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"Environmental Struggles and the Way Forward"

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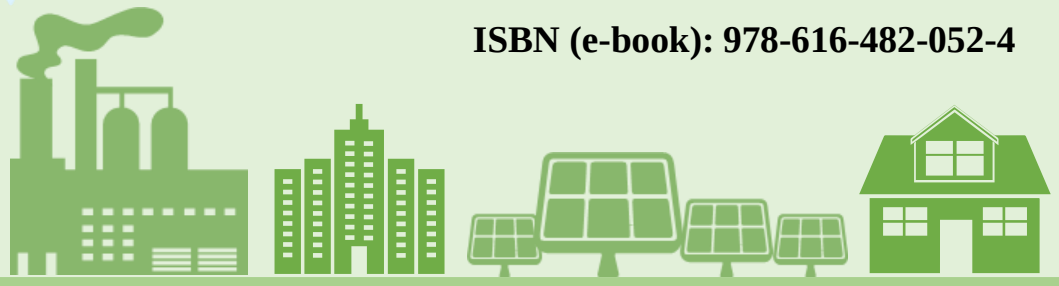

Preface

We are grateful to bring you this collection of articles from the 3rd International Conference on Environmental Development Administration "Environmental Struggles and the Way Forward" held on November 28, 2020 organized by The Graduate School of Environmental Development Administration (NIDA Environment School), National Institute of Development Administration (NIDA). The crucial focus of this conference was to bring together academicians, researchers, master students and Ph.D. students domestically and internationally for knowledge and experience sharing on a variety of environmental struggles which should be innovatively examined and taken into the consideration of their possibilities and feasible resolutions. To implement such a focus, the conference served as a good platform for environmental community where almost 100 participants met to discuss their ideas. In the conference, every submitted paper went through a rigorous review process and are included in this proceeding.

All in all, despite the outbreak of COVID-19 since early 2020, the 3rd International Conference of our NIDA Environment School via online was very successful. The plenary lectures and the special reports bridged the gap between the different fields of collision environment, making it possible for non-experts in a given area to gain insight into new areas. Likewise, included among the speakers were several young researchers who brought meaningful and splendid perspectives to their own fields. Given the rapidity with which knowledge is advancing in all of the key areas covered by the conference, we optimistically expect that the further NIDA Environment School's conferences will be as stimulating as this most recent one was, as indicated by the contributions presented in this proceedings volume.

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Management Model for Power Development Fund Management in Thailand with POSDCORB

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Abstract

This study had purpose to evaluate the operation and management of power development fund in Thailand and to propose management model for managing power development fund in Thailand. This research collected information and data from interviews with key informants such as executives from Energy Regulatory Commission (ERC), Power Development Fund Committee, managers of power development fund in designated area, employees of power development fund in category A and B, sub-district headmen, village headmen and residents who live around the power plant. This study used evaluation model which was Planning, Organizing, Staffing, Directing, Co-ordinating, Reporting and Budgeting (POSCORB) to evaluate the operation and management of power development fund. After the evaluation and analysis of the results, it came out with management model for operating and managing power development fund. The model could help on operating and managing power development fund in Thailand.

Keywords: Management Model, Power Development Fund, POSCORB

Introduction

The "Power Development Fund (the Fund)" has been set up under the Office of the Energy Regulatory Commission (OERC) pursuant to the Energy Industry Act, B.E. 2550 (2007), with the following objectives: to be used as a capital to enhance extensive electrification to various localities, to decentralize the development to provincial areas; to develop or rehabilitate localities affected by power plant operation; to promote the use of renewable energy and technologies for electricity industry operation that have minimal impact on the environment, with due consideration on the balance of natural resources; and to create fairness for power consumers,(Office of the Energy Regulatory Commission.(2016)). Since 2007, the power development fund has been set up. The operation and management of power development fund have provided numerous benefits toward the stakeholders and residents who live around the power plant in each area. For example; the treatment and remedy are provided for residents who have been affected by the operation of power plant, job creation, increased income for community, promotion of renewable energy and technologies, and extension of electrification project to various localities. Nowadays, the operation and management of power development fund in Thailand has faced with some problems. For example, the budget allocation for power development fund in each category is not appropriate because residents near the power plant do not get any benefit from the fund. The participation of the residents and stakeholders to examine and scrutinize the operation of community projects in designated area has also become a significant problem. Some community projects do not provide remedy or treatment to the residents and stakeholders affected by the operation of power plant. Therefore, this study will lead to the study to evaluate the operation and management of power development fund in Thailand. This study will use POSDCORB (Gulick, 1937) to evaluate the operation and management of power development fund. After the evaluation and analysis of the results, it will come out with management model for operating and managing power development fund.

Literature Review

This study focuses on the POSCORB theory because it relates to the operation and management of power development fund.In Thailand, there are no researches which used POSDCORB to evaluate performance of power development fund in Thailand. The related articles about power development fund in Thailand have mainly focused on the specific power

development fund. For example; the study on the management of general and environment projects by applying good governance of power development fund at Huay Pong district, Rayong province (Manida W. & Wisakha P., 2016), the lesson from management of the power development fund, a case study of Plaukdaeng district area, Rayong province (Supassorn K., 2013), a case study of Nam Phong Power Plant Energy Tax Fund (NPP-ETF) (Narong T., 2001).

Methods

This study used three different data collection methods following the concept of triangulation of qualitative data resources which included: 1) Secondary data, for example, books, journals, articles, theses, reports, and other documents 2) Interviews with key informants, for example, executives from Energy Regulatory Commission (ERC), Power Development Fund Committee, Power Development Fund Committee, the managers of power development fund in category A and B, the employees who work for power development fund in category A and B, the sub-district headmen and village headmen in communities, the residents in communities living in the areas that have received impacts and problems from power plant and receive benefits from the operation and management of power development fund, as well as propose community projects, and get approval or refusal by the power development fund and 3) Observation of the existing community projects around the power development fund in designated area. This study also uses content analysis employed for the qualitative analysis in this study that includes: 1) read all information carefully 2) evaluation all the terms; code the word that best describes each piece of information 3) group the terms; coded terms and form a hierarchy 4) look for relationship between the concepts 5) give the concept's structure and 6) discusses the model. The collection method took place between; March 2017 – March 2018. The total key informants for this researches were 102 key informants. The location of power development fund covered power development fund in category A and B by the types of fuel mostly used for electricity generation in power plants in Thailand and the power plants operated by Electricity Generating Authority of Thailand (EGAT) in six provinces around Thailand; Lampang, Nonthaburi, Phra Nakorn Sri Ayutthaya, Chachoengsao, Khon Kaen, and Ratchaburi.

Results (or Results and Discussion)

From qualitative method which used to collected information, it came out with the result under the secondary data, in depth interviews with key informants and observation on the community projects. The content analysis also used to applied in this researches; The result found that

From the interviews with managers and employees of power development fund in six designated areas, it was found that they would like the Energy Regulatory Commission (ERC) to refocus on regulations and policy that have assigned to all power development fund in each category because some regulation and policy are not applicable and not suitable for some types of power development fund.

From the interviews with employees or staff the power development fund in six designated areas found that power development fund supported the participation of residents in the operation and management of power development fund by organizing public forums at village or community level in order to propose community projects. Before organizing public forum, the sub-district headmen and village headmen would inform the residents to think about what they wanted to do and propose for community project in a fiscal year and the residents could propose and vote for community project at the public forum. The sub-district headmen and village headmen would organize meeting with residents in communities to discuss what residents wanted to propose for community projects.

From the interviews with staff or employees in six designated areas, it was found they have received the training and knowledge at least once or twice a year. Most trainings were about procurement and useful knowledge, for example, accounting and finance or new knowledge that could apply to work in the office. But they suggested that the number of trainings should be more than the present and the method of training was not good enough and should be improved.

From the interviews with executives from Energy Regulatory Commission (ERC), Power Development Fund Committee, Power Development Fund Committee, it was found that for the criteria in making decision to approve the community projects, in the past the ERC gave authority to a community development committee to approve community projects. But most community projects were small. Therefore, the Energy Regulatory Commission deployed a policy to determine proportion of large community projects and small community projects in 70%:30%. The reasons why the Energy Regulatory Commission determined the proportion of big and small community

projects because they wanted residents at designated area to propose community projects which create sustainability to the community throughout the community project.

The power development fund in six designated areas cooperated and coordinated with representatives from provinces, local administrative organizations and always reported to Office of the Energy Regulatory Commission on the progress of operation and management, however in some power development fund faced problems the cooperation and coordination between local people and the government officers leading to supporting problems to formulate community projects.

Some power development fund faced the problem of the report of the progress on the operation and management of power development fund to related organizations, stakeholders, and residents who lived around the power plant. The power development fund in designated areas did not regularly report the operation and management of power development fund to related organizations, stakeholders, and residents who lived around the power plant.

Some power development fund, face the problems of the allocation of budget by the Community Development Committee (CDC) to formulate community projects. Because from the interviews, the sub-district headmen and village headmen in six designated areas said that the CDC seems to unfairly allocate budget to other locations. it was found that some power development fund receive comments from residents on the transparency of the operation and management of power development fund, for example, the power development fund, Community Development Committee (CDC), and Tambon Development Committee (TDC) allocate the budget to residents in a specific area but not to residents or communities affected by the power plant.

Some community projects proposed and formulated by local administration, from interviews with residents in communities did not know about the existence of community project. In some areas, it was found that they perceive the existence of community projects. However, for some residents who were not interested in proposing community projects, they did not know about the existence of community projects. After community projects were formulated, the power development fund would set up the sign board to inform residents about the existence of community projects.

From the observation among six designated areas, it was found that community projects were existed in areas and the sign board were set up to inform residents about the existence of community projects.

Discussion

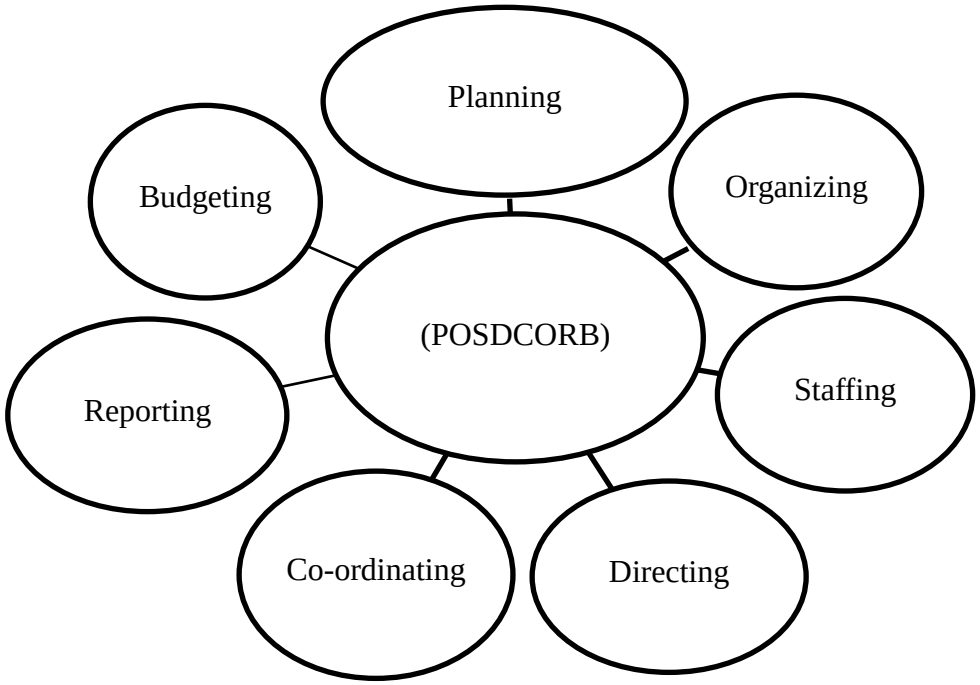

Figure 1: POSDCORB Model

POSCORB is developed to be evaluation model on the structure and analyze on activities and in this study applied POSCORB and focus on POSCORB theory because it related and matched with the operation and management of power development fund in Thailand. The operation and management of power development fund could applied and used POSCORB model to evaluate on operation and management of power development fund. The result from the evaluation could reach management model which was suitable to apply under the operation and management of power development fund and make the operation and management to become more sustainable. As power development fund need to have the planning on the policy framework of power development fund management to accomplish the purpose of power development fund. Power development fund also need organizing to organize the power development fund and provide opportunity for all stakeholders to be part of the operation and management of power development fund, staffing in power development fund that need training and knowledge to improve efficiency and ability at work, the directing that ERC deploy to all of power development fund in designated areas, the coordinating of power development fund with the related organization, the reporting of the operation and management of power development fund to ERC, related organizations and

stakeholders, the budgeting that ERC and power development fund allocate to communities to propose and formulate community projects. Some studies focus on the operation and management of power development fund in the specific location, for example the developing achievement of Nam Phong Power Plant Energy Tax Fund, Khon Kaen province (Narong Trikritwatanakul, 2011), Social Responsibility Communication of the Electricity Generating Authority of Thailand – North Bangkok Power Plant (Pawinsuda Arusawadee.,2012)

Conclusion and Recommendation

This study used POSDCORB to evaluate and assess the operation and management of power development fund in Thailand. With POSDCORB, it helped evaluate the performance of power development fund which create sustainability in power development fund management. The management model for Power Development Fund Management in Thailand under POSDCORB;

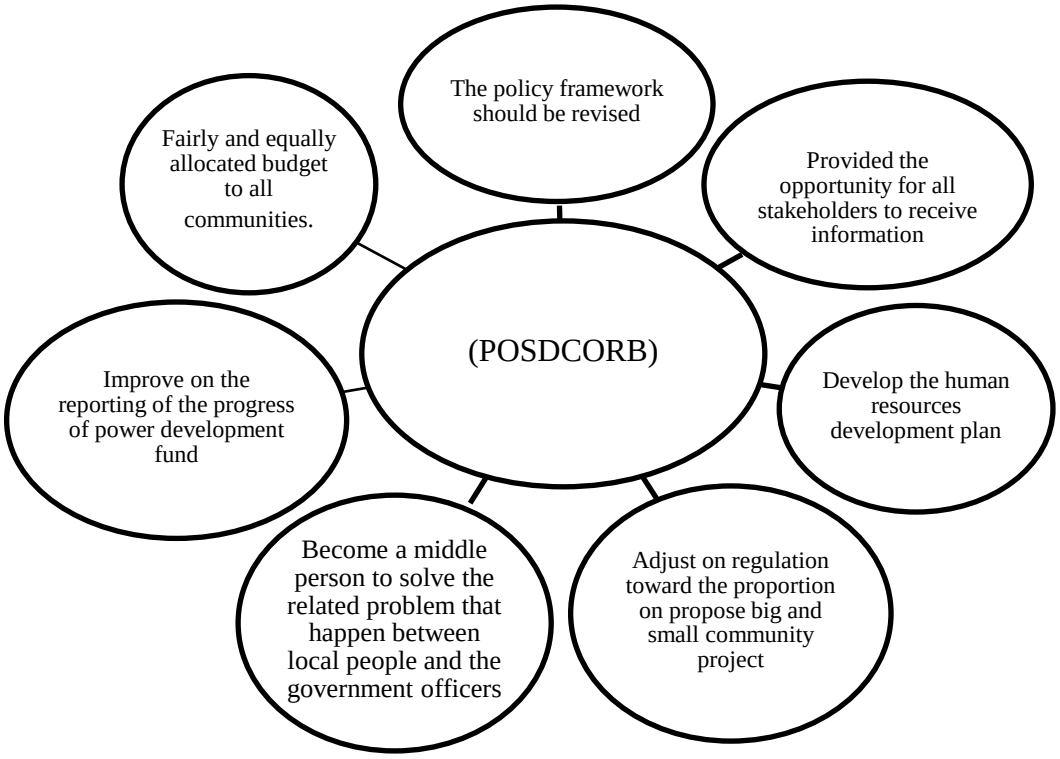

Figure 2: Management Model for Power Development fund in Thailand with POSCORB

With planning, the policy framework of power development fund should be revised because the policy framework was not related and not covered with the operation of power development

fund. The policy and regulation that ERC has deployed to all power development fund in designated area seem not to be applicable. Because each power development fund has different geography and life style of residents, therefore, the Energy Regulatory Commission should reconsider the policy and regulations assigned to all power development funds. With organizing, the power development fund should provide the opportunity for all stakeholders to receive information about the operation and management of power development fund and all stakeholders had the opportunity to participate in the public forum that power development fund organized and propose for community project. With staffing, the power development fund in designated area may develop the human resources development plan each year which become a plan to support and improve the potential and ability of employees on the duties of power development fund. With directing, Energy Regulatory Commission determined the proportion of big and small community projects because they wanted residents at designated area to propose community projects which create sustainability to the community throughout the community project but with that regulation, it affected small community which had more sub-village because small community which had more sub-village couldn't propose for small community projects deal to the regulation of proportion of community projects and deal to the limited of budget that power development fund allocated for them. The residents would not have the opportunity to propose for small community projects because it was limited at 30% and they need to propose for big community projects which is 70% of whole of the budget that they received and they might not have enough budget for propose small community projects, therefore to propose and formulate community project should be adjusted and the proportion should be changed from propose big community projects 70% and propose for small community projects 30% to propose big community projects 50% and propose for small community projects 50% or propose big community projects 60% and propose for small community projects 40% which provided more opportunity for the residents to propose the big and small community projects. With coordinating, the Energy power development fund in designated areas should solve and focus on the coordinating problems by becoming a middle person to solve the related problem that happen between local people and the government officers. It will help power development fund in designated area to be more effective and efficient in the operation and management, leading to successful operation and management. With reporting, the power development fund should make improvement on the reporting of the progress of power development fund will help all related sectors to receive information on the progress of the

operation and management. With budgeting, the budget should be fairly and equally allocated to all communities. The power development fund should equally and fairly allocate budget for residents to propose community projects. The power development fund in designated area should motivate residents to propose communities projects.

References

Gulick, L. (1937). Notes on the Theory of Organization. In Papers on the Science of Administration (pp. 3–45).

Manida W. & Wisakha P. (2016). Management of General and Environmental Projects by Applying Good Governance of the Power development fund at Huay Pong sub district, Rayong province'

Narong T. (2011). The Developing Achievement for Nam Phong Power Plant Energy Tax Fund, Khon Kaen Province. STOU National Research Conference 2011, 461-468

Office of the Energy Regulatory Commission. (2016). Fact sheet: Power development fund. Bangkok, Thailand

Pawinsuda A. (2012). Social Responsibility Communication of the Electricity Generating Authority of Thailand – North Bangkok Power Plant, Thammasat University

Sahas A. (2013). People's Participation in Clean Energy Fund Activities for Community Development Surrounding Kaeng Khoi Power Plant II, UTK Journal, 7(2).

Supassorn K. (2013) 'Lesson from Management of the Power Development Fund, A case study of Pluakdaeng District area (Rayong)'. National Institute of Development Administration.

Climate Change and Household Adaptation in the Central Dry Zone of Myanmar

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Abstract

The most vulnerable to the impacts of climate change have experienced in developing countries, particularly in rural areas. The objective of the study is to observe and analyze the climate change and household adaptation in Pauk Township, Pakokku District, Magway Region, Myanmar where has been frequently suffering from unfavorable rainfall and drought conditions. In terms of the negative impacts of climate change, two villages were randomly selected. Mix methods were used. Total respondents were 102 (household interview), 3 (key informant interview), and 2 (focus group discussion) for data collection in June 2020. Descriptive and content analysis were applied for data analysis. The study found that 90% of respondents knew the climate change, however, 70% of respondents did not know the influencing factors of climate change. Furthermore, 98% of respondents mentioned their livelihood activities have been affected by climate change. The study also revealed two main adaptive measures for combating the impacts of climate change such as loan (67% of respondents used) and alternative income source such as migrant worker (50% of respondents chose). Therefore, the study would recommend that mutual assistance such as shared labor among community people and knowledge sharing activities should be appropriately developed based on their livelihood activities.

Keywords: Climate change; Household adaptation; Rural household; Central Dry Zone; Myanmar

Introduction

Due to the rising of global temperature, climate change has become global issue around the world. In terms of human beings, not only quality of living but also way of living have been affected by the negative impacts of climate change since there have been rising such climate related hazards as storms, floods, earthquakes, heat wave, to name but a few over the globe (Lo, 2016). In addition to this, both natural environment and built environment have been suffered from the adverse effects of climate change. There are common detectable events of climate change such as global warming, unpredictable precipitation, melting ice glaciers, growing ocean temperature and acidity, and rising sea level (Andrić, Koc, & Al-Ghamdi, 2019). Additionally, Elbehri, Challinor, Verchot, and Angelsen (2017) reported that it would be necessary to understand the multiple concepts and different adaptation for eliminating the adverse impacts of climate change.

With reference to the global climate risk index in 2020, Africa, South Asia, and South East Asia regions are the most affected areas of destructive precipitation which are flood and soil degradation. Myanmar is one of the most affected areas due to numerous natural catastrophes which was assessed based on the climate events over the last twenty years (Eckstein, Künzel, Schäfer, & Winges, 2019). Ministry of Environmental Conservation and Forestry (MoECAF, 2012b) described that the average country temperature and total precipitation per year have increased which compared to the climate information of last six decades. There were at least seven powerful tropical cyclones in Myanmar during the last 40 years such as Sittway Cyclone (1968), Pathein Cyclone (1975), Gwa Cyclone (1982), Maungdaw Cyclone (1994), Cyclone Mala (2006), Cyclone Nargis (2008), and Cyclone Giri (2010). Among these strong storms, Cyclone Nargis was the most catastrophic disasters because of a lot of destruction over the infrastructures and lives in the recorded history of Myanmar (MoECAF, 2012a).

Myanmar is identified as a Least Developed Country by the United Nations which consists of several destitute places. Most people are doing farming activities and they are from the different races and ethnic groups. Therefore, it would seem that almost Myanmar's citizens suffer from the adverse impacts of climate change (Ambrosio-Albala, 2015). Furthermore, the world's longest civil wars over the country contribute to Myanmar as a late developing country with an abundant amount of international debts (Slagle, 2014). Therefore, Myanmar is less likely to take prompt appropriate actions for combating the negative impacts of climate change. Kreft reported that Myanmar is incredibly susceptible to the adverse effects of climate change according to the

significant data from 1995 to 2014. Scholar presented that there were just over 40 natural disasters and these climate related hazards brought a loss of around 7,000 lives in annual average. In addition, it negatively affected to country GDP with the decline of 0.74 per cent in annual average within the previous 20 years (MoNREC, 2019).

Myanmar can be generally divided into three regions such as hilly region, delta region, and central dry region. The most climate change affected region is the central part of Myanmar due to unstable and unpredictable rainfall and restricted monsoon period. Approximately 35 per cent of country population lives in the central part of Myanmar. Additionally, the rural areas of the central part of Myanmar have to be developed because there are several remote places which consist of numerous settlements with the large number of people in this region. With regard to the livelihood activities, over the half of people are farmers since their major income comes from cultivation which largely depends on rainwater whereas the remaining people are casual labors at farming activities and out of farming activities (JICA, 2010). When it comes to the climate factors, the yearly precipitation of dry zone was below 1,000 mm while the annual rainfall of delta region represented approximately 5 times more than that of dry zone. Although the range of temperature in Myanmar is from 10 °C to 35 °C, the temperature of central dry zone in some summer season is 40 °C (MoECAF, 2012a). Therefore, drought as well as dry spell has become a significant issue in the central part of Myanmar (Boori, Choudhary, Evers, & Paringer, 2017). In addition to this, inadequate and unfavorable rainfall and the growth of average temperature in the middle of Myanmar would have a detrimental impact on the livelihood activities of dry zone people (Elbehri et al., 2017). According to the report of Myanmar's National Adaptation Programme of Action (NAPA) 2012, around 1,500 people were observed as disorders and deaths in Myanmar due to heatstroke and drought conditions. That happened in the central part of Myanmar which has less rainfall and high temperature compared to other places of Myanmar (MoECAF, 2012b). In this regard, the objective of this study is to observe and analyze the climate change and household adaptation in Pauk Township, Pakokku District, Magway Region, in the middle of Myanmar. The results of this study would contribute to develop the adaptive measures through reinforcing the present household coping mechanisms for climate change in the study area.

Materials and Methods

The village selection was conducted randomly depend on the negative impacts of climate change. These two villages were water scarcity area and there is a creek between village and town since this area faces from not only dry spell but also flood namely Kyauk Tan village and Nat Oo Yin village in Pauk Township, Pakokku District, Magway Region in the central dry zone of Myanmar. Pauk township is located between 21° 10' and 21° 49' north latitude and 94° 18' and 94° 44' east longitude with an area of 2,486 square kilometers (MIMU, 2014). Due to the tropical monsoon climate, warming weather has likely happened throughout the year in the study area. The average temperature is 34 °C in the summer season whereas the average temperature is 27 °C in the winter season. The annual rainfall is around between 500 mm and 850 mm. Due to the comparatively unfavorable rainfall, there has been a prolong rainless period, as a result, insufficient water supply has become a considerable issue in this area. In addition to this, rising of average temperature would lead to increase the concentration of salt in underground water. Consequently, it would tend to stress on the daily life of rural households for both agricultural activities and domestic consumption (FAO, 2014). Figure 1 illustrates the study area in the central dry zone of Myanmar.

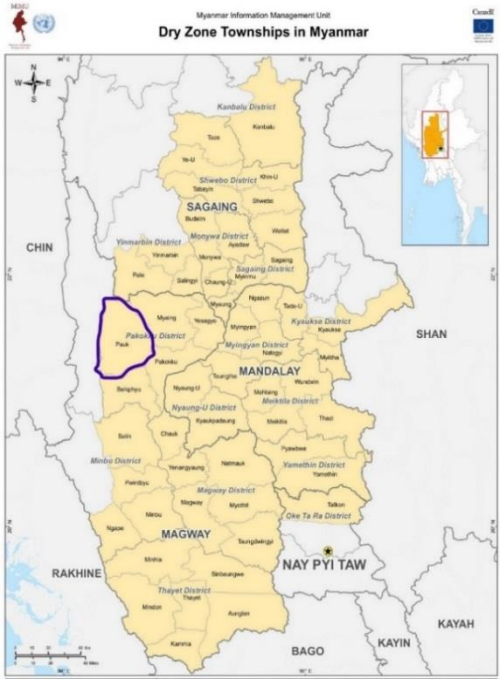

Figure 1: Pauk Township is illustrated with blue color line. Source: (MIMU, 2014)

According to Yamane's sample size formula, there were 102 respondents (47 from Kyauk Tan and 55 from Nat Oo Yin) which is nearly half of total household (210) in study villages. The total population of study villages are 952. There were three sections such as general information of respondents and respondents' households, livelihood difficulties and coping strategies of respondents' households in terms of climate change, and social and supporting activities in the study area which were included in the questionnaires of household interview. 3 officers from agricultural department, rural development department, and non-governmental organization were selected for key informant interview. Implementation activities of each department as well as achievements, challenges, and suggestions were involved in the questionnaire of key informant interview. 2 focus groups were selected for qualitative part in order to know the overall understanding of study area, then Participatory Rural Appraisal's (PRA) tools were applied so that seasonal calendar, resource map, trend line (climate change, income and expenditure for six years), problem tree and objective tree for food security of study area were developed through participating of 6-8 community people who were invited based on gender, age, livelihood activities, and village development committee members at focus group discussion. Data collection was conducted in June 2020. Qualitative analysis was applied for information which received from key informant interview, focus group discussion, and field observation. Descriptive analysis was used in quantitative data analysis.

Results and Discussions

1.Climate information of study area

Climate information of Pauk township were observed in this study which were temperature and rainfall. All data were collected from the Department of Meteorology and Hydrology, Pauk township. According to the data availability of this department, temperature and rainfall of study area could be collected for 19 years from 2001 to 2019. The highest yearly temperature was observed in 2013 with 38.2 degree Celsius which was followed by 2019 with 37.7 degree Celsius whereas the lowest yearly temperature was found in 2012 with 10.7 degree Celsius which was followed by 2017 with 15.8 degree Celsius. The maximum annual rainfall was observed in 2013 with 4.3 inches which was followed by 2002 with 4.2 inches while the minimum annual rainfall was found in 2014 with 1.7 inches which was followed by 2019 with 2.1 inches. Therefore, there had been the fluctuation of average yearly temperature and rainfall in study area from 2001 to 2019.

