ENVIRONMENTAL IMPACT ASSESSMENT OF URBAN AIR TEMPERATURE INCREASE BASED ON ENDPOINT-TYPE LIFE CYCLE IMPACT (PART 1) – ITS FRAMEWORK

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Abstract

We developed an environmental impact assessment framework of urban heat islands (UHI) based on the endpoint-type life cycle impact assessment methodology to evaluate various environmental impacts with single index. Methodology of LCA was used for constructing this framework. Metrological elements such as air temperature, air humidity, wind direction and wind velocity were selected as the impact category. Category endpoint was selected referring to the past research which organize environmental impacts from UHI phenomenon. The relationship between the impact categories and the category endpoints and between the category endpoints and safeguard subjects were organized with reference research.

Key words: life cycle impact assessment, LIME, framework

1. INTRODUCTION

Urban heat island (UHI) phenomenon is recognized as an environmental problem that results in increase of CO2 emission by increase of electricity consumption for air-conditioning in summer, and gives the direct damage on human body by increase of the heat stress. The solution of the UHI problems is a pressing issue. Thus, Japanese government is actually planning the countermeasures for UHI problems through urban renewal projects (www.toshisaisei.go.jp, 2009).
On the other hand, the problems caused by UHI are different in countries and regions. One of the problems caused by UHI in Japan is the increase of energy consumption in summer because of the Japanese extremely hot summer. However, that is not significant problem in European countries because there is not so much cooling demand. According to Brandit 2006, air temperature rise in summer is considered to be preferable in Germany because that will bring them a comfortable night time.
In addition, we should consider the UHI problem together with other environmental problems such as global worming for the reduction of total environmental impacts.
Environmental impacts would not be reduced by the countermeasures that only focus on decreasing air temperature. The decrease of air temperature will decrease the CO2 emission through a reduction of cooling demand in summer in Japan. But the decrease of air temperature would increase the CO2 emission through an increase of heating demand in winter (Ihara, T. et al. 2008, Narumi, D. et al. 2007).
The effectiveness of UHI countermeasures is also changed by the time and spatial condition. For example, the effect of decreasing air temperature by energy-saving in car is expected to be large in office area, but small in residential area (ECCJ, 2005). The decrease of air temperature in daytime will reduce the heat stress in office area. However, it may not be effective in the region where the daytime population is a little. Such region may have better not to introduce the countermeasures for UHI because the CO2 emission caused by countermeasures might be not small. Thus, it is necessary to quantify total environmental impacts for planning of the effective UHI countermeasures.
In this study, we developed the framework for quantification and integration of various environmental impacts from UHI phenomenon influenced by the time and spatial condition based on the methodology of a life cycle impact assessment (LCIA). In addition, we applied the framework to Tokyo area in Japan to quantify considered environmental impacts in category endpoints of UHI from UHI phenomenon in Tokyo (Ihara, et al. 2009).

2. LIFE CYCLE IMPACT ASSESSMENT OF URBAN HEAT ISLAND

2.1. LCIA and LIME

The methodology for quantification of environmental load and impacts has been discussed in the research field of LCA. In the series of ISO14000 (International Standard) which define an environmental management system,

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LCA is standardized as ISO14040, and LCIA is also standardized as ISO14042 (In 2006, after the development of LIME, the original ISO14040~14043 was restructured as ISO14040 and ISO14044.). LCIA is defined by ISO14042 to assess the environmental impacts in 3 steps: Characterization, Damage assessment, and weighting. There are 2 types of LCIA method: midpoint-type and endpoint-type, and both of type can integrate various environmental impacts to a single index for environmental assessment.
The midpoint-type LCIA has long been applied for environmental assessment, however, it has been pointed out that a number of the comparable environmental problem (category endpoint) is limited, the information level of people influence to the weighting value in each environmental problem, and the assessment result is not reliable as it should be because the weighting process is embedded in the total assessment process like a “black box”.
On the other hand, the development of the endpoint-type LCIA method has been developed because it has high possible accuracy and transparency in assessment process which includes weighting process based on the calculation of the damage on safeguard subjects. In Japan, Life-cycle Impact assessment Method based on Endpoint modeling (LIME) (Itsubo, N. et al. 2004) was developed in the 1st. stage of LCA project conducted by the Ministry of Economy, Trade and Industry.
LIME is based on the LCIA methodology of ISO14042. In the damage assessment process in LIME, various category endpoints are integrated into four safeguard subjects: Human health, Social assets, Biodiversity, and Primary productivity, based on the damage calculation by statistic data and physical model. In the weighting process in LIME, the single index is calculated by multiplying the damage amount of each safeguard subjects by the weighting factor of each safeguard subjects. The weighting factor is determined by conjoint analysis of the questionnaire survey asking to Japanese people the willingness to pay for the reduction of damage on each safeguard subjects. UHI causes various kinds of environmental impacts. Therefore it is difficult to calculate a single index by midpoint-type LCIA.
In this study, we assess the environmental impacts from UHI by LIME framework which is endpoint-type LCIA.

