the quality of the simulated results lower. In this study, bank and bed materials had been sampled during both dry and flood seasons at Chaktomuk. Furthermore, depth integrated two

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dimensional bed deformation analysis has been performed to understand the seasonal change of both the flow patter and bed deformation characteristics. The analysis is performed under 3 hydraulic conditions; maximum, minimum and zero water discharge in the Tonle Sap River.

Figure 2 shows the sampling location of bed and bank materials. The bed and bank materials were sampled at four points in a cross-section using a cable operated sediment sampler, respectively.

Equations for the depth integrated two dimensional bed deformation model used in the study is expressed in the moving general coordinate system. Bed and suspended loads are taken into account to estimate the sediment transport rate. Furthermore, both non-cohesive and cohesive material can be treated in the model (L. X. Loc, S. Egashira and H. Takebayashi, 2004). Normal water depth is used as boundary condition at downstream ends.

Figure 3 shows the size distribution of bed material in the Mekong River. The size distribution of the bed material during flood has a small spatial change. Furthermore, their mean diameter is coarse. But the mean diameter of the bed material during dry season distributes in wide range; finer sediment is included in the data. Figure 4 shows the aerial photo taken in 1958 during dry seasons. The Tonle Sap River supplies fine sediment to both the Mekong River and the Bassac River during dry season. In other words, seasonal change of flow direction in the Tonle Sap River contributes to the seasonal change of the sediment size in the Mekong River.

Figure 5 shows the bed deformation characteristics under flat bed conditions. Sediment deposits at the entrance of the Tonle Sap River during dry season. On the other hand, bed is eroded there during flood season. As a result, the entrance of the Tonle Sap River will not have been filled with sediment with time. In other words, it is considered that the Mekong – Tonle sap system can be stable for a long time. Sediment deposits at the right bank side of the entrance of the Bassac River during dry season and the erosion during flood season is small. Hence, the deposition near the right bank causes the erosion at the left bank, as a result, the entrance of the Bassac River has been shifting to southeast. Sediment deposits at the downstream region of the peninsula between the Mekong River and the Tonle Sap River during flood season and there is no erosion period. Hence, the peninsula develops to south with time. Furthermore, the maximum deposition point is slightly far from the south edge of the peninsula. This is why an island is formed at the south of the peninsula.

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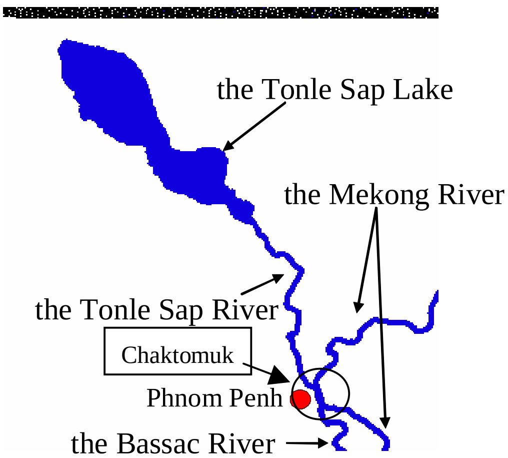


Fig. 1 Tonle Sap System

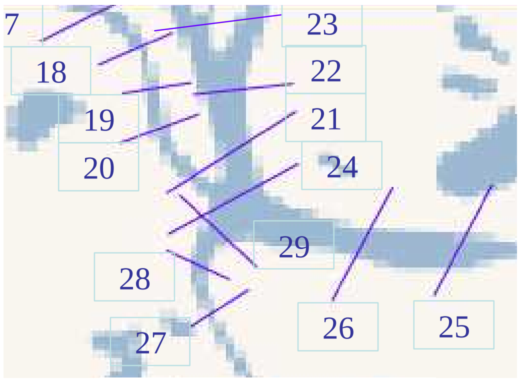
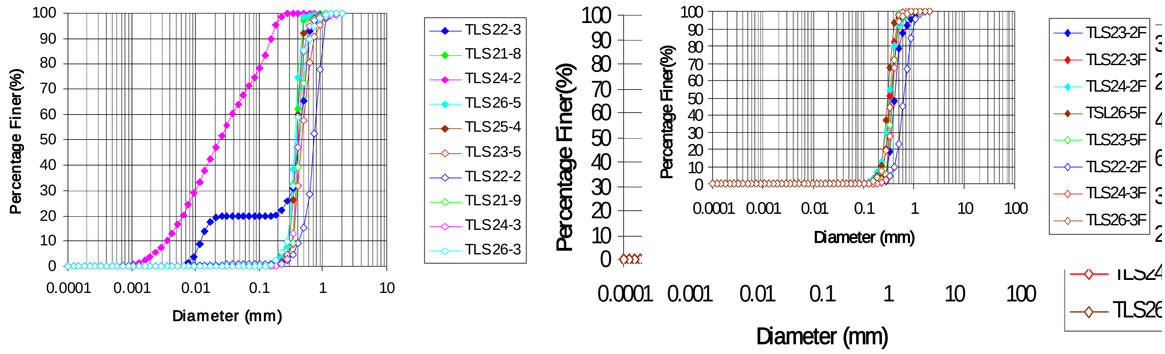


Fig. 2 Sampling cross-section



(a) Dry season (Feburary 2005)

(b) Flood season (September 2005)

Fig. 3 Size distribution of bed material in the Mekong River

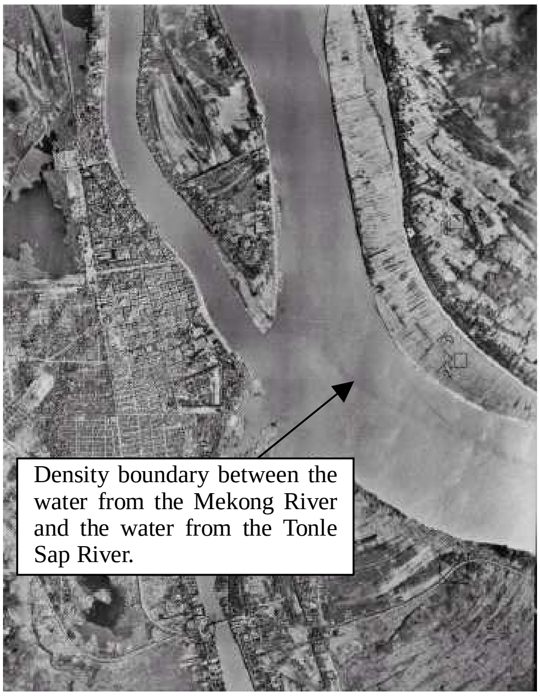
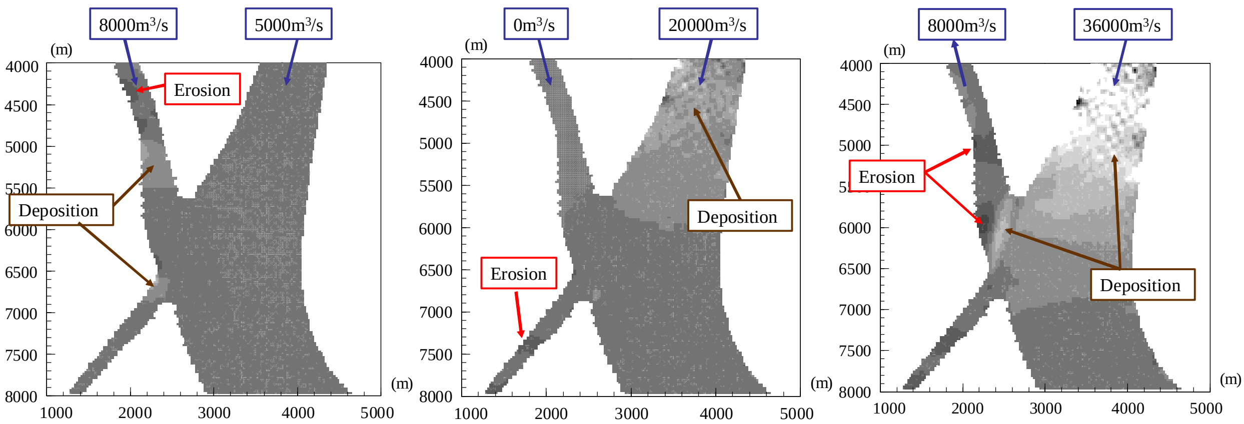


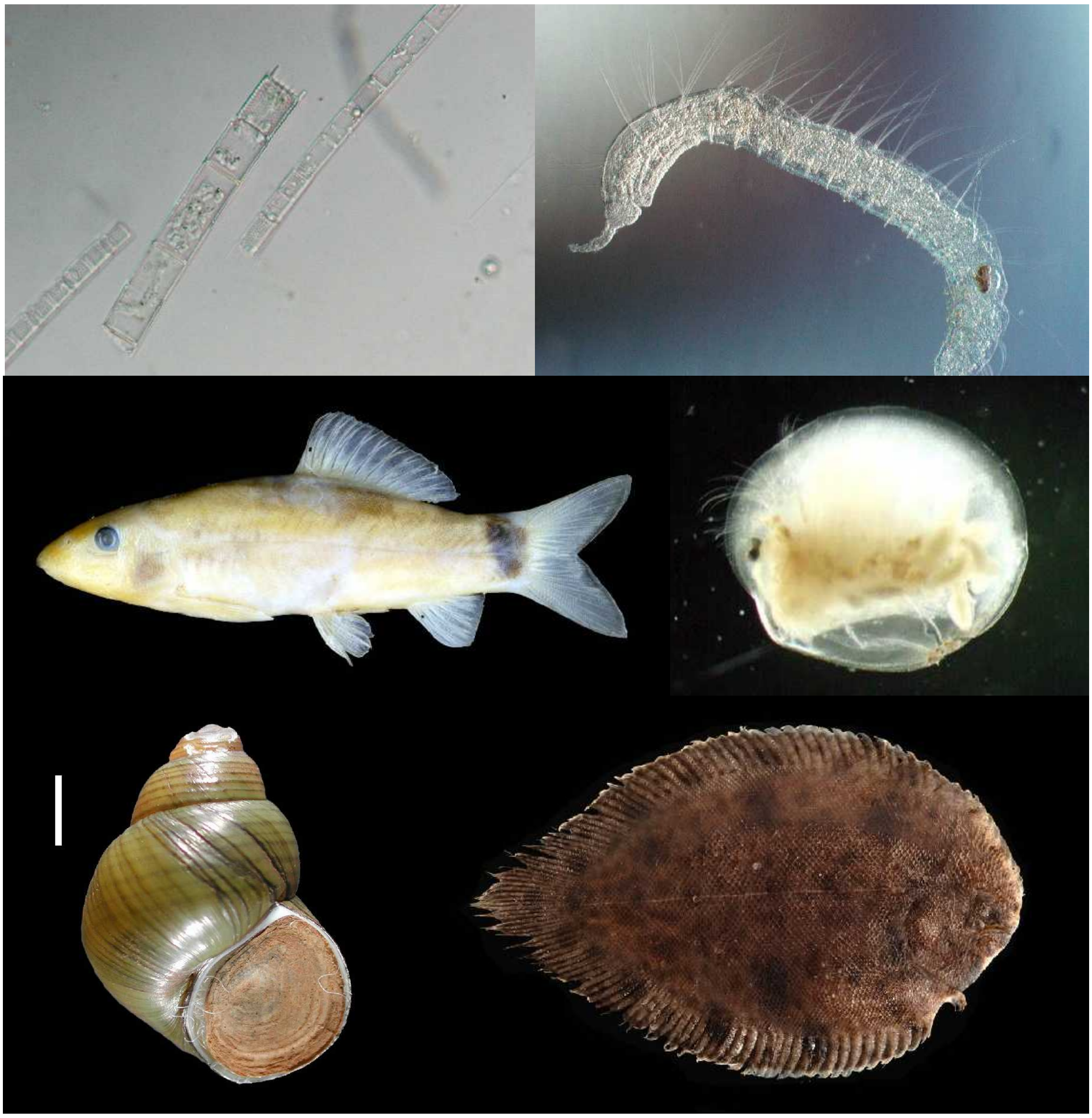
Fig. 4 Arial photo of Chaktomuk (1958, Source: Ministry of Industry, Mines and Energy General Department of Mineral Resources, Phnom Penh, Cambodia)



(a) Normal flow stage (b) Intermediate (c) Inverse flow stage

Fig. 5 Bed deformation characteristics (Numerical analysis, White area indicates deposition. Black area indicates erosion.)

VI. Zoology and Ichthyology



Primary production in Lake Tonle Sap

Toshiyuki Ishikawa[12], Hideo Oyagi[2], Akifumi Ohtaka[3], Tetsuya Narita[4], Im Sim[5] and Shinji Tsukawaki[6]

Abstract

Introduction

In Lake Tonle Sap, fishery harvest ranked within top 5 in freshwater lakes in the world. Areal fishery harvest is also ranked high in the world, which indicates high fish production in the lake. People in Cambodia highly depend upon this fishery resource both as income resource and as food resource. To use this fishery resource sustainably, we have to understand a mechanism which makes fish production is high in the lake. In lake ecosystems, planktonic organisms function as primary producer or secondary producer in pelagic zone, which are fundamental role in biological production in lakes. However, very few knowledge on planktonic organism has been available for Lake Tonle Sap. Therefore, we conducted experiments to measure primary production and collection of planktonic organism to estimate its biomass during 2004-2005. In this presentation, we report the result of measurement of primary production.