2.Characteristics of respondents

The percentage of female respondents (75%) were significantly more than those of male respondents (25%) in this study. Based on the notes of explanatory contents from both household survey and focus group discussion, there have been several male villagers migrated out of villages for alternative income. There were five age groups among respondents. The highest percentage of respondents were 27% in the age range of 31-40 years old which were followed by 51-60 years old with 21%, 41-50 years old with 19%, 18-30 years old with 17%, and over 60 years old with 16%. Primary education was the most common educational status among respondents with 65% while 21% of respondents were without schooling. The rest of respondents completed secondary education (7%), non-formal education (5%), and university education (2%) respectively. Therefore, it would unlikely have attractive work with effective and efficient production due to low education level. The important role of education was pointed out by Belachew et al. (2011) based on the theory of human capital. It was confirmed by the study of Wu et al. (2014) that education is one of the influencing factors for the variation of livelihood activities. It can be seen that getting more income from livelihood diversity of households would conceivably depend on the education level of household members. When three-quarter of sample households had fly proof latrines, 3% of sample households had open pit latrines. Furthermore, the remaining households (22%) had without latrine and practiced open defecation. In terms of health problems, seasonal fever was the most common health issue with 50% which were followed by diarrhea with 18% and hypertension with 9%. The other health related issues were minority with less than 5%. The study of climate change impacts and adaptation in Myanmar which was conducted by Slagle (2014) reported almost similar result that diarrhea was caused by the supportive environment for pathogens such as insufficient clean water and unpredictable rainfall.

3.Difficulties and coping strategies of farm households and non-farm households

Among sample households, 47% of households produced crop-based products from their farms or hire farms for their primary income were regarded as farm household whereas 53% of households did not produce crops were categorized as non-farm household. Livelihood activities of non-farm households were livestock raising (39%), working out of village (30%), and working inside the village (31%) as casual labor at farm and non-farm activities.

3.1 Agriculture

The majority of respondents from farm households had small scale agriculture which is ranging from 0.5 acre to 8 acres. The main crops of study area were groundnut, green gram, corn, pigeon pea, and cotton. With reference to the experience of farm households on income from previous cultivation season, 75% of farm households responded that income from agriculture decreased whereas 8% of farm households mentioned that income from crop production increased. The rest of farm households answered that income from farming was normal. The main reasons of decreasing income from agriculture was unfavorable precipitation which was responded by 72% of sample households. There were followed by unreliable market (7% of respondent answered), massive investment (7% of respondents replied), and decreased farmlands (4% of respondents said). According to Ambrosio-Albala (2015) in Myanmar, the result of study showed that the value of losses and damages due to the devastating effects of climate related hazards would be similar to around 3 per cent of the country's GDP in 2014. However, there are coping mechanisms such as adjust the cultivation time which have been applied by 5% of respondents, apply more agrochemical products (3% of respondents used), and crop diversification (2% of respondents practiced). It can be predicted that global agriculture would be affected by the environmental degradations because of climate change over the globe and its yields would fall by two per cent in every decade (Murray-Tortarolo, Jaramillo, & Larsen, 2018). However, changing the cultivation time, which was one of the adaptive measures for climate change in study villages, was also found by Ali and Erenstein (2017) in Pakistan and it would be advantage to farmers who were affected by climate change in their agriculture. Officer from Department of Agriculture (DoA) said that supporting of certified seeds with extension services and demonstration plots were implemented. Furthermore, client-farmer networking meetings were held by the organizing of DoA in order to develop the reliable market through establishing the direct linkage between farmers and sale centers.

3.2 Livestock

The most common livestock in study villages was poultry with 40% which were followed by cow (31%), goat (20%), and pig (9%). When it comes to the income from livestock raising, 52% of livestock farmers said that income from livestock increased whereas 38% of livestock farmers answered that income from livestock decreased. Normal income from livestock was chosen by the rest of livestock farmers. The main reason for increasing income from livestock farming was

livestock sharing which is one people supported money for purchasing livestock and food to other who will take care of livestock for feeding, housing, grazing, health, etc. After the livestock sells, the net benefits would be divided into equal part or sixty-forty ratio based on the agreement between money giver and caretaker. This system has been used by around 30% of livestock farmers. Other reasons were the feeding supplementary food and getting vaccines. These were suggested by Officer from the Department of Veterinary and these practices have been applied by almost 30% of livestock farmers. The remaining livestock farmers have not used any coping mechanisms. In contrast, the main influencing factors for decreasing income from livestock were pasture lands reduction (45%), heat stress (35%), less labor for grazing (13%), and unstable market (7%). The changes of land use pattern for crop production happened and some farmers transformed pasturelands to non-irrigated cultivation lands in order to enhance the productivity in the study area through coping the negative impacts of climate change in crop production. In addition to this, climatic factors also played prominent role in livestock husbandry of study villages as short monsoon period and high average temperature are associated with health and food issues particular in chicken raising. These findings could be verified by Ministry of Environmental Conservation and Forestry of Myanmar. Climate hazards such as prolong and recurrent drought and flood in dry zone region would tend to have negative impacts on livestock tender households with insufficient food for livestock and fall in domestic production (MoECAF, 2017). Luseno, McPeak, Barrett, Little, and Gebru (2003) indicated that getting the extension services from specialists in terms of climate change adaptation would play vital role for eliminating the negative impacts of climate change.

3.3 Working as labor in the village and out of village

The study revealed that another main income source of non-farm household which does not produce crops and animals were non-migrant and migrant work. Among non-migrant workers, more than half of respondents were casual labors at crop production activities which were followed by selling vegetables (12%), cutting trees (12%), carpenters (5%), making thatched roof (4%), and the minority were brokers, running grocery shops, and masons. While over 70% of non-migrant workers said that income from non-migrant work increased, almost 15% of non-migrant workers mentioned that income from non-migrant work decreased. The rest of non-migrant workers responded that income was stable. Changing the livelihood activities from working at farms as casual labor to selling vegetable direct to home and cutting trees contributed to increase income.

However, due to rainfall variation and less production from farm, farm activities have reduced, and it decreased income from non-migrant work. Therefore, our findings were in line with Shankar and Shikha (2018), it would probably stress on the food accessibility due to less income from climate change affected subsistence farming.

Among migrant workers, almost 55% of respondents worked within the country while around 45% of respondents migrated out of country. Working at construction project was the main type of job among migrant workers outside the country whereas vendor was the major job for migrant workers inside the country. However, due to Covid19 pandemic, migrant workers were unemployed and had to come back their villages because of the closure of their works and as a result, remittance from migrant workers have decreased. This finding is in line with the study of Poe (2011) that was natural disasters and less job opportunities lead dry zone people to be vulnerable. Due to the detrimental impacts of climate change, cultivation areas were reduced by farmers and as a result, the number of vacant farmlands would be increased. This would tend to change from farm household to non-farm household (Vermeulen et al., 2012).

4.Household adaptation

According to the explanatory notes from focus group discussion and key informant interview, study villages have been suffering from the negative impacts of climate change. Within the last ten years, there was low food availability which was resulted from the less production due to the inadequate rainfall in study area. Another difficulty was the limited transportation during the raining season. Secretariat (1992) pointed that there were floods which were resulted in the reduction of crop yields, farmlands, and home yards because of water erosion and landslides. Even though government and non-governmental organizations conducted development activities in study area such as seeds provision, food for work activities through ponds renovation and construction of water retaining walls, adverse impacts of climate change brought villagers to search of new job outside the villages. It would probably reduce production from farming activities (Slagle, 2014). Villagers paid more attention on livestock husbandry, migrant work, cutting trees as alternative income and getting loans as one of adaptive measures. Nevertheless, due to climate change, diseases and unstable market have contributed negative impacts on livestock framers in study villages. Then, villagers have been getting into debt due to low income and high rate of interest in this area. According to the report of World Food Programme, the majority of people in this area sank deeper into debts (Poe, 2011). Additionally, Ministry of Environmental Conservation

and Forestry (MoECAF, 2017) stated that recurrent droughts and floods in study area were the leading conditions of inadequate food for livestock and decline in domestic production.

When it comes to the perception of respondents on climate change based on the findings of household interview, around 90% of respondents knew that climate has been changing around the world whereas 98% of respondent described their livelihood activities were affected by climate change. The central dry zone has more risk to suffer from drought disasters due to the highest temperature (Yi, Hla, & Htun, 2013) whereas the delta region has high chance to meet with flood conditions because of unpredictable rainfall and tropical storms (MoNREC, 2019). Nevertheless, dry zone of Myanmar also encounters waterlogging when it will rain heavily for quite a long time (MoECAF, 2012a). Among 90% of respondents who knew the global climate change, 70% of respondents did not know the causes of climate change. This finding was in line with the study of Suthirat Kittipongvises and Mino (2015) that people from rural area have low environmental awareness in terms of climate change. Hence, according to the study of Vedwan and Rhoades (2001), it can be assumed that the responses of sample households to climate change seem to be low in study area. Additionally, it would be possible that there were some positive correlations among socio-demographic conditions and awareness of climate change, according to the study of S Kittipongvises, Mino, and Polprasert (2011). However, the remining respondents (30%) responded that the influencing factor for climate change was less trees due to deforestation and logging.

There were eight significant difficulties in study villages. The most common constraint was income reduction (92%) which were followed by less job opportunities (89%), unpredictable market (77%), decrease production (69%), pest and disease problems (58%), low capacity to invest (47%), and water scarcity (22%). Shankar and Shikha (2018) mentioned that the majority of crops have suffered from pests and disease problems because of the favorable environment for insects, pests, and pathogens. Ziervogel and Ericksen (2010) recommended that supporting of grant with adaptive measures in agriculture would be advantage to local farmers.

In order to combat the difficulties mentioned above, there were seven coping mechanisms which have been applied by respondents. 89% of respondents borrowed cash or food from the shops (63%), lenders (24%), neighbors (9%), and relatives (2%) as methods for dealing with stress. Secondly, 63% of respondents picked the minimal effort food based on the decision of family head. The third method was that 50% of respondents moved out of the village for new job. The rests were

15% of respondents cut trees, 12% of respondents dropped children from school based on the decision of household head, 12% of respondents sold their domestic animals, and 7% of respondents diminished family food utilization. This result is in line with the study of Khatun and Roy (2012) which was people from rural area relied on loans when they need investment for their livelihood activities. Bro (2020) also found the similar result in the study of climate change adaptation and food security in Nicaragua. Additionally, Bro (2020) pointed out the minimizing of family food consumption as one of the coping strategies for food insecurity.

Conclusion

Overall, adaptive measures related to negative impacts of climate change have been observed in this study. Based on the findings of this study, the large majority of households had experienced the adverse impacts of climate change. Therefore, it would recommend that strengthening such current adaptive measures as, changing of cultivation time, shared livestock raising, and good communication with government officers to mention but a few. Access to climate information is one of the supporting conditions for climate change adaptation that was recommended by Ziervogel and Ericksen (2010). However, since the study area was rural area and most community attained low education level, they did not know the effectiveness of accessing the climate information. Additionally, there are revolving funds and loans in the study area which were pointed by the majority of respondents as their adaptation strategy when they face the adverse impacts of climate change in their livelihood activities. Therefore, it would be better to maintain and support fund management system through building and enhancing the awareness of each livelihood in study villages. Last but not least, networking meetings among producers and sale-centers have to be implemented regularly so that not only producers but also customers would access the stable market. In order to get effectiveness from the activities suggested above, it would be better to establish mutual assistance among villagers such as shared labor, food, money, and adaptive practices from household to household. This practice could bring benefits to rural livelihood activities and its advantages were presented by King, Adler, and Grieves (2013) in the study of long term livelihood approaches in rural area in Mexico.

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References

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management, 16*, 183-194. doi:https://doi.org/10.1016/j.crm.2016.12.001

Ambrosio-Albala, M. (2015). *Myanmar - Post-disaster needs assessment of floods and landslides : July - September 2015*.

Andrić, I., Koc, M., & Al-Ghamdi, S. G. (2019). A review of climate change implications for built environment: Impacts, mitigation measures and associated challenges in developed and developing countries. *Journal of Cleaner Production, 211*, 83-102. doi:https://doi.org/10.1016/j.jclepro.2018.11.128

Belachew, T., Hadley, C., Lindstrom, D., Gebremariam, A., Lachat, C., & Kolsteren, P. (2011). Food insecurity, school absenteeism and educational attainment of adolescents in Jimma Zone Southwest Ethiopia: a longitudinal study. *Nutrition journal*, *10*(1), 29.

Boori, M. S., Choudhary, K., Evers, M., & Paringer, R. (2017). A review of food security and flood risk dynamics in central dry zone area of Myanmar. *Procedia Engineering*, *201*, 231-238. doi:https://doi.org/10.1016/j.proeng.2017.09.600

Bro, A. S. (2020). Climate Change Adaptation, Food Security, and Attitudes Toward Risk among Smallholder Coffee Farmers in Nicaragua. *Sustainability, 12*(17), 6946.

Eckstein, D., Künzel, V., Schäfer, L., & Winges, M. (2019). *Global Climate Risk Index 2020*. Bonn: Germanwatch.

Elbehri, A., Challinor, A., Verchot, L., & Angelsen, A. (2017). *FAO-IPCC Expert Meeting on Climate Change, Land Use and Food Security: Final Meeting Report*. FAO HQ Rome: FAO and IPCC.

FAO. (2014). *Myanmar Dry Zone Development Programme Scoping Report*. Retrieved from The Republic of the Union of Myanmar: https://www.lift-fund.org/sites/lift-fund.org/files/uploads/Dry_Zone/Dry-Zone-Scoping-Report-Final-pdf.pdf

JICA. (2010). *The development study on sustainable agricultural and rural development for poverty reduction programme in the central dry zone of the union of Myanmar*. Retrieved from Tokyo, Japan: http://open_jicareport.jica.go.jp/pdf/12003984_01.pdf

Khatun, D., & Roy, B. C. (2012). Rural livelihood diversification in West Bengal: determinants and constraints. *Agricultural Economics Research Review, 25*(347-2016-16910), 115-124.

King, R., Adler, M. A., & Grieves, M. (2013). Cooperatives as Sustainable Livelihood Strategies in Rural Mexico. *Bulletin of Latin American Research, 32*(2), 163-177. doi:10.1111/j.1470-9856.2012.00796.x

Kittipongvises, S., & Mino, T. (2015). Influence of psychological factors on climate change perceptions held by local farmers in the northeast of Thailand. doi:10.14456/aer.2015.22

Kittipongvises, S., Mino, T., & Polprasert, C. (2011). Local Perspectives on Climate Change Mitigation and Sustainability of Clean Development Mechanism (CDM) Project: A Case Study in Thailand. *International Journal of Environmental and Ecological Engineering, 5*(11), 748-752.

Lo, V. (2016). *Synthesis report on experiences with ecosystem-based approaches to climate change adaptation and disaster risk reduction* (Vol. 85). Montreal, Canada: Secretariat of the Convention on Biological Diversity.

Luseno, W. K., McPeak, J. G., Barrett, C. B., Little, P. D., & Gebru, G. (2003). Assessing the Value of Climate Forecast Information for Pastoralists: Evidence from Southern Ethiopia and Northern Kenya. *World Development, 31*(9), 1477-1494. doi:https://doi.org/10.1016/S0305-750X(03)00113-X

MIMU. (2014). The 2014 Myanmar Population and Housing Census. Retrieved from https://www.themimu.info/census-data

MoECAF. (2012a). *Myanmar's Initial National Communication Under The United Nations Framework Convention on Climate Change (UNFCCC)*. The Republic of the Union of Myanmar: Ministry of Environmental Conservation and Forestry Retrieved from https://unfccc.int/resource/docs/natc/mmrnc1.pdf

MoECAF. (2012b). *Myanmar's National Adaptation programme of Action (NAPA) to Climate Change*. The Republic of the Union of Myanmar: Ministry of Environmental Conservation and Forestry Retrieved from https://unfccc.int/resource/docs/napa/mmr01.pdf

MoECAF. (2017). *Climate-Smart Agriculture, Fisheries, and Livestock for Food Security*. The Republic of the Union of Myanmar: Ministry of Environmental Conservation and Forestry Retrieved from https://www.preventionweb.net/files/65017_brief1web.pdf

MoNREC. (2019). *The Republic of the Union of Myanmar, Ministry of Natural Resources and Environmental Conservation. Myanmar Climate Change Strategy (2018-2030).* Retrieved from https://myanmar.un.org/sites/default/files/2019-11/MyanmarClimateChangeStrategy_2019.pdf

Murray-Tortarolo, G. N., Jaramillo, V. J., & Larsen, J. (2018). Food security and climate change: the case of rainfed maize production in Mexico. *Agricultural and Forest Meteorology, 253-254*, 124-131. doi:https://doi.org/10.1016/j.agrformet.2018.02.011

Poe, C. A. (2011). *Food Security Assessment in the Dry Zone Myanmar*. The Republic of Union of Myanmar: World Food Programme.

Secretariat. (1992). *United Nations Framework Convention on Climate Change*. USA: UNFCCC New York.

Shankar, S., & Shikha. (2018). Chapter 7 - Impacts of Climate Change on Agriculture and Food Security. In R. L. Singh & S. Mondal (Eds.), *Biotechnology for Sustainable Agriculture* (pp. 207-234). India: Woodhead Publishing.

Slagle, J. T. (2014). *Climate change in Myanmar: impacts and adaptation.* (Master). Naval Postgraduate School, Monterey, California.

Vedwan, N., & Rhoades, R. E. (2001). Climate change in the Western Himalayas of India: a study of local perception and response. *Climate research, 19*(2), 109-117.

Vermeulen, S. J., Aggarwal, P. K., Ainslie, A., Angelone, C., Campbell, B. M., Challinor, A. J., . . . Wollenberg, E. (2012). Options for support to agriculture and food security under climate change. *Environmental Science & Policy, 15*(1), 136-144. doi:https://doi.org/10.1016/j.envsci.2011.09.003

Wu, N., Ismail, M., Joshi, S., Yi, S.-l., Shrestha, R. M., & Jasra, A. W. (2014). Livelihood diversification as an adaptation approach to change in the pastoral Hindu-Kush Himalayan region. *Journal of Mountain Science, 11*(5), 1342-1355.

Yi, T., Hla, W., & Htun, A. (2013). Drought conditions and management strategies in Myanmar. *Report of the Department of Meteorology and Hydrology, Myanmar*.

Ziervogel, G., & Ericksen, P. (2010). Adapting to climate change to sustain food security. *Wiley Interdisciplinary Reviews: Climate Change, 1*, 525-540. doi:10.1002/wcc.56

Factors Influencing Fishers' Participation in Marine Litter Collection Scheme in Thailand: Preliminary Results

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Abstract

Marine litter is a global environmental problem posing various threats to the environment, the economy and the society. Several measures are used to tackle marine litter, including prevention, reduction, and removal of litter. The latter is essential to clean already-at-sea litter or marine debris. Trash Back to Shores: Beautiful Seas with Our Hands, implemented by Thai Department of Fisheries, is a marine litter collection scheme asking fishers to voluntarily collect marine litter while they are in their fishing activities. The scheme, however, had not convinced many fishers to participate. Therefore, this paper aimed to indicate factors influencing the intention of participation based on the Theory of Planned Behaviour. The significant influencing factors were subjective norms and environmental attitudes. The important factors for not joining the scheme were found to be lack of information, time limitation and past experience. These preliminary results were from thirty-four fishers in three provinces including Samut Prakarn, Samut Songkhram and Phang Nga using semi-structured interviews.

Keywords: marine litter, marine litter management, marine pollution, motivations

Introduction

Marine litter is an environmental problem that happened all over the world. It is defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (Jeftic, Sheavly, Adler, & Meith, 2009). The sources of the marine litter are from land-based and sea-based activities accounting for 80 and 20 percent respectively (Jambeck et al., 2015; Mouat, Lozno, & Bateson, 2010; Sherrington, 2016; Surfers Against Sewage, 2014).

Marine litter poses a significant threat to the economy, such as the cost of beach cleaning, tourism. Besides, the fisheries and aquaculture which greatly rely on the seas are impacted by the contamination of litter as well (Mouat et al., 2010; Newman, Watkins, Farmer, Brink, & Schweitzer, 2015; Surfers Against Sewage, 2014). The risk exposure to human health from litter occurs at beaches and seas such as injuries from metal, glass or shards of plastic on beaches and discarded fishing gears at sea. Moreover, the society also has negative impacts such as recreational value, and the beauty of the landscape (Mouat et al., 2010; Surfers Against Sewage, 2014; UNEP, 2017). The environmental impacts are found and happened to the marine animals such as injuries, suffocating, drowning and death. In addition, the loss of the lives of marine creatures such as fish can cause damage to ecosystem functions and services as well as economic loss to the fishers (Mouat et al., 2010; Surfers Against Sewage, 2014).

Many countries and organisations have implemented countermeasures to address marine litter issues as well as Thailand, which have 21,700-32,600 tonnes of plastic debris reaching to the marine environment every year--estimated by Department of Marine and Coastal Resources (2019). The scheme is named Trash Back to Shores: Beautiful Seas with Our Hands initiated by Department of Fisheries since October 2019. The scheme aims to raise awareness of fishers on marine litter and proper waste management, to encourage fishing fleets to collect their on-board litter and bring it back to shores, to promote fishing ports to provide waste reception facilities and to reduce disposal containers while at sea (Department of Fisheries, 2020). Fishers voluntarily collect their on-board litter and marine litter caught-up in their fishing gears. When they return, they are required to report the amount of collected waste to Fisheries Port In-Port Out Control Centers (PIPOs). Then, the fishing ports manage the waste reception and coordinate with local governments for further waste disposal (Department of Fisheries, 2020).

Currently, the scheme is running in all sea-connected provinces, and 30 PIPOs are responsible for the waste collection records. Approximately 3,000 of 10,203 Thai commercial vessels have joined the scheme (W. Rattanachu, personal communication, May 14, 2020). The amount of marine litter collected is 74.5 tonnes as of July 2020. Twenty-seven percent of which are caught-up litter floating in the sea (Department of Fisheries, 2020).

The programme, however, has not convinced a significant number of fishers to participate. There is a chance that the scheme might be discontinued if the involvement of participating fishers declined. Therefore, this study aimed to investigate factors that influence or hinder the adoption of marine litter collection practices at sea by fishers. The results could improve the operation of the programme to attract more fishers to participate and to keep the participating fishers to remain in the marine litter collection practices.

Four categories of factors influencing fishers are grouped by using the Theory of Planned Behavior (TPB) of Ajzen (1991). Attitudes, subjective norms and perceived behavioural control are the main categories from Ajzen's theory. Plus, the past experience is the fourth category as the extended theory of planned behavior. The factors and description used in this study are shown in Table 1.

Table 1: Theoretical framework

Category	Factor	Description	Reference
Attitudes	Environmental knowledge and awareness	The personal knowledge about marine pollution and benefits of marine litter collection practice	Brongers (2017); Wyles, Pahl, Carroll, and Thompson (2019); Chen (2010); Liu, Bruins, and Heberling (2018)
	Personal concerns	Hygiene and risks	Brongers (2017); Wyles et al. (2019)
Subjective norms	Social pressure	From the public and Profile and reputation of fishing industry	Brongers (2017); Wyles et al. (2019); Chen (2010); Liu et al. (2018)
	Surrounding people	Family, Fishers, Groups such as Fishermen Associations	Brongers (2017); Wyles et al. (2019); Chen (2010); Liu et al. (2018)

Category	Factor	Description	Reference
Perceived behavioural control	The readiness of supported practice	Sufficient reception facilities and waste management	Brongers (2017)
	Information	The accessibility to the information about the programme	Wyles et al. (2019); Chen (2010)
	Time and interests	Extra time and the interests of the owners of vessels	Wyles et al. (2019)
	Size of vessels and ships adjustment	Size of vessels and ships adjustment	Brongers (2017); Wyles et al. (2019)
Past behaviour	Practice experience	Already in marine litter collection	Brongers (2017); Wyles et al. (2019)

The methods

The selection of the study areas was based on the report of "Trash Back to Shores: Beautiful Seas with Our Hands" indicating the amount of marine litter bringing back to lands, and the fishing gears in each province (Department of Fisheries, 2020). Therefore, the areas of this study were three provinces including Samut Prakarn, Samut Songkhram and Phang Nga.

The qualitative approach was used for data collection for exploring relevant motives of fishers to participate in the marine litter collection scheme. The semi-structured in-depth interviews were used for data collection. The interview questions comprised of three parts including socio-demographic data of fishers, their marine litter practice and questions concerning influencing factors. Besides, the suggestions for the improvement of the scheme and marine litter management were also asked. In total, 21 short questions were used to get insights into the reasons for the scheme participation. The fishers were approached through the Port In-Port Out Control Centers (PIPOs) and the fishery associations. Thirty-four fishers were interviewed at their docking harbours. The 27 of 34 approached fishers were participants of the scheme while the rest was not.

Results

The results from the interviews are shown in two parts. The socio-demographic data and overall marine litter management are described in the first part. Then, the second part describes the factors that influence or hinder the adoption of marine litter collection schemes.

- ***Socio-demographic data and marine litter management***

Based on qualitative research approach, 34 fishers were interviewed. Twelve of them are vessel owners, 18 are commanders in chief and 4 are others. Most of fisher respondents own medium-size vessels (30-59.99 gross tonnage) while 4 of them have small vessels (less than 29.99 gross tonnage) and 3 own large vessels (60-149.99 gross tonnage) and 2 of them did not know the exact size of their vessels. Most of the fishers used surrounding nets, trawl nets, otter board trawls. However, some vessels had no fishing gears because they supported other vessels using the light.

With regard to marine litter management, all of them had kept their own generated waste on-board while 21 fishers also collected and kept floating marine litter. Most of the collected litter on-board were plastic bottles and plastic bags. The floating litter that they mostly found were plastic bags and nets. Most of them collected marine litter and threw them away at ports. Only seven brought and sold recyclables after conducting waste separation. Regarding food waste, some interviewed fishers indicated that they had to throw it away in the ocean because of its odour and the belief that it is naturally degradable.

- ***The factors influencing or hindering the adoption of marine litter collection schemes***

In this part presents the factors that influence or hinder the adoption of marine litter collection schemes. The preliminary results from the interviews are shown for each of the four main categories of the factors consisting of personal attitudes, subjective norms, perceived behavioural control and past behaviour, as shown in Figure 1 and 2.

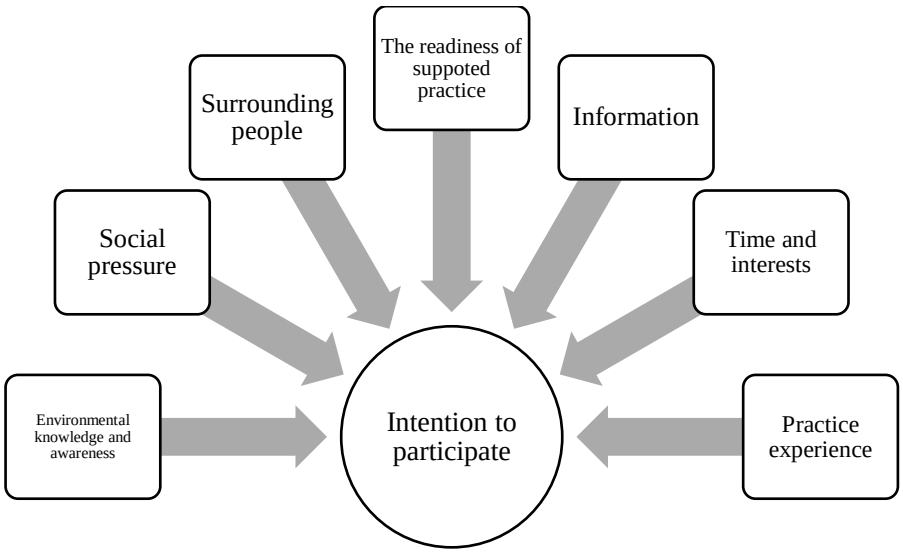

Figure 1: Potential influencing factors from the fishers' interviews

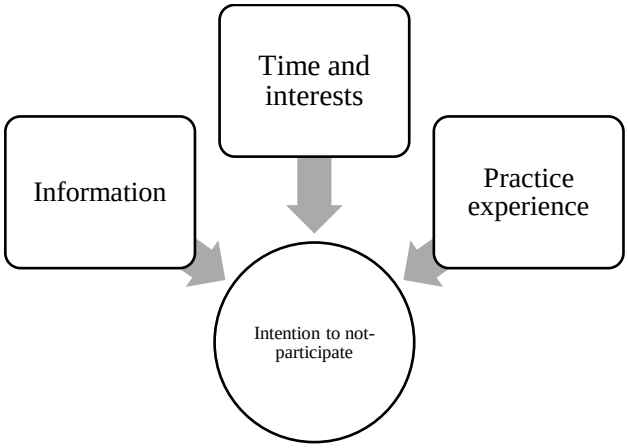

Figure 2: Potential hindering factors from the fishers' interviews

Personal attitudes

The results of personal attitudes are indicated by two factors in this category; the environmental knowledge and awareness and personal concerns. Both participants and non-participants had knowledge of the marine environmental problem. They understood that the problem of marine litter had caused environmental problems to marine flora and fauna. Moreover, they positively saw the action of marine litter collection practice as a means to reduce the marine litter.