2.2. Assessment model for UHI based on LIME

LIME consist 5 steps: Fate analysis, Exposure analysis, Damage assessment, Quality analysis, and Weighting. The fate analysis and exposure analysis are for the characterization in ISO14042. The damage assessment and quality analysis are for damage assessment in ISO14042. The environmental impact, which is integrated into a single index, is calculated through those 5 steps by the emission amount of environmental burden which is a result of Inventory analysis of LCA.
The fate analysis and exposure analysis in LIME can be applied from causes (Inventory) to worldwide phenomena (Impact categories), however, it is difficult to apply directly to UHI phenomenon because UHI is regional phenomenon. In this study, the fate analysis and exposure analysis on UHI was done by other numerical simulation model such as AIST-CM-BEM (Ihara, T., et al. 2008). Those processes were not included in the

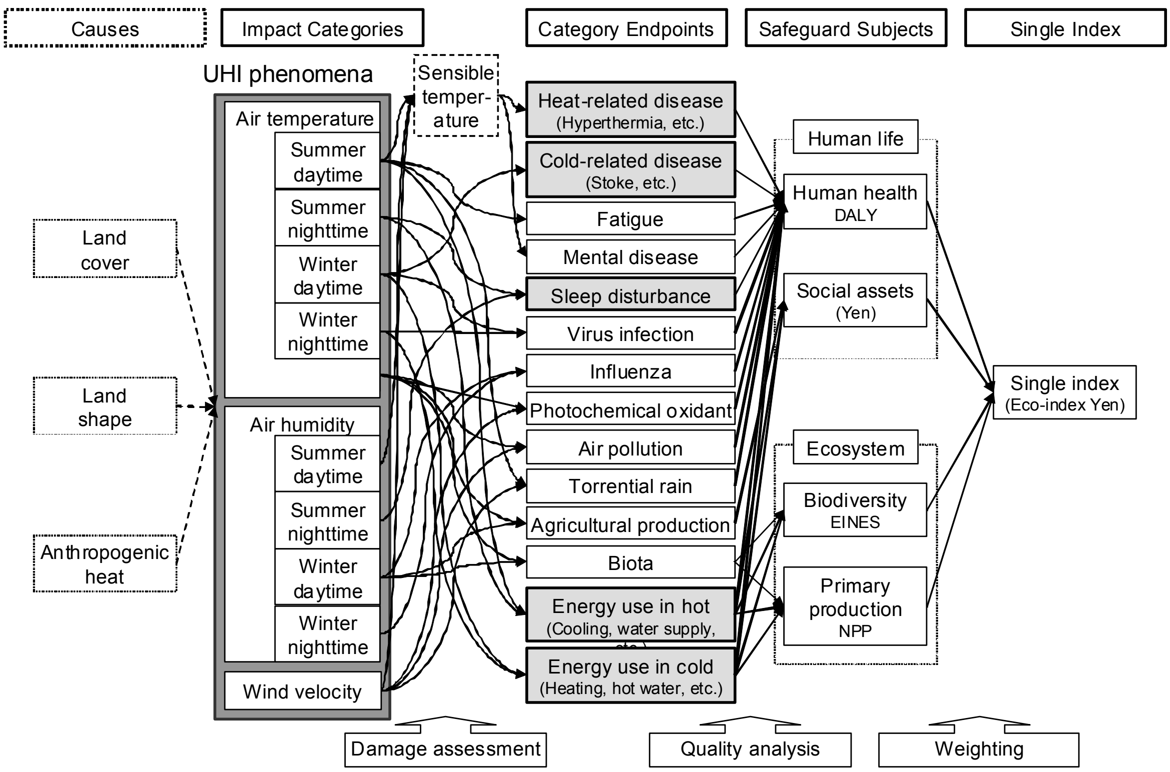

Fig. 1 Framework for evaluating environmental impact of UHI

framework development. The damage assessment, quality analysis, and weighting are applied for the impact assessment (single index) of the phenomena (Impact categories). It is necessary to select each element of the impact category and the category endpoint to describe this process.
First of all, metrological elements such as air temperature, air humidity, wind direction and wind velocity were selected as the impact category. Because the environmental impact changes depending on the time and spatial condition, as it mentioned, it is necessary to calculate each factor of the impact category in different condition of time and space.
Next, the category endpoint was selected referring to the past research which organize environmental impacts from UHI phenomenon. Then, the relationship between the impact categories and the category endpoints and between the category endpoints and safeguard subjects were organized with reference research (Shimoda, Y., 2005, CEIS, 2004, CEIS, 2005, CEIS, 2006). LIME is developed to evaluate the environmental impact considering environmental causal chain in the modern structure of society when the environmentally hazardous materials are emitted. Therefore, the direct impact from the increase of electricity consumption which is caused by the increase of cooling demand due to air temperature rise was evaluated in this study. However, the indirect impact such as the additional construction of the power plant for supplying electricity to the increased energy demand at the peak time was not evaluated in this study. The indirect impacts were not considered this framework. Similarly, we evaluated the heat shock caused by the movement between indoor space where air-conditioning has already been introduced and outdoor space under high temperature in this study. However, it was not evaluated the expansion of air-conditioning space and the avoidance of walking outside to avoid the heat shock.