Methods

In situ experiments on primary production were conducted on Feb-Mar 2005, Apr-May2005, and Jul-Aug2005 at a fixed station in Northern part (offshore Siem Riep City) and in pelagic area of Southern part (Kompong Chnang district) of the lake.

To decide the layer to measure primary production, transparency were measured by secchi disc and light extinction measured by a photometer (Delta OHM, DO9721). Lake water were collected from by 1L Van-Dorn sampler and poured into 100 mL stoppered bottles gently. A couple of bottles were immediately fixed DO by reagent for measurement of initial value, a couple of aluminum foil covered bottles and a couple of uncovered bottles were moored to keep same layer as water collection for 4-5 hours. In May 2005, we measured primary production every 1 hour from 9:30 to 12:30. The DO concentration of bottle was determined by the Winkler method. To determine chlorophyll a concentration, 50mL of surface water were filtered upon pre combusted glass fiber filter (GF/F), then measured by a fluorometric method (Wetzel & Likens 2000).

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To calculate daily production, we hypothesized that areal production per hour around mid-day composed 12.75% of daily production as proposed by Vollenweider (1965). To convert oxygen change rate to carbon production rate, we hypothesized respiration quotient to be 1.

Results & Discussion

Time-series changes in dissolved oxygen measured on March showed linear change (Figure 1), which suggests light saturation and no strong light inhabitation. This linear relationship indicates high validity to estimate daily production from result of several hour bottle experiments around noon.

Estimated daily production was varied between months and locations (Table 1). In Feb-Mar, production exceeds respiration within 50cm both in South and North area. However, respiration further exceeds production in May. In this period, gross production was also lower than on Feb-Mar. This should be due to very low transparency which would make euphotic layer thinner.

In Table 1, we calculated production and respiration within 50cm which does not include those in layer deeper than 50 cm. Because of low light intensity, production in deeper layer might be lower than surface. However, respiration rate should be similar to surface because lake water seems vertically mixed judging from its vertical structure (Oyagi pers. Comm.). Therefore, areal daily production should be lower than respiration rate during the study period, which suggests external energy input.

Blache (1951) reported that abundance of both phytoplankton and zooplankton was higher in flooded season. Our data shown in this study is restricted to in low water season, which indicates that our estimation of areal production should be those of low season. Therefore, we will try to measure primary production in high water season, which enable to explore pelagic productivity of the lake.

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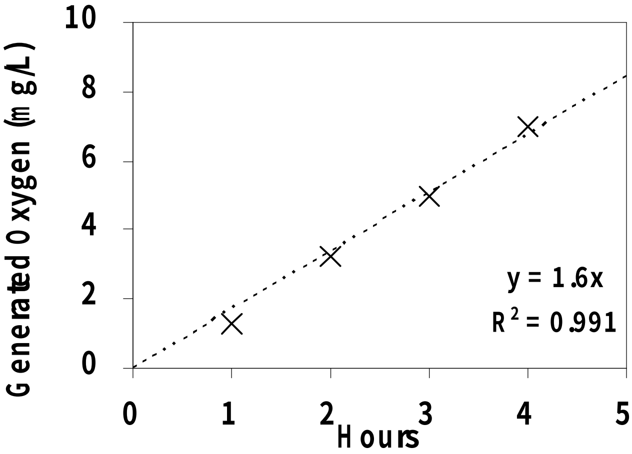

Figure 1. Time series plot of generated oxygen in surface water 8:30-12:30 on May 2005.

Table 1. Estimation of daily production and respiration within surface 50cm layer. Pn: net production, Pg: gross production, R: Respiration

	Transparency(cm)	Chlorophyll (mg/m^3)	Pn (mgC/m^2/day)	Pg (mgC/m^2/day)	R (mgC/m^2/day)
27Feb South	9	68.6	25	320	296
8 March North	10	95.9	98	591	492
20 May South	2	51.8	-794	167	961
28 May North	2	88.4	-373	256	630
29 July South	16	21.9	-8	106	114

Diversity of aquatic invertebrates in Lake Tonle Sap

Akifumi Ohtaka[13], Haruo Katakura[2], Takahiro Kamiya[3], Tetsuya Narita[4], Hiroyuki Motomura[5], Toshiyuki Ishikawa[2], Takahiko Mukai[6], Yasuhiro Kuwahara[7], Shinji Tsukawaki[4], Ven Sophorn[8], Chay Rachna[8] and Tan Vuthy[8]

Abstract

In the Tonle Sap EMSB program, the Zoological Biodiversity Group has studied the following subjects: 1) structure of animal community in Tonle Sap; 2) distribution and abundance of animals in the lake and adjacent area; 3) ecological relationships between biota in the lake. The practical zoo-faunistic investigations were carried out four times from 2003 to 2005 including flooded and dry seasons. The specimens collected are currently in the course of identification in cooperation with specialists of respective taxonomic groups. In this presentation, therefore, overall view of fauna and distribution of aquatic invertebrates in Lake Tonle Sap is given.

Aquatic invertebrates belonging to ten phyla were recorded in the surveys. They include several undescribed species and many taxa new to Cambodia. In flooded seasons, all the higher taxonomic groups but amphipods were recorded from littoral zones where inundated forests and aquatic vegetation developed. On the other hand, offshore zones without vegetation lacked many kinds of the taxonomic groups, including poriferans, bryozoans and the entire insect groups except for dipterans. During dry seasons when the lake diminished and aquatic vegetation almost disappeared, diversity of lacustrine fauna decreased considerably. Therefore, it is suggested that vegetation has an important role sustaining invertebrate diversity. Invertebrate assemblages associated with submerged vegetation in L. Tonle Sap may be characterized by having abundant sessile animals such as poriferans, bryozoans and Limnoperna mussels. Flood currents could be an important factor regulating their distributions.

In contrast to rich littoral fauna, offshore zoobenthic invertebrates were poor and less changed in composition and abundance between seasons and areas. Macrozoobenthic communities were dominated by oligochaetes in number and by molluscs in biomass. Chironomids and an undescribed Kamaka sp. (Amphipoda) also occurred widely, along with meiobenthic nematodes, copepods and ostracods. The oligochaetes were composed of multiple species endemic to or typical for southeast Asia, of which some Aulodrilus species and Branchiura sowerbyi (Tubificidae) dominated. Mean densities of total offshore

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macrozoobenthos were not higher than 1300 m^{-2}. Although no comparable studies exist in tropical Asia, it seems unusual that such a less abundant benthic animals were found in the productive and aerobic Lake Tonle Sap. Further study is needed to make clear the underlying mechanisms for the seemingly strange phenomenon.

At the end of dry season, May 2005, a primarily aquatic oligochaete, Branchiura sowerbyi was found in 30 cm deep layer of soil at landed floodplain of the lake. The worms moved actively in the soil habitat and appeared to turn to “soil animals”. It is expected that floodplain invertebrates have variable strategies to come through dry seasons, however, their life histories were hardly known yet.

Food web structure study by natural stable isotope in Lake Tonle Sap, Cambodia - a preliminary report -

Tetsuya Narita[14], Akifumi Ohtaka[2], Hiroyuki Motomura[3], Takahiko Mukai[4], Toshiyuki Ishikawa[5], Ven Sophorn[6], Chay Rachna[6] and Tan Vuthy[6]

Abstract

Lake Tonle Sap is well known by having rich fish fauna, and in the flooded season tremendous amounts of fish are yielded. Some fishes are said to migrate up from Mekong River through River Tonle Sap, and some migrate down from the small streams adjacent to the Lake. They feed in the lake or in the inundated forests, and complicate food webs are formed in respective season and place.

In the present study, an attempt to analyse the food web structure of Lake Tonle Sap by using natural stable isotope of carbon and nitrogen was made. It is known that carbon isotopic compositions of animals reflect those of the diet within about a few ‰ (usually about 1‰). The nitrogen stable isotope ratio ($\delta^{15}N$; delta N 15) in the organism reflects that of the diet, but in most cases the animal is enriched in 15N relative to the diet (about 3 – 5‰ for one trophic level).

In flooded and dry seasons, samplings were made in the north basin, off Phnom Krom near Siem Reap, and in the south basin, off Chhnok Tru near Kampong Chhnang, of the lake. In most cases fish samples were bought from fishermen who were working in fishing boats on the lake. A small piece of fish meat was taken from the anterior-dorsal side of each fish. Some invertebrates were also collected by using a plankton net, a dip net or light traps.

In December, 2004 (flooded season), the ranges of $\delta^{13}C$ and $\delta^{15}N$ values were –26.82 to –33.02‰, 12.41 to 7.24 ‰ for fish and –23.23 to –25.91‰, 13.18 to 3.49‰ for terrestrial insects in the north basin, and –20.27 to –34.16‰, 10.71 to 5.53‰ for fish and –26.56 to –34.95‰, 8.42 to 4.24‰ for aquatic invertebrates in the south basin. In the fish communities two trophic levels were detected in the analysed samples.

In May, 2005 (dry season), the ranges of δC and δN values were –24.32 to –31.62‰, 12.94 to 5.70‰ for fish and –22.37 to 29.81‰, 13.36 to 3.49‰ for aquatic invertebrates in the north basin, and –20.94 to –41.05‰, 10.68 to 4.42‰ for fish, and –23.63 to –27.83‰, 11.23 to 6.02‰ for aquatic invertebrates in the south basin. The δC and δN of fish in the south basin

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scattered in wide range, it is difficult to decide trophic level. Prawns (Macrobrachium) showed as high δN as carnivorous fishes and they are seemed rarely to form the diet of fishes in this season.

The level of δN of fish was slightly higher in the north basin than in the south basin in both season, which may suggest the anthropogenic pollution in the study area of the north basin.

Study Tour in EMSB and the research of rainfall at NIE

Em Sauth[15], Lim Kannitha[2], Masaomi Kanamori[3] and Tetsuya Murayama[3]

Abstract

National Institute of Education (NIE) is only one teacher-training institute for upper secondary education in Cambodia. Japan International Cooperation Agency (JICA) and Ministry of Education, Youth and Sport (MoEYS) implemented the project for quality development of science and mathematics education at NIE from August, 2000 to March, 2005, which name was the secondary teacher training project for science and mathematics (STEPSAM). When Dr. TSUKAWAKI Shinji, the leader of EMSB, was assigned to STEPSAM as a short-term JICA expert in August,2004, he introduced NIE science team about EMSB research activities in Cambodia. After his assignment and after STEPSAM ended, NIE science team has continued cooperation with EMSB. NIE science team, particularly biology and earth science, often observe EMSB research activities, and EMSB member also often visit NIE and sometimes has volunteer teaching session to them. NIE lecturers have been stimulated by their study with EMSB very much.

The opportunity to study with EMSB is very important and meaningful experience for NIE science lecturers. Science education in Cambodia is still on the way of the rehabilitation from the past collapse of education system. Science teachers in Cambodia usually never have an experience science research by themselves. Students in the school usually study science without any experiences and any observation activities. Most of contents of textbook are introduced from textbook from foreign country, like France and the United State. Local information such as rich biodiversity of this region is very limited in school curriculum. Teachers also do not know well about their own country's nature. Through the activity with EMSB and EMSB-u32, NIE lecturers study what science research is, what the characteristic of our country is.

Date and activities which NIE science team joined EMSB research are following;

[15] NIE biology lecturer; [2] NIE earth science lecturer; [3] NIE advisor

Organization: National Institute of Education

Address: c/o Science and Mathematics Center, National Institute of Education, Nordom St. / Sihanuk St., Phnom Penh, Cambodia

Contact person: Dr. Im Koch, Director of NIE, tel 012-569154

Date	Place	Participants from NIE	Activity
3rd November, 2004	Kampong Chhnang	1 biology lecturers	Joining the preparation of research activity at the Tonle Sap in Kampong Chhnang
8th December, 2004	Kampong Chhnang	4 ES lecturers	Observation of collecting sedimentation of riverbed and water quality at the Tonle Sap in Kampong Chhnang
12th December, 2004	Kampong Chhnang	5	Observation of collecting sedimentation and living thing of riverbed and water at the Tonle Sap in Kampong Chhnang
19th December, 2005	Kampong Chhnang	6 Biology lecturers	Observation of collecting fish at DAI fish net at Kampong Chhnang, and study how to make specimen of fish
2nd March, 2005	Tonle Sap river and Mekong liver, Phnom Penh	3 ES lecturers	Observation of collecting sedimentation of riverbed and water quality
13th -14th March, 2005	The rooftop of Diamond Hotel, Phnom Penh	4 ES lecturers and 1 inspector	Observation of collecting dust of atmosphere
19th August, 2005	Department of Geology Office, Phnom Penh	3 ES lecturers	Observation of opening the soil columns corrected from Tonle Sap River

Not only observation tour, EMSB also gave some opportunity to do a small research to NIE science team. EMSB –u32 member set up a big plastic bottle to collect rainfall at NIE campus. In this opportunity, biology team and Prof. Kanamori have challenged the research of rainfall at NIE campus from July to now. We are collecting rainfall everyday, and record the precipitation and pH. We are going to report what we found from this activity though this is a still very simple and primary research.