Participants had no concerns of hygiene and risks in the practice of marine litter collection because they had containers for marine litter, as shown in Figure 3. Likewise, non-participants had no concerns on hygiene and risks to collect marine litter.

Source: the authors

Figure 3: a small net used for collecting waste

Subjective norms

The second category of factors is subjective norms which are perceived by social pressure to act or not in the circumstances (Ajzen, 1991). This part contains the results from the factors of social pressure and the surrounding people.

Social pressure can be separate into two sets including the public pressure (via media) on the fishing industry and the pressure from receiving the marine environmental damages news. Both participants and non-participants commonly disagreed with the contents that the fishing industry was the source of the marine litter because all of them collected their litter on-board. On the contrary, the news on marine environmental damages had attracted the fishers to do the practice both participants and non-participants.

Surrounding people of fishers can be divided into three groups; their families, other fishers, and the fishery associations. According to the interview of participants, most of them joined because of the encouragement of their fishery associations and the PIPOs. Some of them explicitly stated that the PIPOs asked them to join. However, surrounding people did not hinder the intention to participate of non-participants.

Perceived behavioural control

The role of perceived behavioural control plays an important part in shaping the fishers' decision to participate in the marine litter collection scheme. Ajzen (1991) defines it as the perception of the easiness and difficulty of behavioural performing. Then, the questions about the surrounding circumstances were used to find out the factors that could influence or hinder the participation of fishers. The factors in this category are the readiness of supported practice, information, time and interests and size of vessels and ships adjustment.

The readiness of supported practice includes the waste reception facilities at ports and waste management. The participating fishers enjoyed the waste reception facilities because they can throw away their collected marine litter free of charge. They also strongly agreed that the collected marine litter should be properly disposed of or recycled. The non-participants had shown their interests in participating in the programme if there is proper waste management.

The information of the scheme played an important part in influencing or hindering the participation of fishers. The participants mostly stated that they joined because the PIPOs or their fishery associations told them. In contrast, 5 of 7 non-participants stated that they did not know about the programme. If they knew, they would join.

Time has no relevance with the influence of the participation of the scheme. On the contrary, they relate to the marine litter collection practice. Non-marine litter collectors stated that they did not have time to collect marine litter because of their fishing gears in which demanding them to have a day at sea. Thus, they have to concentrate on catching fish.

The interests of vessel owners have an influence on the vessel commanders. Eight of them explicitly stated that they were in the programme because of their owners.

The size of vessels and ships adjustments are neither the influencing and hindering factor for participants and non-participants to engage in the scheme. The fishers had their containers for collecting marine litter without the adjustment of their ships. Moreover, the containers used only a small space in the vessels as shown in Figure 1.

Past behaviour

Past behaviour is an important driver for the participation of fishers, and it is a good possibility for non-participants to join in the scheme. Most of the fisher respondents stated that they had done the practice before the programme started. Therefore, they saw no difficulty in

joining the scheme. They only had to report the amount of collected litter when they docked. On the contrary, non-participants had also done the practice of marine litter collection before the launch of the programme. Therefore, they saw no difference in participating in the scheme with their normal collection practice.

Incentives

In addition, the fishers were asked about the opinions on incentives. Three different points of views were found. 40 percent of fishers rejected all incentive because they thought that this voluntary approach made the practice lasted long. They did it because they wanted to do it from the bottom of their hearts. 32 percent accepted all incentives. Only 11 percent accepted the non-financial and strongly rejected the financial incentive because they felt that the money should not interfere with the practice. The rest was undecided for the incentives.

Discussion and Conclusion

Trash back to Shores: Beautiful Seas with Our Hands is a scheme trying to save the polluted ocean by bringing fishers to restore it. However, only 30 percent of vessels participated. The factors that associate with the intention of fishers were studied. The influencing factors are the environmental knowledge and awareness, which fishers believe that their acts could diminish marine litter.

The surrounding people that can encourage the fishers to join are the fishery associations and Port In-Port Out Control Centers (PIPOs). These are significant institutions that should promote and provide more information about the scheme towards non-participants.

The supported waste facilities are regarded as one of important factors. Fishers are likely to join the program if the ports provided waste reception facilities free of charge. Furthermore, the provision of waste containers on board could facilitate the marine litter collection practices.The limited time to go out at sea played as major obstacles for fishers not to join the scheme and it is related to the types of fishing gears they used.

The past behaviour in collecting marine litter can be in different points of views. The results of Brongers (2017) and Wyles et al (2019) showed that the past experience could facilitate the participation. So did this study. However, the results of this study showed non-participants did not join because they saw no difference in participation because they were already in practice. Therefore, non-financial incentive, such as certificates, rewards, additional fishing day quota could

play a role in encouraging the practice's continuation of participants and the participation of non-participants for the differences.

It is worth noting that the presented results could benefit the optimisation of the scheme by taking the influencing and hindering factors into consideration. This study only aimed to suggest the adaptation of the programme that can attract non-participants to participate. The government should also make more efforts in reducing mismanaged plastic waste on land in order to reduce marine litter. Moreover, the non-participants could play a part in marine litter collection practice by joining the scheme to avoid the loss of fishing gears, fishing vessels and the loss of income resulted from less marine animals in the ocean.

Limitation of the study

Most of approached fishers of this study were participants which could result in positive bias of the sample. However, the analysis will take place again after the complete interviews.

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Reference

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211. doi:https://doi.org/10.1016/0749-5978(91)90020-T

Brongers, B. (2017). *The Participation of Dutch Fishermen in waste collection practices at sea.* (Master's thesis). Wageningen University, Wageningen, the Netherlands. Retrieved from https://edepot.wur.nl/404099

Chen, C.-L. (2010). Factors influencing participation of 'top-down but voluntary'fishery management—empirical evidence from Taiwan. *Marine policy, 34*(1), 150-155.

Department of Fisheries. (2020). Trash Back to Shores: Beautiful Seas with Our Hands Report.

Department of Marine and Coastal Resources. (2019, September 17). Learning Marine Litter: Thai ocean catrastrophe. Retrieved from https://www.dmcr.go.th/detailAll/35501/nws/141

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., . . . Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science, 347*(6223), 768-771.

Jeftic, L., Sheavly, S., Adler, E., & Meith, N. (2009). *Marine litter: a global challenge*: UNEP.

Liu, T., Bruins, R. J., & Heberling, M. T. (2018). Factors influencing farmers' adoption of best management practices: A review and synthesis. *Sustainability*, *10*(2), 432.

Mouat, J., Lozno, R. L., & Bateson, H. (2010). Economics Impacts of Marine Litter. Retrieved from http://www.kimointernational.org/wp/wp-content/uploads/2017/09/KIMO_Economic-Impacts-of-Marine-Litter.pdf

Newman, S., Watkins, E., Farmer, A., Brink, P. T., & Schweitzer, J.-P. (2015). The economics of marine litter. In *Marine anthropogenic litter* (pp. 367-394): Springer, Cham.

Sherrington, C. (2016). Plastic in the Marine Environment. Retrieved from https://www.eunomia.co.uk/reports-tools/plastics-in-the-marine-environment/

Surfers Against Sewage. (2014). *Marine Litter Report; 2014-2020 Vision*. St. Agnes.

UNEP. (2017). *Marine Litter Socio-Economic Study*. Nairobi, Kenya: United Nations Environment Programme.

Wyles, K. J., Pahl, S., Carroll, L., & Thompson, R. C. (2019). An evaluation of the Fishing For Litter (FFL) scheme in the UK in terms of attitudes, behavior, barriers and opportunities. *Marine Pollution Bulletin*, *144*, 48-60. doi:https://doi.org/10.1016/j.marpolbul.2019.04.035

An IoT in Air Quality Study for Spatial Concentrations of CO during Public Bus Transit in Bangkok

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Abstract

This study used a portable real-time carbon monoxide (CO) instrument as the Internet of Things (IoT) in an environmental study, a lab-built from an electrical circuit and a small sensor and worked with a mobile phone via the Bluetooth connection. The instrument was deployed to observe spatial concentrations of CO during commuting in public buses along the areas around the ambient monitoring stations. Real-time CO concentrations were measured in the morning (7.00-9.00), late morning (10.00-11.00) and evening (16.00-18.00) and the route maps were created from XY coordinates. The results showed that high CO concentrations were in the areas closed to bus stops and BTS stations during the morning period, between 489 and 790 mg/m^3 of CO. The observed CO concentrations measured with the portable instrument were always higher than CO concentrations reported by the hourly concentrations from the air quality monitoring stations in the same areas.

Keywords: Internet of Things (IoT), Spatial concentration, CO, Public bus, Bangkok

Introduction

The conventional air pollutants usually represents in the national ambient air quality standards are nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particulate matter sized smaller than 10 microns (PM_{10}) and 2.5 microns ($PM_{2.5}$). Most serious air pollution episodes occurred in the urban environment. World Health Organization reported on the health effects of traffic related air pollutant showed that people spend 1-1.5 hour per day commuting in many countries (WHO, 2005). Olsson et al. (2013) found that the average commute times vary between 40 to 80 minutes, with public bus transit taking longer than car commutes, the results from literatures on international transportation studies.

CO is a colorless, odorless and tasteless but potentially lethal gas produced by incomplete combustion. A common source of CO in congested urban air mostly originated from motor vehicle exhaust. Symptoms of CO poisoning are headache, dizziness, rapid heartbeat, visual disturbance and the overall adverse health effects of CO have been well established for cardiovascular and central nervous system usually at a blood carboxyhemoglobin (COHb) level 2.4%, corresponding to CO exposure level of 10-15 ppm (Zhuohui et al., 2016). The most important health effects of CO are due to its capacity to form a strong bond with hemoglobin molecules. CO concentrations in ambient air have been monitored for decades in many large urban areas, but it is still difficult to assess the overall human exposure to this pollutant adequately.

A current trend to collect air quality data goes beyond the reference monitoring stations. Many studies have shown the possibility of collecting air quality data using inexpensive sensors. However, legislation is not in place to regulate the usability of these data yet (Castell et al., 2017). Real-time data and specific micro-environment measurements can be achieved to provide higher resolution of air quality in the urban environment. More coverage may enhance the engagement from concerned citizens. Sensor platforms are currently available to monitor a range of air pollutants and new devices are continually being introduced (Aleixandre and Gerboles, 2012; Piedrahita et al., 2014). For example, a sensor platform such as AirCasting (http://aircasting.org) used the mobile platform to monitor air pollution variation while commuting. This study focused on the use of a portable low-cost CO sensor as an Internet of Things (IoT) to collect, process, and send data in real-time.

Materials and methods

1. Study design

This study used the congested areas in Bangkok to demonstrate the use of real-time CO measurements along two designated routes around the areas equipped with the ambient monitoring stations of Pollution Control Department (PCD) as shown in Fig. 1. The data were collected during commuting in the open-air bus and in the winter between January and March 2018 on weekdays (Tuesday, Wednesday and Thursday) to avoid irregular traffic flow. The sampling periods covered morning hours (07.00-09.00), evening hours (16.00-18.00), and late morning hours (10.00-11.00). No measurement was taken during rainy day. The two routes are the followings.

a. Route 1 started from Lat Phrao MRT station bus stop to Victory Monument bus stop (Ratchawithi side), through business and commercial districts and the transfer stations to the sky train (BTS) and the underground train (MRT). The route covers 6.04 km and the ambient monitoring stations (59T) is located in Phaya Thai District.

b. Route 2 started from a supermarket (Big C Lat Phrao) to Lat Phrao intersection bus stop, through the mixed use areas with educational institutions, hospitals, office buildings, markets, and a transfer station to the underground train (MRT blue line). This route is 6.15 km. The ambient monitoring station (53R) is located near Lat Phrao road.

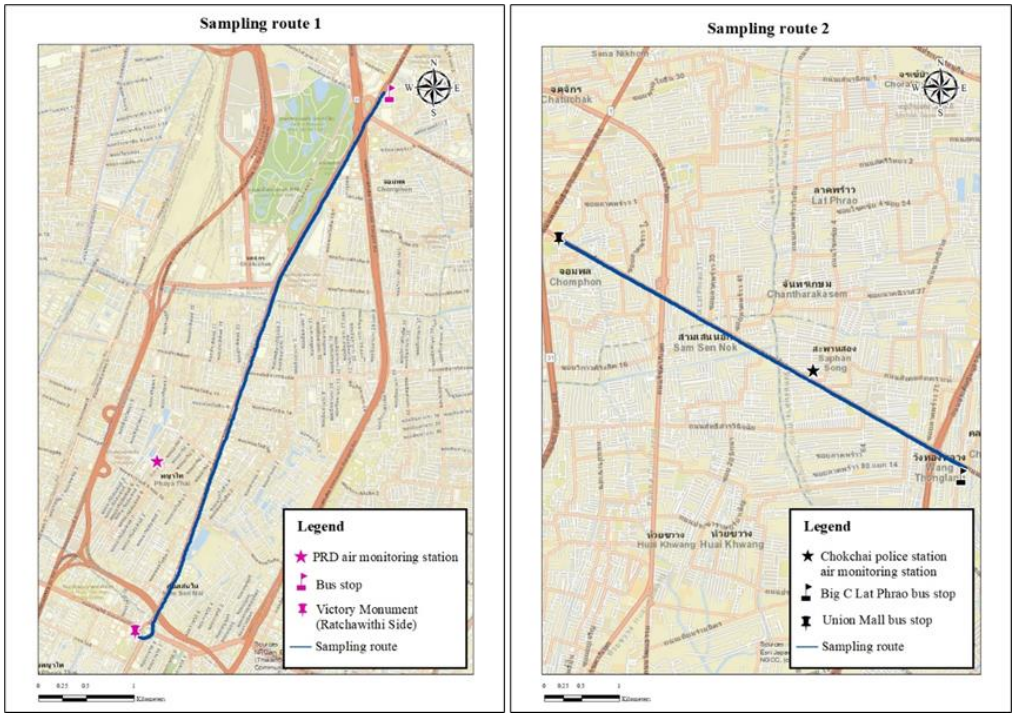

Figure. 1 Map of sampling routes

2. CO measuring instrument

The lab-built CO instrument was built from an electrical circuit and the digital gas sensor – carbon monoxide (DGS-CO) (SPEC Sensors LLC, USA) with a Bluetooth connection. The portable CO sensor was tested against a commercial Testo® 350 analyzer (Testo SE & Co. KGaA, Germany). The analyzer has the electrochemical sensor as the component with the accuracy of ±5 ppm CO (0-199 ppm CO) and ±5% of mv (200-2000 ppm CO) (Testo SE & Co. KGaA, 2017). The DGS-CO is a real-time electrochemical sensing device. The instrument is equipped with the digital-output DHT22 relative humidity and temperature sensor/module (Aosong Electronics Co., Ltd, China) because temperature and relative humidity had variable impacts on the electrochemical sensor response (Wei et al., 2018). The sensors was based on AirCasting platform to display and share data via a mobile phone. The schematic diagram of experimental setup is showed in Fig. 2. The experiments recorded real-time concentrations of CO during straw burning every 5 seconds. The background concentrations of CO were checked prior to each test. The CO sensor, DGS-CO, and the gas analyzer, Testo® 350, presented the linear relationships with the coefficients of determination (R^2) between 0.82 and 0.95. The results suggested that the DGS-CO sensor was capable for CO measurements.

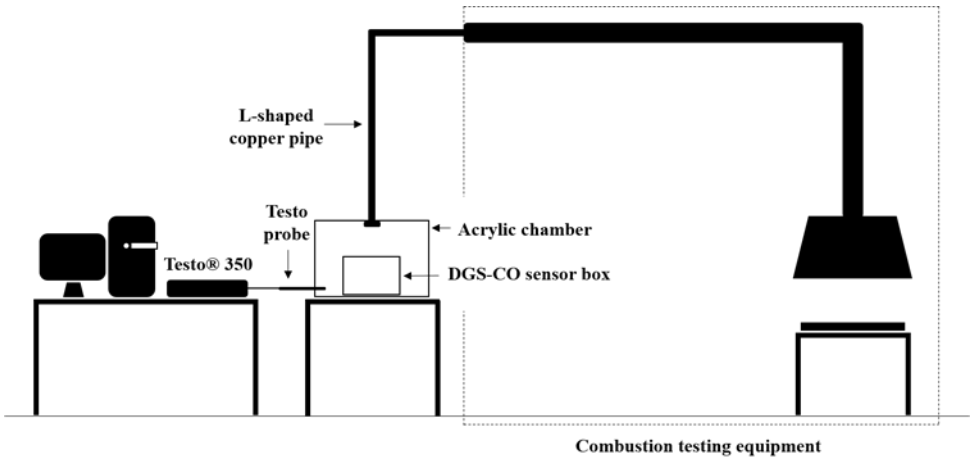

Figure. 2 Schematic of experimental set-up

3. Route map and spatial analysis

Route maps were created from coordinates and imported into the Geographic Information System (GIS) program. The coordinates were recorded during the commuting in the public bus and corresponded to the CO measurements and later were added as the attribute to spatially represent

CO concentrations along the routes. The spatial concentrations were classified using the classification technique

Results and discussion

Thirty-five trips were accounted for two routes. Twenty-four trips were conducted during morning and evening hours and the rest was during lighter traffic hours (10.00-11.00). Higher means of CO concentrations occurred during commuting in the morning hours on both routes than late morning and evening hours. Hourly CO concentrations at fixed monitoring stations were reportedly lower than the levels found during commuting (Table 1). This study provides results similar to other cities (Kaur et al., 2005; Huang et al., 2012). Zagury et al. (2000) suggested that when identifying the representativeness of the fixed monitoring station data, the distance between fixed monitoring station and traffic microenvironment should be considered. In this study, although an air monitoring station was next to a main road, except the station on route 1 (59T), the concentrations were still lower in all cases. These differences are obvious due to the influence from traffic where the measurement was onboard of the open-air bus along the route at all time and also strong influence of vehicle pollution on CO concentrations (Chan et al., 2002). No measurement was performed at night during light traffic. The overall of the spatial concentrations of CO illustrated that high concentrations were found in the areas closed bus stop and BTS stations during the morning period, about 489 and 790 mg/m^3 of CO on route 1 and route 2, respectively as shown in Fig. 3. The highest concentrations of CO on route 1 occurred near Mo Chit BTS station and Chatuchak MRT station on Phahonyothin road, and the highest concentrations of CO on route 2 occurred near Lat Phrao Soi 40 bus stop on Lat Phrao road, which is the area under construction of a new MRT yellow line project (Lat Phrao – Samrong section).

Table 1: CO concentrations (mean ± SD) during public bus transit and ambient monitoring station

Route / Air monitoring station	N (trips)	Hours	CO concentrations (mg/m^3)	
			personal	ambient
1 / 59T	6	07.00-09.00	113 ± 49	1.5 ± 0.3
	5	10.00-11.00	55 ± 35	1.2 ± 0.2
	6	16.00-18.00	47 ± 32	1.2 ± 0.2

Route / Air monitoring station	N (trips)	Hours	CO concentrations (mg/m^3)	
			personal	ambient
2 / 53R	6	07.00-09.00	107 ± 49	0.8 ± 0.3
	6	10.00-11.00	70 ± 41	0.6 ± 0.1
	6	16.00-18.00	34 ± 15	0.6 ± 0.1

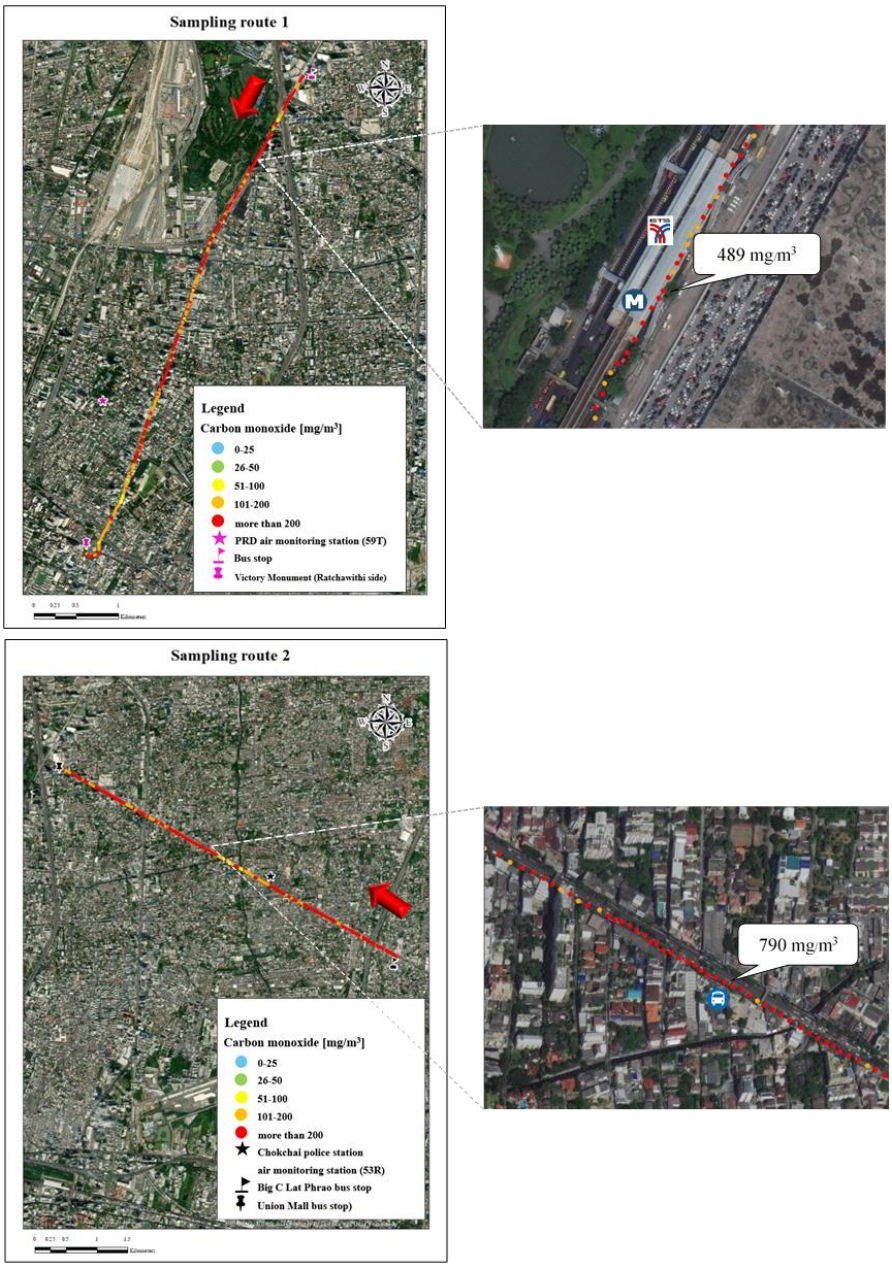

Figure. 3 Spatial concentrations of CO on route 1 and 2

Conclusions

The portable real-time CO instrument was capable of measuring CO concentrations and reporting in real-time during the commuting in open-air public bus in Bangkok. The real-time data showed that the public bus commuting experienced higher CO concentrations in the morning hours than other periods on route 1 (Lat Phrao MRT station – Victory Monument) and 2 (Big C Lat Phrao – Lat Phrao intersection). Short-term averages of CO concentrations at personal levels during commuting were obviously higher than those concentrations reported by the fixed ambient monitoring stations. Discrepancies were clearly the results of near-source exposure of commuters during transit and dilution at receptor locations which the fixed air monitoring stations are used to represent the general zoning rather than the use of personal exposure purposed and short-term observation. Several factors should be considered when using ambient monitoring data to represent personal exposure data for commuting. The portable CO instrument, however, can be used in addition to provide real-time spatial locations and concentrations along the commuting routes. Limited vertical air movement under BTS stations caused high CO concentrations that can be detected by the instrument.

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References

Aleixandre, M., Gerboles, M., 2012. Review of small commercial sensors for indicative monitoring of ambient gas. Chem. Eng. Trans. 30, 169–174.

Castell, N., Dauge, F.R., Schneider, P., Vogt, M., Lerner, U., Fishbain, B., Broday, D. and A. Bartonova (2017). Can commercial low-cost sensor platforms contribute to air quality monitoring and exposure estimates? Environment International, 99, pp. 293–302.

Chan, L.Y., Lau, W., Lee, S., Chan, C.Y., 2002. Commuter exposure to particulate matter in public transportation modes in Hong Kong. Atmospheric Environment 36: 3363-3373.

Huang, J., Deng, F., Wu, S., Guo, X. (2012). Comparisons of personal exposure to PM2.5 and CO by different commuting modes in Beijing, China. Science of the Total Environment 425: 52–59.

Kaur, S., Nieuwenhuijsen, M., Colvile, R., (2005). Personal exposure of street canyon intersection users to PM2.5, ultrafine particle counts and carbon monoxide in Central London, UK. Atmospheric Environment 39: 3629.

Olsson, L. E., Garling, T., Ettema, D., Friman, M., Fujii, S. (2013). Happiness and satisfaction with work commute. Social indicators research 111:255–263.

Piedrahita, R., Xiang, Y., Masson, N., Ortega, J., Collier, A., Jiang, Y., Li, K., Dick, R.P., Lv, Q., Hannigan, M. and Shang, L., 2014. The next generation of low-cost personal air quality sensors for quantitative exposure monitoring. Atmos. Meas. Tech. 7, 3325–3336.

Testo SE & Co. KGaA. (2017). testo 350 instruction mannual [On-line]. Available: https://static-int.testo.com/media/d1/56/d4836ea87dd7/testo-350-Instruction-Manual.pdf

Wei, P., Ning, Z., Ye, S., Sun, L., Yang, F., Wong. K.C., Westerdahl, D., and Peter K. K. Louie (2018). Impact Analysis of Temperature and Humidity Conditions on Electrochemical Sensor Response in Ambient Air Quality Monitoring, Sensors, Vol.18, No.59.

World Health Organization. Health effects of transport related air pollution. Copenhagen: WHO Regional Office for Europe; 2005.

Zagury, E., Le Moullec, Y., Momas, I. (2000). Exposure of Paris taxi drivers to automobile air pollutants within their vehicles. Occup Environ Med 57: 406–410.

Zhuohui, Z., Chen, R., Lin, Z., Cai, J., Yang, Y., Yang, D., Norback, D. and H. Kan (2016). Ambient carbon monoxide associated with alleviated respiratory inflammation in healthy young adults, Environmental Pollution 208, pp. 294-298.

Thermal Insulation Produced from Blady-Grass Fiber and Natural Rubber

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Abstract

This paper presents an investigation on the production of the thermal insulation produced from blady-grass (Imperata cylindrica (L.)) fiber and natural rubber latex. The thermal conductivity of the natural insulation was measured and compared with commercial and other natural fibers insulation. To produce the thermal insulation sheet, the blady-grass was cut to small pieces between 10 and 15 cm long before soaking in the solution of Sodium Hydroxide for 4 hours, cleaning by water and later sun-drying the blady-grass fibers for 2 days. Next, the blady-grass fibers were binding using natural rubber latex at various ratio between the two materials with an intention to use much more blady-grass fibers than natural rubber. The dimension of insulation sheet is 20 cm x 20 cm x 2.5 cm. Then, the natural insulation sheet was taken out of the mold and placed in the hot air oven at 100^{o}C for 3 hours. The results show the apparent density of the insulation sheets ranged from 100 kg/m^3 to 147 kg/m^3. The thermal conductivity of insulation sheets testing under ASTM C 177 standard is ranged from 0.0489 to 0.0557 W/m·K. With low thermal conductivity, the product is classified as thermal insulation. The thermal conductivity comparison between the current natural insulation and others such as fiberglass, polyurethane foam, vetiver fiber insulation and gypsum board show well agreement. In brief, the insulation sheet combining of blady-grass fibers and natural rubber is considerably comparable to conventional thermal insulation as a success environmentally friendly production.

