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Environmental Microbial Monitoring and Risk Assessment of Cleanrooms - A Case Study in Medical Device Pilot Plant

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Abstract

The objective of this study is to determine the risk of environmental microbial contamination in the cleanrooms of a pilot plant that produced sterile microneedles-a type of medical device. Typically, microbial contamination comes from the human body, equipment, raw materials, and production environment. Environmental microbial monitoring in the production areas is frequently overlooked for a variety of reasons, including cumbersome and time-consuming procedures, inadequate facilities, and so on. Therefore, we intend to focus on this subject in the study. The environmental microbial monitoring program was established and implemented in the production area in nine steps: 1) determine risk areas, 2) select samples, 3) determine frequency and conditions, 4) assign persons, 5) select methods, 6) determine control limits, 7) analyze results and discussion, 8) investigate out-of-limit results, and 9) propose corrective actions and risk assessment. In addition, the bioburden of microneedle products was also part of this program. Data on airborne microorganisms were collected by the environmental microbial monitoring program from various risk points inside the pilot plant. This program's results were all data for determining risk assessment parameters. We generated a risk management system for this plant by using the guidelines of ISO 14971 and selecting three parameters to evaluate the risk: the likelihood-contamination rate, impact-bioburden, and deviation factors-out-of-control results of various parameters (consisting of temperature, humidity, differential pressure, and swab test.) in cleanrooms are the deviation. Besides, the process chart for risk control for environmental microbial contamination was established and used to facilitate the risk control of operators. This study aims to provide guidelines for microbial environmental monitoring and risk assessment in medical device pilot plants in accordance with ISO 13485 requirements.

Keywords : bioburden; environmental monitoring; ISO 13485; medical device; risk management

Introduction

A microneedle is a sterilized medical device (MD). The product must be free of microbiological contamination, safe to use, and stable, just like other sterile MDs such as a syringe, blood lancet, and so on. The production proceeds in a cleanroom where microbiological contamination by relevant factors is possible. The main factors causing contamination during operation, in descending order of risk, are raw materials (including water), equipment, personnel, and airborne environment [1, 2].

The fundamental principles of Good Manufacturing Practice (GMP) [3] used to prevent microbial contamination are cleaning, disinfection, and monitoring. Generally, in a factory, cleaning and disinfection are often well planned, while environmental monitoring (EM) does not have a clear action plan. However, a work environment control plan is necessary to implement the quality management system for medical devices

mandated by ISO 13485 [4] and prevent product contamination. Most importantly, the Food and Drug Administration (FDA) mandates that MD companies in several nations, including MD pilot facilities in Thailand, get GMP or ISO 13485 accreditation.

From the foregoing, we aim to examine the direct impact of airborne microorganisms on products and other factors likely to come into direct contact with products, such as equipment, personnel, and other contact surfaces. Therefore, the microbial EM program is established and applied to the pilot plant. Furthermore, the parameters, such as the number of samples, frequency, method, control limit, etc., that impact the program shall be specified. Any problems encountered during operation shall be corrected and prevented from recurring. The analysis data is required to establish criteria for contamination risk assessment. Finally, the risk assessment system can be fully implemented in this plant.

This paper aims to provide guidelines to support non-microbiologist researchers for microbial EM and risk assessment in MD pilot plants or starting production plants in accordance with ISO 13485 requirements.

Methodology

1. Microbiological environmental monitoring

Microbiological EM is a means of demonstrating acceptable microbiological quality in a controlled environment and detecting changes in time. It involves the collection of data relating to microbial numbers recovered from samples of air, surfaces, and people in the cleanrooms [2]. In this study, an EM program was developed and implemented in the plant to detect trends in microbial population changes and microbial growth within cleanrooms. The airborne samples were collected under production with a full staff to obtain the correct data and to collect all data in order to determine the risk control measures for microbial contamination in the products. In addition, this program also includes product sampling for the bioburden test. The application of the EM program came from JPAC [5]. It consists of 9 steps as follows:

Step 1 Determination of risk areas

All production areas in the pilot plant are in cleanrooms with two quality levels, class 10000 for production areas (such as storage of raw materials, molding, and assembling) and class 100000 for packaging areas (such as storage and preparation of packaging materials, packing). Both classes' names came from FED-STD-209E [6] which replaced by ISO 14644-1 [7], in which classes 10000 and 100000 are equivalent to ISO 7 and 8 of ISO 14644-1. Although a cleanroom helps to control the particles and microorganism counts not exceeding the controlled limits, there is still a risk that the number of microorganisms in the room may be out of control. The causes can be attributed to a variety of factors, including poor cleanliness, unauthorized entry, excess storage, introducing foreign objects into the area, abnormalities in the control system, and more. For this reason, the cleanroom also needs to assess the risk of contamination.

Step 2 Selection of samples and methods

According to EU GMP guidelines [3], microbial EM can be performed using four detection methods: air sample, settle plate, contact plate, and glove printing. The first two methods are the main methods for airborne microbial detection in the EM program. We chose the surface swab method instead of the last two methods. The steps of the swab test are according to ISO 18593 [8].

Volumetric air sampling is an active method operated by an air sampler to find the number of microorganisms per cubic meter of air. This method is applicable when the microbial concentration is not very high.

The settle plate is a passive method by EU GMP [3] that uses a petri dish (9 cm) with an agar medium opened and exposed to air for 4 hours. This method is valid and widely used. However, the method from the Index of Microbial Air Contamination (IMA) by C. Pasquarella, O. Pitzurra, and A. Savino [9] describes a method to determine airborne microbial contamination in at-risk environments by measuring the IMA. It stated that a Petri dish 9 cm in diameter containing plate count agar (PCA) is left open to air according to the 1/1/1 scheme (1 h, 1 m from the floor, at least 1 m

away from walls or any relevant physical obstacle). The microbial counted as CFU after 48 hours of incubation at 35±1°C. The number of CFU is the IMA. The IMA method is similar to the 4-hour settle plate method but saves monitoring time.

A swab test is a method for detecting microorganisms on surfaces in CFU per 100 cm^2, such as equipment, tables, doors, walls, hands or gloves, gown coats, etc. It uses a sterile stick with cotton or synthetic material at the tip. Sampling was performed by vigorously sweeping the surface to collect samples. Afterward, the swab was stored in a sealed sterile container and sent to a microbiology laboratory.

The bioburden test is the procedure for identifying microorganisms living on the surface of a product before sterilization. This result could explain the likelihood of microbial contamination in the current environment. The number of microbial species found in this test will reflect the effectiveness of the EM program at that time. The causes of contamination can be unsanitary preparation, packing, or storage, or the non-hygienic practices of staff. In addition, the bioburden results would determine the optimal gamma radiation dose for product sterilization. Excessive gamma radiation can affect product and packaging quality. On the other hand, if the gamma radiation dose is too low, it can lead to the incomplete elimination of microorganisms [10].

Step 3 Determination of frequency and monitoring conditions

We should consider the possibility of microorganisms accumulating within a cleanroom before determining the optimal frequency for the EM program. For example, the frequent production, the possibility of contamination in the manufacturing process, the history of contamination, etc. [2]. We operate the EM program in two stages. At the initial stage, there are two times for environmental microorganism monitoring and one time for the bioburden test. In the routine operation, every production from February 2021 to May 2022 took place a total of six times (because of the infrequency of microneedle production in the pilot plant). The monitoring frequency may be tightened or reduced depending on past results. However, the frequency will be reviewed appropriately by considering the historical data, including adjusting the conditions for monitoring again.

If possible, the monitoring should take place during production at different times when raw materials and all facilities have remained in the production area with all working staff. We should identify the risk points in each cleanroom area and monitor each risk point [11]. In addition, other monitoring activities related to cleanroom functionality should be done too, for example, airborne particle counts, HEPA filter integrity testing, air change rate calculations, air pressure difference, temperature and humidity, etc. [12].

Step 4 Assignment of responsible persons

The person in charge of the EM program should have relevant knowledge in the three areas: microbiology, environmental management, and quality management systems. It is difficult to recruit qualified personnel in all areas. However, the most required knowledge for this work is microbiology. Therefore, the assignment of a microbiologist to manage this program is ideal. Additional training can be another source of information. In addition, the appointed person should have other necessary qualifications, such as experience in this job.

Step 5 Selection of microbiological analysis methods

All microbial testing used in the EM program is the standard method. For the EM, there are two types of microorganisms analyzed: the aerobic plate count (APC) and the fungal count (yeast and mould). Both microorganisms perform in the on-site microbiology laboratory. Tryptic Soy Agar (TSA) is a medium culture for APC culture, and use DG-18 is the medium culture for fungi. All cultural media preparation was carried out in accordance with ISO 11133:2014 [13].

All product samples were sent to an external microbiological laboratory to test for bioburden. The test method is according to ISO 11737-1:2018 [14] to analyze microorganisms on the surface of the non-sterile microneedle samples.

Step 6 Determination of the control limit

The EU GMP Guidelines for Therapy Medicinal Products [3] have recommended maximum limits that are used to control environmental microorganisms in clean areas. It classified clean areas leveled by microbial cleanliness into four grades: A, B, C, and D, as shown in Table 1, where "A" denotes operations in the at-risk area, "B" for operations in the sterile area, "C" for the control area, and "D" for the support area. Table 2 is the comparison table of cleanroom classifications based on air changes per hour between ISO 14644-1:2015 [7], FED-STD-209E [6], and EU GMP [3]. This table states that grades C and D cleanrooms are equivalent to classes 10000 and 100000 of this plant, respectively.