- In the rainy season, the aspect of precipitation are not the same. We recorded over 50mm/day rainfall 5 times in October, but no-day in August.
- Some reference book said that rain in Cambodia has acid tendency. But our research did not recognize rainfall at NIE as acid rain.

Seasonal changes of net-plankton communities in Lake Tonle Sap

Ryusei Watanabe[16], Akifumi Ohtaka[1], Haruo Katakura[2], Takahiro Kamiya[3], Tetsuya Narita[4], Hiroyuki Motomura[5], Toshiyuki Ishikawa[2], Takahiko Mukai[6], Shinji Tsukawaki[3], Ven Sophorn[7], Chay Rachna[7] and Tan Vuthy[7]

Abstract

Lake Tonle Sap is the largest freshwater lake in Southeast Asia, and is characterized by having drastic seasonal changes in water level. The lake is well known to have rich kinds and high production of fish, but its planktonic biota is still poorly known. Therefore, we studied composition and seasonal changes of net phyto- and zooplankton in the lake during 2003-2005.

Plankton samples were collected from surface water with a NXXX25 plankton net (openings 40 µm) at 14 stations on a lines from offshore to littoral of north and south basins of Lake Tonle Sap in May (dry season) and November-December (flooded season). The samples were immediately fixed in 5 % formalin solutions, and examined by an optical microscope.

In flooded seasons, 32 and 35 taxonomic groups (from class to species) were found in phytoplankton and zooplankton, respectively. More than half part of the phytoplankton communities were occupied by a diatom Aulacoseira granulata, followed by blue-green algae Anabaena and Microcystis both in north and south basins. Green alga Volvox and desmids also commonly occurred in north basin. Total cell numbers of net phyotoplankton ranged from 2×10^4 to 3×10^5 L^{-1}. The zooplankton communities were dominated by rhizopods (mostly Difflugia) and several rotifers. Copepods also abundantly occurred. Cladoceran Bosmina and Bosminopsis were found but less than 50 L^{-1}. The total density of zooplankton ranged 40-2500 L^{-1}.

In dry seasons, 9 and 18 taxonomic groups were found in phytoplankton and zooplankton, respectively. In phytoplankton , blue-green alga Microcystis exclusively dominated especially at littoral stations. The Microcystis "Water blooms" were found everywhere in the lake. Total cell numbers of the phytoplankton amounted to 1.7×10^8 L^{-1}. Aulacoseira granulata was secondary dominant alga, but the relative abundance was much decreased lower in dry seasons than flooded seasons. The zooplankton communities were 400-7400 L^{-1} in density. They were mostly composed of ciliates such as Codonella.

In conclusion, diversities of plankton communities were distinctly higher in flooded season whereas densities were much higher in dry season, both in phyto- and zooplankton communities.

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Exclusive dominance of the floating Microcystis in dry season can be relevant to the very turbid lake water in which Secchi Disk transparencies were less than 2cm. The large seasonal changes in phyto- and zooplankton could affect diversity and abundance of variable kinds of animals in the lake through food web.

DNA Analysis of Fishes in Lake Tonle Sap

Takahiko Mukai[17], Hiroyuki Motomura[2], Toshiyuki Ishikawa[3], Hideo Oyagi[4], Yuji Araki[5], Akifumi Ohtaka[6], Tetsuya Narita[7], Shinji Tsukawaki[8], Sieng Sotham[9], Touch Sambath[9], Ben Bunnarin[9], Im Sim[9], Chay Rachna[10] and Dorng Powkhy[11]

Abstract

DNA analysis is contributed to understand biological diversity. For example, genetic analysis can distinguish cryptic (morphologically similar) species, reveal intraspecific population structures, and identify egg and larvae of animals. We collected DNA samples of over 116 species in 36 families and 11 orders of fishes in Lake Tonle Sap and around the lake during December 2004 to August 2005. The DNA samples will be used to determine partial nucleotide sequences of mitochondrial DNA (mtDNA) to construct database, which can be available for ecological studies of fishes in Lake Tonle Sap.

In this preliminary report, we show a result of the DNA analysis of a fish in Lake Tonle Sap. A gobiid fish, Glossogobius aureus is one of the common species in Lake Tonle Sap, and this goby is the only species which dstributed in both Lake Tonle Sap and the Japanese Islands. Habitats of this species, however, are different between in the lake and in the Japanese islands, one is a freshwater lake and another is brackishwater stream in mangrove forest. Thus we attempted to analyze partial nucleotide sequences of mtDNA of the species and compared them between the two areas. The result indicated that the mtDNA of the goby collected from Lake Tonle Sap and Japanese island (Tanegashima) were very similar, but the nucleotide sequences showed slight genetic differentiation. Although there are no published records of their ecology, there is a possibility that the freshwater population of G. aureus in Lake Tonle Sap (and maybe in Mekong River) may completed their life-cycle in the freshwater environment, and may be isolated from coastal populations in mangrove area of South East Asia.

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Fishes of Lake Tonle Sap and Tonle Sap River, Cambodia

Hiroyuki Motomura[18], Takahiko Mukai[2], Akifumi Ohtaka[3], Haruo Katakura[4], Takahiro Kamiya[5], Tetsuya Narita[6], Toshiyuki Ishikawa[4], Shinji Tsukawaki[5], Sieng Sotham[7], Touch Sambath[7], Ben Bunnarin[7], Nut Sokhom[8], Chay Rachna[9] and Dorng Powkhy[10]

Abstract

Ichthyofauna surveys in Lake Tonle Sap and Tonle Sap River, Cambodia, during the current study have recorded 140 species in 80 genera and 35 families on the basis of specimens collected. Prior to the current study about 500 species were believed to occur in the region. Based on reliable literature and museum specimens, the current number of species is in fact probably around 200. The freshwater fish fauna was dominated by the family Cyprinidae, which comprised 40.0% of the total number of confirmed species. Five non-native species were collected during this study, one of the five being a large South American fish, Piaractus brachypomus (Cuvier, 1818). Although the Cambodian Department of Fisheries recently prohibited aquaculture of P. brachypomus, it was confirmed for the first time during this study that this species has already established a wild population in the northern part of Lake Tonle Sap. During the last five years, two new species (Siluridae and Polynemidae) and one subspecies (Polynemidae) have been known to be described on the basis of specimens collected from the lake and/or river. In addition, one new genus and species (Callionymidae) and one new species (Cyprinidae) were collected in the region this year. Of these recent new taxa, Polynemus melanochir dulcis Motomura and Sabaj, 2002, and the two undescribed species are only known from Cambodia. Although Lake Tonle Sap belongs to the same biogeographic region as the Mekong River, intraspecific variation in morphological and color characters were found in populations of at least seven species in Lake Tonle Sap and Tonle Sap River (Mekong River).

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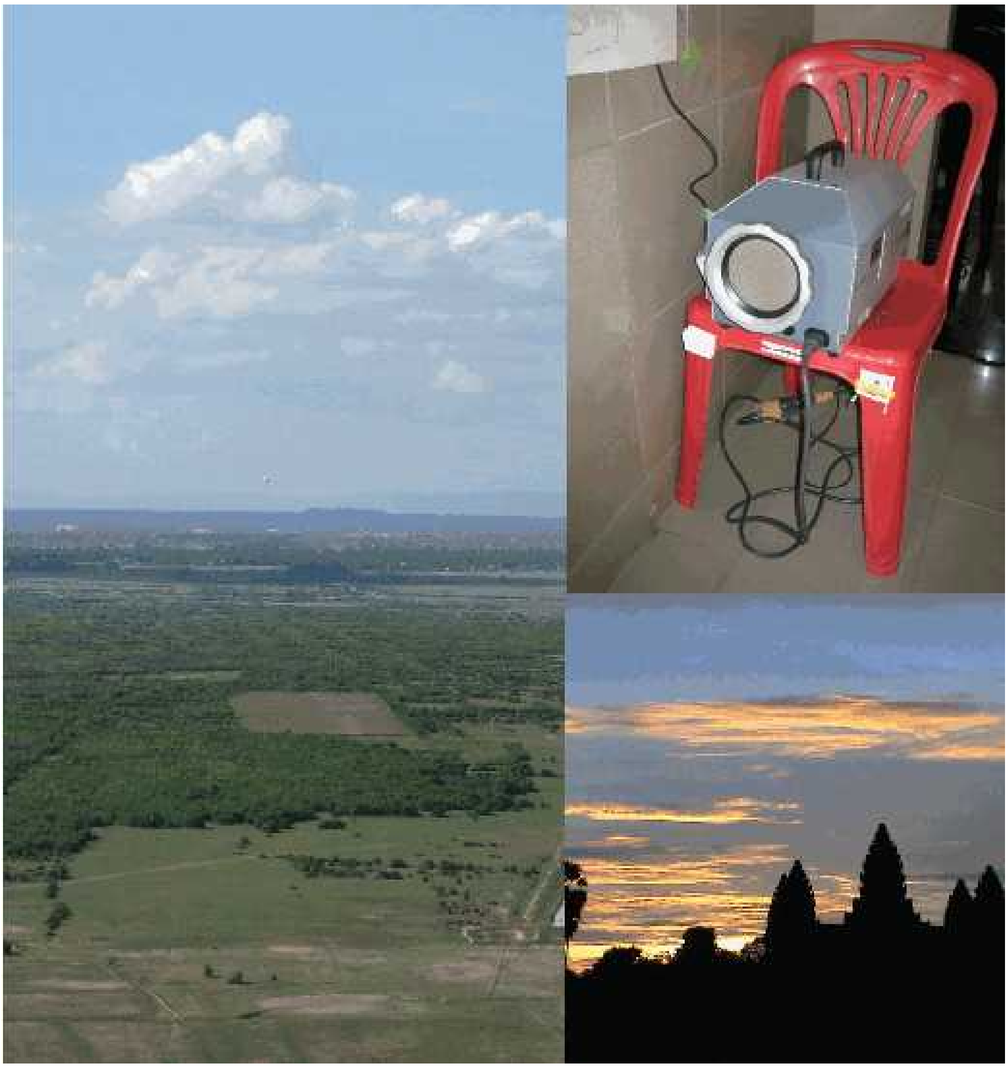
VII. Atmospheric Sciences



From ground to clouds

Air Pollution in Angkor Monuments Area in Cambodia

Masami Furuuchi[19], Takahiro Murase[1], Shinji Tsukawaki[20], Sieng Sotham[21], Hang Peou[22]

Abstract

Air pollution in the Angkor monuments area in Cambodia was evaluated to discuss the present status of air pollution and related emission sources. Ambient particulates were sampled at three different sites, or, Angkor Wat, Siem Reap downtown and Phnom Krom as well as using NO_2 passive samplers. The size fractionated samples were also collected inside the Angkor Wat and Route 6 road side in the central Siem Reap to discuss the particle size distribution. Concentrations of total suspended particulates, poly-cyclic aromatic hydro-carbons and total, organic and elemental carbons (TC/OC/EC) and gaseous pollutants were analyzed to discuss the influence of anthropogenic emission sources.

The concentration of total PAHs summed for four or more rings was almost same in downtown and Angkor Wat while TSP concentration was much higher in downtown because of road dusts. NO_2 and CO concentrations nearby the Angkor Wat were similar to downtown area and PM2.5 was shown to have a larger fraction in the Angkor Wat, suggesting larger contributions from the neighbor traffic. Total carbon concentration was about three times larger in downtown but a lager carbon fraction was in the Angkor Wat. A large portion of carbons in downtown might be contributed from some fuel burning other than traffic.

1. Introduction

During past ten years, the tourism to the Angkor monuments area has been growing drastically along with a significant increase in population living in Siem Reap and the monuments area[1)]. Such social changes should also lead to serious environmental impacts to this area. The air pollution is plausibly one of these unexpected impacts although it has not been certainly recognized. Because of an increased amount of energy consumption, such as power generation for the electricity, burning fuels for cooking and lighting, traffic, probably as well as the incineration of waste materials, the amount of air pollutants may have been increasing so far, significantly. As already known, in most cities in Cambodia, more 90% of cooking fuel is from wood burning[2)]. The air pollution may severely influence not only the human health but also bio-diversity as well as sustainability of the Angkor monuments. Deforesting in the monument

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area for biomass fuels and agriculture may change the climate in this area as well as increase the pollution. It may accelerate the degradation of the monuments under a changed climate of less humidity and high temperature with higher concentration of air pollutants. In order to reduce the air pollution, the monitoring of pollutants is essentially important. However, there has been a very little information in this area although the department of water and forestry (DW&F), APSARA, recently started the monitoring of gaseous pollutants in the monument area.