Keywords: Thermal insulation, Thermal conductivity, Blady-grass fiber, Natural rubber

Introduction

A good insulation is important in preventing heat, mostly come from the sun, from extreme outdoor weather to indoor. Particularly in warm climate countries where high outdoor temperature is observed long hours through the year. Large amount of energy is consumed, to sustain human thermal satisfaction, by air conditioning systems. The climate change causes an increase of global temperature which also add up the demand of building energy that has been realized by air conditioning system shared of more than 50%. The utilization of suitable thermal insulation could reduce carbon emission due to the reduction of thermal transmission into building the energy consumption decreased hence fossil-fuel energy production diminish. Commercial insulation products are commonly employed in buildings the drawback is high cost and health safety concern in the production process and end user. Alternatively, a bio-based material is potentially used for producing building insulator as environmentally friendly thermal insulation. Review of building thermal insulation as an efficient way of energy utilization was presented (Aditya et al, 2017). Environmental concern has caused people to pay more attention on the natural bio-based building insulator for protecting indoor environment and providing cost saving (Adamczyk & Dylewski, 2017). Agricultural straws are particularly attracted by the public because of its abundance and economic. Many researches present the production method and its physical properties such as thermal conductivity, moisture and density. A number of local natural bio-based materials are used in insulation production process thus has no transportation and less cost. Thermal insulation produced from vetiver and natural latex was investigated (Patcharaphun et al, 2007). The latex was used as a binder by spraying natural rubber latex onto vetiver fiber to form a flat sheet of 20x20 cm^2 and 1.5 cm thick. The density of the vetiver fiber thermal insulation is 180 kg/m^3. The measurement of thermal conductivity referred ASTM C 177 standard, it was found at 0.0564 W/m K which is similar to conventional insulations. Another research presents the building thermal insulation produced form corncob and natural rubber latex (Sakulpanich, 2015). The ratio of latex and water were varied. The appropriate ratio of 2:1 (latex : water) was selected and found the sample density of 310 kg/m^3 and thermal conductivity of 0.066 W/m.K. The insulation sheet of 40x40x1.5 cm^3 was test using test box for inside temperature reduction. The result shows similar temperature reduction effect to the use of 10 mm polyethylene foam but 49% lesser cost. Insulation produced from rice straw and latex as a binder by the cold press was investigated (Pimprom et al, 2017). The ratio between rice straw and binder is seventy per thirty percent by volume. Some

physical properties of this insulation were found as follows; the optimal density of 400 kg/m^3, the moisture content of 5.13%, and the thermal conductivity of 0.896 W/m.K. The proposed application of the product is to use as the flat pressed particleboard. In addition to the application of natural materials, the research shown the natural materials reinforced polyurethane foam can be used as thermal insulation of building (Shao et al, 2020). Wood fiber, bamboo fiber, rice husk and polyol, a solvent and a precursor, are the component of reinforced polyurethane insulation. The important properties of the natural fiber insulation were measured. The results show thermal conductivity ranged from 0.045 to 0.065 W/m.K.

More than 46 percent of the land used in Thailand is for cultivation (Thailand. Department of Agricultural Extension, 2014). Several agricultural residues have been utilized to produce thermal insulation while one has not been seen much (Roseleena, 2016). The weed preventing crop grow has not been paid much attention that is blady-grass (Imperata cylindrica (L.)) with great potential in excluding other crops on the land due to its living mechanism that release substance to restrain other crops growing. Its distributing root structure on the soil surface is also hard for growing other crops. On the other hand, dried blady-grass has been commonly used for making the roof or wall panel of the Thai style remote houses because of economic and its physical strength. Accordingly, the current study found the potential of blady-grass in producing the building thermal insulation because of its high fiber, abundance and no cost.

The research aims to investigate the rare use blady-grass fiber, bio-based material, for producing thermal insulation through simple process of binding with natural rubber latex and mold pressing. The important property of thermal insulation like thermal conductivity is measured to ensure the heat protection. Density of blady-grass thermal insulation is also studied for an intention utilization on building envelope. The thermal insulation produced from natural materials is environmentally friendly. The building thermal insulation from natural material is benefit to occupant health since it releases no toxic substance while some commercial building insulations are questioned on the safeness. The blady-grass fiber thermal insulation could replace synthetic commercial insulation and be kind to environment.

Experiment and methods

In this study the blady-grass fiber was prepared then binding with natural rubber latex and pressing in the square shape mold as well as an investigation on thermal and physical properties of

the thermal insulation. The process used to produce the sample thermal insulation from blady-grass fiber and natural rubber is indicated later in this section.

1.Blady-grass fiber preparation

In the fiber preparation process, the blady-grass were cut to small pieces with the length of 10 to 15 cm as shown in Figure.1. Then put them into boiled NaOH solution (NaOH 5kg: H_2O 12 kg or 25% by mass) for 4 hours as shown in Figure.2. After pieces of blady-grass become frayed fiber, they were rinsed by water then sun-drying for 2 days as shown in Figure.3.

Figure 1 Blady-grass cut into 10 - 15 cm long

Figure 2 Blady-grass in NaOH solution

Figure 3 Sun dry frayed fiber for 2 days

2. Blady-grass thermal insulation sheet

The dried blady-grass fibers were binding using the natural rubber latex at various ratio between the two bio-based materials as follows; 90:10, 80:20, 70:30, 60:40 and 50:50 respectively. The current study intends to use as much blady-grass fiber as possible in order to produce the thermal insulation; therefore, variable material ratios were design accordingly. To form the insulation sheet, the natural latex was poured into the container then spray on the dried blady-grass fibers as to binding all frayed fibers together. Then press the soft sticky fibers into the square shape mold to form an insulation sheet for the dimension of 20 cm x 20 cm x 2.5 cm (width x length x thick) as can be seen in Figure. 4. The insulation sheets were finally dried in the hot air oven at 100 ^{o}C shown in Figure.5 and a ready product is in Figure.6.

Figure 4 Blady-grass fiber binding with natural latex in the mold

Figure 5 Blady-grass insulation plate dry in the hot air oven at 100^{o}C

Figure 6 Blady-grass insulation plate

3. Thermal and physical properties measurement

Blady-grass thermal insulation sheet is brought to find the thermal conductivity and density. The thermal conductivity of the thermal insulation from blady-grass fiber were measured in accordance with ASTM C177 standard. The apparent density of the insulation can be calculated from the ratio of mass per volume of each sample.

Results and Discussion

The blady-grass thermal insulation in the form of flat sheet shown in Figure.6. The apparent density of the insulation ranged from 100 to 147 kg/m^3. According to the measurement of thermal conductivity refer to ASTM C 177 standard, the results are shown in Table 1. It was found that the density is increasing with the increase of natural rubber latex while the thermal conductivity is varied little from 0.0489 to 0.0557 W/m.K according to the ratio of two bio-based materials from 90:10 to 50:50 respectively. The results show that even less rubber latex the thermal insulation sheet is consistently form and provide lowest thermal conductivity. In other words, the highest ratio of blady-grass fiber to the rubber latex as 90:10 is the best thermal insulation according to the measurement of thermal conductivity provided lowest value. Moreover, this insulation cost is lesser than any other samples with higher magnitude on rubber latex because the lower amount of rubber latex is the lesser investment.

Table 1: Thermal conductivity and apparent density of the thermal insulation sheets from blady-grass and natural rubber latex

Specimen No.	Ratio of Blady-grass fiber to natural rubber latex	Thermal conductivity (W/m.K)	Density (kg/m^3)
1	90 : 10	0.0489	100
2	80 : 20	0.0553	105
3	70 : 30	0.0557	121
4	60 : 40	0.055	126
5	50 : 50	0.0523	147

The comparison between the natural thermal insulation and commercial insulation is shown in Table 2. Thermal insulation produced form blady-grass fiber and natural rubber latex have low thermal conductivity which is similar to the one produced from vetiver fiber and within the range of conventional commercial like fiber glass. However, it found better than the insulation produced from rice straw in terms of higher heat protection due to lower thermal conductivity. Regarding to the ratio of the two bio-based materials of the natural insulation, it was found that the current blady grass thermal insulation sample has higher thermal conductivity than another even at the same ratio between the blady-grass fiber and rubber latex of 60 : 40 (Roseleena, 2016) for 0.055 W/m.K versus 0.022 W/m.K respectively. One can be realized that the production process is slightly difference as the current study employ Sodium Hydroxide only at the fiber preparation while the other use both during fiber preparation and insulation formation with lesser concentration at 5%. The structure of fiber as well as the weight of frayed fiber would be difference and would be affect when used to form the insulation sheet thus provide greater density in the current study sample. Accordingly, the thermal insulation sheet from blady-grass fiber and natural rubber latex produced in this study can be used as thermal insulation for the building and could prevent building heat gain as the same to commercial insulation like fiber glass and mineral wool (Levinson et al, 2020; Pavelek et al, 2019). The possible application of the current insulation is similar to fiber glass and mineral wool that can be used for heat protecting through building roof and wall.

Table 2: Comparison between the current insulation and others

Insulation materials	**Density (kg/m^3)**	**Thermal conductivity (W/m·K)**
Blady-grass fiber and natural rubber latex (current study)	100.80 – 146.92	0.0489 – 0.0557
Vetiver fiber and natural rubber latex (Patcharaphun et al, 2007)	180	0.0564
Rice straw and latex (Pimprom et al, 2017)	400	0.896
Fiberglass (Levinson et al, 2020)	12 – 48	0.028 – 0.070
Blady-grass fiber and natural rubber latex *	21	0.022
Coconut fiber and natural rubber latex *	21	0.023
Gypsum plasterboard (Wakili et al, 2012)	2200	0.1 - 0.3

Noted: * The ratio of first material to second material is 60 : 40 (Roseleena, 2016).

Conclusions

Blady-grass treated by NaOH solution was used as main ingredient for the natural thermal insulation. The natural rubber latex is a binder to form the blady-grass fiber thermal insulation sheet that offer best thermal conductivity of 0.0489 W/m.K at the ratio of 90:10 (blady-grass fiber: natural rubber latex). It was found that all samples provide very close thermal conductivity value between 0.0489 and 0.0557 W/m.K. The current blady-grass thermal insulation is comparable to other natural and commercial insulation thus can be used as building wall insulation. The performance of temperature reduction using this insulation in the test box would be presented subsequently. Further study on the production cost comparison between blady-grass thermal insulation and commercial one shall be carried out.

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References

Thailand. Department of Agricultural Extension, Ministry of Agriculture and Cooperatives. (2014). Land use for agriculture (in Thai)http://www.agriinfo.doae.go.th/ year60/ general/land/ land60.pdf

Aditya, L., Mahlia, TMI., Rismanchi, B., Ng, HM., Hasan, MH., Metselaar, HSC., Muraza, O. & Aditiya, HB. (2017). A review on insulation materials for energy conservation in buildings. *Renewable Sustainable Energy Review,* 73, 1352–1365.

Adamczyk, J. & Dylewski, R. (2017). The impact of thermal insulation investments on sustainability in the construction sector. *Renewable Sustainable Energy Review*, 80, 421 – 429.

Shao, H., Zhang, Q., Liu, H., Guo, W., Jiang, Y., Chen, L., He, L., Qi, J., Xiao, H., Chen, Y., Huang, X., Xie, J. & Shupe, T. (2020). Renewable natural resources reinforced polyurethane foam for use of lightweight thermal insulation. *Materials Research Express*. 7, 055302. https://doi.org/10.1088/2053-1591/ab8d87

Patcharaphun, S., Rugkwamsook, P., Na-Ranong, N., Somboonvit, S. & Prasertsak, R. (2007). Thermal insulation produced from vetiver fiber and natural rubber latex. *Kasetsart Engineering Journal*, 61, 87-94.

Sakulpanich, A. (2015). The development of building thermal insulation from corncob and natural rubber latex, Thesis, Master of Architecture Program in Architecture, Silpakorn University

Pimprom, B., Dengna, P., Saueprasearsit, P. (2017, September). Development of Thermal Insulation from Rice Straw [Paper presentation], Journal of Science and Technology Mahasarakham University special issue, 13th Mahasarakham University Research Conference, 358-367.

Roseleena, J. (2016). The development of insulation from local plants. Report. Yala Rajabhat University.

Levinson, R, Akbari, H, and Gartland, L. (1996). Impact of the temperature dependency of fiberglass insulation R-value on cooling energy use in buildings. United States

Wakili, KG., Koebel, M., Kaufmann, J., Derluyn, H., Hofer, M., Glaettli, T., Modregger, P. (2012). Thermal conductivity of gypsum plasterboard beyond dehydration and its correlation with the pore structure. HEFAT2012. 9th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics. Malta. 5p.

Pavelek, M., Adamová, T. (2019). Bio-Waste Thermal Insulation Panel for Sustainable Building Construction in Steady and Unsteady-State Conditions. Materials. 12. 2004. 10.3390/ma12122004.

Identification of Enabling Factors for Sustainable Spent Fluorescent Lamp Recycling Process in Thailand

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Abstract

Current licensed recycling practices for spent fluorescent lamps (SFLs) generated by industries in Thailand only recovers the mercury without entering it back to the value chains. Improvement of the recycling practice often only considers the environmental benefits in the policy formulation, with less consideration of the social challenge, which offset the sustainability of the recycling process. This research aims to identify enabling factors for the creation of sustainable recycling process of SFFs using life cycle analysis (SimaPro 8) and semi-structured interviews with recycling business representatives. Increasing the recycling rate provides higher environmental benefits but the benefits are countervailed by limited mercury emission monitoring that risk workers' health and barriers faced by business stakeholders challenging the sustainability of electronic (E-waste) waste practices. This research found that institutional capacity to comply with environmental and occupational safety standards supported with informal-formal partnership and sustainable financing schemes are the enabling factors to sustainable SFLs recycling process.

Keywords: Spent Fluorescent lamps, social impact assessment, sustainable recycling

Introduction

As one of the lighting equipment, fluorescent lamp uses mercury that considered as a hazardous substance to generate visible light from the electric energy and contains other components such as glass tube, cathode, phosphor powder, and fill gas to operate (Lecler et al., 2018; Thavornvong, 2016). Being initially introduced in 1996 in Thailand, FL consists of different mercury concentrations according to the year production, manufacturer, and models. However, following RoHS (Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment) the concentration should be kept below 2.5 mg for production after 2013 to diminish health and environmental hazards (Hobohm et al., 2017). In Thailand itself, the protective measure was put under Notification of Ministry of Industry Re: Industrial Waste Disposal B.E. 2548 (2005) that classified spent FL (SFL) as hazardous waste with waste code 16 02 15 HA (hazardous component removed from discarded equipment). However, this policy only covers SF discharged by industries that became the research focus.

The focus was chosen because ICS (industrial, commercial, and service) sector dominated 52% of FL consumption in 2010 (Wongsoonthornchai, Kwonpongsagoon, & Scheidegger, 2016) while proper management of electronic waste (E-waste) from industrial discharge is still far from efficient due to low enforcement, unclear E-waste management, and limited technology capability (Apisitpuvakul, 2007; Pharino, 2017). Therefore, SFL still plays a role in the ecosystem's health after the usage, regardless that it has been replaced partially or fully with Light Emitting Diode (LED) (Thavornvong, 2016). Realizing the hazard of mercury to humans and the ecosystem, SFL recycling is strongly encouraged to recover the valuable materials (e.g. mercury, aluminum, nickel, copper, and phosphor).

Studies showed that recycling increased 77.40% of human health, 21.99% resource protection, and 1.03% ecosystem quality compared to landfilling (Thavornvong, 2016). Similar results were identified in other SF recycling studies (Apisitpuvakul, 2007; Wongsoonthornchai et al., 2016) in Thailand, additionally, stated such benefits were associated with lower electricity use and mercury release. Such environmental benefits directed the Ministry of Environment and Natural Resources to target a 100% treatment rate of industrial waste in the Master Plan on Solid Waste Management (MPSWM) (2016-2020) and promoted the 3R (Reduce, Reuse, and Recycle) Action Plan to achieve the goal (Pollution Control Department, 2015).

Licensed recycling businesses equipped with advanced technology and safety measures had a major role to realize it. While they showed considerable impacts on improved environmental, occupational safety, and decent working conditions compared to the informal (Gunarathne, de Alwis, & Alahakoon, 2020; Henzler; et al., 2017), they are facing some common challenges such as lack of control and monitoring emissions inside and outside the facility, low/irregular flow of material collected, and lack of technologies enabling the final stage of recycling (Gunarathne et al., 2020; Pathak, Srivastava, & Ojasvi, 2017). These hindered their business performance in E-waste management and poses further occupational health.

Under the approach by Sustainable Recycling Industry (Mathias, 2017) and integrated sustainable e-waste management (Gunarathne et al., 2020), environmental and social impacts are the two aspects to assess for a sustainable recycling process. However, studies of SFL recycling in Thailand (Apisitpuvakul, 2007; Thavornvong, 2016; Wongsoonthornchai et al., 2016) only highlighted the quantitative measurement of the increased waste collection, treatment, and secure disposal, putting behind social challenges experienced by the formal business, in consequence, hampered the holistic approach of efforts to MPSWM target. Therefore, this study was conducted to answer questions of enabling factors to create a sustainable SFL recycling process in Thailand based on the analysis of the environmental and social impacts of current SFL recycling practice in Thailand.

Methodology

The research consisted of environmental and social impact assessment including challenges faced by the formal recycler to generate information of the enabling factors. Environmental analysis followed ISO 14040 series standards and the social analysis reflected UNEP/SETAC Guidelines for workers, local community, and the business with indicators of health and safety, management performance, fair salary, local employment and working hours. Desk review and primary data collection from the studied formal recycling plant was obtained for the environmental impact analysis. While a semi-structured questionnaire was developed for an in-depth interview with only two business representatives from the company for analyzing the social impacts. Analysis outputs were presented in quantitative and qualitative nature.

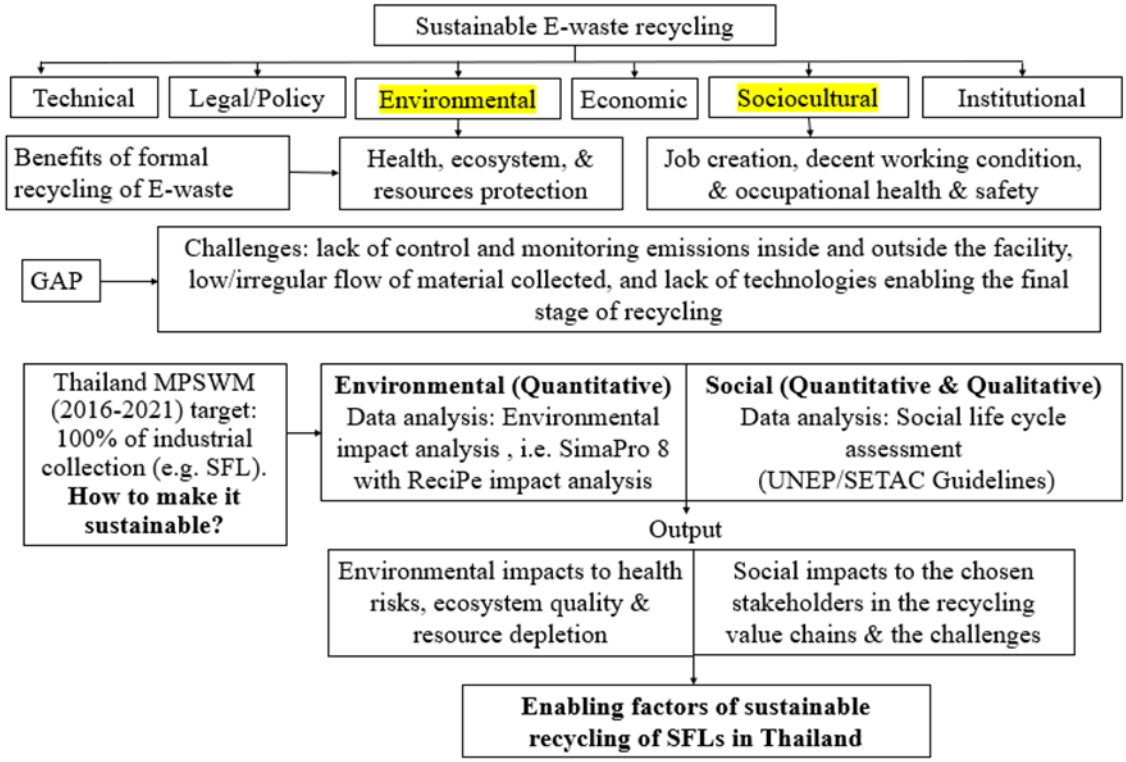

Figure 1: Research conceptual framework

Results And Discussion

1. Environmental Impact Assessment

The studied recycling plant averagely processed 10,000 units of tubular SFLs in 2019 generating a significant adverse impact on human health (14.96 µPt), followed by ecosystem quality (7.36×10^{-1} µPt) and resource depletion (8.61×10^{-3} µPt) (Table 1).

Table 1 single score of ReCiPe impact analysis

Damage category	**Unit**	**Total** (µPt)	**Spent fluorescent lamps** (µPt)	**Electricity consumption** (µPt)
Human health	µPt	14.96	2.18×10^{-3}	14.96
Ecosystems damage	µPt	7.36×10^{-1}	1.34×10^{-7}	7.4×10^{-1}
Resources depletion	µPt	8.61×10^{-3}	0	8.61×10^{-3}
Total	µPt	15.71	2.18×10^{-3}	15.71

In details, ReCiPe midpoint analysis (Figure 1) demonstrated damage pathway from each damage category, for instance, human health was altered through global warming, ozone depletion, ionizing radiation, human carcinogen and non-carcinogen, and fine particulate effects generated from this recycling activity while the rest relate to the other categories. These effects were associated with the input and output of the recycling process, e.g. SFLs, electricity consumption and mercury release that affect disproportionately.

Electricity consumption contributed 100% to the overall impacts putting it for further formulation. This finding was consistent with Apisitpuvakul (2007). This was correlated with Thai's dominating energy sources, coal and natural gas that associated with multiple ecosystem damage and health risks.

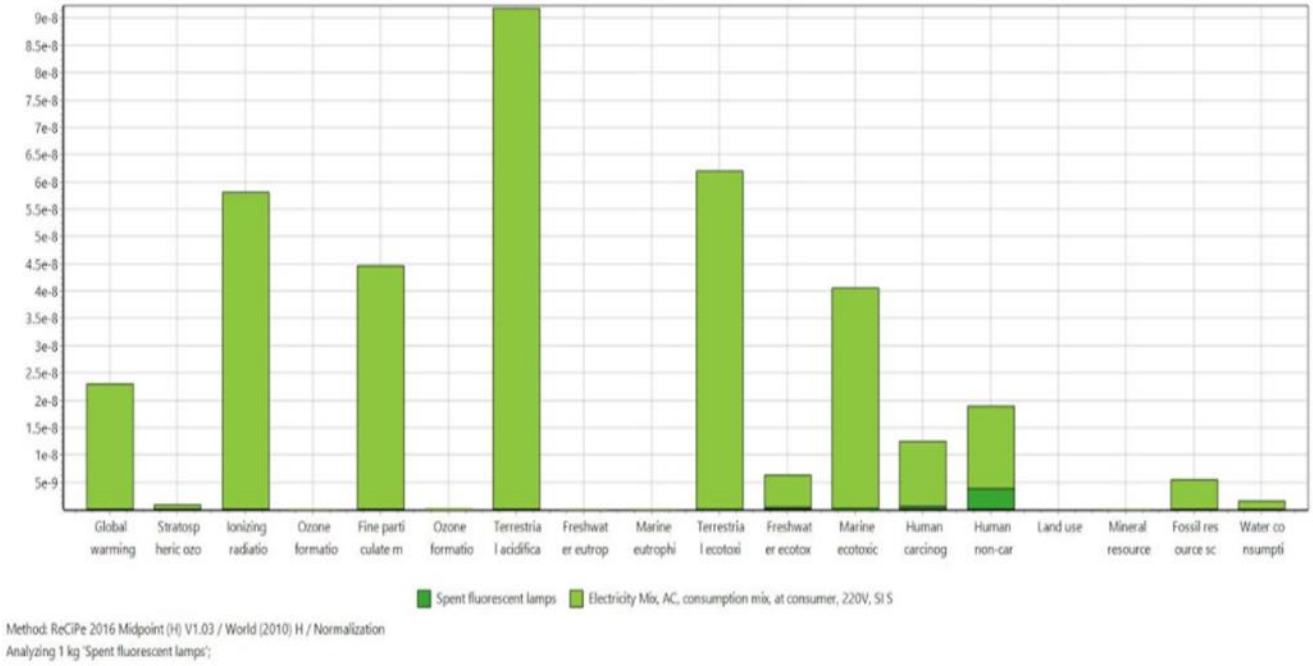

Figure 2: ReCiPe midpoint result

2. Social Impact Assessment

The social context analyzed were the social impacts relating to formal E-waste recycling, i.e. health and safety, management performance, fair salary, local employment and working hours experienced by the stakeholders. Questionnaire answers (Figure 2) given by the formal business representatives were quantified and determined by the researcher following UNEP/SETAC Guideline of score scale from 0-4 (a higher number indicates better performance). Indicator measurement referred to relevant standards of the opted social indicators.

The results pointed that the formal recycling practices contributed positively to local employment, fair salary, and working hours (Score of 4), meanwhile lower score given to community and workers' health and safety due to lack of information on the real indoor and outdoor mercury concentration that limits the score determination. Although, there was that an installed indoor mercury monitoring device and monthly monitoring as well as personal protective equipment (PPE) promotion to the workers, it was unclear to analyze.

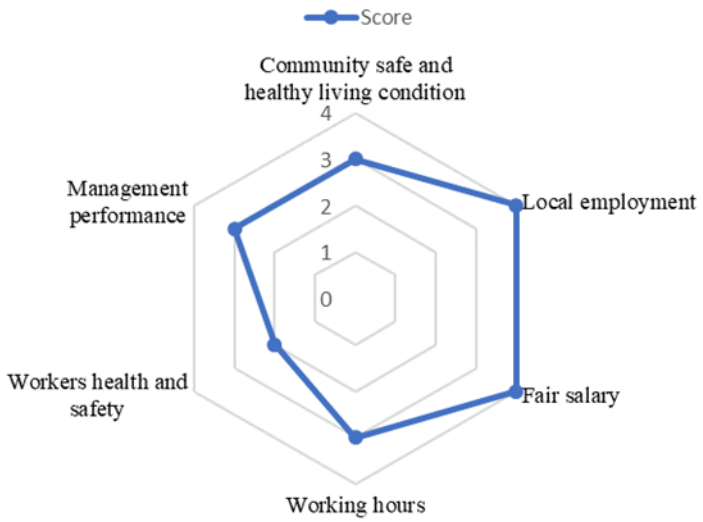

Figure 3: Social impact assessment of SFL recycling practice in Thailand

3. Challenges Experienced by Formal SFL Recycling Business

Challenges experienced by the studied recycler was none related to the limited technology to recover the mercury since it has sufficient mercury filter system, instead about the low material flow due to the inability to compete with informal business that able to give higher compensation to the customers. Moreover, low investment, insufficient policy instruments to control the informal sector, and low capacity building from the government to promote supporting policies were mentioned. These challenges were also identified in Sri Lanka (Gunarathne et al., 2020) and India (Pathak et al., 2017) hindering the sustainable E-waste recycling practice.

Therefore, Thailand governments should include this social context from formal business perspectives for attaining a higher rate of industrial waste recycling that benefits the environment while addressing the business challenges for them to take a role in the targeted recycling rate.

4. Enabling Factors for Sustainable SFL Recycling Practices in Thailand

Generated from questionnaire answers and SimaPro analysis, it was summarized several keys enabling factors to create sustainable SFL recycling practices in the country, such as:

4.1 Informal-formal recycling stakeholder partnership. Much discussion in Thailand is given to how to assist formal sectors to increase their waste-buying competitiveness to attract a higher material supply (Pharino, 2017) without considering a potential partnership between the two and how such a relationship could benefit both and create a clear waste flow record. Since in E-waste informal sector there are many smaller collectors or aggregators (Gunarathne et al., 2020), the government could try to establish a local collecting facility that buys the waste collected from the small collectors instead of volunteer consumers as conducted by the Pollution Control Department (PCD) in 2004 (Apisitpuvakul, 2007).

Besides increasing material supply, this measure is, consequently, potentially 1) bringing more investment into formal recyclers that was previously hindered by the low supply and small revenue, and 2) preventing waste from entering larger informal aggregators increasing potential illegal dumping and endangering the local community health.

Meanwhile, for the larger informal aggregators, they should be formalized and supported by proper recycling facilities, clear funding mechanisms, and capacity building for environmental and occupational health education. Such mechanism opens a space for private sectors to help electronic producers and the government to implement the MPSWM target.