Table 1 Microbiological cleanliness levels in operation [3]

Grade	Air Sample (cfu/m^3)	Dia. 90 mm. Settle Plate (cfu/4h)	Dia. 55 mm. Contact Plate (cfu/plate)	Glove print (cfu/glove)
A	< 1	< 1	< 1	< 1
B	10	5	5	5
C	100	50	25	-
D	200	100	50	-

Table 2 Comparison of cleanroom classifications [3, 6, 7]

Cleanroom Std.	Cleanroom Classification Guidelines					
ISO 14644-1	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
FED-STD-209E	1	10	100	1000	10000	100000
EU GMP	-	-	A / B	-	C	D

In the early adoption of the EM program, the control limits of the air sampler and settle plate from Table 1 can be used as the tentative criteria for evaluating airborne microbial counts in both cleanrooms. In the case of swab tests, we use them to assess the efficiency of cleaning and sanitation by using the control criteria of microorganisms found to be less than or equal to 100 CFU/100 cm^2 (adapted from Griffiths 2016) [15]. (See Table 3).

Table 3 The tentative control criteria used in the EM Program

Class of cleanroom	Air Sample (cfu/m^3)	Dia. 90 mm. Settle Plate (cfu/4h)	Swab test on surface (cfu/100cm^2)	Swab test Glove & cloth (cfu/100cm^2)
10000 (C)	100	50	100	100
100000 (D)	200	100	100	100

To establish a risk management plan for airborne microbial contamination in this plant, it is necessary to determine the contamination rate (CR), where CR is a key parameter used to assess the likelihood of microbial contamination. We can calculate CR as a percent by referring to the formula in Sandle's Numerical Approaches to Risk Assessment, T (2019) [2], as follow:

$$\% \text{ CR} = \text{Settle plate count} \times \frac{\text{Area of product}}{\text{Area of Petri-dish}} \times \frac{\text{Time product exposure}}{\text{Time settle plate}} \times 100$$

The settle plate count means microbial count, the area of a product is 12.57 sq. cm, the Petri-dish area is 63.64 sq. cm, the time of product exposure is 2.5 min, and the time of settle plate exposure is four hours (EU GMP) or one hour (IMA). Additionally, the IMA method [9] in Table 4 divides the IMA into five classes. The table specifies microbial content as IMA, CFU/dm^2/h, quality class, and risk status. The values in this table can be used to compute the % CR of airborne microorganisms.

Table 4 The index of microbial air contamination (IMA) [9]

IMA value	cfu/dm^2/h	Quality class	Risk status
0-5	0-9	Very good	Very low
6-25	10-39	Good	Low
26-50	40-84	Fair	Medium
51-75	85-124	Poor	High
$\geq$ 76	$\geq$ 125	Very poor	Very high

Step 7 Data for trend analysis and discussion

At the start of the EM program, we monitored environmental microorganisms in the plant twice, in November 2020 and February 2021. We used a settling plate and air sampler for airborne microbial monitoring and the swab test on many surfaces that may be contamination risk points. In routine operations, we used the IMA method for airborne microbial monitoring. Four monitoring areas in the plant were defined: the class 10000 cleanroom, the class 100000 cleanroom, the changing rooms, and the corridor. Airborne microorganisms are monitored every time in pre- and post-production to compare the differences. All activities have been done six times from February 2021 until May 2022. We can evaluate the results from the starting stage by comparing the data with the tentative control criteria in Table 3 and the data results from the

routine operation by comparing them with the control criteria in Table 4.

Step 8 Investigation of out-of-limit results

From step 7, if some data were out of the control limit, an investigation of the root cause should act quickly. We should consider all defects that could be the causes and provide appropriate countermeasures immediately.

Step 9 Corrective actions and risk assessment

All defects detected in EM programs should be effectively corrected every time. By establishing and implementing a risk assessment system in the plant, we can reduce environmental microbial contamination as much as possible in the long run. There are several ways to approach risk assessment. We choose to use the guidelines of ISO 14971:2019 - Application of Risk Management to Medical Devices [16], which will be explained in the next topic.

2. Establishment of a risk assessment system

Referring to the regulations of the U. S. FDA [17], microneedle products are MDs for use in specified areas of the human body. It is an instrument with technological features, having many tiny needles, tips, or pins on the surface to create many small puncture holes in the skin. They used them in various biomedical areas such as drug delivery systems, disease wound repair, and cancer therapy. Because microneedles come into direct contact with the body, product safety must be recognized in order to avoid infection or dangers in use to the user. Therefore, it is necessary to control the various characteristics related to product safety, such as sterility, surface roughness, material properties, energy sources, etc.

In designing a system of environmental microbial contamination prevention for this plant, we developed it by following the guidelines of ISO 14971:2019 [16]. This standard specifies the five steps of the risk management process: 1) risk assessment, including risk analysis and risk evaluation; 2) risk control; 3) evaluation of overall residual risk; 4) risk management review; and 5) production and post-production activities.

Step 1 Risk assessment

The steps for risk assessment comprised a risk analysis and a risk evaluation, as follows:

Step 1.1 Risk analysis

Microbial contamination can cause a before-sterilized microneedle product to have an excessive amount of microorganisms that lead to an inadequate sterilization dose, making this product dangerous when used due to the risk of infection. To estimate the risk of microbial contamination, we shall assign the possibility of contamination, called "Likelihood," and the consequences of this contamination, called "Impact." The likelihood relates to the contamination rate from the airborne environment, calculated as a percentage of contamination rate (% CR), while the impact means the microbial load count found on the before-sterilized microneedle products.

Step 1.2 Risk evaluation

We need to create a risk matrix based on the likelihood-impact relationship to assess the risk of airborne microbial contamination. In this case, the likelihood is CR% and the impact is bioburden. We can use the maximum values in each IMA class from Table 4 to calculate % CR. The results of the % CR values can be used to generate the likelihood tables for the contamination at the five levels shown in Table 5 below.

Table 5 The five likelihood levels of microbial contamination

Likelihood Level	% Contamination rate (%CR)		Score Level
	From Max. of IMA	From Max. of CFU/dm^3/h	
Improbable	$\leq$ 4 %	$\leq$ 7 %	1
Remote	5 - 20 %	8 - 32 %	2
Occasional	21 - 41 %	33 - 69 %	3
Probable	42 - 62 %	70 -102 %	4
Frequent	$\geq$ 63 %	$\geq$ 103 %	5

Referring to ISO 11137-2 [18], the impact rating can be determined by considering the sterilization dose of gamma-ray on the product. If using 25 KGy, the microbial count from the bioburden test shall be less than or equal to 1000 CFU, and if using 15 KGy, it shall be less than or equal to 1.5 CFU. As a result, the number of microorganisms on the product shall be between 1.5 and 1,000 CFU. We can use this range of numbers to establish the impact table of the bioburden products by

dividing the impact by the five levels within this range (see Table 6).

Table 6 The five levels of impact from the bioburden product

Impact Level	Bioburden Result (CFU)	Score Level
Negligible	< 1.5*	1
Minor	1.5 - 10	2
Moderate	> 10 - 100	3
Major	> 100 - 1000*	4
Critical	> 1000	5

** Refer to ISO 11137-2, at Topic 9.2.1.1 and Topic 9.4.1.1*

We can multiply each likelihood and impact level to establish the risk matrix shown in Figure 1. The microbial contamination risk can be estimated from the risk matrix. This matrix contains five colored boxes. The red boxes are very high-risk, the orange boxes are high-risk, the yellow boxes are moderate-risk, the light blue boxes are low risk, and the green boxes are very low-risk.

Matrix	Impact level					
Likelihood Levels	Risk Rating	Negligible	Minor	Moderate	Major	Critical
	Frequent	5	10	15	**20**	**25**
	Probable	4	8	12	**16**	**20**
	Occasional	3	6	9	12	15
	Remote	2	4	6	8	10
	Improbable	1	2	3	4	5

Figure 1 The risk matrix by multiplying likelihood and impact

Step 2 Risk control

In the determination of risk control measures to cover all factors that affect the risk, in addition to the likelihood and impact mentioned in Step 1.2, the parameters related to the cleanliness measurement within the cleanroom are also factors that shall be taken into account. There are two essential parameters: the swab tests and the controlled conditions within the cleanroom, including temperature, relative humidity, and different pressures inside and outside the cleanroom. The risk of deviation from the control value of these two parameters is called the "Deviation Factor." We can calculate the deviation factor in percentage, as shown in the following calculating formula:

1) Calculation of deviation factor from swab test

$$\%\text{Deviation}_{\text{Swab}} = \frac{\text{Sum of swab test results deviating from the control value}}{\text{The total chosen risk point for the swab test}} \times 100$$

2) Calculation of the controlling parameter (CP) in cleanrooms

$$\%\ \text{Deviation}_{\text{CP}} = \text{Sum of \% deviating from the control value of T, RH, and DP}$$

By referring to ANSI/ASQ Z1.4 [19], we use the acceptance limit of the summation of percent deviation from the swab test plus CP at a maximum of 3% and use this figure to classify the level of deviation risk shown in Table 7.