In this study, as the first step, air pollution in the Angkor monuments area in Cambodia was evaluated to discuss the present status of air pollution and related emission sources. Ambient particulates were sampled using high volume air samplers simultaneously at three different sites, or, Angkor Wat, Siem Reap downtown and Phnom Krom, a mountain beside the Lake Tonle Sap, as well as using NO_2 passive samplers. The size fractionated samples were also collected using a cascade impactor inside the Angkor Wat and Route 6 road side in the central Siem Reap to discuss the size distribution of particulates. Concentrations of total suspended particulates (TSP), poly-cyclic aromatic hydro-carbons (PAHs) and total, organic and elemental carbons (TC/OC/EC) were analyzed to discuss the influence of anthropogenic emission sources along with measured NO_2 concentration and gas monitoring data from DW&F, APSARA.

2. Sampling and analysis

Total suspended particulates (TSP) were sampled using high volume air samplers (SHIBATA HV-500F). To collect size fractionated samples, a cascade impactor with three stages (> 10μm, 10-2.5μm, < 2.5μm (PM2.5))(Tokyo-dyrec MCI) was used. NO_2 was sampled using passive samplers(ADVANTEC Personal Passive Sampler: Filter badge NO_2). Figure 1 shows sampling sites for simultaneous sampling:1) Angkor Monuments area (Angkor Wat), 2) Siem Reap downtown (Ta prohm Hotel), and 3)Phnom Krom (a mountain (ca. 200m elevation) beside the Lake Tonle Sap). At each sampling site, the high volume air sampler was installed along with a NO_2 passive sampler and a temperature-hygro sensor with data logger, which runs over the whole sampling period. At the Angkor Wat and a temple adjacent to Route 6 road side in downtown, samplings using the cascade impactor were conducted along with NO_2 sampling. Quartz fibrous filters (ADVANTEC QR-100) weighed after keeping them in a constant humidity and temperature for 72 hours using a descicator were used for the sampling.

The samplings were conducted in May and September 2005, being in the rainy season. One should note that May 2005 was unusually dried as the rainy season. Temperature and humidity was monitored during all samplings. Sampling data are summarized in Table 1.

The filters were weighed after the 72 hours conditioning then analyzed to obtain concentrations of PAHs and carbon. 15 different PAH compositions (Nap, Ace, Fle, Phe, Ant, Flu, Pyr, BaA, Chr, BbF, BkF, BaP, DBA, BghiPe, IDP) were analyzed using HPLC with a fluorescence detector + acetonitril/ultra pure water moving phase after ultrasonically dissolving samples in ethanol/benzene (1:3) solution and condensing with a rotary vacuum evaporator. Total carbon (TC) and organic carbon (OC) were analyzed using CHNS elemental coder, where TC is defined as carbon measured at 1150°C with the carrier gas of He+10%O_2 and OC at 350°C only with He gas. NO_2 filter badge was dipped in the coloring solution then the absorbance of the solution is measured at a wavelength of 545 nm. The average concentration is calculated from the absorbance using the conversion factor for the tropical area[3)].

3. Results and Discussion

3.1 Concentrations of particulates and gaseous pollutants

Average concentrations of particulate and gaseous pollutants are listed in Table 2, where monitoring data of gaseous pollutants for Fed.2004 - May.2005 by DW&F, APSARA are also shown. TSP concentration in downtown (Ta prohm H.) was extremely high plausibly because of the re-suspension of road dust although that value at Route 6 was not high as Ta prohm H. due to a more improved pavement. In Angkor Wat, TSP concentration was slightly lower than Phom Krom where the anthropogenic emission comes only from the lake direction because of the rainy monsoon. NO_2 and CO concentrations are measures of traffic and NO_2 was high clearly at Route 6 road side as well as in front of the Angkor Wat. CO was higher in front of Angkor Wat. Figure 2 compares particle size distributions at a temple beside the Route 6 and inside the Angkor Wat. PM2.5 had a larger fraction in the Angkor Wat although that concentration was about three times higher at Route 6 as shown in Table 2. These results may suggest possibilities of a large influence of traffic emission around the Angkor Wat and also the transportation of fine particles from downtown.

3.2 Carbon and PAHs concentrations

Results of carbon analysis are summarized in Table 3. The average TC concentration in downtown (Ta prohm H.) is about five times higher than in Angkor Wat Apportionments of EC and OC were, however, similar at both sites while TC mass fraction in particles was about 30 % in Angkor Wat. This may correspond to a larger fraction of fine particles in Angkor Wat, where carbon is frequently included in fine soot particles. Emission sources of carbons are not clear at this moment but wood burning and diesel engines may be main sources.

Figure 3 shows the concentrations of PAHs with four or more rings, whose concentration are indices of anthropogenic emissions from fuel burning[4)], in particles collected at downtown and Angkor Wat, compared with those in other cities in Cambodia[5)], Thailand[6,7)] and Japan[8)]. The total concentration inside the Angkor Wat was almost same with the downtown in spite of much lower carbon concentrations. This quite high PAHs concentration in Angkor Wat cannot be explained only by the influence of neighbor traffic because PAHs should be emitted also from other sources. This will be investigated more in detail but there might be an influence of transportation of PAHs from downtown or surrounding area, making fine particles as carrier: finer particles contain lager amount of PAHs[9)]. The total concentration of PAHs summed for 4-6 rings was about 10 times higher inside the Angkor Wat than Kanazawa in May, or, 4-5 times than Tokyo, 2 times than Bangkok although 1/4 of Phnom Penh. Figure 4 compares fractions of each PAH composition at different sites. Apportionment of each PAH at the Angkor Wat was rather similar to Phnom Penh or Bangkok although BghiPe fraction was larger in both sites in Siem Reap probably due to differences in contribution of emission sources, that is, more influences from traffic in downtown Phnom Penh. Mass fraction of total PAHs in the Angkor Wat (0.216ng/μg) was similar to that in Phnom Penh (0.267ng/μg).

Although one should conclude based on more detailed data such as concentrations in different locations, the size dependency of carbon concentrations and source profiles of each emission sources, a large fraction of carbons might be from different sources other than those for PAHs, or, some fuel burnings while PAHs may be both from the neighbor traffic and transportation from downtown and surrounding area by southwest monsoon wind.

4. Conclusion

The concentration of PAHs with four or more rings was found to be almost same in downtown and Angkor Wat while TSP concentration was much higher in downtown probably because of road dusts. The PAHs concentration was about 4-5 times higher than Tokyo, 3 times than Bangkok. NO_2 and CO concentration nearby the Angkor Wat were similar to downtown area and PM2.5 was shown to have a larger fraction in the Angkor Wat, probably suggesting larger contributions from the neighbor traffic. Total carbon concentration was about three times larger in downtown but a lager carbon fraction was in the Angkor Wat and occupied ca. 30% of particulate. A large portion of carbons in downtown might be from some fuel burning other than traffic. There might be a possibility of PAHs transportation from downtown area.

Acknowledgement

The authors would gratefully acknowledge to the kind cooperation of the Ta prohm Hotel and also to staffs in APSARA and Department of Geology, MIME.for the king assistance in sampling as well as to staffs in the Sofia University office in Siem Reap for a kind rent of an electric generator.

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Table 1 Sampling conditions

No.	Location	Sample	Sampling date	Sampling duration (min)	weather
1	Downtown	TSP, NO_2	26/05/2005 10:30〜26/05/2005 17:40	395	fine
2	Downtown	TSP, NO_2	27/05/2005 5:09〜27/05/2005 16:00	657	cloudy/fine
3	Angkor Wat	TSP, NO_2	27/05/2005 6:20〜27/05/2005 17:10	710	cloudy/fine
4	Angkor Wat	Size classified, NO_2	30/09/2005 6:11〜27/05/2005 10:26	255	fine/cloudy/rain
5	Route 6	Size classified, NO_2	01/10/2005 7:03〜27/05/2005 18:57	714	fine

Table 2 Concentration of particulate and gaseous pollutants

	Angkor Wat		Route 6	Downtown	Phnom Krom	Check point
	Inside	Front				
TSP (μg/m^3)	33.1±0.4(n=2)	-	135.5(n=1)	431.3±240(n=2)	51.3(n=1)	-
> 10μm (μg/^{3})	< 0.1(n=1)	-	35.8(n=1)	-	-	-
2.5-10μm (μg/m^3)	9.8(n=1)	-	37.3(n=1)	-	-	-
< 2.5 μm (μg/^{3})	23.5(n=1)	-	62.4(n=1)	-	-	-
NO_2 (ppb)	11.8±5(n=2)	13.9±4(n=21)	15.3(n=1)	11.0±1(n=2)	7.03(n=1)	10.0±6 (n=21)
SO_2 (ppm)	-	<0.02(n=21)	-	-	-	<0.02(n=21)
CO (ppm)	-	0.95±0.2(n=21)	-	-	-	0.78±0.3(n=21)

Table3 Carbon concentrations

Sampling site	TC		OC		EC		OC/TC	EC/TC
	(μg/m^3)	(%)	(μg/m^3)	(%)	(μg/m^3)	(%)	(-)	(-)
Angkor Wat (n=1)	9.68	29.5	2.24	6.85	7.43	22.7	0.23	0.77
Downtown (n=2)	50.1±25	11.9±0.8	9.1±6.5	2.0±0.4	41.0±19	9.8±1.2	0.17±0.04	0.83±0.04

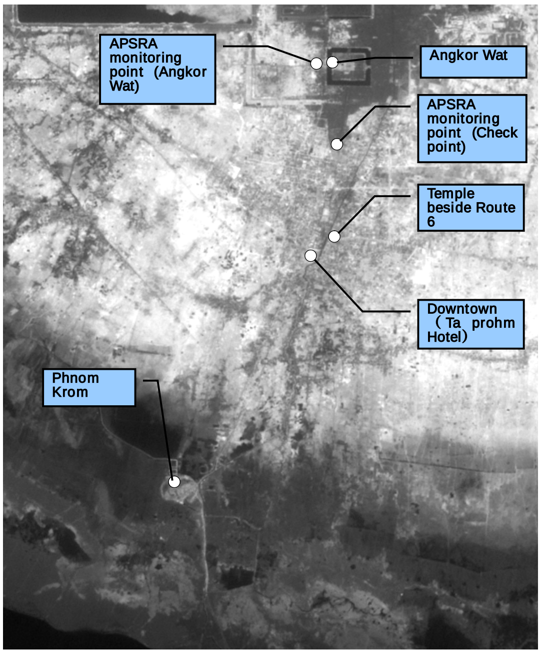

Fig.1 Locations of sampling sites

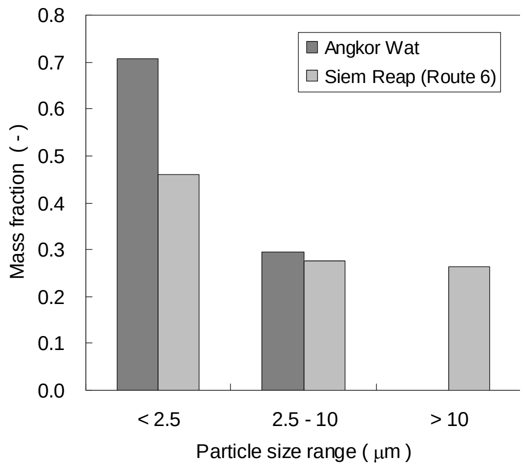

Fig.2 Mass fractions of each sized particles collected at Route 6 side and Angkor Wat

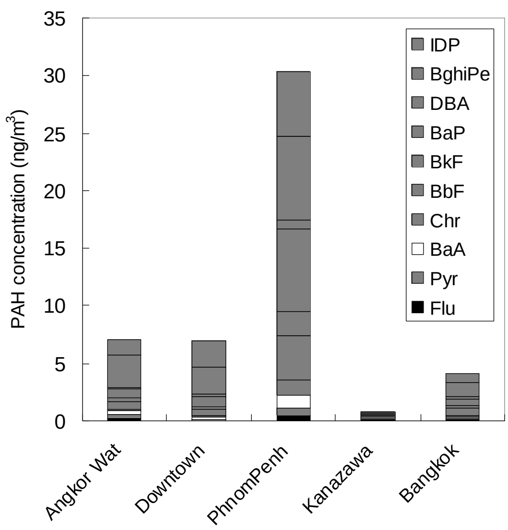

Fig.3 Concentrations of PAHs with four or more rings at downtown site and Angkor Wat compared with cities in other countries and Phnom Penh

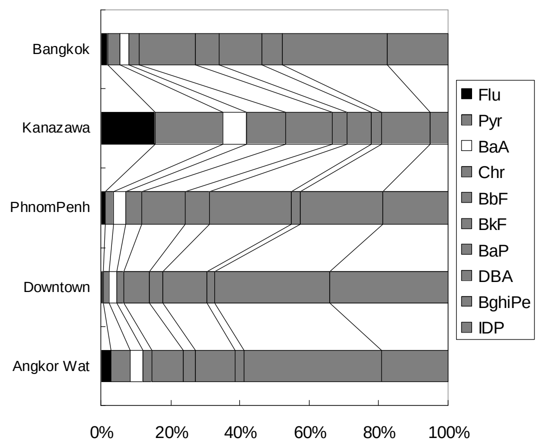

Fig.4 Partitioning of each PAH composition with four or more rings.