4.2 Creation of financial support in the partnership. In the draft Thai WEEE Act, proposed financial support to the formal recyclers through the national committee on electronic waste management to buy E-waste from consumers is derived from producers (Manomaivibool, 2018). This scheme was on pending as it was criticized for not able to cover many types of electronic products. It was suggested that the funding instead is used to formalize the larger informal aggregators and subsidize the collection centers to buy waste from the smaller waste collectors. Besides, the microfinance method is proposed to help.

4.3 Institutional capacity building to coordinate fragmented collaboration in E-waste management. E-waste management is an intersectoral issue between government agencies such as the Ministry of Energy, Industry, Fiscal, Public Health, the Environment, and Natural Resources, and so on, which requires a collaborative approach in addressing the different interests in E-waste management. Previously shown, the biggest contributor from SFL recycling to the health and environmental risk is rather electricity consumption, which pointed out the need for collaboration with stakeholders in the energy sector to promote renewable energy sources replacing coal and natural gas as the current dominant energy sources.

Unlike, recycling technology assessed in Apisitpuvakul (2007) that uses wet scrubber technology to filter the mercury, the studied recycling plant uses bulb eater technology that does not require water in the process resulting in no mercury-containing-wastewater and has 99% efficiency of mercury filter but requires higher electricity consumption (1.97 kWh/kg SFL vs <1 kWh/kg) (Apisitpuvakul, 2007). The government's understanding of such technical aspects is necessary to provide capacity building to the formalized informal recyclers, facilitate smaller waste collectors locally, and to promote knowledge exchange between experts and actors in the recycling value chains including government officers to address technical obstacles in sustainable recycling up to local level.

Conclusion

The government motivation to 100% of industrial waste treatment in MPSWM (2016-2020) was examined as unsustainable for SFL management in Thailand as only reflects the environmental benefits of recycling without considering social challenges encountered by the formal recycling business as the important actor. Therefore, this research tried to formulate an enabling environment to create a sustainable SFL recycling practice in Thailand based on environmental and social impact assessment of the current practice. Three identified enabling factors were creating a partnership between formal and informal E-waste recyclers to increase material flow to the formal recycler supported with financial mechanism, and the last is institutional capacity building to tackle technical barriers related to electricity consumption as the main contributor to environmental damage. Due to pandemic, this study is limited to provide 1) direct perspectives of the workers and local communities related to their health and safety impacted from the recycling process and 2) direct mercury indoor concentration measurement. It is recommended to use this consideration for the review of MSWP (2016-2020) progress and barriers to the achievement.

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References

Apisitpuvakul, W. (2007). *A Decision-Making Model Incorporating the Life Cycle Assessment for the Optimal Recycling of Spent Fluorescent Lamps in Bangkok and the Vacinity.* (Doctor of Philosophy). Chulalongkorn University,

Gunarathne, N., de Alwis, A., & Alahakoon, Y. (2020). Challenges facing sustainable urban mining in the e-waste recycling industry in Sri Lanka. *Journal of Cleaner Production, 251*. doi:10.1016/j.jclepro.2019.119641

Henzler;, M., Eisinger;, F., Gaurav;, J., Hemkhaus;, M., Sinha;, S., Mahesh;, P., & Mehra;, G. (2017). *Building the Link: Leveraging Formal-Informal Partnerships in the Indian E-Waste Sector*. Retrieved from https://www.giz.de/en/downloads/giz2017-en-formal-informal-partnerships-e-waste-india.pdf

Hobohm, J., Kruger, O., Basu, S., Kuchta, K., van Wasen, S., & Adam, C. (2017). Recycling oriented comparison of mercury distribution in new and spent fluorescent lamps and their potential risk. *Chemosphere, 169*, 618-626. doi:10.1016/j.chemosphere.2016.11.104

Lecler, M. T., Zimmermann, F., Silvente, E., Masson, A., Morele, Y., Remy, A., & Chollot, A. (2018). Improving the work environment in the fluorescent lamp recycling sector by optimizing mercury elimination. *Waste Manag, 76*, 250-260. doi:10.1016/j.wasman.2018.02.037

Manomaivibool, P. (2018). Policy issues and challenges in formalizing the e-waste recycling sector - A case of Thailand. Retrieved from http://graham.umich.edu/media/files/15-2018-Manomaivibool-Policy-issues-and-challenges-in-formalizing-the-ewaste-recycling-sector-A-case-of-Thailand(1).pdf

Mathias. (2017). Stakeholders gather in Geneva to reiterate their ambition to tackle e-waste worldwide. Retrieved from https://www.sustainable-recycling.org/stakeholders-gather-in-geneva-to-reiterate-their-ambition-to-tackle-e-waste-worldwide/

Pathak, P., Srivastava, R. R., & Ojasvi. (2017). Assessment of legislation and practices for the sustainable management of waste electrical and electronic equipment in India. *Renewable and Sustainable Energy Reviews, 78*, 220-232. doi:10.1016/j.rser.2017.04.062

Pharino, C. (2017). Electronic Waste Management in Thailand. In *Challenges for Sustainable Solid Waste Management. Lessons Learned from Thailand* (pp. 93-115). Singapore: Spinger.

Pollution Control Department. (2015). *Thailand State of Pollution Report 2015*. Pollution Control Department Retrieved from http://infofile.pcd.go.th/mgt/PollutionReport2015_en.pdf

Thavornvong, W. (2016). *Life cycle assessment of lighting equipment: A comparison of fluorescent lamp and light emitting diode lamp in Thailand.* (Master of Science Program). Chulalongkorn University,

Wongsoonthornchai, M., Kwonpongsagoon, S., & Scheidegger, R. (2016). Assessment of Mercury Flows through Fluorescent Lamps and Potential Reduction Scenarios in Thailand. *International Journal of Environmental Science and Development, 7*(5), 340-345. doi:10.7763/ijesd.2016.V7.796

Guidelines for Sustainably Developing Smart People in Thailand

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Abstract

The article aimed to 1). Analyze internal and external factors for developing smart people in Thailand and 2) Propose its guidelines. The conceptual framework is composed of two main aspects factors of developing current smart people and those of future smart people. Included in-depth interviews with executives at provincial and district levels, and focus groups with relevant persons at the local level were carried out. Data analysis using content analysis, grouping and SWOT was done.

The findings revealed that internal factors included personal such as lack of recognition of own roles, duties, and responsibilities, lack of sentiment of area ownership, lack of respect of social order, and lack of knowledge and ability to earn a living. Therefore, they were unable to develop their own occupation to generate more income. The external factors included economic recession; expenditure exceeding income; lack of opportunity to gain access to knowledge sources and occupation-generating source, increased social problems; and problems of inefficient services offered by government sector. The development of smart people also faced limitations that did not facilitate the creation of smart Thais, in terms of economic, social, environmental, and personal factors. Therefore, the guidelines of appropriately and sustainably developing smart people included creation and promotion of income-generating occupation, creation of good conscience, recognition of own roles, duties, and responsibilities, and creation of conscience and recognition of the value of natural resources and environment that could eliminate limitations of the internal and external factors, and promote Thais to become the country's sustainably smart people.

Keywords: Smart people in Thailand, Sustainability, Guidelines for developing people

Introduction

Man is one of the eight major management resources that has an important role to drive the operation of an organization (8M representing Man, Money, Material, Management, Market, Machine, Method, and Minute). Without Man, other management resources cannot operate due to the lack of those who use the resources in managing work. Similarly, the country's management or drive forward relies on Man as a major factor to promote and support the national development towards the set goals. However, Man or population driving the country requires the desired qualifications of the people who are ready for development, and for change, and are appropriate to drive the country towards development. Therefore, Man needs various desired qualifications to act as quality social gear. In other words, Man constitutes sustainably smart people in the development of Thailand.

The guidelines of the national development are influenced by the guidelines of global development that have the role of determining the direction of development. The current globalization also emphasizes the goals of sustainable development or Sustainable Development Goals (SDGs) (United Nations Thailand, 2015). The goals comprise 17 target plans of the world's social development, with the relevant target plans for the development of smart people such as 1) No poverty 2) Good health and well-being 3) Quality education 4) Decent work and economic growth 5) Reduced inequality 6) Sustainable cities and communities 7) Life below water and life on land 8) Peace and justice strong institutions, and 9) Partnership to achieve the goal. Moreover, the goals of the development of global society consist of five main groups of goals namely 1) People focusing development of people in all major dimensions 2) Prosperity focusing on sustainable economic growth 3) Planet focusing on environmentally-friendly development 4) Peace focusing on equality and fairness of people and society, and 5) Partnership focusing on the use of resources and public administration for sustainable development. The development of sustainable global society also links with the guideline of Thailand's development towards the goals of the 20-year National Strategy under the conceptual framework of "Security, Prosperity, and Sustainability" with readiness to move towards being a developed country. The vision of the development is "the developed country based on security, prosperity, and sustainability in accordance with the Sufficiency Economy Philosophy". The guidelines of the development under the 20-Year National Strategy (Office of the National Economic and Social Development Board, 2018a) consist of six main strategic goals connecting with the goals of development of global society namely 1) Security; 2)Competitiveness enhancement; 3)Human resource development; 4)Social equality; 5)Green

growth; and 6) Rebalancing and public sector development. Moreover, the 20-Year National Strategy impacting the guidelines of national development is in accordance with the formulation of the national economic and social develop plans, comparable to the plans to formulate the guidelines of development or the direction of national development in each dimension. Therefore, Thailand's current national economic and social development plan is the 12th National Economic and Social Development Plan which is the guideline to drive the country with goals and direction in accordance with the National Strategy and Sustainable Development Goals (SDGs) of the global society. The integrated goals of the National Economic and Social Development Plan consists of the following (Office of the National Economic and Social Development Board, 2018b):

1. Goals of people consist of the following: Thais must possess complete qualifications of being Thais, discipline, value, behavior based on the society's good norm. They must be citizens with awareness and ability to adapt themselves to keep abreast with situations. They must have responsibility and perform useful deeds for the common good. They must have healthy mind and body, spiritual growth, sufficient livelihood, and qualifications of Thainess.
2. Goals to reduce economic inequality include the following: reduced income inequality and poverty, robust economic foundation, all people have the opportunity to gain access to resources, occupation, and widespread social services based on quality and fairness.
3. Goals to establish strong and competitive economic system include the following: the shift of economic structure to service- and digital- based economy, new generation of entrepreneurs and entrepreneurial society, strong SME entrepreneurs with the ability to use innovation and digital technology to create value to goods and services, environmental- and community – friendly production system, as well as expansion of production base and service delivery to regions to reduce inequality.
4. Goals to preserve natural capital and quality of environmental quality include the following: promotion of environmental-friendly growth, food and energy security.
5. Goals to create security in sovereignty include the following: safe society, unity, good image, increased confidence of other countries in Thailand, reduced ideological conflicts and conflicts of social ideas.
6. Goals of efficient public administration include the following: modernity, transparency, accountability, decentralization, public participation, reduced services provided by the government sector and shift to services better provided by the private sector, increased use of digital system to offer services, reduced corruption problems, and more independent management of local administrative organizations.

It can be seen that the guidelines of global development do not focus merely on national economic growth or global economic growth or progress, but also on the social and environmental development in parallel in order to create balance of the development of the three dimensions at the same time. One of them is the development of manpower or people in the country with readiness to deal with changes and strengthen people as a major factor to promote and develop other dimensions as well.

Therefore, this article focused on answering the questions derived from the study by conducting analysis of the factors that impact the development of sustainable smart people and propose the guidelines to promote and sustainably develop smart people appropriate to the country's context in the era of THAILAND 4.0. The study was conducted under Thailand's current context by focusing on the readiness of the Thais to deal with the changes in the economic, social, and environmental development. This article conducted the study in eight provinces in four regions comprising the north with Chiang Mai and Phitsanulok, the northeast with Khon Kaen and Nakhon Ratchasima, the central plains with Bangkok and Chonburi, and the south with Songkhla and Chumphon. Each area had its own local context in term of e.g. cultural, tradition, life style and with different outstanding economic, social, and environmental features: The central region is the heart of the country for administrative and political purposes. The north-eastern region is characterised by a unique culture very close to that of Laos, while the culture of the region is rich. The northern region of Thailand has a landscape defined by mountain ranges and valleys, which the slower paced lifestyle, cooler temperatures and greenery. The south of the country, benefits from the warm temperatures and pleasant waters of the Gulf of Thailand and Andaman Sea as tourism hotspots (A, C, 2018). As a result, the study revealed findings that would further benefit the sustainable development of smart people in Thailand for all the regions.

Objectives

1. Analyze the internal and external factors for developing smart people in Thailand
2. Propose the guidelines for sustainably developing smart people in Thailand

Literature Review

1. The thinking tool accompanying planning is called "Problem solving Process". It is the thinking tool that relies on the answers to the four following questions (Pakorn Priyakorn, 2013):

1.1 What are the problems?

1.2 What are the main causes of the problems?

1.3 What are the purposes or objectives to solve the problems?

1.4 What should be approaches or strategies to solve the problems?

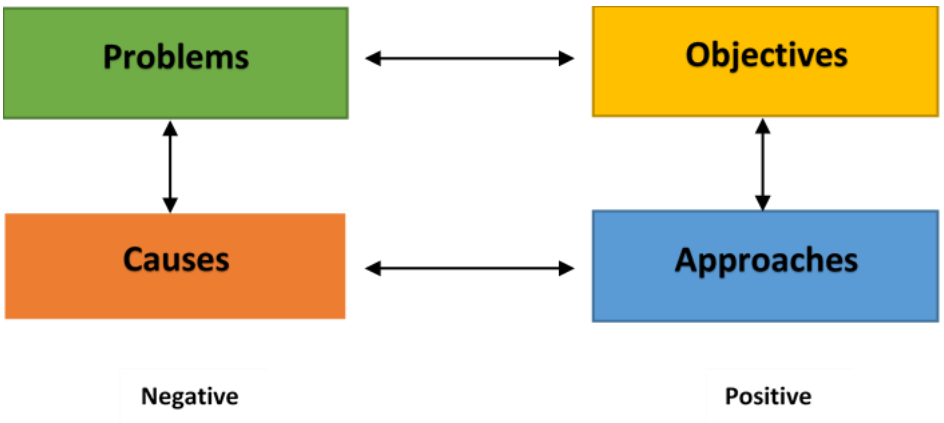


Chart 1 Problem Solving Process

The analysis of problems and causes is the relationship of cause and effect between each other. Therefore, problem consideration requires the analysis of the causes of problems. Problem solving needs in-depth analysis. What are the causes of a problem? How many causes? The analysis of problems and causes require information based on real situations to show the complexities of problems and causes, with the ability to show the levels of importance that will cause damage or negative impact on groups of people or reflect violence or emergency that can raise relevant people's awareness of the importance of the problems and causes.

The analysis of objectives and approaches is the positive condition that should occur in the future. The objectives represent the needs or desires in the future, and reduced or eliminated problems during the particular time. There must be Logical Relationship between problems and approaches, or alternatives of strategies of operation to reach the set objectives. The consideration of cause and effect shows the relationship with the analyzed cause. The thinking tool accompanying planning will help understand problems, causes, and Gap Analysis of what has happened with positive condition of what is desired, leading to objectives, targets, methods that can solve and deal with the complexities of the problems.

2. The analytical tool of the basic model of planning is called Core "Design School" Model of Strategy Formation or SWOT Model (Pakorn Priyakorn, 2013). The core is to determine through consideration, opportunities, and limitations of external conditions impacting the particular analysis units. It is considered the main success factors and assessment of internal strengths and weaknesses in order to identify outstanding competencies of analysis

units and external factors are compiled as competitiveness of the analysis units by using internal strengths whereas the limitations which are threats will be considered internal weaknesses that are forbidden, should be avoided, and require solutions to problems.

Moreover, literature review, relevant theoretical concepts such as theoretical concept of smart people and smart society, concept of social development management, concept of development of Thais and Thai society, as well as national economic and social development plans were used as basic concept of the analytical study, the selection of tools, and the determination of forms, and methodology. This study compiled information from sample group in eight provinces through in-depth interviews, and focus group sessions from the stakeholders in relevant locations.

Methodology

Conceptual Framework

The conceptual framework of the study of Guidelines for Sustainably Developing Smart People in Thailand conducted the study, research, and relevant literature review. The conceptual framework conducted the study in two main parts namely conceptual framework of the analysis of factors to develop current smart people and conceptual framework of the analysis of factors to develop future smart people in order to be the guidelines for study and selection of tools of study, compilation of information, and analysis of the research findings.

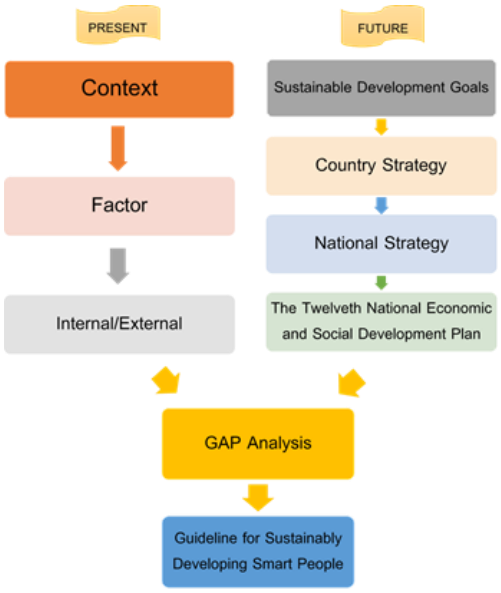


Chart 2 Conceptual Framework

The study was divided into two parts. The first part was the study of secondary data such as theoretical concept of smart people and smart society, concept of social development management, concept of development of Thais and Thai society, including SDGs, National Strategy, National Economic and Social Development Plans that look at the economic, social, and physical environmental contexts that accommodated the development of the country's smart people. The second part was the study of the primary and qualitative data. It was the study of the data at the executive level and at the local level through in-depth interviews with 24 executives at the provincial and district levels and focus groups with relevant persons at the local level comprising 160 community leaders and community opinion leaders in eight provinces in four regions namely the north with Chiang Mai and Phitsanulok, the northeast with Khon Kaen and Nakhon Ratchasima, the central plains with Bangkok and Chonburi, and the south with Songkhla and Chumphon. The analysis and the synthesis of the information obtained from the study used the Context Analysis, key issue capturing groups from the analysis of primary and secondary data, and SWOT analysis.

Study Findings

The study of the guidelines for sustainably developing smart people in Thailand could explain the study findings from the analysis of information derived from compilation, in-depth interviews, and focus groups to answer the questions of the objectives of the study as follows:

1. Analyze the internal and external factors for developing smart people in Thailand

The analysis of both the internal and external factors of Thais impacting the sustainable development of smart people in the country could be explained as follows:

The study findings, from the in-depth interviews of executives at the local level relevant to the development of people's quality of life and focus groups with community leaders in local areas on the issues of development or promotion of smart people for people in target areas in eight provinces in four regions, revealed the gaps and limitations that were factors for developing smart people as follows:

- Local economic conditions that were different and diverse at the income level and economic recession caused the plunging prices of yields or agricultural goods.
- Income from occupation and problems of cost of living, income was not in proportion with expenditure, lack of knowledge and ability to correctly earn a living.

- Occupation and income from occupation such as wage earners or general service etc. that generated low income, causing expenditure to exceed income, leading to household debts.
- Lack of opportunity to reach benefits of one person to be developed into smart person.
- Lack of providing knowledge, promoting learning process at the personal level for correct understanding, recognition of the King's Philosophy and Sufficiency Economy Concept which allowed people to have good quality of life leading to self-reliant communities.
- Local people did not recognize their own duties and responsibilities, lack of area ownership, lack of conscience or public mind to participate in community development.
- Awareness of rights of people in communities at low level, lack of conscience of co-existence in society, slowing down people's development and not on a par with changes.
- People were not properly eager to develop themselves, not open for novelty, they lived their old lives or lifestyle with misunderstanding of livelihood.
- People's incorrect recognition and their misunderstanding such as people's participation was merely benefit-driven.
- Advancement of information technology was compared to a two-sided coin. Self-development and reception of news might disseminate news more easily than in the past. On the contrary, with the ability to easily learn and self-develop via various media, it was viewed as not necessary to join projects or activities organized by agencies.
- Lack of knowledge and skills in correctly using technology to better quality of life such as knowledge of computer, creative use of media.
- Lack of good leaders who would lead people from wrong thoughts such as agricultural practice that destroyed the environment, lack of leaders with knowledge and ability to promote livelihood that discouraged wrongdoings and destruction of community culture.
- Lack of respect of social rules both for enforcers and citizens such as enforcers neglected their duties, discriminated or enforced in some cases whereas citizens lacked discipline in abiding by law and order.

- People's changing value in society such as extravagances, lack of savings, leading to expenditure that exceeded income.
- Lack of policy continuity with the change in government or executives in various agencies, leading to new policies, lack of policy continuity, and lack of continuous development.
- The government agencies' database system was not based on facts or lack of good database system. With good database system, the exact problems could be solved.
- Number of government officials was not proportioned with assigned workload, time spent on work and division of administrative work were not clear and redundant. Due to the shortage of officials, some work was too redundant. Officials could not perform their work on time in all areas.
- Communication from the government sector was inefficient and sometimes the received news and information were not factual.
- Increased social problems as a result of economic problems, costs of living, lack of good conscience of people in society, including crime, petty theft, and drug problems. The problems of the shortage of manpower necessitated the employment of more migrant workers causing impact of ensuing social problems.

Therefore, the initial study findings revealed that the development or creation of smart people in Thailand under the limitations of each area differed in economic, social, and environmental dimensions which would create appropriate gaps or limitations for developing smart people in Thailand and in demand for Thailand. The analysis findings of the occurred gaps and desired conditions necessary to the development of smart people used the thinking tool called "Problem solving process".

Problems

Gaps, limitations for sustainably developing smart people in Thailand

Causes

Internal Factors

1. Lack of recognition of own roles, duties, and responsibilities
2. Lack of sentiment of area ownership, conscience or public mind for participation in community development
3. Changing social values such as extravagances, lack of savings
4. Lack of respect for social rules, lack of discipline to abide by the country's laws, rules, and regulations

5. Lack of knowledge and ability to earn a living so inability to create more income-generating occupation

External Factors

1. Local economic conditions provided diverse and different income levels, and economic recession
2. Occupation was disproportioned to income, causing expenditure to exceed income
3. Lack of opportunity to have access to learning sources in order to earn a living or have access to benefits for self-development
4. Increased social problems as a result of economic problems, costs of living, and lack of good conscience of people in society
5. Number of government officials was not in proportion with assigned workload, including the problems of lack of continuity of policy and lack of continuous development, as well as lack of budget for development
6. Communication and reception of information and news from the government agencies caused misunderstanding of the people towards the government sector

Goals

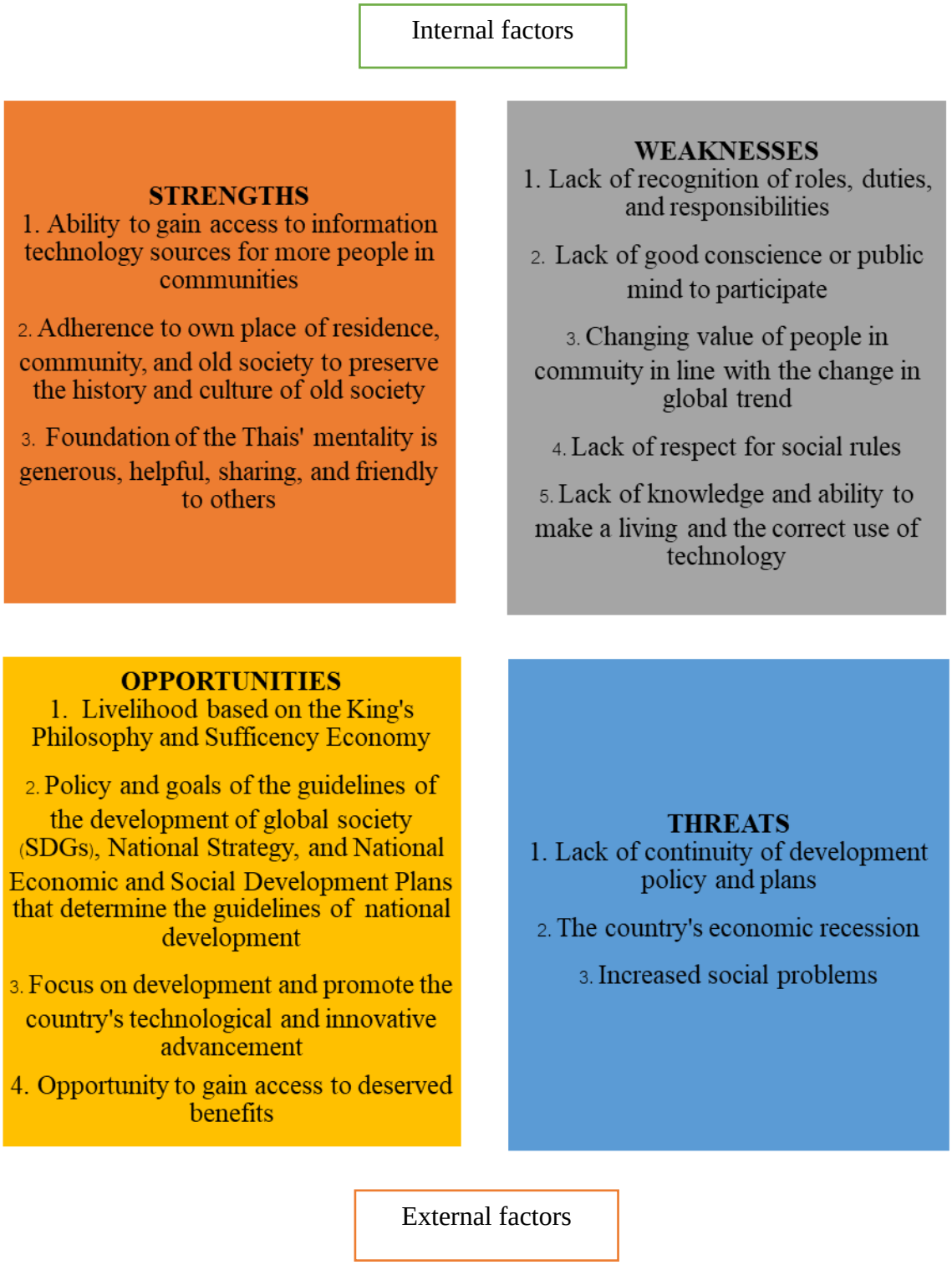
Develop Thais so that they would be sustainable smart people for Thailand in the era of THAILAND 4.0

Approaches

Appropriate guidelines to create and develop smart people in Thailand consist of the following:

The economic dimensions include creation and promotion of income-generating occupation. The social dimensions include promotion and recognition of the importance of learning both in the education system and self-learning, creation of good conscience, acknowledgement of own roles, duties, and responsibilities. The environmental dimensions include creation of awareness and recognition of the value of natural resources and environment.

The analysis of the internal and external factors impacting the development of smart people used the basic analytical tool called SWOT Analysis to analyze the internal and external factors of the study findings and could be summarized into the issues of internal and external factors as follows



2. Propose the guidelines for sustainably developing smart people in Thailand

The development of Thais so that they possess the qualifications necessary for national development requires people development factors. Therefore, the guidelines for the development of smart people from this study will be in accordance with the guidelines of national development at the global level that is Sustainable Development Goals (SDGs) and

Thailand's development guidelines namely 20-Year National Strategy and National Economic and Social Development Plan as follows:

The analysis of the study findings extracted the guidelines for developing smart people in Thailand, to eliminate the internal and external factors that constituted gaps and limitations, as well as demand for developing themselves as the country's smart people. The guidelines for developing smart people integrated the factors of economic, social, and environmental dimensions to create smart people with readiness in all dimensions for the future national development as follows:

The guidelines for developing smart people in Thailand in the economic dimension include promotion of debt-free households, secure occupation, occupation creation, development of advancement of occupation, self-reliance, focus on training in order to use knowledge obtained to create diverse occupations, earn a living for themselves and their families without being burden to society and earning secure income, occupational skill necessary for work or occupation, ability to work based on expertise, dexterity, sufficient income for expenditure, leading to self-reliance, with knowledge, occupation, stable income, ability to integrate knowledge to work and livelihood, in order to adapt to use in daily life and in accordance with changes in current situations, self- reliance with ability to live in society without being burden or trouble to others, as well as creation of secure economic system at communal, social, and national levels, innovation-driven economic system, new technology-based creativity and development of changes so that smart people are ready in the field of economy with the ability to be developed towards being sustainable smart people in other fields.

The guidelines for developing smart people in Thailand in the social dimension are the following:

Issues on Learning

Provide opportunity and promote the access to learning of Thais, people in communities must receive good and accessible education in all channels such as access to information and news, access to learning process and channels to access to learning, learning in education system, and readiness in self-learning and in constant self-development, constant learning in knowledge, thinking, and occupation-based skills.