We combine the likelihood, impact, and deviation factors to establish the risk control table by multiplying the scores of these factors at the same level. The total scores are between 1 and 125. The risk consists of five levels, and each score level is in the appropriate range (see Table 8). We will use this risk control table in the pilot plant to check the status of microbial contamination risk.

Table 7 The level of risk from deviation factor

Deviation Level	Percent acceptance of deviation	Score Level
Negligible	$\%\ \text{Deviation}_{\text{Swab}}$+$\%\ \text{Deviation}_{\text{CP}}$ < 1%	1
Minor	$\%\ \text{Deviation}_{\text{Swab}}$+$\%\ \text{Deviation}_{\text{CP}}$ 1-2%	2
Moderate	$\%\ \text{Deviation}_{\text{Swab}}$+$\%\ \text{Deviation}_{\text{CP}}$ >2-3%	3
Major	$\%\ \text{Deviation}_{\text{Swab}}$+$\%\ \text{Deviation}_{\text{CP}}$ >3-5%	4
Critical	$\%\ \text{Deviation}_{\text{Swab}}$+$\%\ \text{Deviation}_{\text{CP}}$ >5%	5

Table 8 Risk control table of environmental microbial contamination

Risk Rating	Possibility of Hazard Situation	Risk Score
Very low risk	No contamination happens to the products	1 - 4
Low risk	Difficult to contaminate the products.	>4 - 8
Moderate risk	There is still a chance of product contamination	>8 - 27
High risk	There is a risk of product contamination easily.	>27 - 64
Very high risk	Product contamination can occur at any time	>64 - 125

Step 3 Evaluation of Overall Residual Risk

We have established the risk control process for environmental microbial contamination in the plant (see Figure 2) for operators to use as the guideline to continuously monitor and control the overall residual risk in the plant. After that, performance results are collected and used to re-assess residual risks in pilot plants at least once a year.

Step 4 Risk management review

It needs to collect the performance records from the EM program and the relevant information to summarize the result and any problems or limitations between operations. After that, we should send all the information to management for review in three aspects: 1) the suitability of operation in the system, 2) the acceptability of overall residual risk, and 3) taking appropriate and timely corrective measures, including verifying data during and after production. The responsible person should take action in accordance with the opinions and recommendations received from the risk management review appropriately.

Step 5 Production & post-production activities

Besides the sources causing the risk of microbial contamination in the environment directly, we should not ignore the other sources that involve microbial contamination too, such as sources of raw materials or packaging in their supply chain and the chances of cross-contamination from storage, transportation, and use. An instruction manual for collecting and reviewing all information relevant to every activity during and post-production is needed. Moreover, it must have other necessary data, such as technical data and specifications of the microneedle, related reference standards, and others. Statistical techniques should be used to analyze data trends. The complicated work should be documented as a standard operating procedure (SOP). The EM program should be improved in light of the current hazard situation, and risk control measures should be added (if necessary).

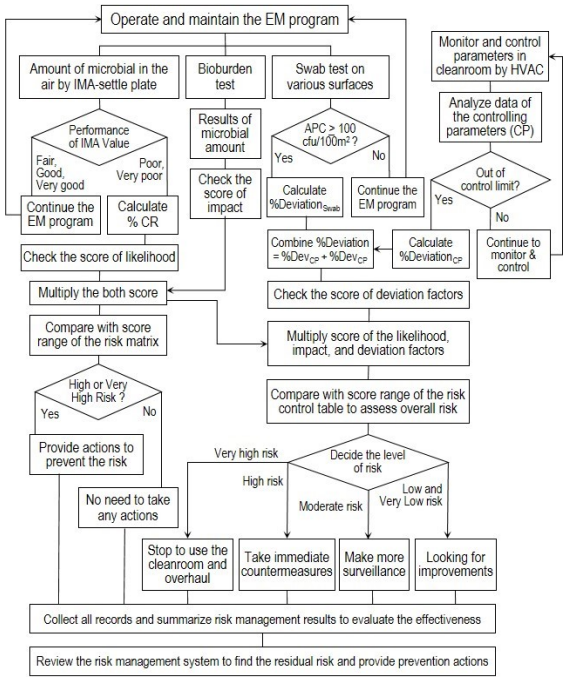

Figure 2 Process of risk control for environmental microbial contamination

Results and Discussion

1. Results from the EM program

At the initial stage of the EM program, the results from the method of the settle plate and the air sampler could be concluded, as shown in Tables 9 and 10, respectively. Table 9 showed the results of APC from the settle plate in both cleanrooms. In the first result, we monitored six risk points for class 10000 cleanroom and nine for class 100000. In the second, the monitoring was done at two and six risk points, respectively. Values of APC in minimum, maximum, and mean were shown in the table and pass evaluations. In addition, we found a few fungi in both cleanrooms in the first monitoring, so there is no need to monitor them a second time. The bacterial types in the air were identified and found to be gram-positive cocci at 82%, gram-positive bacilli at 5%, gram-negative bacteria at 6%, and mold at 7%. Many of the gram-positive cocci bacteria in the air of occupied areas (such as *Staphylococcus* spp.) came from the skin of personnel [20].

Table 9 Evaluation of APC in Cleanrooms by Settle Plate (4 h)

Class of cleanroom	Sampling date	APC by Settle plate (4h)				Results
		Control limit	Min. CFU	Max. CFU	Mean CFU	
10000	26/11/20	50	0	7	3.7	passed
	23/02/21		3	4	3.5	passed
100000	26/11/20	100	0	3	1.4	passed
	23/02/21		2	9	5.0	passed

Table 10 showed the results from the air sampler. In the first result, we monitored one risk point in the class 10000 cleanroom and two in the class 100000 cleanroom. In the second, they were two and one risk point, respectively. All results of APC passed the control criteria in Table 3. In the case of the fungal test, the results were small counts of mould detected in each cleanroom (between 0 and 7 CFU).

Table 10 Evaluation of APC in Cleanrooms by Air Sampler

Class of cleanroom	Sampling date	APC by Air Sample				Results
		Control limit	Min. CFU	Max. CFU	Mean CFU	
10000	26/11/20	100	18	18	18.0	passed
	23/02/21		28	61	44.5	passed
100000	26/11/20	200	7	60	33.5	passed
	23/02/21		34	34	34.0	passed

From the swab test results, the eighteen samples were from many surfaces within both cleanrooms, such as tables, door handles, storage cabinets, plastic bags, blister packs, cartons, gown coats, and equipment. All results found small amounts of APC between 0 and 6 CFU on each surface.

We also monitored airborne bacteria outside the cleanroom by the settle plate and found the max value of APC to 96 CFU and fungi to 116 CFU. In addition, on the sleeves of gown coats hanging in the closet of the changing room, we found the max value of APC to be 129 CFU. It seems that gown coat was a high-risk factor for contamination.

We compared the airborne microbial monitoring method between the 4-hour settle plate and the 1-hour settle plate (IMA) to check for differences in results. The number of ten samples per method was picked up from the same point in the cleanroom, changing room, and outside the cleanroom to find APC in the air. We used ANOVA Single Factor to analyze the APC data from both methods. This statistical analysis result stated that the APC values were not significantly different. So, we could use the IMA method instead of the 4-hour settle plate in routine operations.

We were unable to identify the type of bacteria from the bioburden test results because none of the thirty microneedle samples had any microorganisms visible.

In routine operations, the airborne microbial monitoring by IMA had been done six times from February 2021 until May 2022. The trends in the six monitoring results were shown in Figures 3 and 4 as follows: We could conclude from Figure 3 that most of the microbial counts obtained by monitoring in both cleanrooms met the criteria of "good" to "very good," and some results met the criteria of "fair" (IMA criteria [9] in Table 4). Based on the microbial monitoring trend in both cleanrooms, most microorganisms in post-production were lower than in pre-production, except in the first monitoring, which gave the opposite result. Perhaps it is because raw materials and packaging materials were stored a lot during that time. Figure 4 showed the trend of airborne microorganisms outside the cleanroom. All results met the "good to fair" criteria.

In Figure 5, the red dotted line graph was the average APC value of the four areas obtained from the swab test. This graph showed the APC increase trend of the swab test and found that the APC in a class 10000 cleanroom was higher than in the other areas. The reason may be due to incomplete cleaning and disinfection of these surfaces. This trend may further increase the risk of microbial contamination.