Meteorological Characteristics of Siem Reap City, Cambodia

Yasuaki Okumura[23], Shuichi Endoh[2], Ea Darith[3] and Hideo Oyagi[4]

Abstract

The only meteorological observatory around Lake Tonle Sap is situated at Siem Reap airport, which is far from the lake. Its weather database is insufficient for discussing the climatic characteristics of the lake. Therefore, we started weather observations by Evaluation of Mechanisms Sustaining Biodiversity (EMSB) at Lake Tonle Sap, Cambodia.

Even though installing a weather station near the lake was best, there were problems at the installation site, maintenance, and data evaluation etc. Finally we decided to install it at a private house in Siem Reap City. The location of Siem Reap City and Lake Tonle Sap are shown in Fig. 1. The station was equipped with five kinds of sensors to detect wind speed and direction, indoor and outdoor air temperature, relative humidity, atmospheric pressure, and precipitation. The data could be observed in real-time, recorded every 30 minutes, and then averaged. The weather station was manufactured by Davis Instruments Co. Ltd (USA), Vantage Pro., as shown by Photo 1.

Observation started on November 6, 2003. The example data are shown in Fig. 2, which shows the meteorological data in November 2003. The top graph of the figure shows the outdoor air temperature, relative humidity, and wind speed; the middle graph shows wind speed and direction by a stick diagram, and the bottom graph shows the distribution of the wind direction by a wind rose.

Diurnal changes of meteorological elements are visible for all data. Outdoor relative humidity is about 90% at night time and about 40% in the day time. The diurnal amplitude of outdoor relative humidity was very large. The air temperature also showed large diurnal peak to peak differences, about 20ºC at night time and almost 35ºC in the day time.

The wind blew only in the day, and it was calm at night. The wind was usually blew from the north or south, and an east wind was dominant only in January.

We compared the weather data of Siem Reap with Hikone, Japan. For example, the precipitation of Siem Reap has an annual pattern, a dry season and a rainy season. But it always rains in Hikone, as shown by Fig. 3.

[23] Osaka Electro-Communication University; [2] Shiga University; [3] APSARA, Cambodia; [4] Nihon University

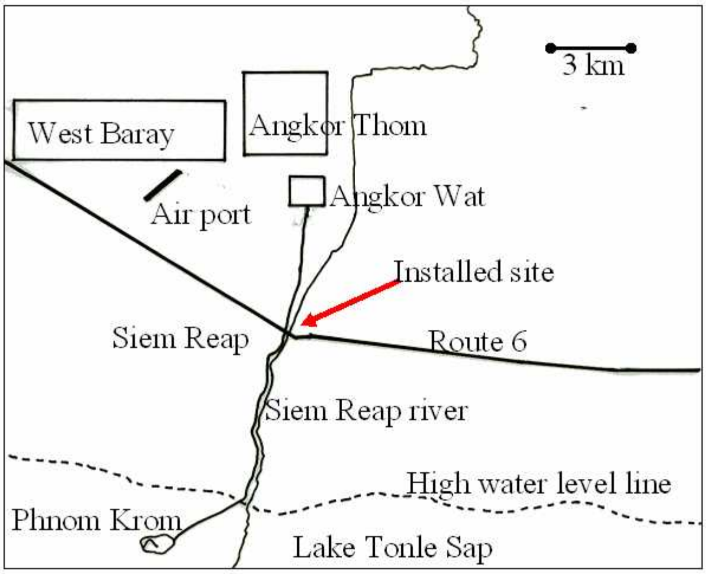

Fig. 1 Map of observation station

Photo 1 The weather station

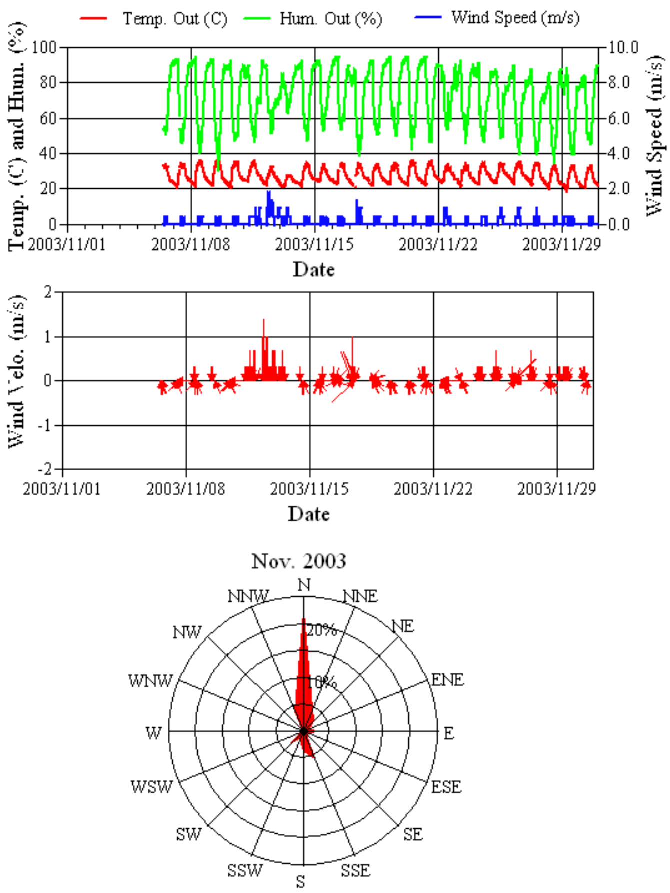

Fig. 2 Monthly weather data for November 2003

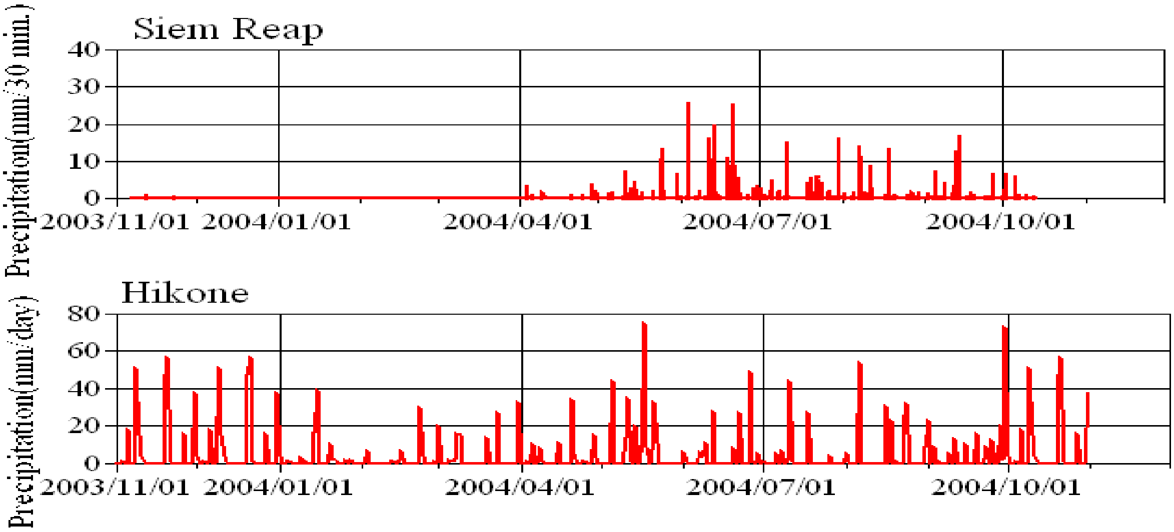

Fig. 3 Comparison of precipitation of Siem Reap, Cambodia with Hikone, Japan

Air Pollution in Phnom Penh: Concentration and Chemical Compositions of Ambient Particles

Masami Furuuchi[24], Takahiro Murase[1], Shinji Tsukawaki[2], Sieng Sotham[3], Michiko Yamashita[1]

Abstract

Ambient particulate matters were sampled at three different sites in Phnom Penh including the central part of downtown area. Day and night samplings of total suspended particulates (TSP) were done in the city center as well as NO_2 sampling. TSP concentration was evaluated and chemical composition of particulates, that is, poly-cyclic aromatic hydrocarbons (PAHs) and heavy metals were analyzed to discuss contributions respectively from road dust and anthropogenic emission sources.

TSP concentration at the city center was 100-250μg/m^3, being higher in daytime than night as well as the concentration of trace elements, such as Al, Ca and Fe, which are indices of soil particles such as road dust or the soil re-suspended by wind. The concentration of PAHs with four or more aromatic rings was higher in night where PAHs mass per unit collected particle mass was about 2-3 times higher in night. This may be due to emissions from diesel and other generators for the emergency electric supply, kerosene for light and biomass fuel for cooking etc. Rivers Macon and Tonle Sap may influence significantly the ambient air flow and pollutants dispersion. PAHs concentration in Phnom Penh was ca. 40 times higher than Kanazawa, Japan, being around 6 times higher than Bangkok, Thailand as well.

1. Introduction

The atmospheric environment has not been monitored continuously in Phnom Penh but only in the period from 1996 to 2002 during which the observation by Japanese research group has been done on total suspended particulates (TSP), NO_2 and SO_2[1, 2]. However, as to particulate matters, only the information at a city center was available. During past 10years after the election 1993, Cambodia economy has been growing very rapidly[3,4]. The number of automobiles has been also rapidly increasing and recently the number of automobiles including cars and motorcycles per population became similar to Thailand[5]. This inevitably leads to serious environmental problems but only a small potion of events has been recognized. Although the problems with the lack of infrastructure of the environmental monitoring

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instruments and network, it has to be clarified to recognize the present serious situation then start a step to the pollution control.

In this study, suspended particulates were sampled at three sites in Phnom Penh including central downtown, residential area and peninsula between rivers Macon and Tonle Sap. At the central downtown, TSP was sampled both during day and night to discuss differences in concentrations and chemical compositions which may be related to the sort of emission source. Characteristics of anthropogenic emissions in Phnom Penh were discussed by comparing with other countries, or, Japan and Thailand. As chemical compositions analyzed, poly-cyclic aromatic hydrocarbons (PAHs) and heavy metals were chosen to discuss respectively influences of anthropogenic and soil emissions.

2. Sampling and analysis

Suspended particulates were sampled using high volume air samplers (SHIBATA HV-500F) and NO_2 using passive samplers (ADVANTEC Personal Passive Sampler: Filter badge NO_2). Figure 1 shows sampling sites: 1) Central down town (Diamond Hotel), 2) Residential area (Office of Department of Geology, Ministry of Industry, Mines and Energy), 3) Peninsula between rivers Macon and Tonle Sap. At each sampling site, the high volume air sampler was installed along with a NO_2 passive sampler and a temperature-hygro sensor with data logger, which run over the whole sampling period. Quartz fibrous filters (ADVANTEC QR-100) weighed after keeping them in a constant humidity and temperature for 72 hours using a descicator were used for the sampling.

The samplings were conducted in March and May 2005. At the Diamond hotel, or at the city center, TSP was sampled both during day and night to discuss differences in the influence of emission sources. The simultaneous sampling at the three sampling sites was done only in May. Sampling data are summarized in Table 1. One should note that May 2005 was unusually dried as the rainy season.

The filters were weighed after the 72 hours conditioning then analyzed to obtain concentrations of heavy metals and PAHs. The heavy metals were analyzed using ICP-AES for the samples decomposed by nitric, hydrofluoric and perchloric acids. 15 different PAH compositions (Nap, Ace, Fle, Phe, Ant, Flu, Pyr, BaA, Chr, BbF, BkF, BaP, DBA, BghiPe, IDP) were analyzed using HPLC with a fluorescence detector + acetonitril/ultra pure water moving phase after ultrasonically dissolving samples on the filter in ethanol/benzene (1:3) solution and condensing with a rotary vacuum evaporator.

3. Results and Discussion

3.1 Day and night difference

Figure 2 shows TSP concentrations at the Diamond hotel in May and March. There is a very clear difference between day and night regardless to month: the daytime concentration is about two times higher than nighttime in average and was slightly (ca. 30 %) higher in March than May. TSP concentration in March is very similar to that at the main road side in Bagkok[6]. The reason why the difference in TSP concentrations between March and May is not so significant in spite of that May is usually in rainy season is that the rainy season lately started in 2005.

The clear dependency of TSP concentration on the sampling timing may be related to emission sources and emitted amount as well as the weather condition such as the thickness of mixing layer. In order to discuss influences of these factors, information about emission sources, detailed meteorological data should be obtained. However, this is eventually impossible because of the present situation in Cambodia. Hence, in the followings, possible influences are discussed based on chemical compositions of each sample.