Issues on Skills in Life and in Solving Problems

Cultivate awareness and use Sufficiency concept for living, self-reliance in economic, social, and environmental dimensions, promote lifestyle based on sustainable Sufficiency Economy, encourage Thais to solve problems by themselves, think and seek the best

appropriate alternatives for themselves in solving and managing problems. Particularly, in the 21st Century with the age of the changes of information and news and borderless communication, smart people must be able to fully communicate with others, by using words and gestures to communicate and exchange news, able to express thoughts for other people's understanding in various circumstances, based on appropriateness, correctness, and benefit of communication.

Issues on Health

Encourage healthy mind and body, ability of co-existence with others, ability to respond to changes, adaptation, robust physical health in order to fully perform activities such as exercises for health, recreation, and social acquaintances

Issues on Work

Encourage establishments or offices to have good work environment, welfare, guarantee, and opportunity to work, work facilities and others apart from salary or compensation for security and opportunity for career advancement.

Issues on Family

Support of fostering warm and strong family institutions, families that contribute to inspiration and encouragement for people to de good deeds and accomplish their intentions, good upbringing, family attention, sufficient time with families, time spent with families after work or personal activities to pursue activities, exchanges of opinions among family members, as well as daily routines within families.

Issues on Access to Services and Equality

The government agencies must be aware of people's benefits and needs. The government sector's occupational promotion include public-private partnership markets or community shops and must disperse the government sector's assistance so that it is not concentrated to any particular group, support of projects and budget from the government sector, assistance, support, capital for establishment or grouping in communities, activities, or projects relating to smart people development in communities or societies, including promotion of the government sector's good policy and plans, activities or projects selected to operate to create smart people in communities, establish good public utility and basic infrastructure system to accommodate people for necessities in life such as electricity, water, bus routes, etc., support of good public services that respond to the needs of the people and provide the opportunity for them to have easy and convenient access to the government services, reception of news from the government with openness and correctness, efficient service provided by the government sector to respond to the needs of the people. Moreover,

the government must provide the opportunity and support people in society for independent thinking - joint thinking, courageous action- joint action, expression in the right direction to promote strength and unity in community, transparency in performing duties, opportunity and equality to the people.

Issues on Morality and Ethics

Recognition, awareness, and cultivation of value in terms of their own roles, duties, and responsibilities, or roles and duties towards the public, awareness of the scope of what can or cannot be done, good conscience, good thoughts, good deeds, focus on the benefits for the public rather than on personal benefits, smart people with morality and ethics in living their lives, promotion of good conscience of people in community towards themselves and society. Cultivation or understanding of people in community towards others in the same community from one generation to another, similarly to passing on the teaching from fathers to children, or from elderly brothers to younger ones, strengthening people's social aspect, livelihood where people know more of one another, focus on spiritual development, and promotion of quality of life in training and development of mind, cultivation of conscience to abide by social regulations and rules, as well as other non-violation of other people's rights for the sake of co-existence with others in society.

Issues on Communities, Society, and People's Participation

Social problems are problems that require everyone to cooperate to solve, participate in all aspects, without being burden or duties of any agency or government sector because the causes of social problems derive from everyone, creation of readiness and willingness to cooperate to perform activities with others in society, cooperation between network partners including the government, private, and people sectors in the joint efforts to think, act, develop communities, conscience to love own communities, love and unity within communities, interest in community activities, generosity, mutual assistance, and mechanism of participation from the people sector to strengthen people in communities and society, as well as joint efforts to preserve the community's culture and tradition.

The guidelines for developing smart people in Thailand in the environmental aspect include fostering awareness of the value of surrounding natural resources and environment in communities, in the country, and in the world, knowledge of benefit or value of all living and non-living things around people, conscience to respect environmental rules and regulations, including care, preservation, awareness of importance, and participation in operation, development, and respect of environmental rules and regulations, as well as lack of pollution sources in communities impacting livelihood, good landscape, good environmental health

management, appropriate green zones, both natural green zones such as forests and green zones for people's recreation and urban landscape such as parks etc.

Conclusion and Discussions of Findings

The economic, social, and environmental changes in the world occurred in the 21st Century have necessitated all countries in the world to develop their countries to keep abreast with the era of the global changes (The Organization for Economic Cooperation and Development OECD, 2018) . People as the drivers of the national development must be ready for development and changes. The trends of changes have inevitably impacted people's livelihood in the society (United Nations Development Programme, 2011). Therefore, people must be alert and ready to develop themselves so that they are equipped with the desired qualifications for national development and development of themselves as smart people as an appropriate major factor for national development in line with changes in the world (Ministry of Education, 2018). Based on the study findings and the analysis of the internal and external factors impacting the development of smart people in Thailand (Chittmittrapap, P, n.d.), the study findings of the internal factors included uncertain income, lack of income and occupation stability, lack of potential of learning, lack of access to learning sources, lack of recognition and awareness of own roles and duties, and lack of participation to develop themselves and communities, etc. The external factors included the country's economic recession, lack of occupational development, lack of occupational support from the government, lack of opportunity to gain access and use of public services and good basic infrastructure, lack of mechanism of participation, or lack of cooperation between social networks, etc. The findings based on the analysis of both internal and external factors of developing smart people in the field of education remained limitations for the Thais. They constituted conditions to create people as smart people in accordance with the guidelines of national and global development and the guidelines that focus on the economic, social, and environmental development using people as the center of development, in particular, in accordance with the 12th National Economic and Social Development Plan (Office of the National Economic and Social Development Board, 2018b). The Plan aims to lay the foundation for the Thais with complete qualifications of being Thais, ability to adapt themselves to keep abreast with changing situations, responsibilities, livelihood based on Sufficiency. The Plan leads to Thais who are promoted to reach targets of robust economy, reduce income inequality, good public administration, natural capital to support environmental-friendly growth, by using smart people

as drivers. Thus, the limitations of study findings lead to propose the guidelines for developing smart people appropriate to the country's changes and guidelines to amend or reduce limitations of the internal and external factors to develop smart people and to correspond to the concept of the development of global society, the national development according to the 20-Year National Strategy , and the National Economic and Social Development Plans in the future. The guidelines for sustainably developing smart people in Thailand can be summarized as follows. The guidelines for developing smart people in the economic dimension include creation and promotion of income-generating occupation, opening of market of goods or centers for selling community goods or agricultural goods, cultivate and promote livelihood and operation of activities under the Sufficiency principles, etc. The guidelines for developing smart people in the social dimension (United Nations Development Programme, 2011) include promotion and awareness of the importance of learning both in the education system and self-learning, creation of good conscience, recognition of own roles, duties, and responsibilities, public consciousness, cooperation and promotion of mechanism for participation of network partners, promotion, support, and opportunities provided by the government sector to gain access and use public services beneficial to livelihood, etc. The guidelines for developing smart people in the environmental dimension include awareness and knowledge of the value of natural resources and environment, conscience in respecting environmental rules and regulations, and preservation of the environment surrounding people, in society, and in the country, etc.

The guidelines for sustainably developing smart people in Thailand are defined in accordance with the world's development guidelines and Thailand's development guidelines. Moreover, the smart people in the age of THAILAND 4.0 and the 21st Century must be ready in one more important aspect. It is the readiness in the personal skill to live under the changing landscape of global society. The skills of people in the 21st Century include various aspects of livelihood (Upper Secondary Education Bureau, OBEC, n.d.) such as knowledge of the world, knowledge of good citizens, and knowledge of health, etc. The skills of learning and innovation include creativity, critical thinking, problem solving, etc. The skills of information technology include knowledge of media, technology, media literacy, etc. The skills of livelihood and occupation include flexibility and adaptation, responsibility, etc. Other major skills (ispacethailand, 2018) include the learning of 3R and 7C while 3R include 1) Reading (Able to read) 2) (W) Riting (Able to write), and 3) (A) Rithemetics (Able to calculate), 7C include 1) Critical Thinking and Problem Solving 2) Creativity and Innovation 3) Cross-cultural

Understanding 4) Collaboration, Teamwork and Leadership 5) Communications, Information, and Media Literacy 6) Computing and ICT Literacy, and 7) Career and Learning Skills.

Based on the study, the guidelines for developing smart people will promote the implementation for the country's smart people, depending on the limitations of the factors of numerous variables. But the main factor and variable that can best respond to the guidelines for developing smart people in other dimensions start with people themselves who are committed to develop themselves, reduce the gaps and limitations of themselves such as recognition of their own roles and duties, good awareness of themselves, society, and environment, awareness and understanding of the foundation of livelihood, livelihood based on Sufficiency principles, seek and create opportunities to learn and make their own living, development of their own knowledge, vocation, and occupation to generate income. With development at the personal level, people can rely on themselves. They are not burden to others, and build on the guidelines to develop families so that their families, communities, and society are strong, and free from social problems and peril.

Recommendation

1. Continuously promote the quality of life development.

2. Promote the action guideline that is consistent with the people's way of life in the area through the public participation.

3. Implement human resource development in accordance with local needs, expectations, and area approach.

4. Develop quality people through learning design, knowledge transfer and knowledge integration in all level of education.

5. Promote the quality of human development consistent with the sufficiency economy philosophy in the local level because they understand the context of the area, cultural traditions and the way of life of the local people.

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Reference

A, C. (2018). The Regions of Thailand | Ling App. Ling Learn Languages. https://ling-app.com/th/regions-of-thailand/

Chittmittrapap, P. (n.d.). KEY SUCCESS FACTORS FOR SMART CITY DEVELOPMENT. 6.

Ispacethailand. 2018. **Skills for living in the 21st century "3R+7C".** Retrieved November 9, 2018 from www.ispacethailand.org/%E0%B8%AA%E0%B8%B1%E0%B8%87%E0%B8%84%E0%B8%A1/16889.html#_ftnref1

Ministry of Education. 2018. Adult vocational training. Retrieved September 14, 2018 from: http://www.eng.uvm.dk/adult-education-and-continuing-training/adult-vocational-training

Office of the National Economic and Social Development Board. 2018a. **National Strategy 2018 - 2037 (Summary)**. Retrieved November 2, 2018 from www.nesdb.go.th/download/document/SAC/National%20Strategy%20(Summary).pdf

_____. 2018b. The twelve-national economic and social development Plan (2017 – 2021). Retrieved November 2, 2018 from www.nesdb.go.th/ewt_news.php?nid=6420&filename=develop_issue

Priyakorn, P. 2013. **Strategic planning: Concepts and guidelines.** 18th ed. Bangkok: Samadham Publishing.

The Organization for Economic Cooperation and Development OECD. 2018**. OECD Better life index**. Retrieved September 13, 2018 from: http://www.oecdbetterlifeindex.org

United Nations Development Programme. 2011. Social Progress for Human Development. Retrieved September 15, 2018 from: http://hdr.undp.org/en/content/social-progresshuman-development

United Nations Development Programme. 2011. Social Progress for Human Development.Retrieved September 15, 2018 from: http://hdr.undp.org/en/content/social-progresshuman- developmen

United Nations Thailand. 2015. **The global goals for sustainable development**. Retrieved November 2, 2018 from www.un.or.th/globalgoals/th/the-goals/

Upper Secondary Education Bureau, Office of the Basic Education Commission. n.d. **21st Century Skill**. Retrieved November 9, 2018 from https://webs.rmutl.ac.th/assets/upload/files/2016/09/20160908101755_51855.pdf

Synthesis and Characterization of Nano-Calcium Oxide derived from Calcination of Eggshell Waste

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Abstract

Nano-calcium oxide has attached much attention as a sustainable material for using as fillers and catalysts in broad industries. The nano-calcium oxide derived from calcination of eggshell waste in a laboratory-scale rotary furnace was firstly reported in this study. The eggshell waste was prepared by washed several times then sundried and followed by grinded and sieved through 250 micrometers sieve size. Calcination of the sieved eggshells waste was conducted in a single zone rotary tube furnace at 800 °C with 5 degree slope and with 1 rpm. Both physical and chemical properties of calcium oxide derived from calcination of eggshell waste were systematically observed by various scientific instruments. The results from powder X-Ray Diffraction (PXRD) and X-Ray Fluorescence: (XRF) showed most of calcium carbonate in eggshell thermally transform to nano-calcium oxide with mean crystallite size of 47.5 nm and with a purity of 97.8% calcium oxide. The results from this study indicated the optimum condition for mass production of nano-calcium oxide via rotary furnace and the obtained nano-calcium oxide is comparable to the commercial chemical.

Keywords: Eggshell, Calcium oxide, Nano-catalyst

Introduction

Recently, Thailand has been ranked in the top five frozen chicken exporter in world. Several hundreds of hatchery farms were located in all part of Thailand for producing both egg-laying and broiler chickens. Additionally, thousands of eggshell waste has been generated during the chicken production also. This large amount of eggshell wastes is normally discarded into landfill and causes a broad concern on both environmental and social problems. [1-2]

Eggshells contain of 96% of calcium carbonate (the weight of the shell), and some important content such as protein fibers, magnesium carbonate and calcium phosphate, and also organic matter [3-4]. From recent reports and our recent studied indicated that eggshell is a crucial renewable-raw materials for producing both calcium carbonate and calcium oxide. Both calcium carbonate and calcium oxide are non-toxic and be used as a low cost heterogeneous catalysis and fillers for diverse industrial sectors. Potential applications of both calcium oxide and calcium carbonate are bio-ceramics, biodiesel production, additive in refractory, carbon dioxide capturing and pollutant emission control. High purity of calcium carbonate can be produced via thermal decomposition of eggshell at the temperature lower than 600 °C while production of calcium oxide can be made at high temperature decomposition ($\geq$ 800 °C) [2-3,5-7]. Pornchai et al. also reported that calcium oxide synthesized from eggshell waste at 800 °C with 1 hour calcination time exhibit about 98% by weight of calcium oxide which comparable to commercial calcium oxide. Prolongation of calcination time with higher calcination temperature leads to low surface area and pore volume of calcium oxide product [1]. However, previous research reports on synthesis of calcium oxide from eggshell were normally performed in laboratory furnace which one batch of the furnace operation is able to produce only a tiny amount of calcium oxide. Rotary kiln is an alternative instrument for large scale production of calcium oxide. The rotary kiln is a cylindrical vessel, inclined slightly to the horizontal, which is rotated slowly about its longitudinal axis and acts as a tool for transferring heat to material inside the vessel. The operating conditions of the kiln are the main factors that effect on product properties and yield e.g. rotating speed, volume loading and size of raw material. Nowadays, the kiln is commercially available for various industries such as lime and cement industry [8-9]. From the best of our knowledge, synthesis of calcium oxide from eggshell waste via laboratory- scale rotary kiln was reported in this studied. Additionally, the main objective of this study is to determine both physical and chemical properties of calcium oxide derived from eggshell via thermal composition process in rotary kiln.

Materials and Methods

1.Materials

Eggshell waste was collected from large hatchery farms located in Nakhon Ratchasima, north east of Thailand. Two commercial available chemicals where used for comparing with the eggshell samples. Two commercial chemical are an industrial-grade (burnt lime or quick lime) and laboratory grade of CaO which were obtained from Lime Master Co., Ltd., Thailand and Ajax Finechem Pty Ltd, respectively. Acetic acid 37% was obtained from RCI Labscan limited. All chemicals in this study were used without any further purification.

2. Preparation of eggshell samples

The eggshell waste obtained from a hatchery farm contained both eggshell, eggshell membrane and dirt. So, the eggshell waste was washed with tap water 3 times for removing dirt from the waste samples, sun-dried, and further dried in a hot air oven at 105 °C for 24 hours. Additionally, the eggshell membranes were separated from the cleaned eggshell waste by immersing it in a stainless-steel tank with contained 0.1 M acetic acid solution and stirred for 60 minutes. The acetic solution was drain from the tank and the eggshell was further washed with tap water several times for washing the trace acid solution. Then, the eggshell membrane was handy removed and sun dried again for 24 hour. The eggshell waste without membrane was gridded with a Panasonic blender (MX-AC400) and sieved to a 250 micrometers size. The powdered eggshell was kept in a desiccator for further calcination.

3. Calcination of eggshell waste in a lab-scale rotary kiln

The calcination of eggshells was carried out using a lab-scale rotary kiln as shown in Figure 1. This indirect heat rotary kiln chamber was made of a quartz tube with an inner diameter of 80 mm, the effective heated length was about 440 mm and the overall length was 1.2 m. The 6 kW PID- controlled heaters were used to heat the kiln. The temperature inside the kiln chamber is measured directly using type K- thermocouple. Before bath calcination, the temperature at the effective heated zone was set to be 800 °C and under air atmosphere. Two replications of 10.3 g of the sample were then fed into the entrance of rotary kiln. The samples were transported in the rotary kiln with rotating speed of 1 rpm. Calcium oxide exiting the kiln were collected and kept in desiccators. Both first and second replications of the obtained calcined eggshell were denoted as CaOES-1 and CaOES-2, respectively.

4. Characterization of the samples

The following instruments were employed for the characterization of both eggshell waste and calcined eggshell samples. The crystalline structure and size of crystal samples were

examined by X-ray powder diffraction (XRD - Bruker D8 Advance) using Cu-Kα radiation at 40 kV. The XRD patterns of samples were recorded with a scanning rate of 2° min^{-1} and with different angles 2θ ranging from 5° to 80°. The presence of functional groups (Perkin Elmer-FT-IR Spectrometer Frontier) in the samples was determined by Fourier transform infrared spectroscopy in the range of 4000-450 cm^{-1}. The X-ray fluorescence (XRF - Bruker S4 Explorer) was used for analyzed the elemental composition of the samples. Scanning electron microscopy (SEM) -) was conducted with a JEOL Scanning electron microscope (JSM-5410LV) to observed the surface microstructure of the samples.

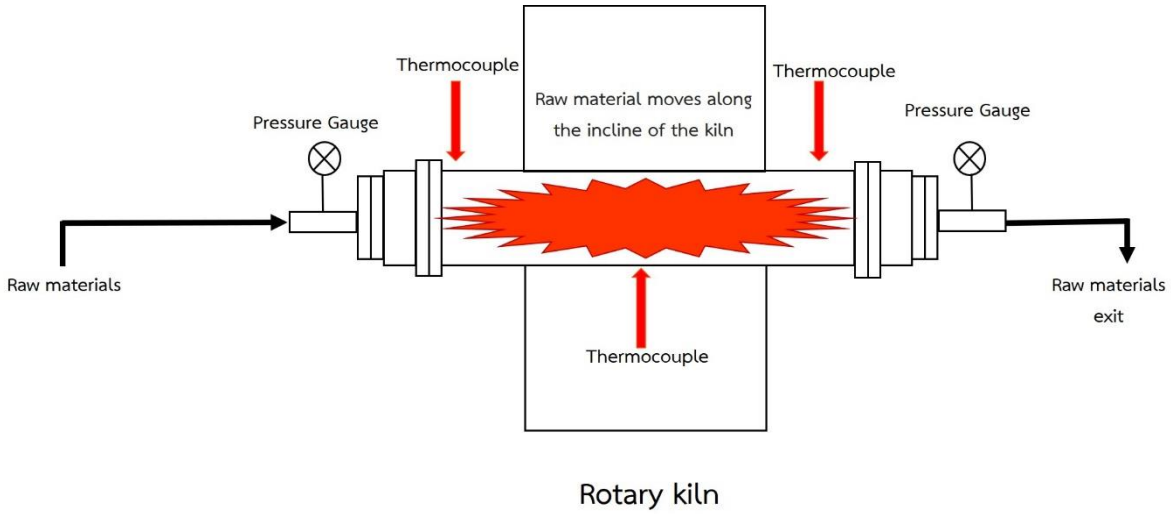

Figure 1: Schematic of a lab-scale rotary kiln

Results and Discussion

1. Physical properties of calcium oxide product

The results of surface morphology analysis using scanning electron microscope at 7,500 times magnification showed that the morphology of the washed eggshell and the eggshell separated from the membranes (Fig. 2A and 2B) had similar smooth surface and had some small pores distribute throughout the surface of the eggshell. These results indicates that using 0.1 M of acetic acid to separate the membranes from the eggshell did not change the morphology of the eggshell, which is similar to the report of Pornchai et al.[1]

Figure 3 shows the images of scanning electron microscopy at 7,500 times magnification of the calcined eggshell powder and industrial-grade calcium oxide. It indicates that surface of calcium oxide synthesized from eggshell powder (CaOES-1) has a cylindrical or a dumbbell liked – shape which is completely changed compare to an uncalcined eggshell,

as shown in Fig. 3A. Changing of shape and pore evolution on the surface of calcined eggshells are due to the eggshell transforming from calcium carbonate to calcium oxide and releasing carbon dioxide. These changes are similar as described by Vijayan et al. [8] However, in the case of industrial-grade calcium oxide, the particle shapes can be described as having an irregular shape and the calcium oxide particles were still agglomerated together as shown in Figure 3B. This is because of the industrial-grade calcium oxide was made from limestone which has a higher density than eggshell. High density of quicklime normally leads to large particle due to lime grain fusion mechanism.[12]

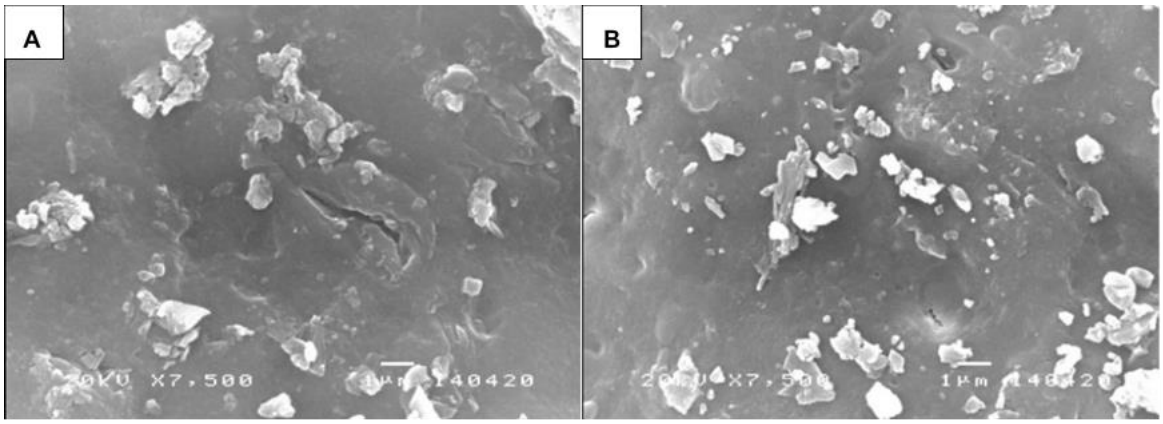

Figure 2: SEM photographs with 7,500x, (A) The eggshell - washed with water, (B) The eggshell – with chemical treatment and membrane had been removed

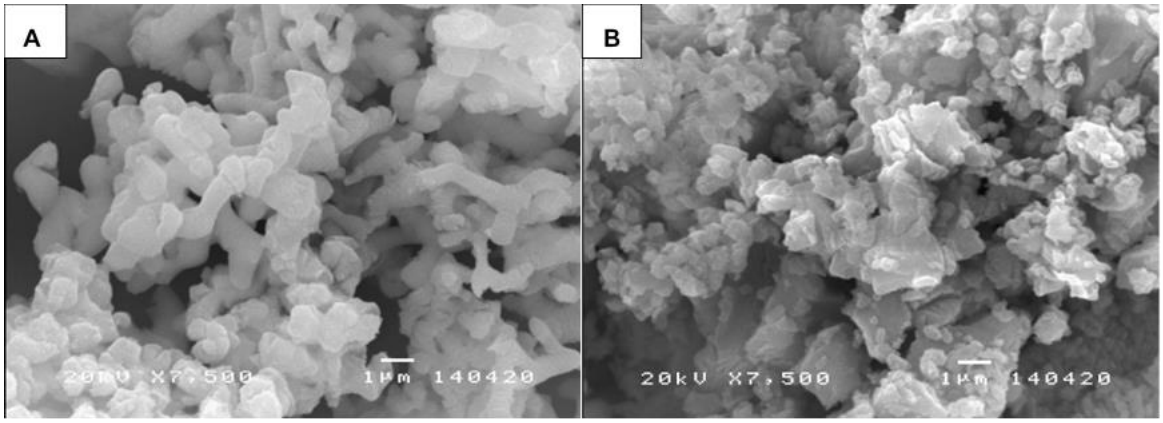

Figure 3 SEM photographs with 7,500x, (A) CaOES-1 and (B) Industrial-grade calcium oxide (quicklime).

2. Chemical properties of calcined eggshell samples

The results of X-ray diffraction of CaOES-1 and CaOES-2 are shown in Figure 4. Both XRD diffractograms exhibits the major peaks at position 29.7º 32.5º 37.7º 54.2º 64.5º 67.7º. In contrast, the major peaks of calcium oxide derived from Joint Committee on Powder Diffraction Standards data (JCPDS) and Pornchai et al [1] are 32.2º 37.3º 58.3º 64.1º 67.3º. The

present of peaks at 29.7º and at 54.2º of both CaOES-1 and CaOES-2 were indicated that calcium carbonate in both samples were not completely decomposed to carbon dioxide and left small amount of calcium carbonate in the samples. Presenting of small amount of unconverted calcium carbonate can be considered as an impurity in calcium oxide product. In comparison, these calcium carbonate peaks of both CaOES-1 and CaOES-2 are similar to XRD diffractograms of the calcium oxide made from limestone. However, the XRD diffractograms of both industrial and laboratory grade chemical also contained hydroxide molecule which is indicate by present of the peak at 28.8º 34.2º 50.9º. This is due to some molecule of calcium oxide react to humid environment and then the calcium hydroxide is formed as shown in Table 1. Based on the XRD analysis, the crystal size of CaO was analyzed using Scherrer equation[15] and the calculation results are presented in Table 2. The average CaO crystal size of CaOES-1 and CaOES-2 is 48.4 ± 1.2 nm. This average of crystal size is not much different from that done by Abass et al.[13] Additionally, crystallinity of the CaOES-1 and CaOES-2 is about 87.9 ± 0.01 which indicates that the calcined sample presence both major crystallite phase and trace amount of amorphous phase.

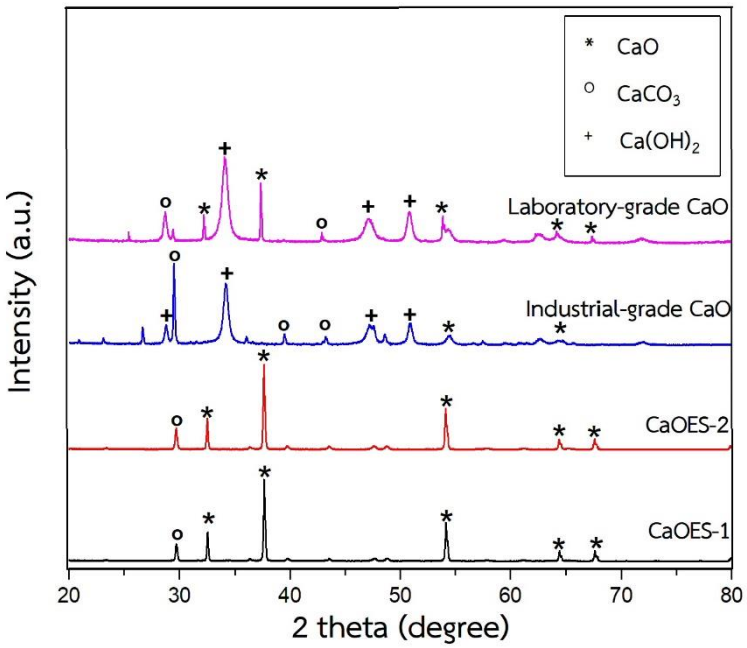

Figure 4: XRD of calcium oxide from eggshell, industrial grade and laboratory grade calcium oxide.

The bulk composition of the both CaOES-1 and CaOES-2 were determined by XRF and the results are depicted in Table 3. The results revealed that it contained about 97.8 % of calcium oxide which is the most abundant component in both CaOES-1 and CaOES-2. Besides CaOES-1 and CaOES-2, it also contained the other minor ~2 % of components such as MgO,

P_2O_5, SO_3, SiO_2, and Na_2O. In comparison, both CaOES-1 and CaOES-2 have similar oxide components to an industrial-grade and laboratory-grade calcium oxide. Furthermore, the purity of calcium oxide consisted in the calcined eggshell samples are a slightly higher than the purity of an industrial-grade calcium oxide (94.3%) but also slightly lower than the purity of a laboratory-grade calcium oxide (98.2%). However, the purity of calcium oxide derived from calcination of eggshell in rotary kiln is comparable to those calcium oxides calcined in the furnace.[1,5,11] This result indicates the possible potential for large scale production of calcium oxide from eggshell via the rotary kiln.