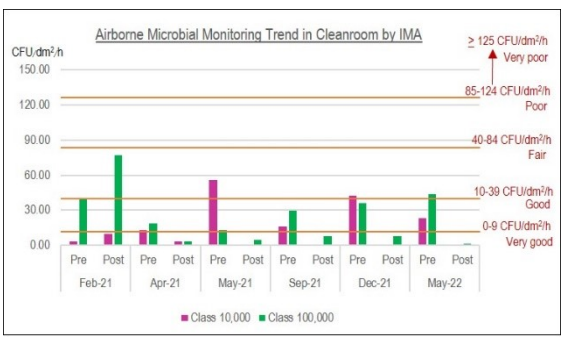

Figure 3 Airborne Microbial Monitoring Result in Cleanroom

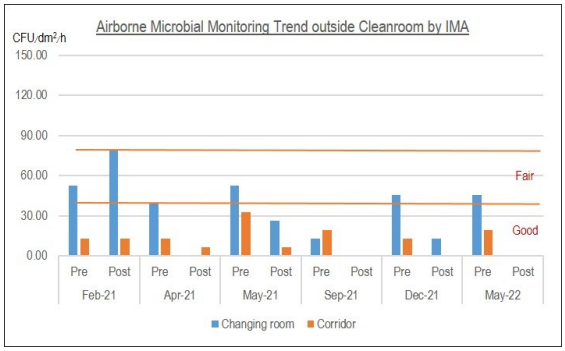

Figure 4 Airborne Microbial Monitoring Result outside Cleanroom

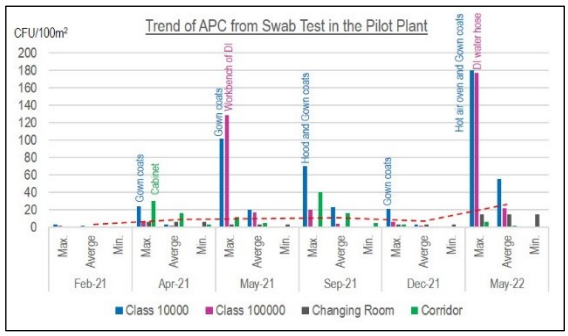

Figure 5 Results of Swab Test in Four Areas of the Pilot Plant

From the operation of the EM program, the results of all airborne microbial tests in the cleanrooms were within the control limit, except some swab test results were out of control values, especially on the surfaces of the table and pipe of the DI, the hem of gown coats, and some device surfaces, which were trending upward. These were already correct or need to be changed, such as the creation of SOPs for operators to serve as cleaning guidelines in each area.

Microbiological quality control represented a cornerstone in the MDs production process. With evolving regulatory requirements, products of greater complexity were elevating the challenges related to maintaining microbiological integrity. The fundamental role of GMP needs to be closely monitored, especially the EM program. EM can be achieved in practice with the long-term trend for validation studies and risk assessment [2, 21, 22].

2. Results from risk assessment

2.1) The likelihood score

In 2021, airborne microorganisms were monitored five times each in class 10000 and class 100000 cleanrooms using the IMA method. All microbial results were calculated as % CR by Sandle's formula, and the % CR values appeared in Table 11. The max value of % CR in the table was used to check the likelihood score with Table 5 and it was found that the scores for the cleanroom classes 10000 and 100000 were 2 and 3, respectively.

Table 11 The Likelihood Score in the year 2021

Class of Cleanroom	% CR from Sandle's Calculation Formula					Likelihood Score
	Feb-21	Apr-21	May-21	Sep-21	Dec-21	
10000	5.18	6.90	29.34	8.63	22.44	2
100000	40.73	9.78	6.90	15.01	18.98	3

2.2) The impact score

There were no microorganisms found in the thirty samples of the bioburden test. We can find the impact score in Table 6, and the impact score of both cleanrooms was 1.

2.3) The deviation score

2.3.1) Deviation from the swab test

4 of 46 swab test results this year in cleanroom class 10000 were out of control, resulting in an 8.7% deviation. In the cleanroom class 100000, 2 of 73 tests were out of control, resulting in a 2.74% deviation.

2.3.2) Deviation from temperature, relative humidity, and different pressure

The control criteria for temperature in a clean room were 22.2±2.8°C, the relative humidity is between 30-65% [23], and the pressure difference of the class 10000 cleanroom is more than 12.5. Pa. In cleanroom class 100000, we used the criteria of 5-20 Pa according to ISO 14644-4. Figures 6 and 7 showed the values of temperature (T), relative humidity (RH), and air pressure difference (DP), including the trend of their control results, in which all the data are under control criteria. Both figures showed the monthly average values of temperature, relative humidity, and pressure differences in both cleanrooms (a total of 12 times). It turns out that each parameter was under control every month.

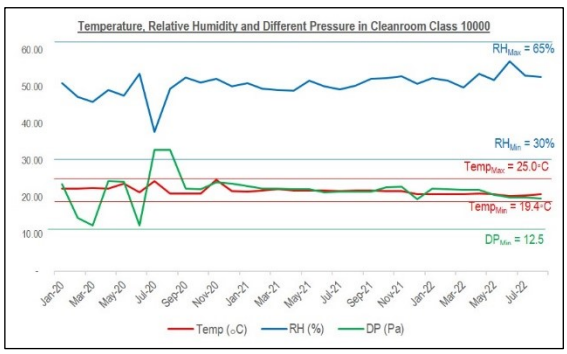

Figure 6 Trend of T, RH, and DP in Cleanroom Class 10000 at Operation Condition

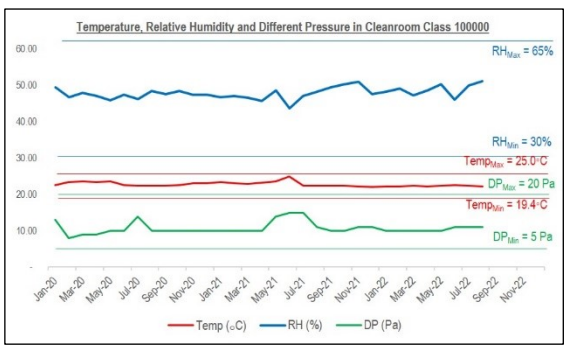

Figure 7 Trend of T, RH, and DP in Cleanroom Class 100000 at Operation Condition

Table 12 showed the sum of the % deviations in class 10000 and 100000 cleanrooms were 8.70% and 2.74%, respectively. It can be found that the deviation score in Table 7, and the scores of each cleanroom were 5 and 3, respectively.

Table 12 The Deviation Score in the year 2021

Control Factors in Cleanroom	No. of times to monitor		No. of times out of control		% Deviation	
	C.10000	C.100000	C.10000	C.100000	C.10000	C.100000
Swab test	46	73	4	2	8.70%	2.74%
Temp (T)	12	12	0	0	0.00%	0.00%
Humidity (RH)	12	12	0	0	0.00%	0.00%
Diff Pres (DP)	12	12	0	0	0.00%	0.00%
Sum of % deviation					8.70%	2.74%
Deviation score					5	3

2.4) The risk score

The result of multiplying the likelihood score, the impact score, and the deviation score was called the risk score. From Table 13, the risk scores of class 10000 and 100000 cleanrooms were 10 and 9, respectively.

Table 13 The Risk Score in the year 2021

Cleanroom	Likelihood Score	Impact Score	Deviation Score	Risk Score	Risk Rating
Class 10000	2	1	5	10	Moderate
Class 100000	3	1	3	9	Moderate

There were no case studies of microbial risk assessment in MD; there were only cases in pharmaceuticals [24-26].

Conclusions

The microbial EM program was established and implemented in the production area with nine steps (applied from JPAC [5]):

1. Determination of risk areas
2. Selection of samples and methods
3. Determination of frequency and monitoring conditions
4. Assignment of responsible persons
5. Selection of microbiological analysis methods
6. Determination of the control limit
7. Data for trend analysis and discussion
8. Investigation of out-of-limit results
9. Corrective actions and risk assessment

Figure 1 Flow chart of the EM Program

We generated a risk management system for this plant by using the guidelines in ISO 14971:2019 and selecting three parameters to evaluate the risk: the likelihood, impact, and deviation factors. In this study, the percentage of contamination rate is the likelihood, the number of microorganisms from the bioburden test is the impact, and the out-of-control results of various parameters (consisting of temperature, humidity, differential pressure, and a swab test) in cleanrooms are the deviation.

The risk evaluation result of the plant in 2021 was a moderate risk that was acceptable. A critical point of the risk came from the deviation factor of the swab test, especially from the gown coats. This risk factor was

already corrected and did not find a recurrence. The EM program continued to be followed today, including accurate and complete records of operating results to maintain an effective risk management system at all times. All performance results would be analyzed and concluded for review by management in three aspects: 1) suitability of correction measures, 2) overall residual risk remaining in the plant, and 3) more activities to do. Many outputs from the review should be applied to improve or develop the system.

Acknowledgments

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Development of Pedestrian Walkways Model for the City Nucleus of Bangkok, Thailand

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Abstract

The research of the Pedestrian Walkways Model for the City Nucleus of Bangkok presents a criteria for creating an infrastructure based on people's engagement in expressing their opinions and requirements for example, adequate pedestrian width, safety when walking on the sidewalk, the cleanliness of the pavement and shady environment. This research uses qualitative research, observation procedures, and collecting data from 400 sets of multiple choice questionnaires for documentary studies to analyze fundamental data. This study shows that people's needs can be divided into 3 groups: 1) The safety of pedestrians which concern on install a crossing signal for maximum safety, 2) The environment of pedestrians which concern on appropriate cleaning policy for pedestrian walkways, and 3) The comfort of pedestrians which concern on utilities should be maintained in a systematic manner. Even in most developing nations, typical pedestrian walkway designs and the concept of involvement in expressing attitudes and needs not only respond to demand use but may also maintain political stability.