Figure 3(a) and (b) respectively show comparison of heavy metal concentrations in day and night samples respectively expressed in mass concentration and that normalized by particle mass concentration. During day time, soil components such as Al, Ca and Fe have larger mass fractions in particles, indicating lager influences from road dust or soil particles re-suspended by wind.

Since anthropogenic emission sources in downtown such as burning of fossil and biomass fuels and diesel engine should also affect chemical compositions in particles, in the followings, PAHs with four or more aromatic rings (Flu, Pyr, BaA, Chr, BbF, BkF, BaP, DBA, BghiPe, IDP) were used to discuss their contributions. Figure 4 shows concentrations of each PAH composition and their summation, compared between day and night. Contrarily to TSP concentration, the total PAHs concentration is always higher in night: about three times larger concentration was observed in May. As can be seen from Fig.5 showing PAHs mass normalized by particle mass, average PAHs mass fraction during the night is ca. 2.4 times larger than day time.

Taking into account the fact that the traffic is much less heavy during the night, such large difference may not be explained by a decrease in the thickness of mixing layer. The reason why lager influence of anthropogenic emission was observed during the night may be related to sources for electric supply, use of kerosene for light and fuels for cooking in houses and restaurants. In Phnom Penh, there are two electric power plants, which supply 75.5% of electric demand while remaining is covered by small but numerous numbers of electric generators and kerosene[4]. In hotels in Phnom Penh, in order to keep the emergency electricity, they have diesel generators with rather large capacity and small generators are widely distributed in houses. As fuels for cooking, city gas supply 16.3% of demand while charcoal and woods cover 34.4 and 43.1 %, respectively[4)]. In order to specify contribution from each emission source, source profiles of traffic, generators, kerosene and wood burning should be obtained. Figure 6 depicts such possibility to know emission characteristics, where the mass fraction of four or more aromatic ringed PAH composition is shown to compare day and night characteristics. Fractions of compositions with four rings, e.g., Fle, Pyr, BaA and Chr, are larger in day time while BghiPe and IDP, frequently contained in finer fraction of particles[7,8)] , have larger fractions in the night.

3.2 Influence of location inside the city

TSP concentrations at three different sampling sites are compared in Figure 7. The reason for higher TSP concentrations at the residential area and river peninsula may be due to the re-suspension of soil particles from unpaved roads and river bank, which will be proven by the element analysis. Figure 8 shows the concentration of PAHs with four or more aromatic rings, indicating PAHs concentration was the lowest in the peninsula and the highest at the Diamond hotel. It should be noted that the concentration at the residential area was just about 20% below at the city center in spite of that the amount of road traffic is much lower than that at the city center. As shown in Table 2, NO_2 concentration at the residential area is about 40% less than the city center. This may show a less influence of traffic. is As shown in Fig.9, PAHs mass fraction in particles at the peninsula was 1/10 of the city center and 1/5 of the residential area, indicating much less contribution of particles from fuel burning. NO_2 concentration in the peninsula was also less than 40 % of the city center, indicating much less influence of traffic. Figure 10 shows the mass fraction of each PAH composition. Portions of each composition are similar between the city center and residential area, indicating there may be a similar influence from same sort of emission sources. Contrarily, the partitioning is slightly different, e.g., BaP fraction is smaller, in the peninsula. Since the river peninsula locates downstream the city center for the south-west monsoon wind, less but similar concentration and fractioning of PAHs were expected before sampling. The reason why the PAHs concentration and fractioning at the peninsula are quite different from the city center may be due to the air stream along large rivers, Tonle Sap and Macon. This can be reinforced by the observation that over the almost whole period of sampling, the north wind along the river Tonle Sap was confirmed from flags along the river bank. The river wind might protect the transportation of pollutants from the down town area to the peninsula.

3.3 Comparison with Japan and Thailand

In Figure 11, the average concentration of PAHs with four or more aromatic rings in Phnom Penh is compared with that in Sihanoukville, Japan (Kanazawa)[9,10)] and Thailand (Bangkok[9,10)] and Hat Yai[11)]). The PAHs concentration in Phnom Penh is abut hundred times higher than Sihanoukville, 40 times than Kanazawa and 6 times than Bangkok, where a severe problem with heavy traffic still exists. This is similar for the mass fraction of PAHs in particles as shown in Fig.12. Figure 13 shows the mass fraction of each PAH composition averaged for samples at each sampling site. The partitioning of PAHs is similar in cities in Indo-China peninsula, suggesting contribution from similar emission sources. However, slight differences in fractions of BghiPe, which is higher in Phnom Penh and DBA, which is higher in Hat Yai, also exist. In Kanazawa, the fraction of four aromatic rings (Flu, Pyr, BaA, Chr) is more than 50% while it is less than 20% both in Cambodia and Thailand. This may be due to the temperature difference and intensity of ultra violet ray as well as the difference in emission sources. The fraction of PAHs with five or more aromatic rings is similar in cities except Sihanoukville probably because of a less influence of temperature. In Sihanoukville, the fraction of IDP, which has a higher fraction in fine particles less than 1 μm[7], is about 50 %. Although more data are requited, this might be so because that some portion of particulates collected in Sihanoukville was transported over the Gulf of Thailand while experiencing the rain- and wash-out , sedimentation and chemical degradation.

Conclusion

Samplings of ambient particulates were conducted in three different sites in Phnom Penh and concentrations of TSP, PAHs and heavy metals were compared to discuss the influence of day and night, location and country dependencies. As results, following conclusions are drawn:

1) The average concentration of PAHs per particle mass in Phnom Penh was about 2.5 times higher during the night. This may be due to emissions from electric generators, kerosene for light, biomass fuel for cooking.
2) PAHs concentration and partitioning of PAHs in the residential area were similar to the central downtown but less concentration of NO_2 indicating less influence of traffic.
3) There may exits a significant influence of air flow along Tonle Sap and Macon Rivers, which reduces the transportation of air pollutants to the river peninsula.
4) The PAHs concentration in Phnom Penh was extremely high and the partitioning of PAHs is similar to cities in Thailand: 6 times higher than Bangkok and 40 times higher than that in Kanazawa, Japan.

Acknowledgement

The authors would gratefully acknowledge to the kind cooperation of the Diamond Hotel and also to Mr. Sambath for his help to the sampling, as well as a Cambodian family living in the river peninsula.

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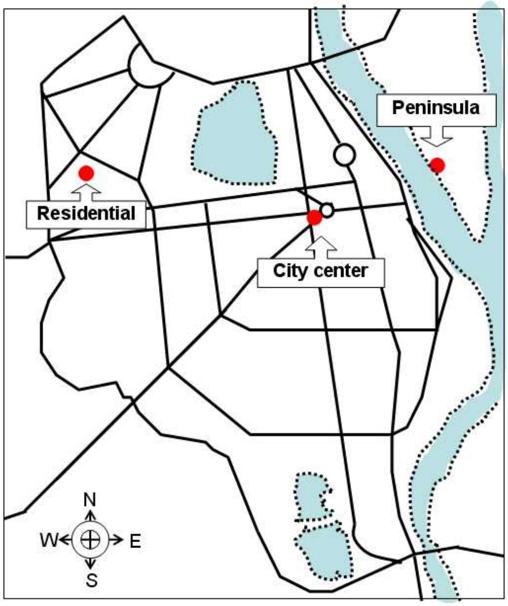

Fig.1 Sampling sites in Phnom Penh

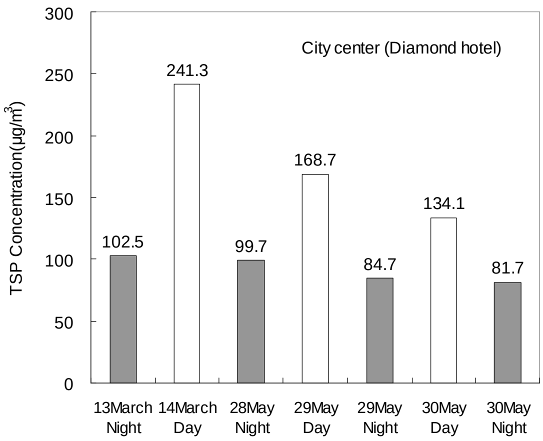

Fig.2 TSP concentration in day and night sampling period

Table 1 Information on samplings

Location	Sampling date	Sampling duration (min)	weather
City center	13/03/2005 21:09〜14/03/2005 9:19	730	sunny
City center	14/03/2005 9:23〜14/03/2005 20:32	664	sunny･cloudy
City center	28/05/2005 17:41〜29/05/2005 8:05	742	fine
City center	29/05/2005 8:20〜29/05/2005 18:49	629	fine
City center	29/05/2005 19:02〜30/05/2005 7:10	722	rainy/fine
City center	30/05/2005 7:20〜30/05/2005 18:50	690	fine
City center	30/05/2005 19:07〜31/05/2005 6:54	673	fine
Residential area	30/05/2005 9:06〜31/05/2005 7:54	648	fine
River Peninsula	30/05/2005 10:43〜30/05/2005 16:05	231	fine/cloudy･rainy

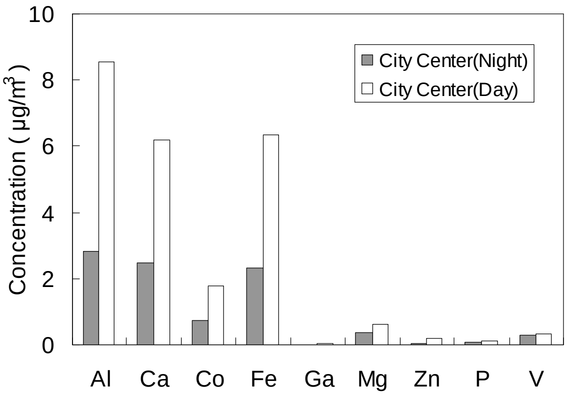

Fig.3(a) Heavy metal concentration at Phnom Penh city center (day and night)

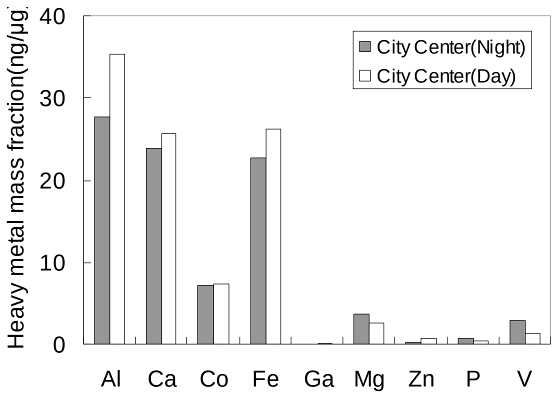

Fig.3(b) Heavy metal mass fraction in particles at Phnom Penh city center (day and night)

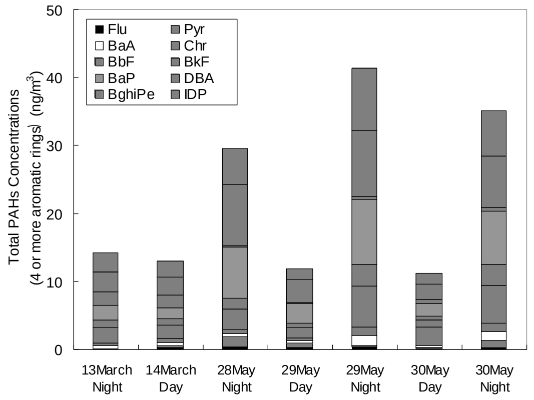

Fig.4 PAHs concentration at Phnom Penh city center (day and night)

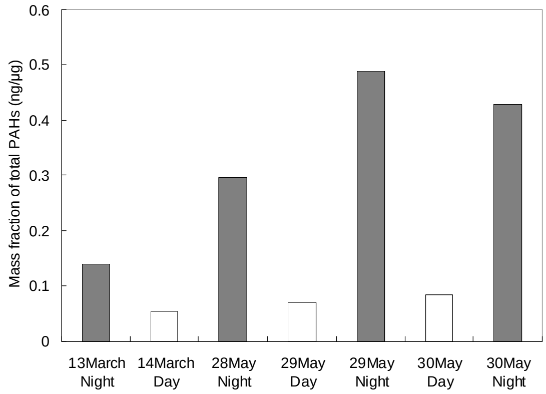

Fig.5 PAHs mass fraction in particles at Phnom Penh city center (day and night)