Table 1: Peaks of Calcium Oxide by X-Ray Diffraction

Samples	**Condition**	**Amount of raw material**	**2θ**	**References**
CaOES-1	800 ºC for 1 hr. in rotary kiln	10.3 g (41.7%)*	29.7º 32.5º 37.7º 54.2º 64.5º 67.7º	This study
CaOES-2	800 ºC for 1 hr. in rotary kiln	10.3 g (41.9%)*	29.7º 32.5º 37.7º 54.2º 64.5º 67.7º	This study
CaO-1	800 ºC for 1 hr. in furnace	1.0 g	- 32.2º 37.4º 53.9º 64.2º 67.4º	[1]
CaO-2	800 ºC for 2 hr. in furnace	1.0 g	- 32.2º 37.4º 53.9º 64.2º 67.4º	
CaO-3	800 ºC for 3 hr. in furnace	1.0 g	- 32.2º 37.4º 53.9º 64.2º 67.4º	
CaO-4	800 ºC for 4 hr. in furnace	1.0 g	- 32.2º 37.4º 53.9º 64.2º 67.4º	
CaO-Eggshell	850 ºC for 1 hr. in furnace	-	29.0º 32.5º 47.5º 54.0º	[5]
JCPDS data CaO			- 32.2º 37.3º 58.3º 64.1º 67.3º	[9]
JCPDS data $CaCO_3$			29.4º 39.4º 43.2º 47.4º 48.5º	
JCPDS data $Ca(OH)_2$			28.6º 34.1º 47.1º 50.8º	

Note: * Parenthesis is the % yield of calcium oxide

Table 2: Crystallinity and crystallite size of calcium oxide synthesized from eggshells Diffraction Technique

Samples	Mean crystallite size (nm)	Crystallinity (%)	References
CaOES-1	49.3	87.1	This study
CaOES-2	47.5	88.7	This study
Average	48.4 ± 1.2	87.9 ± 0.01	This study
CaO- calcined lime stone	39.6	-	[13]
CaO- eggshell		~85-90	[14]

Table 3: Chemical composition of calcium oxide synthesized from eggshells industrial-grad calcium oxide and laboratory-grade calcium oxide by analyzing with X-ray fluorescence spectrophotometer

Composition	CaO ES-1	CaO ES-2	Industrial grade CaO	Laboratory grade CaO	CaO [1]	CaO [5]	CaO [11]
CaO	97.8	97.8	94.3	98.2	97.9	97.080	98.56
MgO	1.07	1.06	1.51	0.66	0.977	0.544	0.690
P_2O_5	0.353	0.0374	0.0198	0.57	0.543	0.316	-
SO_3	0.284	0.344	0.273	0.15	0.111	0.123	-
SiO_2	0.175	0.0964	2.90	0.05	-	1.266	-
Na_2O	0.127	0.112	-	0.14	0.223	-	-
SrO	0.0409	0.0406	0.170	0.04	-	0.263	0.051
K_2O	0.0425	0.0373	0.0330	0.08	0.065	0.103	-
Fe_2O_3	0.0208	0.0188	0.363	0.03	-	0.013	-
CuO	0.00834	0.0136	0.00953	0.009	-	-	0.027
ZnO	0.00477	0.0133	0.00628	-	-	-	-
ZrO_2	-	0.00209	0.00468	-	-	-	-
Al_2O_3	-	-	0.289	-	-	0.255	0.100
Cl	-	0.0120	-	0.02	-	-	-
TiO_2	-	-	0.0224	-	-	-	-
Cr_2O_3	-	-	0.0127	-	-	-	-
MnO	-	-	0.0114	-	-	-	-

The composition and structure of calcined eggshell samples were further demonstated by FTIR spectra as shown in Fig. 5. The FTIR spectra of calcined sample were obtained using KBr method at room temperature and the spectra were recorded at 400-4000 cm^{-1}. The FTIR spectra of both CaOES-1 and CaOES-2 exhibited one broad peak at 1410 cm^{-1} and two small sharp peaks at 719 cm^{-1} and 876 cm^{-1}. These peaks corresponding to functional group of CO_3^{2-}.These peaks also found in both industrial and laboratory grade of CaO. This result indicates the present of calcium carbonate in the samples which are matched well with the characteristic peaks of the CaOES-1 and CaOES-2 samples as shown in XRD patterns. The sharp bands at 3641 found on the commercial samples represent the O-H stretching modes of calcium hydroxide ($Ca(OH)_2$). In contrast, the peak of calcium hydroxide did not found on the calcined samples. The wide bands between 500 to 580 cm^{-1} found on CaOES-1 and CaOES-2 and both commercial samples are assigned to the vibration of Ca-O band.[16] This indicates that both calcined samples and commercial samples have the same phase. In addition, it can be implied that the calcium oxide derived from samples appear to have peaks that tend to be the same as commercials CaO.

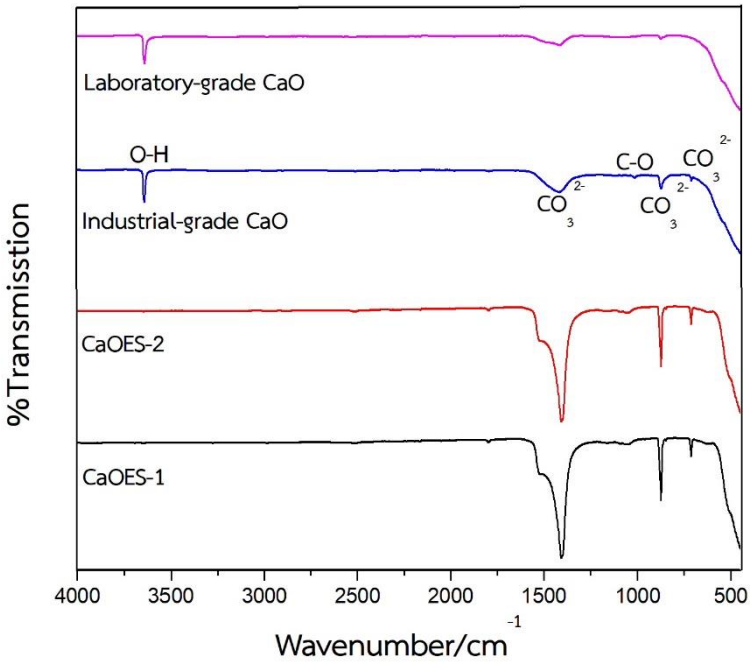

Figure 5: The results of the calcium oxide function group analysis calcium oxide from eggshell, industrial-grade calcium oxide and laboratory-grade calcium oxide

Table 4: Shows the infrared (IR) waveform numbers comparing the calcium oxide function groups

CaO ES-1	**CaO ES-2**	**Industrial grade CaO**	**Laboratory grade CaO**	**CaO [1]**	**CaO [11]**	**CaO [10]**	**Assignments**
-	-	3641	3641	3642	3600	3641	-O-H
1410	1410	1416	1416	1410	1414	1428	CO_3^{2-}
1050	1050	1022	-	1053	1063	-	-C-O
876	876	876	876	875	-	875	CO_3^{2-}
719	719	713	-	-	710	712	CO_3^{2-}
500-580	500-580	500-580	500-580				Ca-O bonds

Conclusion

In this paper, nano crystallite calcium oxide was synthesized from chicken eggshell waste via thermochemical conversion in a laboratory scale rotary kiln. The optimum condition of rotary kiln test run is at 800 °C with a rotational speed of 1 RPM. Both chemical and physical properties of the obtained calcium oxide were indicated that purity of the obtained calcium oxide (97.8 %) was comparable with the commercial calcium oxide. In comparison, yield of calcium oxide derived from eggshell decomposition in rotary kiln is about ten times higher than yield of calcium oxide produced from muffle furnace. These results indicates high potential for commercial production of calcium oxide from eggshell waste. However, economical analysis e.g. production cost, payback period, and net present value will be made in further study.

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References

Pornchai, T., Putkham, A. I., & Putkham, A. (2016). Effect of Calcination Time on Physical and Chemical Properties of CaO-catalyst Derived from Industrial-eggshell Wastes. *Journal of Science and Technology Mahasarakham University*, *35*(6), 693–697.

Putkham, A. I., Ladhan, S., & Putkham, A. (2018). Factors Affecting the Particle Size of Bio-Calcium Carbonate Synthesized from Industrial Eggshell Waste. *Materials Transactions*, *59*(8), 1220–1224.

Apipong Putkham, Somchai Landhan, Ajchara I. Putkham. (2020). Changing of Particle Size and Pore Structures of Calcium Oxide during Calcinations of Industrial Eggshell Waste. *Materials Science Forum*. Vol. 998, 90-95.

Hincke, M. T., Nys, Y., Gautron, J., Mann, K., Rodriguez-Navarro, A. B., & Al., M. D. M. et. (2012). The eggshell: structure, composition and mineralization. *Frontiers in Bioscience*, *17*(1), 1266–1280.

Ayodeji, A. A., Ojewumi, M. E., Rasheed, B., & Ayodele, J. M. (2018). Data on CaO and eggshell catalysts used for biodiesel production. *Data in Brief*, *19*, 1466–1473.

Karoshi, G., Kolar, P., Shah, S. B., & Gilleskie, G. (2020). Recycled eggshells as precursors for iron-impregnated calcium oxide catalysts for partial oxidation of methane. *Bioresources and Bioprocessing*, *7*(1).

Cree, D., & Rutter, A. (2015). Sustainable Bio-Inspired Limestone Eggshell Powder for Potential Industrialized Applications. *ACS Sustainable Chemistry and Engineering*, *3*(5), 941–949.

Vijayan, S. N., & Sendhilkumar, S. (2014). Industrial Applications of Rotary Kiln in Various Sectors - A Review. *International Journal of Engineering Innovation & Research*, *3*(3), 342–345.

Lesbani, A., Tamba, P., Mohadi, R., & Fahmariyanti. (2013). Preparation of calcium oxide from Achatina fulica as catalyst for production of biodiesel from waste cooking oil. *Indonesian Journal of Chemistry*, *13*(2), 176–180.

Naemchan, K., Meejoo, S., Onreabroy, W., Limsuwan, P. (2008). *Temperature Effect on Chicken Egg Shell Investigated by XRD, TGA and FTIR*. 333–336.

Rohim, R., Ahmad, R., Ibrahim, N., Hamidin, N., & Azner Abidin, C. Z. (2014). Characterization of calcium oxide catalyst from eggshell waste, Advances in Environmental Biology, 8(22), 35–38.

Owuamanam, S., & Cree, D. (2020). Progress of Bio-Calcium Carbonate Waste Eggshell and Seashell Fillers in Polymer Composites: A Review. *Journal of Composites Science*, *4*(2), 70.

Abass, S. A., Almamori, A. F., & Hussain, A. D. (2014). Effect of decomposition temperature on crystallite size and strain of CaO. *Physical Sciences Research International*, *2*(4), 68–76.

Zaman, T., Mostari, M. S., Mahmood, M. A. Al, & Rahman, M. S. (2018). Evolution and characterization of eggshell as a potential candidate of raw material. *Cerâmica*, *64*(370), 236–241.

Habte, L., Shiferaw, N., Mulatu, D., Thenepalli, T., Chilakala, R., & Ahn, J. W. (2019). Synthesis of nano-calcium oxide fromwaste eggshell by sol-gel method. *Sustainability (Switzerland)*, *11*(11), 1–10.

Mirghiasi, Z., Bakhtiari, F., & Darezereshki, E. (2014). Preparation and characterization of CaO nanoparticles from $Ca(OH)_2$ by direct thermal decomposition method. *Journal of Industrial and Engineering Chemistry*, *20*(1), 113–117.

Thermal Performance of Wastewater Recovery from Air Conditioning for Cannabis Production

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Abstract

This research presents thermal simulation of selection working fluids of air conditioning from R-32, R-2452b, and R-466 for cannabis process. R-32 is a suitable working fluid in terms of a lowest mass of refrigerant of 0.65, a lowest mass of refrigerant per unit heat output of 0.0037, and a highest thermal COP of 7.53. The testing data from a Daikin R-32 air conditioning model of 12,300 BTU/h also shows that the simulation results are nearly with the experimental data in terms of a COP of 6.94 and a condensed wastewater of 18.302 litre/day. A cannabis lighting set is designed at a sizing of 1.0 m × 1.0 m × 1.8 m, one-violet LED of 300 W_e, and two-daylight LEDs at each of 100 W_e. A plant watering system is developed from Arduino board, solenoid valve, selector switch, LCD monitor, and drip emitter.

Keywords: Wastewater recovery; Air conditioning; Cannabis production; Thermal simulation

Introduction

Cannabis and smart farming topics are a popular topic in the present medication in Thailand. Internet of things (IOT) is implemented to enhance cannabis cultivation such as temperature, humidity, lighting, and etc. Cannabis is highly promoted for medical products to cure cancer, Alzheimer's disease, and etc. Indoor and outdoor techniques are several discussed for cannabis cultivation. The advantage of outdoor method is low cost, while the main point of indoor method is controllable conditions. The indoor and outdoor cultivation methods are presented in the various research works of design, simulation, construction, and technology. Vanhove et al. [1], Zhang et al. [2], Niam et al. [3], Lim and Kim [4], and Yongson et al. [5] presented a computational fluid dynamics (CFD) technique to design the optimal temperature, relative humidity, air velocity, air flow pattern, and pressure drop for indoor planting room. The CFD was also used to evaluate the suitable conditions for reducing the crop period, investment cost, and operating cost from indoor plant cultivation. In addition, Chaiyat and Kiatsiriroat [6] presented a thermodynamic simulation for selection the suitable working fluid in heat pump and air conditioning. R-290, R-123, R-32, and R-410a were used to contain in both heat engines. This work was supported by Taira et al. [7] and Dalkilic and Wongwises [8], which also represented a new type working fluid by using mixed refrigerants in heat pump and air conditioning.

From the above study works, thermal simulation was the popular technique to investigate the obtimal condition in air conditioning system, heat pump system, and air ventilation for the closed system.

The objective of this study aims to:

1. Evaluate the optimal conditions for cannabis cultivation by using thermal simulation technique.
2. Design a cannabis lighting set for cannabis production.
3. Develop an automatic plant watering system from wastewater of air conditioning.

Conceptual framework

Figure 1 shows schematic diagram of an integrated system of air conditioning cycle, wastewater recovery system, and plant watering system. Cooling load (Q_E) from the closed system (indoor room) releases heat into an evaporator at a fan coil unit of air conditioning. A low boiling temperature refrigerant absorbs heat from moist air. After that, refrigerant at the mixture phase transfers to be the pure vapor, which is increased enthalpy, pressure, and

temperature by a compressor (W_{Comp}). Then, the high-energy fluid is rejected heat to the environment by a condenser (Q_C) at a condensing unit of air conditioning. The vapor phase is condensed to be the liquid phase, and sent through an expansion value for decreasing pressure in form of the mixture fluid. At the evaporator, a condensed wastewater from the moist air is kept in a wastewater tank for cannabis process. Cooling efficiency in terms of a coefficient of performance (COP) can be defined as follows:

$$COP_{AC} = \frac{Q_E}{W_{Comp}}, \quad (1)$$

$$Q_E = \dot{m}_{da,E}(h_{a,E,i} - h_{a,E,o}) - \dot{m}_W h_{fg,W}, \quad (2)$$

$$\dot{m}_W = \dot{m}_{da,E}(\omega_{a,E,i} - \omega_{a,E,o}). \quad (3)$$

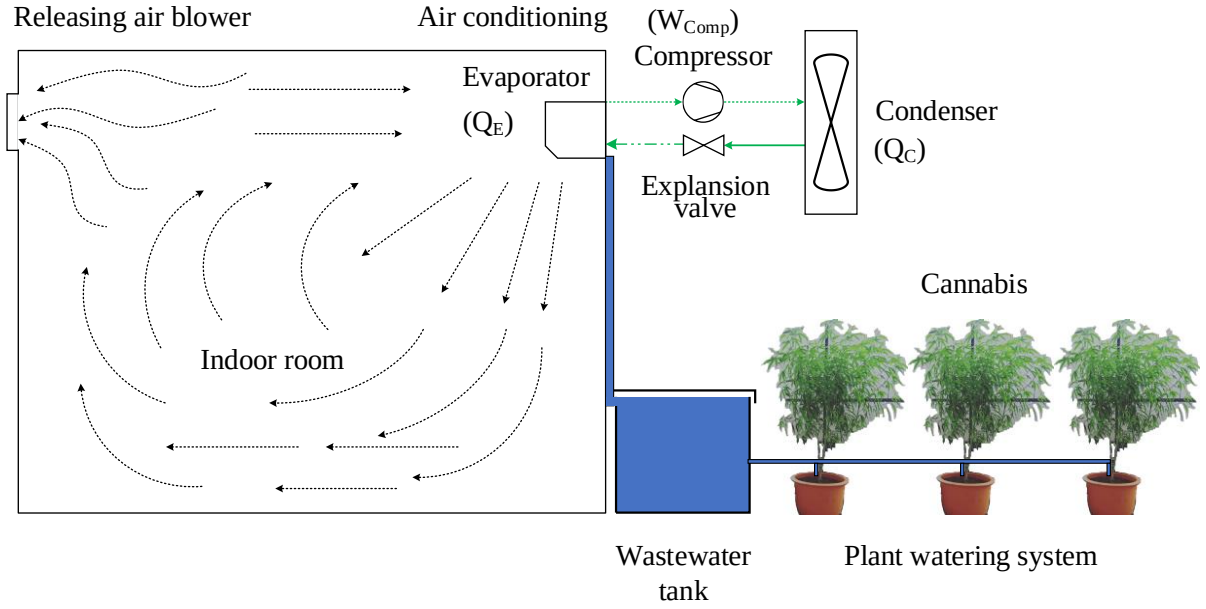

Figure 1: A schematic diagram of wastewater recovery system from air conditioning.

Methods and apparatus

The methods and apparatus of this study are as follows:

1. The suitable working fluid of air conditioning is investigated by using a first law of thermodynamic simulation. Three new environmental refrigerants of R-32, R-2452b, and R-466 are selected in this study, which are focused on an Ozone Depletion Potential impact, as shown in Table 1.

Table 1: The properties of 3 type working fluids.

Descriptions	R-32[1]	R-452b[2]	R-466a[3]
Molecular mass (kg/kmol)	52.03	63.5	80.7
Critical temperature (^oC)	78.11	77.1	83.8
Critical pressure (MPa)	5.78	5.22	5.91
Boiling point temperature (^oC)	-51.65	-51.0	-51.7
Safety group[4]	A2	A2	A1
Ozone Depletion Potential (ODP, R11-ralated)	0	0	0
Global warming potential (GWP, CO_2-100 y)	675	698	733

Remark: [1] ASHRAE (2009) [9].

[2] Honeywell (2020) [10].

[3] Atilla and Vedat (2020) [11].

[4] A1 is nontoxicity and no flammability, A2 is nontoxicity and lower flammability.

2. The thermal simulation result is implemented the indoor room to verify the simulation and testing data. The COP and condensed wastewater from air conditioning values are investigated and compared between the simulation and testing data under the controlled conditions at a room temperature of 25 ^oC and a relative humidity of 50-55%.

3. The cannabis lighting set for cannabis process is developed from the comparison results. Daylight and violet light emitting diodes (LED) are used to implement the lighting set. In addition, the wavelength, spectral irradiance, and photosynthetic photon flux density (PPFD) parameters are measured by a PG100N handheld spectral PAR meter.

4. The plant watering system is also designed and constructed from the verified data to support the nursery, vegetative, and flowering stages.

Results and discussion

1. Thermal simulation

Four thermal indicators of mass of refrigerant, mass of refrigerant per unit heat output, carbon dioxide emission per mass of refrigerant, and COP are used to select the suitable working fluid in this study.

Table 2 shows comparison of the thermal simulation results under the control conditions of a room temperature of 25 °C, humidity ratio of the inlet and outlet air from evaporator of 55% and 50%, respectively. R-32 reveals the advantage points in terms of a lowest mass of refrigerant of 0.65, a lowest mass of refrigerant per unit heat output of 0.0037,

and a highest thermal COP of 7.53. From the above data, R-32 shows a low value of working fluid, which directly effects to the working fluid cost and power consumption of compressor. In addition, R-32 can save the operating cost under a same cooling capacity of 3.517 kW. While, R-452b shows a best environmental impact of 5.22 kg CO_2/kg_{ref}. Thus, the suitable working fluid in air conditioning from the simulation results is R-32.

Table 2: The properties of 3 type working fluids.

Thermal value	R-32	R-452b	R-466a
Mass of refrigerant (kg)	0.65	0.68	0.79
Mass of refrigerant per cooling capacity (kg/kJ)	0.0037	0.0044	0.0064
CO_2 emission per mass of refrigerant (kg CO_2/kg_{ref})	5.78	5.22	5.91
COP (-)	7.53	7.21	6.56

2. Comparison results of thermal simulation and testing data

A Daikin commercial R-32 air conditioning model of 12,300 BTU/h (a fan coil unit model of FTKQ12SV2S and a condensing unit model of RKQ12SV2S) is chosen for experimental process in an insulator room at a sizing of width 2.4 m × long 3.4 m × high 2.5 m, as show in Figure 2. The comparison results found that the real performance of COP is 6.94, which is lower than that of the simulation result of approximately 5.71%. In addition, the condensed wastewater from R-32 air conditioning is found approximately 18.302 litre/day, which is slightly with a simulation result of 18.742 litre/day. The wastewater recovery value of approximately 18 litre/day is used to design the plant watering system in the next part.

The different values of COP and condensed water of the comparison results are occurred from the uncontrolled cooling load of cannabis room. In the simulation, the cooling load can be fixed to be 3.517 kW. On the other hand, the real testing process cannot control the cooling load as steady state.

3.Cannabis lighting set

The cannabis lighting set at a sizing of approximately 1.0 m × 1.0 m × 1.8 m is designed for four cannabis pots at each volume of approximately 12 L. One-violet LED at a power of 300 W_e and two-daylight LEDs at each power of 100 W_e are selected for generating a wavelength of approximately 600 nm, a spectral irradiance of approximately 200 $mW/m^2 \cdot nm$, and a PPFD of approximately 100 $\mu mol/m^2 \cdot s$, as shown in Figure 3. The violet LED can adjust the high level following the sizing of cannabis.

The measurement data indicates that the lighting set should be enhanced all light intensity parameters, especially violet LED. The spectral irradiance of all lighting area should be increased to be 200 mW/m^2·nm.

Figure 2: A photograph of indoor room and air conditioning system.

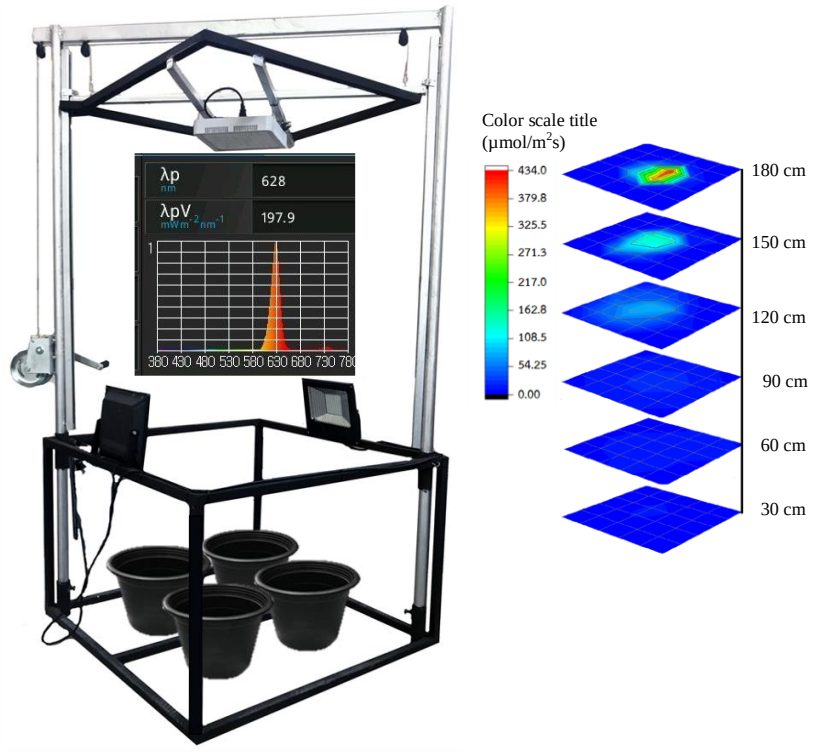

Figure 3: A prototype cannabis lighting set.

4. Wastewater recovery of air conditioning

From the thermal simulation, wastewater from the 12,300 BTU/h air conditioning at approximately 18 L/day can supply for 20 plants and 5 cannabis lighting sets. Thus, the plant watering system is designed for three modes of 24 h, 48 h, and 72 h. The control devices of Arduino board, solenoid valve, selector switch, LCD monitor, and drip emitter are used to develop the plant watering system, as shown in Figure 4.

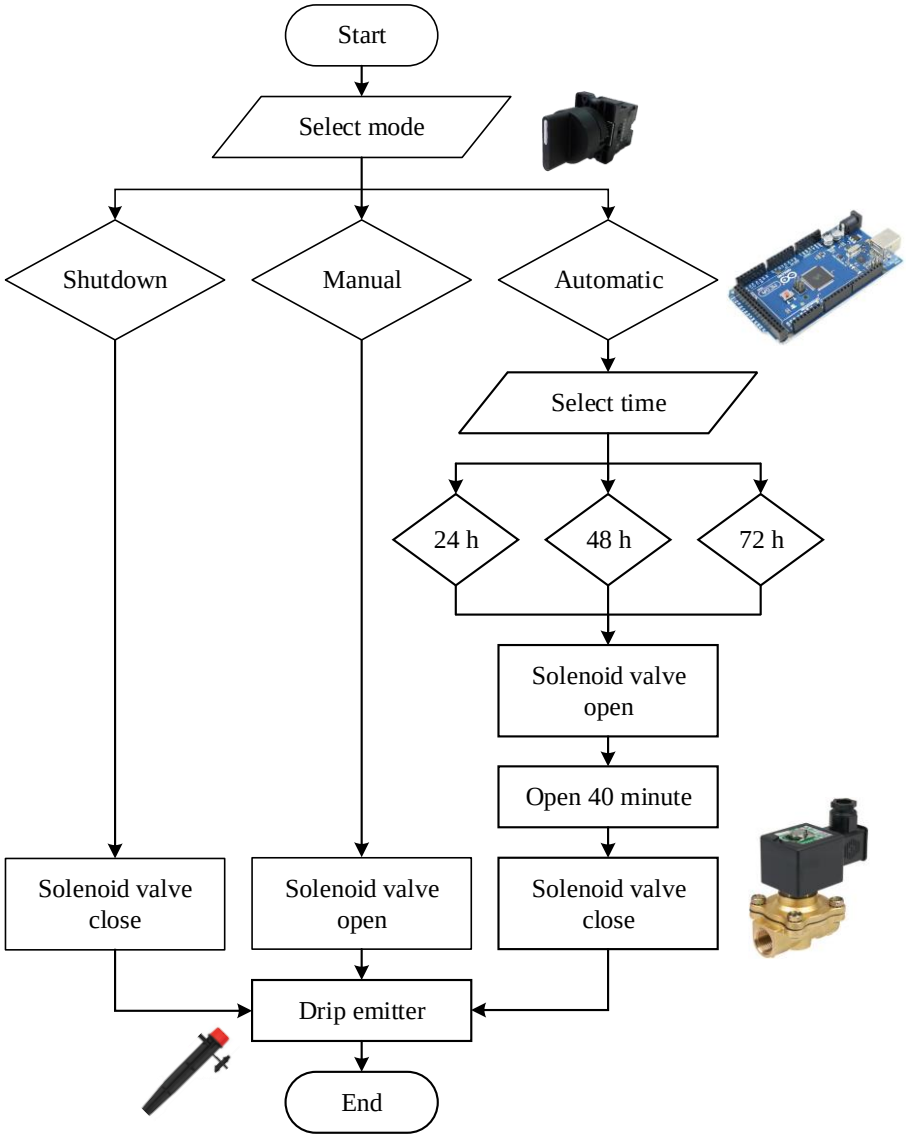

Figure 4: A conceptual design of plant watering system.

From the testing process, the plant watering system is found the error point from electrical power outage. Timer system on microcontroller board is automatically reset, which directly effects to overall plant watering time. Thus, in the next version, timer system of the plant watering system is programmed from the online internet system.