According to these discussions, we developed the framework for evaluating environmental impact of UHI. The framework is shown in Fig. 1.
We applied this framework to Tokyo area in Japan to quantify considered environmental impacts in category endpoints of UHI from UHI phenomenon in Tokyo (Ihara, et al. 2009).

3. SUMMARY

We developed the framework for quantification and integration of various environmental impacts from UHI phenomenon based on the methodology of LIME.

References
http://www.toshisaisei.go.jp/05suisin/06.html (in Japanese, access 2009/05/14)
Karsten Brandt, 2006, Dose an “IDEAL” Urban Climate Exist?, *6th International Conference on Urban Climate preprint*, 443-445.
Ihara T., Kikegawa Y., Asahi K., Genchi Y., Kondo H.2008, Changes in year-round air temperature and annual energy consumption in office building areas by urban heat island countermeasures and energy-saving measures. *Applied Energy*, 85(1),12-25
Narumi, D., Hashimoto, S., Shimoda, Y., Mizuno, M., 2007, Influence of air temperature on regional characteristics of energy consumption in residential and commercial sector, *Energy and resources*, 28(6), 395-402 (in Japanese)
The Energy Conservation Center, Japan (ECCJ), 2005, Report on UHI mitigation effect by energy saving countermeasures (in Japanese)
ISO14042: Environmental management –Life cycle assessment– Life cycle impact assessment, 2000
Itsubo, N., Sakagami, M., Washida, T., Kokubu, K., Inaba, A., 2004: Weighting across safeguard subjects for LCIA through the application of conjoint analysis. *Int. J. LCA*, 9(3), 196-205
Shimoda Y., Narumi D., Mizuno M., 2005, Environmental impact of urban heat island phenomena –cause effect chain and evaluation in Osaka city-. *Journal of Life Cycle Assessment, Japan*, 1(2), 144-148
Center for Environmental Information Science (CEIS), 2004, Report on environmental impact caused by Urban Heat Island (2004) (in Japanese)
Center for Environmental Information Science (CEIS), 2005, Report on environmental impact caused by Urban Heat Island (2005) (in Japanese)
Center for Environmental Information Science (CEIS), 2006, Report on environmental impact caused by Urban Heat Island (2006) (in Japanese)
Ihara, T., Genchi, Y., 2009, Environmental impact assessment of Urban air temperature increase based on endpoint-type Life Cycle Impact (part 2) – Quantification of environmental impact in Tokyo-, *7th International Conference on Urban Climate preprint*, in press.