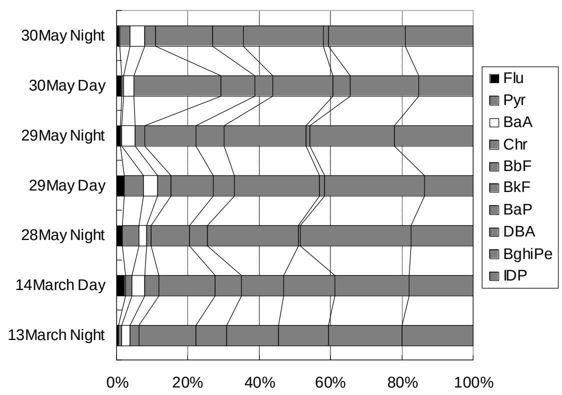

Fig.6 Mass fraction of each PAH composition

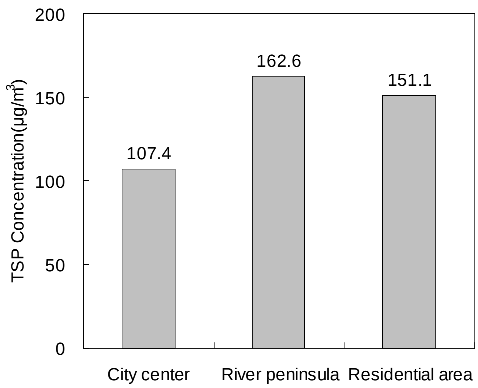

Fig.7 TSP concentration in different sampling sites

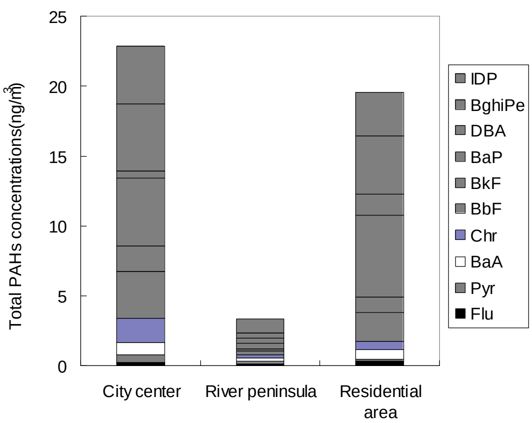

Fig.8 PAHs concentration at three different sites

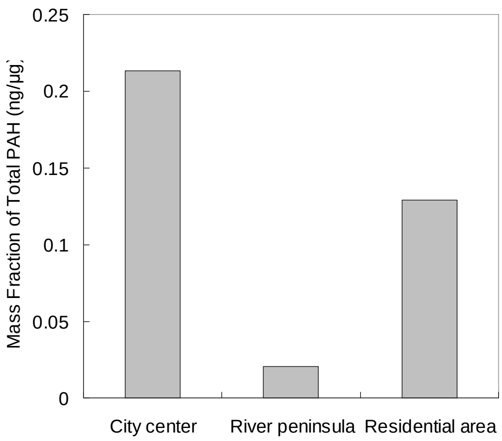

Fig.9 PAHs mass fraction in particles at different sampling sites

Table 2 Concentrations of air pollutants at each site

Site	Place	Concentration		
		TSP ($\mu g/m^3$)	PAHs (ng/m^3)	NO_2 (ppb)
1	City Center	107.4	22.89	25.2
2	Residential area	151.1	19.53	16.4
3	River peninsula	162.6	3.37	9.66

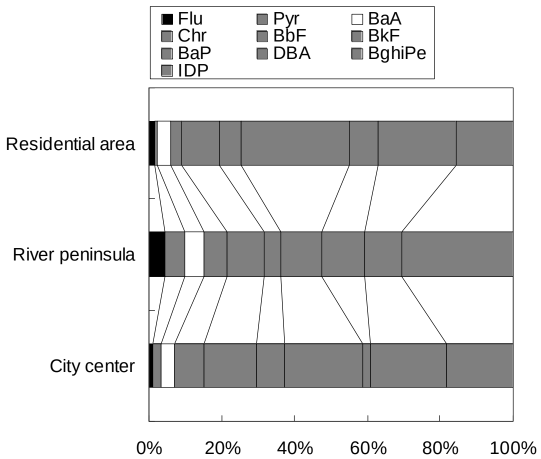

Fig.10 Mass fraction of each PAH composition at different sampling sites

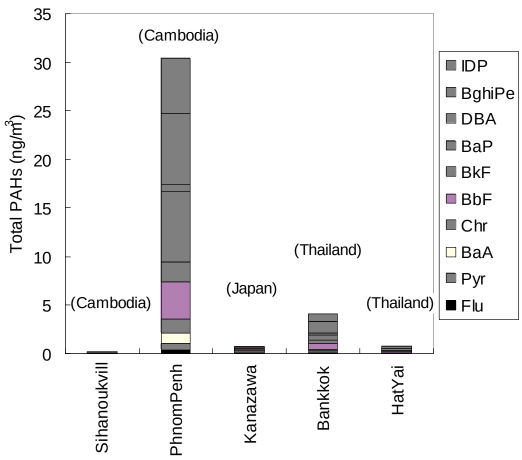

Fig.11 Average PAHs concentration at different cities

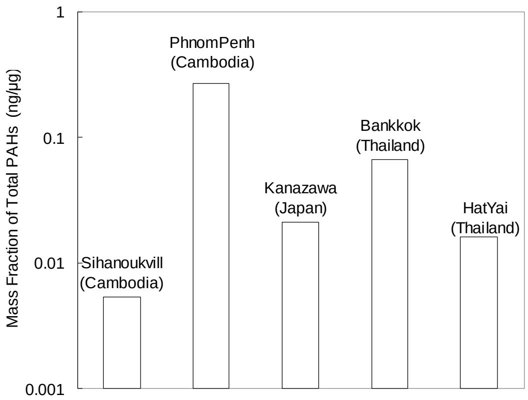

Fig.12 PAHs mass fraction in particles at different cities

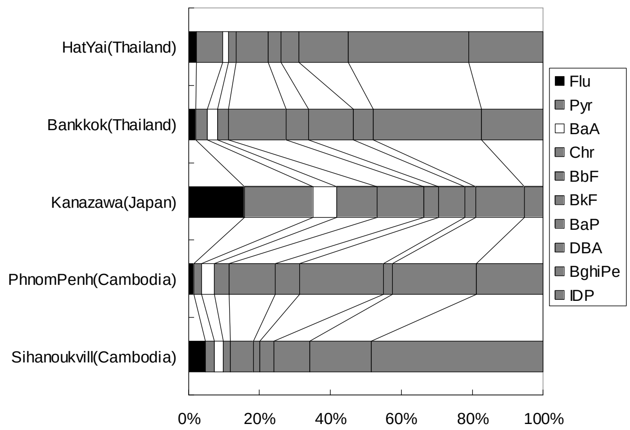

Fig.13 Mass fraction of each PAH in different cities

Ambient Air Temperature Distribution in Phnom Penh: Influences of Land Use and Mekong and Tonle Sap Rivers

Masami Furuuchi[25], Takahiro Murase[1], Michiko Yamashita[1], Shinji Tsukawaki[2], Sieng Sotham[3], Tsuyoshi Jinno[1] and Ken-ichi Sakai[1]

Abstract

Temperature distribution inside Phnom Penh was measured using a car to discuss the thermal characteristics and air pollution in the city. Measurements using two sets of temp-hygro sensor with data logger installed on the car roof were conducted both during day and night to evaluate influences of heat sources. By measuring temperature as a function of distance from the river side of Mekong and Sap, the cooling effect of the river was investigated. Temperature distribution was compared with the concentration of ambient particulate matters and NO_2.

The maximum temperature difference, which is so called heat island intensity, was observed during the day time and was around 4-5^oC, while being 1.3^oC during the night. The maximum and minimum temperatures were respectively observed at the traffic circle at the north end of Monivong Street and the river island between Tonle Sap and Mekong or the river side, indicating the strong influence of chilled wind over the river. The temperature along roads perpendicular to the river bank was found to increase with the distance from the river bank, suggesting the extent of chilled area to inland. Comparison with concentrations of ambient particulates and anthropogenic composition shows a close relation between temperature and concentration of anthropogenic compositions.

1. Introduction

During past 10years after the election 1993, Cambodian economy has been growing very rapidly[1,2)] and the urban area of Phnom Penh, the capital of Cambodia, has been also expanding, as well as a significant increase in the energy consumption and the number of automobiles. These inevitably give rise to increase in the air pollution as well as an increase in the temperature, or, the thermal pollution, which lead to health problems and uncomfortable living environment[3)]. Since emission sources of air pollutants and heat are frequently same, the air and heat pollutions are closely linked with each other[4,5)]. Although being still not enough data, there have been a few investigation and measurement to the air pollution[6,7)], showing serious

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environmental situations. However, the thermal pollution has not been evaluated in Phnom Penh.

In this study, temperature distribution inside Phnom Penh was measured using a car to discuss the thermal characteristics and air pollution in the city. Measurements using two sets of temp-hygro sensor with data logger installed on the car roof were conducted both during day and night to evaluate influences of heat sources. By measuring temperature as a function of distance from the river side of Mekong and Sap, the cooling effect of the river was investigated. Temperature distribution was compared with the concentration of ambient particulate matters.

2. Structure and land use of Phnom Penh and Method of Temperature Measurement

Figure.1 shows the land use data evaluated from a satellite data (ASTER, AST3A1, 20/02/2002) using a commercial GIS software （ENVI ver.4.2） based on the supervised classification method[8,9]. Each land use is designated by 6 different gray levels (25(forest), 75(blank space 2), 100(water area), 130(blank space1), 200(paddy field) and 255(urban area)). The urban area, denoted by white color, is widely spread along streets on the left bank of the river Sap from the central market and there are no skyscrapers but 6-8 stories buildings dominate the central area particularly along main roads and lower buildings cover a large area of the city. As can be seen from Fig.1, vegetation area has a very small fraction but there are large rivers, Mekong, Tonle Sap and Bassac on the east side of the city, as well as rather large water ponds in north and south.

A measuring probe consisting of a temperature-hygro sensor with data logger (SATO KEIRYOKI SK-L200TH II) attached inside a PVC tube (55mm I.D., 300mm length and 2mm thickness) covered by an aluminum coated urethane foam sheet (6mm thickness) was devised (See Fig.2). This probe has almost same geometry used in the published paper[10]. In order to avoid the influence of air flow, the probe axis was directed perpendicular to the car traveling direction. For the compensation, two sets of observation prove were installed on both roof sides of a sedan car as shown in Fig.3.

Focal points of the observation were as follows: 1) influences of land use on temperature distribution, 2) difference between the day and night temperature distribution and influencing factors, and 3) cooling effect of rivers. Observation routes and conditions are shown respectively in Figs.4-6 and Table 1, where route 1 was for the grasp of the overall situation of temperature distribution as the first observation, route 2 was almost same with route 1 and for the observation during night time along with the measurement of temperature as a function of the distance form the river and route 3 was focused on the influence of the river.

In every observation, check points were determined in advance. After leaving the starting point, or, the Diamond Hotel locating in the city central, the observing car passed though check points A, B, C… in turn following traffic lights. The average speed and total travel distance for each route are also show in Table 1. Temperature and humidity were recorded at preset time interval (10 sec. – 1 min.) while the time was recorded at each check point. The temperature was measured also at the top of the Diamond Hotel, or 8 stories building, to monitor the temperature and humidity change during observations.

3. Results and Discussion

3.1 Day and night difference and temperature distribution along main streets

Figure 7 shows the temperature distribution along the Route 1, where the temperature change during observation was modified based on the temperature at the Diamond Hotel. The temperature increased along the main road with two lanes (A->B->C) and dressed around the residential area (D) with more vegetation. The temperature then reached to a peak in the traffic circle (F). In the area inside the island between rivers Mekong and Tonle Sap, the temperature drastically decreased down to the minimum in the Route 1 at the cape of the peninsula (I). Along the main road (Monivoung Street) running from north to south, the temperature increased gradually through the city center (A) to south (A->M->N->L->O->P) and became a peak (P->Q). After this peak, the temperature increase was not so clear around the city center. However, it decreased along the river bank (V->W->X) and became the lowest (X). A rapid decrease just before arriving at the starting point corresponded to an initiation of precipitation. The maximum temperature difference, so called “heat island intensity” was 4.6^{o}C. This is almost on a correlation between the heat island intensity and population for cities in Japan[11)].

Figure 8 shows the temperature distribution during the night (Route 2). The temperature difference was not as large as in day time but the highest temperature gradually increased toward south through the Monivoung Street and the highest value was recorded in south (N) and the lowest at the bank of river peninsula (G). The maximum temperature difference was 1.3^{o}C. The temperature in the central urban area was around 27.0, being about the average temperature over the route.