Keywords : Pedestrian; Convenience; Safety; Environment of Pedestrian

Introduction

The smart city concept is used in the design of pedestrian zones in the world's largest cities. The components of a smart city include Smart Infrastructure, Green Building, Eco Mobility, Nature and Environment, Smart Economy, Smart Citizen & Community and Smart Government. In the Eco Mobility issue, there is the topic of walking ability. (Walkability) included [1]. According to Repko and DeBroux (2012) [2], the building of pedestrian zones cannot be separated from the integrative framework of the smart city concept. The presence of pedestrian zones on either side of the roadway exemplifies the tension between mobility and public space. The pedestrian zone represents the battle to integrate the functions of mobility, economic function (efficient and rapid), and socio-political, which can lead to contestation and negotiation [3-5], as well as the role of a transportation system extension.

The survey exposes a possible conflict between the government and the people, particularly street vendors, in emerging countries. Street vendors do not have access to pedestrian zones since they are not involved in the design of public spaces or the development of public policies [6-7]. Pedestrian zones function as public spaces in urban areas by encouraging trade, mobility, and social interaction [8-10]. As a result, people's involvement every person who used walking in attitudes and wants may be a notion worth considering.

According to Whyte (2000) [11], the party in charge of public spaces such as malls, plazas, and parks would be closely identified with conflict and negotiation between the government and the community. The problem has arisen as a result of a conflict over the functioning of these spaces. Ho Chi Minh (Vietnam) is an example of pedestrian zone monitoring (expanding its pedestrian friendly streets by creating continuous footways and in

addition a walking friendly downtown could be pursued to expand the pedestrianised Nygen Street), since it is heavily guarded by the city administration and its use ensures flexibility for pedestrians.

The public owns urban spaces, which catalyses social and cultural connections. The way we use space is defined by our behavioural patterns. As a result, a successful urban design is determined by how well it satisfies human values. Although the majority of accidents occur while walking on sidewalks and crossing streets to board or exit a bus [12], conflicts over the nature of and rights associated with public space have a long history in the United States.

The importance of working in urban planning and the problems that city pedestrians encounter have been established [13-14]. Accidents on pedestrian routes kill and injure many people, especially in underdeveloped countries [15-17]. Bangkok is a fast-expanding city with a linear distribution of mixed-use zones. A fine-scale land-use strategy is required to deal with the challenge of such a land-use mixture [18]. Natural gas and gasoline resources are wasted as a result of the heavy traffic during rush hour, and Bangkokians' stress levels rise.

Criteria for Pedestrian Walkways Model (PWM) to be prepared in this study which suitable for users, play an important role in the urban management plan in a city with a mix of land uses, such as Bangkok. The study's goal is to look at public life on Bangkok's pedestrian walkways with the notion that users' wants and satisfaction should be considered while designing pedestrian walkways which user need.

An ecology-culture-behaviour paradigm is offered to accurately justify the link between pedestrian path design. Bangkok pedestrian walkways users and their activities within the pedestrian walkways area are also observed and surveyed to provide an overall picture of the attitudes and expectations of the users in Bangkok's City Nucleus, Dust District (CNB). Then came the invention of the PWM.

Study Site

The research was carried out at the main crossroads in CNB. This is a particularly significant zone, since it contains the administrative hub of the monarchy, including the National Assembly, the Dusit Grand Palace, and various ministries. Ananta Samakhom Throne Hall, another former house of King Chulalongkorn and subsequently utilized as the first parliament building, is an important structure in the district. It was designed by Annibale Rigotti and Mario Tamagno, two Italian architects, between 1907 and 1915. The Amphion Sathan Residential Hall, the official house of the current monarch King Vajiralongkorn, is located next to the throne hall. We analysed Samsen Road from the Vajira Hospital intersection (A) to the Sri Ayutthaya Road intersection (B), a distance of 3.5 kilometres, and from the foot of the Krung Thon Bridge (C) to the Kan-Ruen junction (D), a distance of around 1.7 kilometres (Figure 1).

Material and Method

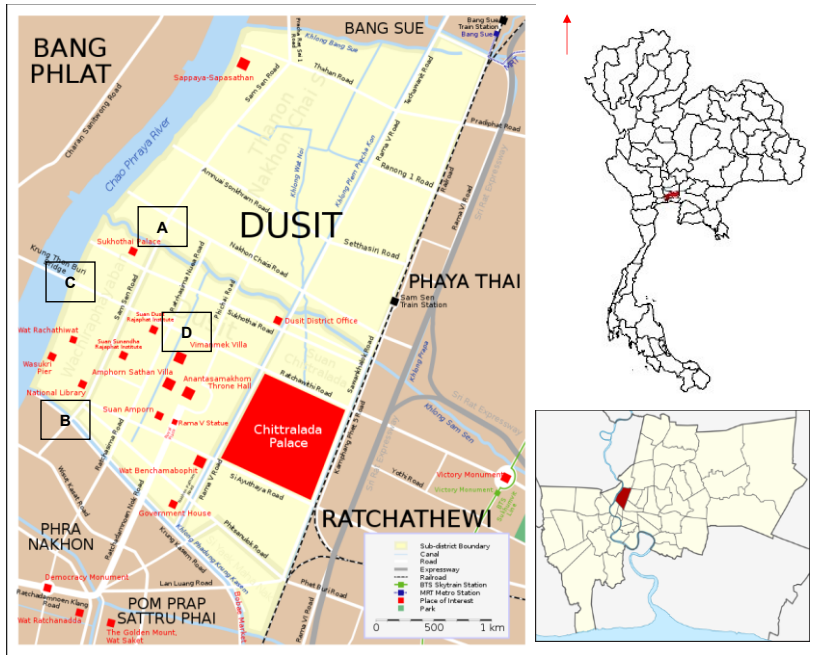
To create PWM in CNB, we followed the four procedures outlined below to locate eligible Bangkok Pedestrian Walkways.

Step 1: Field observation and preliminary information gathering. In this area have school, government office, public health service facility, and commercial buildings. The total distance is approximately 5.2 kilometers and takes approximately 2 months to explore (February – March 2021).

Step 2: Questionnaire and sample size. CNB population which totalled 83,897 people. A total of 394 people were randomly selected and sampled using the Taro Yamane table at the 0.95 statistically significant confidence level. We conducted a questionnaire study of 400 accidental samples from Bangkok's pedestrian users (BPU) to determine the views and requirements of the people who live in CNB and the BPU about improved pedestrian paths. (between February – March 2021). The reliability ratings for the attitudes and needs questionnaires were 0.85 and 0.89, respectively.

Step 3: Using descriptive statistics, analyse the data to summarize the major points acquired from the research findings of questionnaire surveys.

Step 4: Suggest an appropriate PWM based on the attitudes and demands of the people in CNB.



Source: Department of City Planning, Bangkok Metropolitan Administration, 2019

Figure 1 Study area around the city nucleus of Bangkok, Dusit District

Results

1. Field observation and preliminary information gathering

1.1 The physical of the pavement of CNB

As a consequence of the findings, we can conclude that there were three primary concerns at the research site:

1) Concerns about the ease of usage of the pedestrian walkways.

The pedestrian walkways in CNB are unusually narrow, with barriers such as police posts, power poles, overpasses, billboards, unused telephone boxes, and post boxes along the pedestrian route. BPU experience surface issues problems as well as a lack of shade from the sun and rain (Figure 2).

Figure 2 Nonstandard width pedestrian with obstacles and surface problems

2) Concerns about the safety of walking.

There are risks of pavement accidents, such as riding a motorcycle on the sidewalk, and difficulties walking at night, such as insufficient lighting at certain times. Crime hazards like poorly lit hallway corners and lonely alleyways may be the result of concealed crimes like homelessness or criminal gangs.

3) Concerns about the walking environment.

CNB has a congested retail setting between the sidewalks. There are several selling activities as well as autos, taxis, and bikers on the sidewalk. Solid trash contributes to an unpleasant physical environment that inhibits walking. Solid waste is to blame for the pollution around the pedestrians. This is owing to the presence of roadside food stalls (Figure 3).

Figure 3 The roadside food shop makes solid waste on the pedestrian of CNB

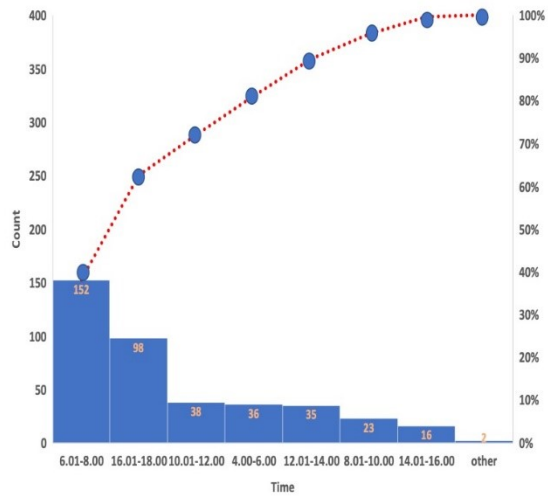
1.2 The pattern of use by the BPU

The assessment of 400 unintentional samples (Table 1) revealed that 152 BPP samples always utilize the pedestrian path early in the morning (06.01-08.00 am) for their everyday activities (Figure 4), while BPP takes between 10 and 30 minutes to complete on sidewalks in each day.

Figure 5 demonstrates that the majority of BPP utilize pedestrian paths within a 41-50 meter radius. Because of CNB's extremely hot and humid weather, Thai people walk differently than those from other nations. Most BPPs, however, require a pedestrian path for their daily travel to work.