Conclusions and recommendations

From the above study results, it can be concluded as follows:

- R-32 is the suitable working fluid of wastewater recovery system from air conditioning for cannabis production in terms of the low-mass of refrigerant, low-mass of refrigerant per unit heat output, and high-thermal COP.
- The testing data from the Daikin commercial R-32 air conditioning model of 12,300 BTU/h shows nearly with the simulation results in terms of the COP of 6.94 and the condensed wastewater of 18.302 litre/day.
- The cannabis lighting set is designed at the sizing of 1.0 m □ 1.0 m □ 1.8 m, one violet LED of 300 W_e, and 2-daylight LEDs at each of 100 W_e.
- The prototype of plant watering system is developed from Arduino board, solenoid valve, selector switch, LCD monitor, and drip emitter for three modes of 24 h, 48 h, and 72 h, respectively.

For the future study, the economic (levelized product cost) and environmental (life cycle assessment, LCA) impacts will be investigated and reported in the next work.

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Abbreviations and symbols

Nomenclature

EER	energy efficiency ratio, (kW_{th}/kW_e)
h	enthalpy, (kJ/kg)
M	mass, (kg)
$\dot{m}$	mass flow rate, (kg/s)
P	pressure, (bar)
Q	heat capacity, (kW)
T	temperature, (°C)
W	Power, (kW_e)

Abbreviations

AC	air conditioning

Greek

ω	humidity ratio, (kg_W/kg_{da})

Subscript

a	moist air
C	condenser
Comp	compressor
da	dry air
e	electricity
E	evaporator
f	liquid fluid
g	vapor fluid
i	inlet
o	outlet
ref	refrigerant
th	thermal
W	water

References

Vanhove W., Damme P.V. and Meert N. (2011). Factors determining yield and quality of illicit indoor cannabis (Cannabis spp.) production. Forensic Science International 212: 158-163.

Zhang Y., Kacira M and An L. (2016). A CFD study on improving air flow uniformity in indoor plant factory system. Biosystems Engineering 147: 193-205.

Niam AG., Muharam TR., Widodo S., Solahudin M and Sucahyo L. (2018). CFD simulation approach in determining air conditioners position in the mini plant factory for shallot seed production. The 10th International Meeting of Advances in Thermofluids. 2062: 020017.

Lim, T. G. and Kim, Y. H. (2014). Analysis of airflow pattern in Plant Factory with Different Inlet and Outlet Locations using Computational Fluid Dynamics. Journal of Biosystems Engineering 39(4): 310-317.

Yongson O., Badruddin I. A., Zainal Z.A. and Narayana A. (2007). Airflow analysis in an air conditioning room. Building and Environment 42: 1531-1537.

Chaiyat, N. and Kiatsiriroat, T. (2014). Study on Thermal Performance of R-32 Air-conditioner. Engineering Journal Chiang Mai University 22(2): 38-46.

Taira, S., Haikawa, T. and Minamida, T. (2016). Evaluation of performance of heat pump using R32 and HFO-mixed refrigerant by refrigeration cycle simulation and loss analysis. International Refrigeration and Air Conditioning Conference: 1737.

Dalkilic, A.S. and Wongwises, S. (2010). A performance comparison of vapour-compression refrigeration system using various alternative refrigerants. International Communications in Heat and Mass Transfer 37: 1340-1349.

ASHRAE Handbook fundamentals, 2009. Properties of refrigerant.

Honeywell. Solstice L41y (R-452B). https://www. Honeywell- refrigerants.com/ europe/ product/solstice-l41y/. Accessed date: 20 August 2020.

Atilla G. D. and Vedat O. (2020). Energetic performance analysis of R466A as an alternative to R410A in VRF systems. https://doi.org/10.1016/j.jestch.2020.04.003.

Challenges and Barriers to Behavior Change in Voluntary GHG Mitigation Actions: Case study of Phayathai, Bangkok

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Abstract

This study aims to explore behavior and analyze factors, challenges, and barriers to behavior change in voluntary mitigation actions in Thailand. The quantitative analysis was conducted, using the online questionnaire survey of 246 respondents in Phayathai, Bangkok, in April 2020. The results were analyzed using both descriptive and inferential statistics such as mean, percentage, t-test, F-test, and correlation at the statistical significance level of 0.05.

The result reveals that the respondents have high level of knowledge and perception on climate change and GHG mitigation, very high level of awareness and support on incentives, and moderate level of support/access to enabling environment. The respondents have moderate level of behavior change in voluntary mitigation actions and most of their behavior changes are related to energy efficiency in the household and building sectors, such as unplugging/turning off switch and reducing water consumption. Gender and the receipt of information on climate change are the two factors found to be significantly affecting behavior change ($p<0.05$).

Keyword: Behavior Change, GHG Mitigation, Voluntary Mitigation Actions

Introduction

Climate change is a global environmental agenda. It is among the top pressing environmental threats in the 21st century and is the key challenge in the achievement of the sustainable development goals. Rising in the average global temperature resulted in severe and unprecedented impacts on human and ecosystem, such as seasonal changes, change in rainfall pattern, sea-level rise, extreme weather, flood, drought, heat wave, storm, and wildfire. Such temperature increase is largely caused by the emission of greenhouse gases into the atmosphere. These greenhouse gases are generated from various human activities, particularly the burning of fossil fuels in the power generation in order to support industrialization and economic growth. Since the industrial revolution, greenhouse gas emissions continue to rise and the same trend is observed for the average global temperature. To response to such alarming circumstances and to protect humanity and ecosystem from the impacts of climate change, the United Nations Framework Convention on Climate Change (UNFCCC) was established as the international framework to enhance global collaboration aiming to limit the concentration of greenhouse gases in the atmosphere in order to prevent catastrophic consequences on humanity and sustainable development.

Thailand is among the most vulnerable countries to the adverse impact of climate change. It was ranked 10th most affected countries to the long-term climate impact in 2017 as it encountered drought and severed flood in many regions and resulted in loss of lives and extensive damage to property and crops (David Eckstein, Marie-Lena Hutfils and Maik Winges 2019). Thailand is a Party to the UNFCCC, Kyoto Protocol and Paris Agreement and has pledged the contributions to reduce its GHG emissions by 7-20 percent in the energy and transport sectors by 2020 compared to BAU under the Nationally Appropriate Mitigation Action (NAMA) and by 20-25 percent economy-wide by 2030 compared to BAU under the Nationally Determined Contributions (NDC). To achieve its GHG emissions reduction targets, Thailand has formulated various policies, plans, and measures at both national and sectoral levels that incorporated the climate change mitigation and adaptation, such as the National Strategy B.E. 2561-2580, 12th National Economic and Social Development Plan, Climate Change Master Plan B.E. 2558-2593, NDC Roadmap on Mitigation B.E. 2564-2573, and National Adaptation Plan (NAP).

According to the UN Environment Emissions Gap Report 2019, the assessment of the current unconditional national mitigation efforts of all countries under submitted NDCs indicates the emissions gap of 15 $GtCO_2e$ by 2030 under the pathway of limiting the average

global temperature to below 2°C according to the goal of the Paris Agreement (United Nations Environment Programme, 2019). Evidently, the efforts of government alone will not be sufficient to reduce global GHG emissions to the level required by science. All sectors, including the public, should play a role in reducing their GHG emissions. Voluntary mitigation actions, through behavior change towards a low GHG emissions pathway, can substantially contribute to closing this emission gap, particularly in the energy, transport and waste sectors. Previous studies indicated that factors influencing one's behavior are age, gender, education, income, occupation, home ownership, knowledge, attitude, awareness, and incentives (Wimonpan Arpawet and Chantana Papattha, 2013; Office of the National Economic and Social Development Board (2009); Alexa Spence and Nick Pidgeon, 2009; Lorraine Whitmarsh, Gill Seyfang, and Saffron O'Neill, 2010; Irene Lorenzoni, Sophie Nicholson-Cole, and Lorraine Whitmarsh, 2007; Elizabeth Shove, 2010; Jan Semenza, David Hall, Daviel Wilson et.al., 2009). This study aims to study behavior and analyze factors influencing voluntary GHG mitigation actions of Thai residents whose spending their everyday lives in Phayathai district, Bangkok in order to gain understanding on the challenges and barriers to voluntary mitigation actions in Thailand. Phayathai is selected as it represents the inner city area with a high density of office buildings, universities, government offices, hospitals, and residential areas. It also equipped with enabling environment to support voluntary GHG mitigation actions, such as network of public transport such as bus and sky train and pedestrian footpath. The outcomes will be useful to provide recommendations on possible measures to encourage behavior change and inform the policy-makers on how to enhance sustainable behavior change in voluntary GHG mitigation actions in Thailand's cities.

Methodology

The quantitative study was conducted in Phayathai district, Bangkok, Thailand in April 2020 using online questionnaire and accidental sampling to explore public's behavior in voluntary mitigation actions as well as factors influencing such behavior change. A total of 246 questionnaires were conducted from the respondents spending everyday life in Phayathai district, in which representing the inner city area with high population density and equipped with various options for low-carbon lifestyle that can facilitate behavior change, such as public bus, sky train, and sidewalk. The representative samples reflect a range of different age, educational level, and occupation. The questionnaire is divided into 10 parts, comprising of questions in relation to (1) general background information, namely, sex, age, educational level, occupation, income level, and tenure type, (2) receipt of climate change information, (3)

knowledge and understanding about climate change and voluntary mitigation actions, (4) awareness on climate change, (5) awareness on the public participation in voluntary mitigation actions, (6) perception on climate change and voluntary mitigation actions, (7) enabling environment for voluntary mitigation actions, (8) incentives for voluntary mitigation actions, (9) behavior related to voluntary mitigation actions, and (10) opened-questions to provide recommendations on how to facilitate behavior change in Thailand. The data were analyzed by descriptive statistics and inferential statistics using SPSS program to identify factors influencing public's behavior change in voluntary mitigation actions in Thailand. Figure 1 shows the conceptual framework of this study.

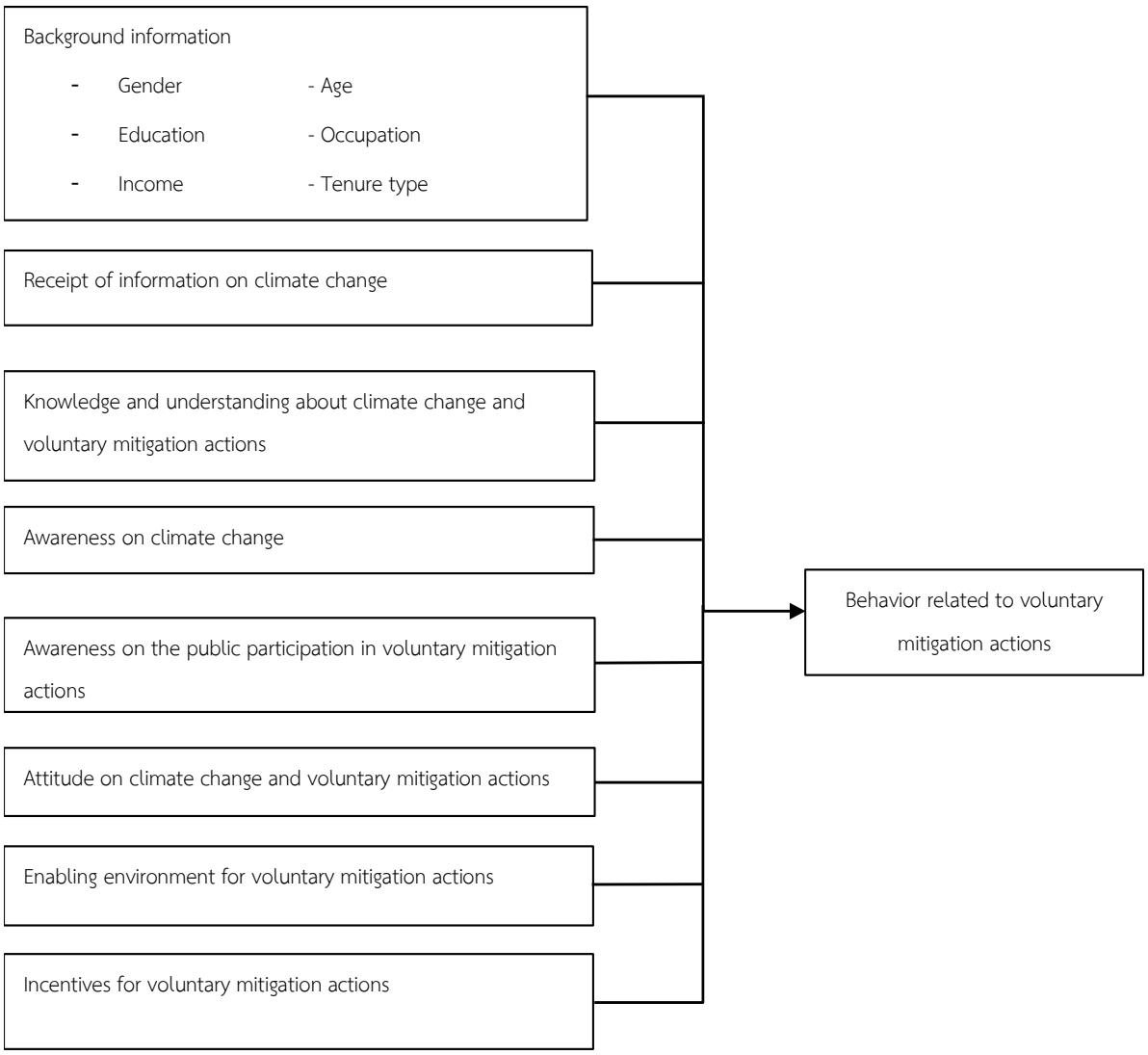

Figure 1: Conceptual framework

Results

A total of 246 individuals have completed the online questionnaires. The sample populations are found to have similar proportion of male (48.78%) and female (51.22%). More than half of the respondents are between 26-40 years of age (62.60%), followed by 18-24 years of age (18.70) and the least majority are 56 years of age or over (4.88%). Approximately half of the respondents are post-graduate degree graduate (49.59%), followed by graduate degree (42.28), and the least majority are primary school graduate (0.81%). The majority of the respondents have an average monthly income between 15,001-25,000 baht (35.77%), followed by 25,001-35,000 baht (23.58%), and the least majority have an average monthly income between 45,001-55,000 baht (5.69%). The majority of the respondents are governmental officials (34.96%), followed by private company employee (28.46%), and the least majority are housewife (0.81%). Table 1 presents the general background information of the questionnaire respondents.

Table 1 General background information of the questionnaire respondents

Background data	Number of individual	Percentage
Gender		
1. Male	120	48.78
2. Female	126	51.22
Age (years)		
1. 18-25	46	18.70
2. 26-40	154	62.60
3. 41-55	34	13.82
4. 56 and over	12	4.88
Highest educational level		
1. Primary school	2	0.81
2. Junior high school	3	1.22
3. High school	15	6.10
4. Undergraduate	104	42.28

Background data	Number of individual	Percentage
5. Post-graduate and higher	122	49.59
Monthly income (baht)		
1. 5,000-15,000	42	17.07
2. 15,001-25,000	88	35.77
3. 25,001-35,000	58	23.58
4. 35,001-45,000	24	9.76
5. 45,001-55,000	14	5.69
6. 55,001 and over	20	8.13
Occupation		
1. Contractor	9	3.66
2. Business owner	6	2.44
3. Student	32	13.01
4. Government officials	86	34.96
5. Private company employee	70	28.46
6. State enterprise employee	12	4.88
7. Merchant	4	1.63
8. Housewife	2	0.81
9. Others	25	10.16

The majority of the respondents know about climate change (95.12%) and the main sources of information are internet (81.71%), followed by television (69.51%), and mobile applications, such as line and facebook (67.48%). The study found that the respondents had high level of knowledge and understanding about climate change and GHG mitigation (score = 0.76). The questions that received the highest score (most respondents answer correctly) are "Climate change is a natural phenomenon" and "Climate change causes the increase in the average global temperature" (both score = 0.91) and the question with the lowest score (most

respondents answer incorrectly) is "Eating less meat will not help to reducing GHG emission" (score = 0.48). The respondents have very high level of awareness on climate change (score = 0.97), in which the question that received the highest score is "Climate change affects economic, social and environment" (score = 0.99) and the question with the lowest score is "Climate change does not affect human and environment" (score = 0.91). Likewise, the respondents have very high awareness on public participation in voluntary mitigation action (score = 0.99). The perception about climate change and voluntary mitigation actions among the respondents is high (score = 0.80). The question that receives the highest score is "Climate change is not really happening" (score = 0.92) and the question with the lowest score is "Behavior change is not sufficient to solve climate change problem" (score = 0.64). The respondents moderately support/have access to enabling environment to facilitate voluntary mitigation actions (score = 0.41). The question with the highest score is "Agree that using public transport is cheaper than personal car" (score = 0.70), followed by "My household (rent or live with relatives) does not provide options to choose low-energy electrical equipment, such as air condition or light bulb" (score = 0.56) and the questions with the lowest score are "I think that low-carbon lifestyle is expensive, such as purchasing products with green label/organic products, and electrical vehicles" and "Weather condition and air quality in Thailand is not appealing to walk" (both score = 0.21). The respondents have very high level of support on the use of incentives to facilitate behavior change in voluntary mitigation actions (score = 0.92) and the incentive that receives the highest score is "Fare reduction in public electric train service" (score = 0.95), followed by "Tax refund to those who have purchased green products/energy-saving appliances" and "Reduction in electricity bills for households with lower electrical usage than the same month of the previous year" (both score = 0.94) and the incentives that receive the lowest score is "Organize an annual green office contest for both public and private sectors" and "Organize a competition for low-carbon community" (both score = 0.88).

The survey found the respondents have moderate behavior change towards voluntary mitigation actions (score = 0.42). The behavior changes that receive the highest score is "Unplugging/switching off electrical appliances when not in use" and "Use water efficiently" (both score = 0.56), followed by "Buy energy-saving electrical appliances, such as those with energy-efficiency of label no. 5 or LED lights" and "Reduce the use of plastic bags/use cotton bags" (both score = 0.52) and the behavior with the lowest score is "Choose carbon offsets for air travel" (score = 0.18).

Recommendations on additional voluntary mitigation actions by the respondents include the integration of policies among various agencies to drive towards a low carbon society; implementation of polluter-pay principle, formulation of regulations to enforce behavior change; promotion of waste-to-energy power generation, promotion of renewable energy; promotion of electrical vehicle; improvement of waste collection system to promote waste separation at source; promotion of green industry; promotion of tree-planting; promotion of public participation in climate change; and the application of economic incentives, such as carbon tax and subsidy.

The analysis of the questionnaire results from 246 respondents reveal the following outcomes at the statistical significance level of 0.05.

Table 2 The analysis of questionnaire results at the statistical significance level of 0.05.

Hypothesis	Results
1. Male have higher rate of behavior change towards voluntary mitigation actions than female.	Accept
2. People with different age differ in their behavior change towards voluntary mitigation actions.	Reject
3. People with different educational level differ in their behavior change towards voluntary mitigation actions.	Reject
4. People with different income differ in their behavior change towards voluntary mitigation actions.	Reject
5. People with different occupation differ in their behavior change towards voluntary mitigation actions.	Reject
6. People with different household types differ in their behavior change towards voluntary mitigation actions.	Reject
7. People with different reception of climate change information differ in their behavior change towards voluntary mitigation actions.	Accept
8. Knowledge on climate change and GHG mitigation has a positive correlation with people's behavior change towards voluntary mitigation actions.	Very low
9. Awareness on climate change has a positive correlation with people's behavior change towards voluntary mitigation actions.	Very low

Hypothesis	Results
10. Awareness on public participation in GHG mitigation has a positive correlation with people's behavior change towards voluntary mitigation actions.	No correlation
11. Attitude on climate change and GHG mitigation has a positive correlation with people's behavior change towards voluntary mitigation actions.	Low
12. People living in the suitable enabling environment has a positive correlation with behavior change towards voluntary mitigation actions	Very low
13. People with access to incentives, such as tax incentive has a positive correlation with behavior change towards voluntary mitigation actions.	No correlation

The study found that male respondents had higher level of behavior change towards voluntary mitigation actions than female respondents at the significance level of 0.05 ($t = -2.41$, $p = 0.020$). However, people with different age, educational level, income, occupation, and tenure type do not differ in their behavior change towards voluntary mitigation actions at the significance level of 0.05 ($F = 1.58$, sig = 0.19), ($F = 1.10$, sig = 0.36), ($F = 0.34$, sig = 0.89), ($F = 1.81$, sig = 0.08), and ($F = 0.72$, sig = 0.54) respectively. The respondents with different reception of climate change information differs in their behavior change towards voluntary mitigation actions at the significance level of 0.05 ($t = 2.217$, $p = 0.03$). Knowledge on climate change and GHG mitigation, awareness on climate change, and enabling environment to facilitate GHG mitigation are found to have very low positive correlation with the behavior change towards voluntary mitigation actions at the significance level of 0.05 ($r = 0.14$, sig = 0.03), ($r = 0.17$, sig = 0.01), and ($r = 0.17$, sig = 0.01) respectively. Attitude towards climate change and GHG mitigation is found to have low positive correlation with the behavior change towards voluntary mitigation actions at the significance level of 0.05 ($r = 0.33$, sig = 0.00). Awareness on public participation in GHG mitigation and the support of/access to GHG mitigation initiatives, such as carbon tax have no correlation with the behavior change towards voluntary mitigation actions at the significance level of 0.05 ($r = 0.09$, sig = 0.17) and ($r = 0.11$, sig = 0.08) respectively.

Discussion

The study reveals that behavior change toward voluntary mitigation actions of those 246 respondents in Phayathai, Bangkok, Thailand is predominantly in the areas of water-saving and energy-saving in building and household sectors, such as unplugging/switching off electrical appliances, using energy-saving appliances, and setting up suitable temperature for air-conditioning. However, behavior change in other areas, such as transportation (for example, using public transport, and riding bicycle), food consumption (for example, reducing meat consumption, and buying local products), agriculture and land use (for example, tree-planting), and waste management (for example, sorting waste at sources according to 3Rs principle) is still limited. The study suggests that the government should focus its attention to enhancing behavior change toward voluntary mitigation actions to accelerate public participation in GHG mitigation in Thailand by firstly, sustaining those already practiced behaviors, especially on water-saving and energy-saving and shifting them towards a complete lifestyle change as it is the highest level of behavior change according to the stages of change model (Prochaska and Velicer, 1997 retrieved from Kulthida Panichkul and Atiporn Samranbua, 2013). This can be done by implementing measures/providing incentives with high level of support, such as reduction in electricity bills for households that can lower their electricity/water bills, with a close coordination of various agencies and sectors, particularly the Ministry of Energy, Ministry of Interior, and local government. Secondly, the government should collaborate with private sectors and civil society in enhancing those behavior changes that people still have limited practice, such as improving the public transport to be more reliable, convenient, safe and affordable, and promoting local products, tree-planting in household areas and building, introducing garbage collection system that encourages waste-separation at source and enhancing public awareness and knowledge to contribute to voluntary mitigation actions.

The result of this study shows both similarities and differences to the previous study by Wimolpan Arpavet and Chantana Pattha (2013) that explores the receipt of information, awareness, knowledge, attitude and behavior of people living in Bangkok and neighboring provinces toward global warming. Similarly, it found that people learnt about global warming from television, radio, newspaper, and internet and they had high level of awareness and attitude toward global warming problem. However, this study found that people in Phayathai had high level of the receipt of information on climate change whereas the previous study found people in Bangkok and neighboring provinces had moderately receipt information on climate change. This study found people in Phayathai had high level of knowledge on climate change,

however the previous study found people in Bangkok and neighboring provinces had low level of knowledge on global warming. This study found that people's behavior change toward voluntary mitigation actions was at the moderate level but the previous study found people had high level of behavior change. Lastly, the previous study found that the receipt of information, awareness on global warming, and attitude toward global warming had positive correlation with behavior change while this study found only the receipt of information resulted in the difference in behavior change toward voluntary mitigation actions. This study supports the previous study by the Office of the National Economic and Social Development Board (2009) in exploring the opinions and attitudes of Thai people on global warming and Thai society that most people receive information about climate change; television is a key source of information; people has high level of knowledge and awareness on climate change and public participation in GHG mitigation; and the majority of people change their behavior towards voluntary mitigation actions by switching to energy-saving appliances as it provide co-benefits of long-term cost saving.

This study supports the study by Jan Semenza, David Hall, and Daniel Wilson, et.al. (2008) that explored public attitude on voluntary mitigation actions and challenges in their behavior change in Portland and Houston, U.S., in which they found a moderate level of public behavior change and the majority was related to energy-saving and water-saving in household sector. Lastly, this study supports the previous study by Irene Lorenzoni, Sophie Nicholson-Cole, and Lorraine Whitmarsh (2007) in exploring the barriers to public participation in climate change in U.K.. Similarly, the study found that people in the U.K. had high level of knowledge, awareness, concern, and good attitude towards climate change, however, these factors did not lead to public's behavior change as suggested by the stage of change model. It is suggested that other factors might contribute to the reason why people do not change their behavior towards voluntary mitigation actions, including personal factors, such as lack of understanding/uncertainty on the effectiveness of behavior change in addressing climate change, and their trust and reliability on modern technology to tackle the problem of climate change; and social factors, such as their trust on the government to effectively handle climate change problem and concern on the free-rider effect that those who do nothing will also benefit from one's behavior change.

Conclusion

The quantitative study on challenges and barriers to behavior change in voluntary mitigation actions in Phayathai, Bangkok using online questionnaire with 246 respondents

reveals that the respondents have high level of knowledge and perception on climate change and GHG mitigation, very high level of awareness and support on incentives, and moderate level of support/access to enabling environment. The respondents have moderate level of behavior change in voluntary mitigation action and most of their behavior changes are related to energy efficiency in household and building, such as unplugged/turn off switch and reduce water consumption. Gender and the receipt of information on climate change are the two factors found to be significantly affecting behavior change ($p<0.05$). The government should focus its attention on implementing measures to sustaining behavior change in the well practice areas, such as energy-saving and water-saving and accelerating actions toward a complete lifestyle change. It should also introduce new incentives/measures to overcome challenges and barriers in the sectors with limited behavior change, such as transport and waste with the aim to encourage more behavior change in the future.

References

Eckstein, D., Hutfils, M.L. and Winges, M. 2019. **Global Climate Risk Index 2019: Who Suffers Most From Extreme Weather Events? Weather-related Loss Events in 2017 and 1998 to 2017**. Retrieved on 16 December 2019 from www.germanwatch.org.

Lorenzoni, I., Nicholson-Cole, S. and Whitmarsh, L. 2007. **Barriers perceived to engaging with climate change among the UK public and their policy implications.** Global Environmental Change. 17: 445-459

Office of the National Economic and Social Development Board. 2009. **Final Report Project on the quarterly exploration of public opinions and attitudes on social issue: Global warming and Thai society.** Bangkok. Office of the National Economic and Social Development Board

Prochaska and Velicer. 1997. Citing in Kulthida Panichkul and Atiporn Samranbua, 2013. **Application of the Transtheoretical Model to promote exercise habits**. The Journal of Boromarajonani College of Nursing Nakhonrathasima. 19 (1): 66-76.

Semenza, J., Hall, D., Wilson, D., Bontempo, B., Sailor D., and George, L. 2008. **Public Perception of Climate Change: Voluntary Mitigation and Barriers to Behaviour Change.** American Journal of Preventive Medicine. 5: 479-487.

Shove, E. 2010. **Beyond the ABC: climate change policy and theories of social change. Environment and Planning.** 42: 1273-1285.

Spence, A. and Pidgeon, N. 2009. **Psychology, Climate Change, and Sustainable Behaviour Environment: Science and Policy for Sustainable Development.** Retrieved on 20 January 2020 from http://www.environmentmagazine.org/Archive.

United Nations Environment Programme. 2019. **Emissions Gap Report 2019**. Retrieved on 18 January 2020 from https://wedocs.unep.org/bitstream/handle/20.500.11822/30797

/EGR2019.pdf?sequence=1&isAllowed=y

Whitmarsh, L., and O'Neill, S. 2011. **Public Engagement with Carbon and Climate Change: To what extent is the public 'carbon capable"?.** Global Environmental Change. 21 (1): 56 -65.

Wimonpan Arpawet and Chantana Papattha. 2013. **The receipt of information, awareness, knowledge, attitude, and behavior toward global warming of people in Bangkok and neighboring provinces.** APHEIT International Journal. 2: 101-113 (in Thai)

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