Temperature variation through the Monivong Street (F->P in Route 1 and 2), which is one of the main axis of the city running from north to south almost parallel but having some distance to the river, is shown in Fig. 9 for each observation, where a temperature difference from point F is plotted against the distance from point F. During the night time, the temperature increased as approaching to the city center then became a peak around L-N, followed by a gradual decrease toward the peripheral of urban area ((O->P). Trends during day time were not same in different days but a tendency that the temperature increase from the city center (A) to south seems to be similar. The temperature increment ranged 0.6-1.5^{o}C, being slightly larger in the day time. The reason why the temperature peak was not in the busiest area, that is, beside the central market and Diamond hotel may be due the structure and land use of Phnom Penh and the position of the Monivong Street. The urban area of Phnom Penh has a rather uniform land use characteristic, that is, a mixed structure of commercial and residential areas, roads and other blank areas with gradual decrease in the density of urbanized area as shown in Fig.1. This may make a center of “heat island” shift from the busiest area to the south. The results shown in Fig.9 may be to the fact that the Monivong Street runs through the center of urban area as well as the busiest district and the center of heat. The measured temperature may be also influenced by the weather condition such as wind direction as well as the amount of traffic at each part of roads. The temperature peak around point F was possibly caused by a heavy traffic. Since the temperature was observed always on roads, it has to be affected by the amount of surrounding traffic although it has to be also affected by the land use. Hence, one should know these to discuss rigorously the influence of land use and traffic. The difference between daytime distributions may be related to the weather condition and influences of rivers discussed bellow.

The temperature at check points beside the river, particularly in the river peninsula (H-J) was clearly and always lower than others. This is plausibly the chilling effect of river with lower temperature, which chills the air flowing over the river. In order to discuss to what extent the chilling effect expands, the temperature difference along the roads running nearly perpendicular to the river was plotted against the distance from the river bank as shown in Fig.10, where the temperature distribution both in day and night periods are shown. During the day time, it is clear that the temperature increased with the distance from the river bank in every road and the chilled area extended to about 2km form the river bank. There is also a chilling effect during the night but it is not as clear as in the day time. Taking also into account the results shown in Fig.9, the temperature variation in the night is more influenced by the land use than the chilling effect of rivers.

3.2 Relation between temperature and concentrations of ambient pollutants

For the understanding of the chilling effect of the rivers, the local meteorological information such as wind direction and velocity is important. However, it is difficult to obtain at this moment so that in the followings, reported data for the air pollution in Phnom Penh are used to discuss the influence of the river wind both on temperature and air pollution. In Table 2, concentrations of total suspended particulates, total poly-cyclic aromatic hydro carbons (PAHs) with four or more aromatic rings (Flu, Pyr, BaA, Chr, BbF, BkF, BaP, DBA, BghiPe, IDP) and NO_2 at three observations sites for the ambient air pollution in Phnom Penh done in May[12]. These PAHs are carcinogenic and their concentration is a measure of anthropogenic emission sources[13,14] and NO_2 index of emission from traffic. TSP concentration was high in residential area and river peninsula probably because of the re-suspension of soil dust from un-paved roads and river bank. The concentrations of PAHs and NO_2 were considerably lower than those in sites in the other side of the river Tonle Sap. According to the observation during the pollutant sampling, the wind has blown from north to south along the river Tonle Sap while the Monsoon wind has blown from south west in the down town area[12)]. Based on these results, one can say the wind over the Tonle Sap and Mekong Rivers blowing from the north chilled the atmosphere and protected the transportation of pollutants from the downtown area to the river peninsula. It means the temperature and pollutants distributions in Phnom Penh strongly depend on the wind over the rivers.

Conclusion

Temperature distribution inside Phnom Penh was measured to discuss the thermal characteristics and air pollution in the city. The influences of land use and cooling effect of Mekong and Sap rivers were discussed. Temperature distribution was compared with the concentration of ambient pollutants. As results, following conclusions are drawn:

1) The maximum temperature was observed not in the busiest area but in the southern part of the city both in day and night. The maximum temperature difference so called the heat island density was 4.6^{o}C which is almost on the correlation between the intensity and population for cities in Japan.
2) There were clear influences of Mekong and Tonle Sap Rivers for the chilling of ambient temperature in downtown area, extending up to around 2km from the river bank.
3) The wind over the river Tonle Sap seemed to protect the transportation of ambient pollutants.
4) The Mekong and Tonle Sap Rivers have very important roles on the thermal and environmental characteristics of ambient atmosphere in Phnom Penh

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Table 1 Observing conditions

Route	Measuring period	Measuring interval	trevel distance (km)	average speed (km/h)	Weather
1	25/09/05 11:14 - 25/09/05 12:45	1 min	37.3	24.9	Cloudy/fine->rainy
2	25/09/05 19:09 - 25/09/05 21:45	10 sec.	48.9	22.6	fine
3	27/09/05 11:11 - 27/09/05 12:45	10 sec.	44.3	29.8	fine

Fig.1 Structure and land use in Phnom Penh evaluated from Satellite (ASTER) data:

Fig.2 Observation probe (a temp-hygro sensor with data logger)

Fig.3 Observation probes installed on the roof top a car

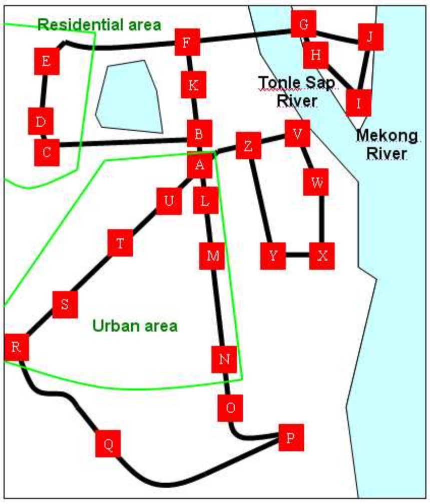

Fig.4 Observation route map (Route 1)

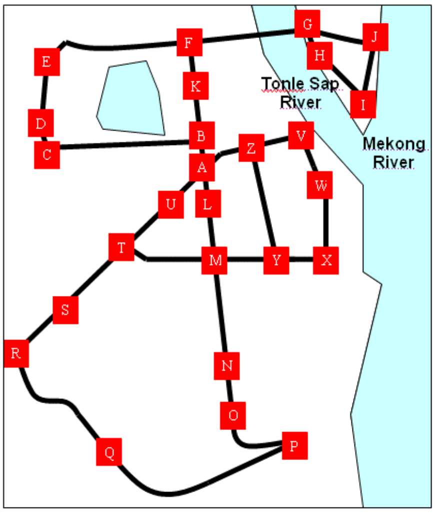

Fig5 Observation route map (Route 2)

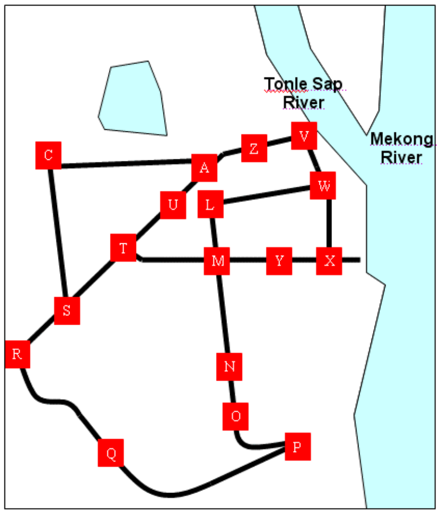

Fig.6 Observation route map (Route 3)

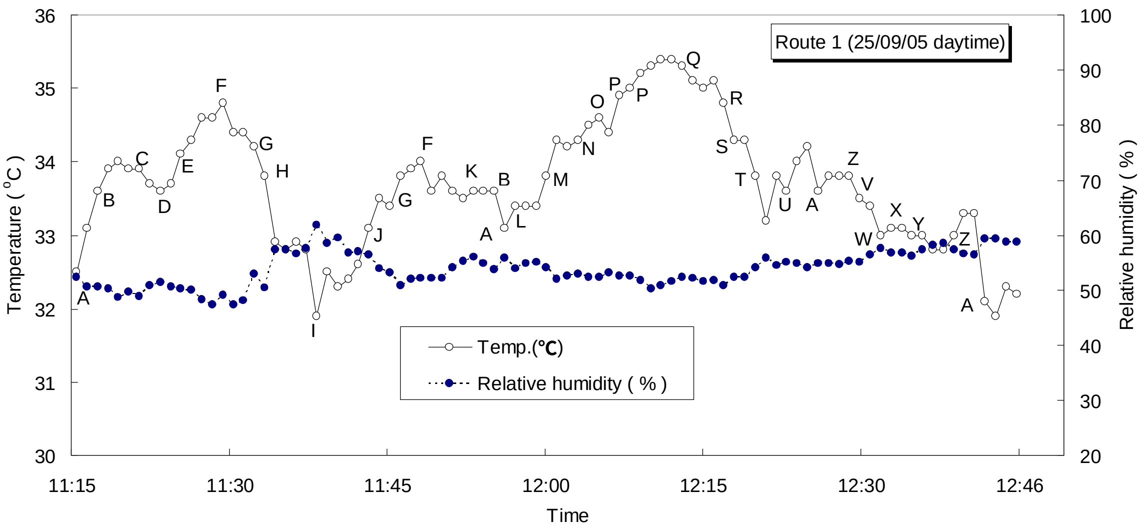

Fig.7 Temperature distribution along the route 1 (day time)

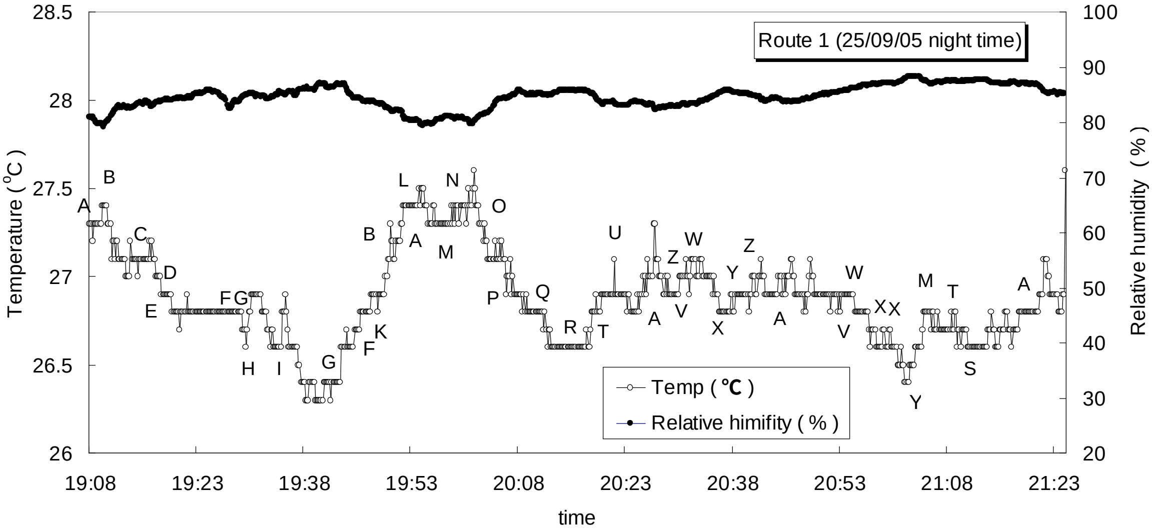

Fig.8 Temperature distribution along the route 2 (night time)

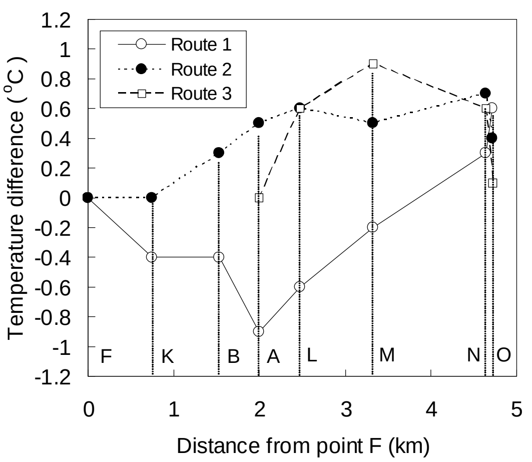

Fig.9 Temperature variation along the main road (Monivong Street) running from north to south through the city center

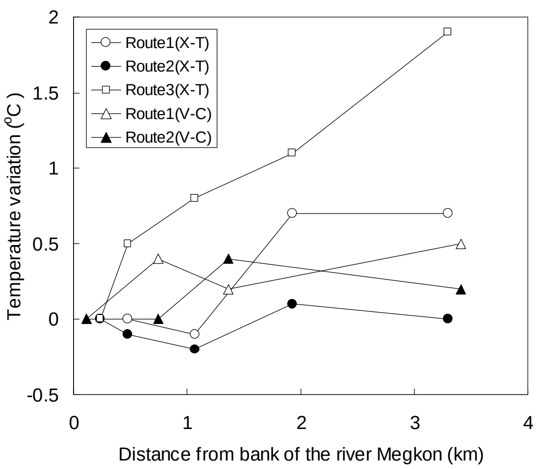

Fig.10 Temperature variation along the direction perpendicular to the bank of the river Mekong

Table 2 Concentrations of air pollutants near check points

Site	Place	Nearest check point	Concentration TSP ($\mu g/m^3$)	PAHs (ng/m^3)	NO_2 (ppb)
1	Central downtown	A	107.4	22.89	25.2
2	Residential area	C	151.1	19.53	16.4
3	River peninsula	H	162.6	3.37	9.66

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