Table 1 Base data of survey population

Base Data	Amount
1. Sex	
1.1 Male	162
1.2 Female	238
2. Domicile	
2.1 Bangkok	152
2.2 Provincial	248
3. Age	
3.1 <20 yrs.	41
3.2 20-30 yrs	197
3.3 31-40 yrs	98
3.4 41-40 yrs	51
3.5 51-60 yrs	13
3.6 >60yrs	-
4. Education	
4.1 Junior high school	13
4.2 Senior high school	32
4.3 Vocational Certificate	24
4.4 High Vocational Certificate	27
4.5 Bachelor's degree	286
4.6 > Bachelor's degree	18
5. Occupation	
5.1 Government service / state enterprise	6
5.2 Company employee	219
5.3 Own business	15
5.4 General employee	7
5.5 Student	152
5.6 Other	1



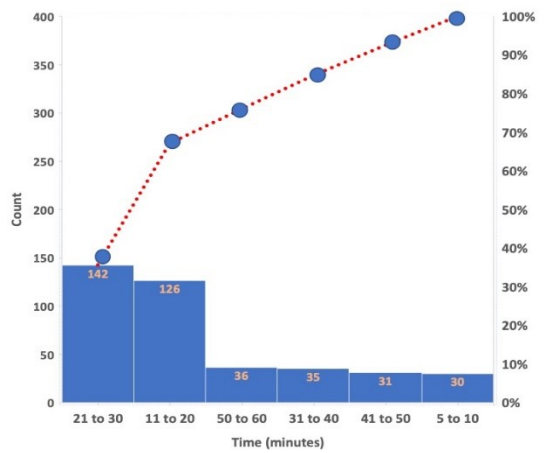
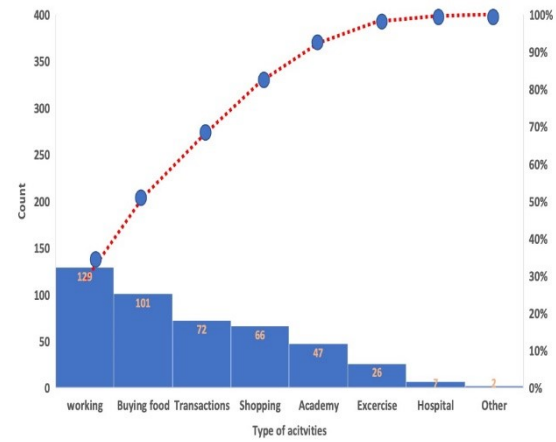


Figure 4 Pareto graphs of time interval and time used on a pedestrian walkway by BPU



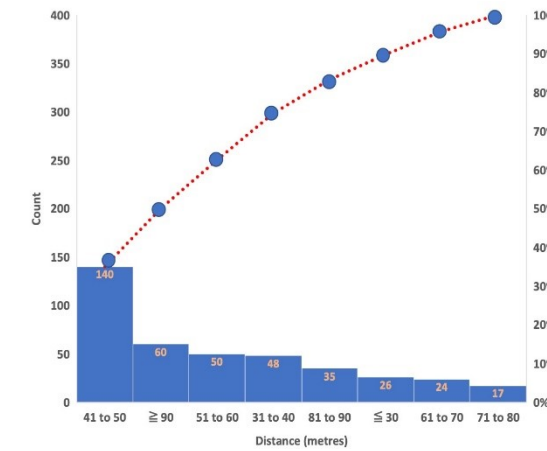


Figure 5 Pareto graphs of distance and type of activities at a pedestrian walkway by BPU

2. Attitudes and needs regarding the improvement of the pedestrian walkways

The questionnaire study revealed the attitudes and demands of the population dwelling in CNB and the BPP in three major areas: (1) by giving importance to the issue of install a crossing signal for maximum safety, (2) to improve appropriate cleaning policy for pedestrian walkways, and (3) utilities should be maintained in a systematic manner (Table 2).

3. The suitable PWM according to the attitudes and needs of the people in CNB

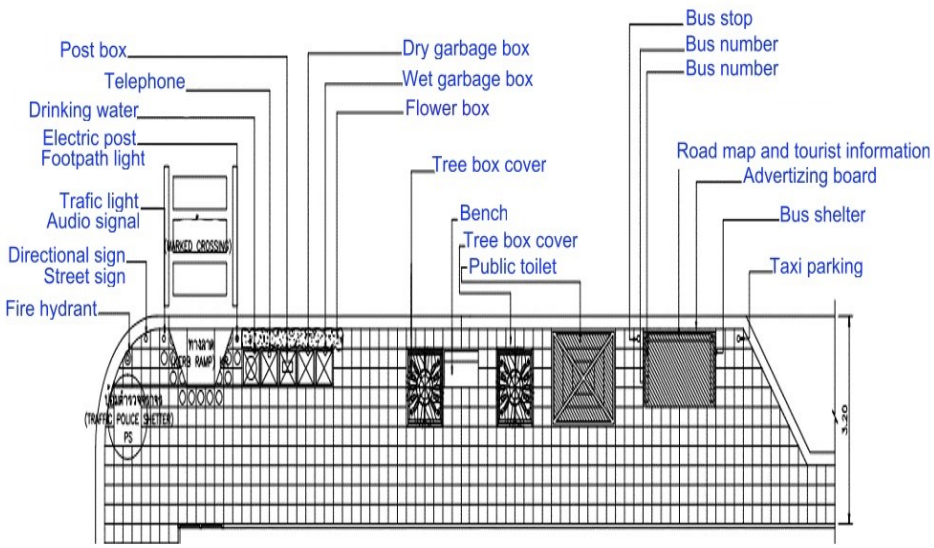
1) The Bangkok Metropolitan Administration always uses the standard pedestrian walkways design (Figure 6). However, the pavement design should be adjusted to suit that area of CNB.

The pedestrian walkways are designed to suit the context of each area. The design of the pedestrian walkway must concern the potential order of the road. The width of the lane, the number of people who use the pedestrian walkways, and the activity of pedestrian users by focusing on each target group. The pedestrian walkways design should be of high quality and contain advantages for the users in CNB.

2) In CNB, several pedestrian walkways are narrow (less than 1 meter wide), uneven, and broken. Many barriers, such as unused telephone booths, power poles, plant pots, billboards, footbridges, and pedestrian crossings, should be eliminated. The space should be flattened to maintain continuity, and large trees should not be planted in the restricted area.

Table 2 Attitudes and needs on the pedestrian walkways improving

Attitudes and needs	Mean	SD
1. The safety of pedestrians		
1.1 When constructing pedestrian pathways, crime prevention should be considered.	3.94	1.88
1.2 Illumination when walking in the dark.	4.33	2.15
1.3 Consideration must be given to pedestrian safety.	4.24	2.18
1.4 Width and slope are standard.	4.27	2.17
1.5 Preventing and resolving homeless problems.	4.21	2.15
1.6 Addressing the issue of insecurity caused by tangled cables.	4.32	2.20
1.7 Large trees on pedestrian paths can be uncomfortable and obstructive.	4.06	2.08
1.8 Sufficient equipment for comfort and safety.	4.30	2.18
1.9 Create a mechanism to address the issue of motorcyclists on pedestrian pathways.	4.36	2.21
1.10 Install a crossing signal for maximum safety.	**4.41**	2.22
2. The environment of pedestrians		
2.1 Appropriate cleaning policy for pedestrian walkways.	**4.27**	2.33
2.2 Strict rules for setting up a store on pedestrian pathways.	3.95	2.03
2.3 Stores are classified into zones.	4.06	2.07
2.4 Landscaping and gardening to maximize vistas.	4.03	2.05
2.5 System for solid waste management and stray dog control.	4.17	2.12
3. The comfort of pedestrians		
3.1 The pedestrian walkways' surface is not smooth.	4.17	2.13
3.2 There is a demand for pedestrian pathways that allow people to stroll freely and rapidly.	4.04	2.07
3.3 A sufficiently wide pedestrian path is required.	3.90	2.03
3.4 Shaded sidewalks with a roof cover surrounding pedestrian paths are required.	3.99	2.05
3.5 The pedestrian pathways must be extended.	4.14	2.11
3.6 Utilities should be maintained in a systematic manner.	**4.22**	2.16
3.7 Passenger lodging at the passenger pick-up location.	4.05	2.21
3.8 Disabled people's accessibility requirements.	4.07	2.20
3.9 The requirement for pedestrian traffic control.	4.09	2.19



Source: Department of City Planning, Bangkok Metropolitan Administration, 2019.

Figure 6 The standard pedestrian walkways design of Bangkok Metropolitan

3) In CNB, there are different activities on both sides of the road. As a result, the management strategy is critical for greater scenery and comfort.

4) Pedestrian pathways and renovations should employ high-quality materials and produce designs that are in keeping with the surrounding architecture's architectural style.

5) In congested areas, crosswalks with a width of at least 2 meters should be built instead of overpasses. To avoid accidents, traffic signs should be installed.

6) Only the required utility places should be aligned.

7) Huge trees should be cleared out of the path of pedestrian routes.

8) The relevant department must be inspected in accordance with the rules and regulations once the construction, renovations, and repairs are done.

9) Public participation should be encouraged in order to coordinate information to government agencies for safety.

According to the attitudes and needs of the people in CNB, we can make the suitable PWM by SCS (S-Safety, C-Comfortable, S-Scenery and Environment) as shown in Figure 7.

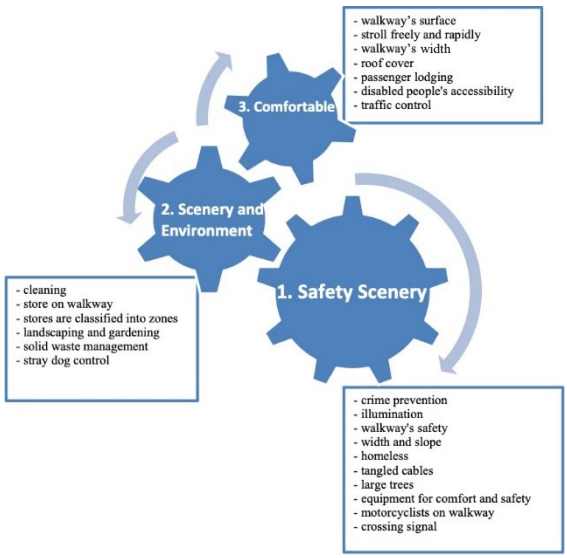


Figure 7 Pedestrian Walkways Model of SCS (S-Safety, C-Comfortable, S-Scenery)

Discussion

The management of walkways is a responsibility of the city so as to focus on assisting people who need to utilize them in order to live in the city in a harmonious manner [19-20]. It also promotes people to exercise and reduces the usage of private and public vehicles as well as the city's energy consumption. It also provides them with the possibility for social connection. According to the study, consumers choose a safe walkway as their first priority, followed by time for nice scenery, and an environment to walk in. Finally, people must be able to stroll comfortably. In Bangkok, there is a traffic congestion problem, particularly with motorcycles that use sidewalks instead of roadways, which have been reported to cause numerous accidents.

Furthermore, there may be limits in persuading urban inhabitants, particularly in Bangkok, to use more walkways, such as the hot climate and air pollution from vehicles on the street. As a result, the city must first address the issue of poor air quality. Pedestrian traffic, particularly during the COVID-19 outbreak, must include steps to limit sidewalk congestion for public safety.

This study can also show that human attitudes and needs are imperative to building utilities, which is consistent with research by Daniel M. Goldstein [21].

According to the evidence in this case study, if these changes are effective, they will result in more extensive regulation of public life and additional restrictions on the freedoms traditionally provided to citizen engagement in public areas.

Citizens' ability to communicate their thoughts and desires will increase governance security. According to Aminah [22], the smart city system's sidewalk transformation was a significant barrier for pedestrians because the transformation as a public site restricted citizens' accessibility [21-22]. These have provided the most efficient mechanism for each country to achieve their goal of administrative simplification in the City Nucleus while preserving appropriate pedestrian and vehicular access [23].

Conclusion

The creation of pedestrian walkways in CNB discovered that people desired the safest pedestrian path, install a crossing signal for maximum safety. The second is appropriate cleaning policy for pedestrian walkways, the third criterion need for development is utilities should be maintained in a systematic manner. However, Bangkok continues to have issues with air quality, particularly the PM-2.5 dust from the city's heavy traffic. As a result, it is one of the reasons why people of CNB avoid using the sidewalk for daily commuting.

Pavement building in Thailand is often done in accordance with standard pedestrian path designs. This study proposes the concept of using the Pedestrian Walkways Model of SCS (S-Safety, C-Comfortable, S-Scenery) to provide a realistic response. The standard pedestrian path designs do not address the needs of pedestrian users. Proposing the idea of developing pedestrian walkways by incorporating people's attitudes and need is thus a very important concept in the development of public utilities in metropolitan areas. Finally, the public will be able to participate in the construction of the pedestrian pattern based on the needs. It will be not only convenient but also beneficial to political stability.

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Performance of Synthetic Urine-Fed Microbial Fuel Cell at Various Substrate Concentrations and Flow Rates

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Abstract

The purpose of this study was to evaluate the performance of microbial fuel cells (MFCs) fed with urine at various substrate concentrations and flow rates. In this work, 3 MFCs were used to process synthetic human urine (SU-D0) and diluted synthetic human urine (SU-D1) at flow rates of 20 L/d (MFC1, HRT=6h), 30 L/d (MFC2, HRT=4h), and 40 L/d (MFC3, HRT=3h). The results showed that MFC2 was the best energy producer (1.221±1.579 mW/m^2 for SU-D0, 0.153 ±0.133 mW/m^2 for SU-D1) and the best nutrient remover due to its maximum removal efficiencies in both SU–D0 (45.6±2.8% for NO_3^-, 41.2±20.0% for NO_2^-, 40.6±12.8% for TN, 36.1±27.7% for PO_4^{3-}) and SU-D1 (39.0±32.4% for NO_3^-, 31.4±10.3% for PO_4^{3-}) conditions. The modified Lineweaver-Burk plot with the determination coefficient (R2) of 0.922-0.975 revealed that the increased substrate loading rate contributed to the higher nutrient removal rate. Furthermore, this study found that the power densities and the removal efficiencies of NO_3^-, NO_2^-, and PO_4^{3-} were positively correlated.

Keywords : Synthetic urine; Microbial fuel cel; Nutrient; Chemical oxygen demand; Removal rate; Power density

Introduction

Human urine mostly comprises 93-96% of water and 4-7% of urea, inorganic salts (chloride, potassium, sodium), ammonia, creatinine, organic acids, and numerous toxins and hemoglobin breakdown products [1]. Udert et al. observed that fresh urine contained 9,200 mg/L total nitrogen, 480 mg/L total ammonia nitrogen, 740 mg/L phosphate, and 10,000 mg/L chemical oxygen demand (COD) [1]. Eighty percent of the nitrogen and fifty of the phosphorus load that enter wastewater treatment facilities come from urine [2], which should be thoroughly removed from wastewater before being discharged into a water source. In Thailand, human waste such as urine and feces is often collected and processed in septic tanks before being released into the ground or wastewater pipelines. Septic tanks can be drained by a municipal service when they are full by pumping the septage out and transferring it to the municipal area's prepared pond. Since source-separated urine can lower the operating costs of wastewater treatment plants (WWTPs) and also help to improve the effluent quality of WWTPs, different European groups began exploring the concept in the 1990s to improve the sustainability of wastewater management [3]. Although human urine in Thailand was not immediately released to wastewater treatment plants or surface water in the environment, it is still better if the nitrogen and phosphorus can be recovered and used at source points. If the human urine was processed independently utilizing microbial fuel cell (MFC) technology, there is also additional benefit, notably ability to harvest electrical energy.

Ieropoulos et al. published the first publications introducing the use of human urine as substrate in MFC systems in 2012 [4]. The benefit of utilizing urine as a substrate for MFCs was shown in this experiment, which ran for more than 11 years [4]. Up to present, it has been proved that MFC-systems fueled by urine can power the low-power equipments such as telecommunication devices [5], LED-lighting systems [6], microcomputers [7] and smart phones [5].

In terms of nutrient removal, the natural transformation of nitrogen and phosphorus-containing compounds during urine hydrolysis was critical. The majority of the nitrogen in fresh urine is urea [1]. During the hydrolysis reaction, $NH_2(CO)NH_2 + 2H_2O \rightarrow NH_3 + NH_4^+ + HCO_3$, urea is broken down to ammonia/ammonium [1]. During this reaction, the pH shifts to more alkaline values between 8.5 and 9.5 [8,] resulting in an increase in ammonia concentration [1]. Because ammonia is volatile, it can easily escape into the atmosphere [1]. Another form of nitrogen in stored urine is struvite ($MgNH_4PO_4 \cdot 6H_2O$) and hydroxyapatite (HAP, $Ca_5(PO_4)_3(OH)$) [9-10] which can deposit at the bottom of the reactor. These processes lower the nitrogen concentration in the urine. In terms of phosphorus removal, 95-100% of phosphorus in fresh urine is in soluble phosphate form [11]. When the pH of the solution rises due to urea hydrolysis, 30-40% of the dissolved phosphorus precipitates as struvite or hydroxyapatite [1, 12-13]. Santoro et al. studied urine-fed microbial fuel cells [1]. The results showed that urea hydrolysis increased ammonium ion concentrations fourfold, while sulfate and phosphorous concentrations decreased due to significant reductions in calcium and magnesium levels [1]. Struvite, potassium struvite, and hydroxyapatite were discovered in the precipitate on the bottom of MFC reactors [1].

Despite the fact that MFC has been demonstrated by numerous groups of researchers to be one of the most effective nutrient removal technologies capable of producing electrical energy during urine treatment, the application of urine-fed MFC in Thailand is not widely pursued. Therefore, this study was planned to provide information on the performance of urine-fed MFCs in terms of both nutrient removal and energy production. In this study, Thai human urine was used as the substrate during the inoculum period, while synthetic human urine was used as the influent during the treatment period.

In a number of MFC studies, flow rate and substrate concentration are major parameters influencing MFC performance. Potrykus et al., for example, observed that increasing the MFC influent flow rate resulted in greater COD removal rates of up to 396 g/(L/d) and higher electric power output of nearly 18 mW/m^2 [14]. Ni et al. had found that the concentration of a selected substrate is positively correlated with the output voltage of MFC and COD removal rate [15]. In order to better understand how urine-fed MFCs function, this study was conducted with the primary goal of evaluating the performance of urine-fed MFCs at various substrate concentrations and flow rates. Higher flow rates and greater substrate concentrations, according to our hypothesis, might lead to increased removal rates and power output. The findings of this study should assist in the development and application of urine-fed MFCs in Thailand.

Materials and Methods

Construction of the MFC systems

As depicted in Figure 1, the authors constructed 3 upflow MFCs. A 10-cm-diameter, 85.4-cm-long PVC (polyethylene) pipe was used to create the anode chamber of each MFC. The anode chamber's media bed, which has a height of 50 cm and a void ratio of 75%, and a total pore volume of 5 L, was built using 1,575 bundles of nylon strands (1.6 mm in diameter, 10 cm long). Each MFC's upper portion has a cathode compartment built on it by joining a 35.4-cm-long PVC reducer junction to the top of the anode chamber without any partitions (Adapted from the work of Sukkasem et al. [16]). The anode chamber was constructed with an outlet port at the top and an inlet port at the bottom. Before being employed as the electrodes, graphite plates (Kimtech Technology Ltd., Part.) underwent pretreatment by being heated at 450 ºC for 30 minutes [17]. The media bed of each anode chamber was equipped with a triangular

graphite plate (20.77 cm^2) acting as an anode. On the water's surface of each outlet port, an ellipse-shaped graphite plate (20.79 cm^2) was positioned as an air cathode.

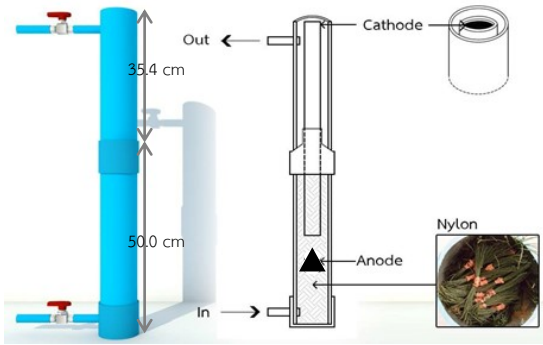

Figure 1 The synthetic urine-fed MFC

Inoculation for Experimental setup

Real human urine was combined in a 1:10 volume ratio with activated sludge collected from the Mahasarakham hospital wastewater treatment plant and stirred for 6 hours. The mixture's supernatant was used as the inoculum after being left in the mixture for 30 minutes. Synthetic urine contained 0.651 g/L of $CaCl_2 \cdot H_2O$, 0.651 g/L of $MgCl_2 \cdot 6H_2O$, 4.6 g/L of NaCl, 2.3 g/L Na_2SO_4, 0.65 g/L of Sodium citrate, 0.02 g/L of Sodium oxalate, 2.8 g/L of KH_2PO_4, 1.6 g/L of KCl, 1.0 g/L of NH_4Cl, 25 g/L of Urea, 1.1 g/L of Creatine, and 10 g/L of Tryptic soy broth [18]. Each MFC was loaded with 12-L inoculum, and the substrate—a combination of 30-L genuine human urine and 90-L synthetic urine—was pumped into each anode compartment. The desired influent flow rates were generated by combining DC dosing pumps (maximum flow rate = 4 L/min, 6.8 bar, 12 V, 3 A, Chao Pra Ya Karn Kaset Co. Ltd) with DC voltage control devices (Chao Pra Ya Karn Kaset Co. Ltd) to reduce the pump power and applying multiple PVC tubes into the feeding lines to create hydraulic resistance. With flow rates of 20 L/d for MFC1 (6-h hydraulic retention time [HRT]), 30 L/d for MFC2 (4-h HRT), and 40 L/d for MFC3 (3-h HRT), the substrate was continuously delivered to the 3 reactors (100 % recycle) for two weeks. The HRTs in this study were calculated based on void volume and flow rate (HRT = void volume/flow rate). Using a multimeter (GW INSTEK Model: GDM - 8255A), electrical voltages (OCVs: open circuit voltages) between the cathode and anode of each MFC were monitored in real time. After the inoculation, each MFC underwent a polarization experiment to determine the suitable external resistor for the MFC system's operation.

MFC System operation

The treatment of synthetic urine by MFC systems was mostly done in a closed electrical circuit in which a cathode and an anode of each MFC were connected to the external resistor defined in the polarization experiment. During the first phase of the treatment, each MFC was fed synthetic urine (SU-D0) continuously for 11 days. Concentrations of COD, NO_3, NO_2, TAN, TN, and PO_4 in SU-D0 were 3,078.8 ± 83.3 mgCOD/L, 2.0 ± 0.2 mgNO_3-N/L, 4.2 ± 1.4 mgNO_2-N/L, 31.4 ± 6.9mgTAN-N/L, 53.8 ± 7.6mgTN/L, and 369 ± 174 mgPO_4-P/L, respectively. The MFCs were operated in open circuit mode for the first 129 hours. At the end of 129 hours, the polarization experiment was performed to select suitable external resistors for the MFCs. The MFCs were then connected to the selected external resistors and performed in a closed electrical circuit from the 130^{th} to 334^{th} h. In the second phase, new suitable external resistors were determined by the second polarization experiment and equipped in the MFCs. The MFCs were then fed continuously for 19 days with diluted synthetic urine (SU-D1, synthetic urine: tap water = 1:1 by volume). Concentrations of COD, NO_3, NO_2, TAN, TN, and PO_4 in SU-D1 were 1,919.1 ± 527.2 mgCOD/L, 1.2 ± 0.7 mgNO_3-N/L, 6.3 ± 1.2 mgNO_2-N/L, 1.8 ± 0.4 mgTAN-N/L, 12.4 ± 3.5mgTN/L, and 27.4 ± 3.0 mgPO_4-P/L, respectively. The flow rates used in both the SU-D0 and SU-D1 treatment periods were the same as those used in the inoculation period, i.e. 20 L/d for MFC1, 30 L/d for MFC2, and 40 L/d for MFC3. Throughout the operation period, influent and effluent samples from each reactor were collected and analyzed for water quality. The multimeter was used to measure the electrical voltage drops across the resistor at each MFC (CCVs: closed circuit voltages).

Polarization test

In this study, a polarization test was performed to determine the external resistor that resulted in the maximum power output for each MFC system. The MFC circuit was closed by connecting an external resistor to a cathode and an anode. CCV values across the resistor were measured for 5 minutes before replacing the current external resistor with a new external resistor with a different resistance value. In the test, the resistance value of an external resistor (R_{ex}) was changed from 51 to 10,000 ohms. The MFC power output (P) was then calculated based on the CCV and R_{ex} values derived from equation (1). The R_{ex} that resulted in the highest P for each MFC system was defined as the suitable R_{ex} and was chosen to be used in the system during wastewater treatment.

$$P = CCV/ R_{ex}^2 \quad (1)$$

Analytical methods and calculation

The following methods were used to analyze water samples: closed reflux, titrimetric method [19] for COD, phenol disulphonic acid method for nitrate (NO_3^-) [20], colorimetric method for nitrite (NO_2^-) [19], closed reflux, nesslerization method for total ammonia ion (TAN) [19, 21], Spectrophotometry using phenol after alkaline peroxodisulfate digestion method for total nitrogen (TN) [22], vanadomolybdophosphoric acid method for phosphate (PO_4^{3-}) [19]. Dissolved oxygen (DO), pH, and oxidation-reduction potential (ORP) were measured using the meters. Wastewater treatment capability was considered from removal efficiencies ($Efficiency_{removal}$) and removal rate ($Rate_{removal}$) shown in equation (2) and (3). C_0 is a pollutant concentration of the influent and C is a pollutant concentration of the effluent. The average value of parameters such as $Efficiency_{removal}$, $Rate_{removal}$, C, and so on was shown with the standard deviation in the form of average value ± standard deviation of the data.

$$Efficiency_{removal} = (C_0\text{-}C)\times 100/C_0 \quad (2)$$

$$Rate_{removal} = (C_0\text{-}C)/HRT \quad (3)$$

For the kinetic analysis of the removal performance, the experimental data were plotted in a modified Lineweaver-Burk model based on the Michaelis-Menten kinetics equation (equation (4) [23]), where Q is the flow rate (L/d), and V is the total volume of the MFC. The regression analysis of the plot defined two constants: U_{max} (the possible maximum removal rate (mg/L·h)), and K_{m*} (the modified Michaelis-Menten saturation constant (mg/L)).

$$V/Q(C_0\text{-}C) = (K_{m*}/U_{max})\ (V/QC_0) + (1/ U_{max}) \quad (4)$$

The external resistor resistance (R_{ex}) and CCV values measured during MFC system operation were used to calculate P (see equation (1)) and power density (PD) (see equation (5)) for each MFC. An anode's projected area is referred to as A_{anode}.

$$PD = CCV/ (R_{ex}^2 \cdot A_{anode}) \quad (5)$$

Results and Discussions

Synthetic Urine Treatment Capability

During the SU-D0 and SU-D1 treatment periods, the pH of the influent ranges between 6.07-8.57, while the pH of the MFC1-3 effluent ranges between 8.35-8.86. The alkaline quality of all effluent and most influent samples implied a high concentration of ammonia nitrogen in un-ionized form [24]. ORP values of -54 to 35 mV and -128 to -3 mV were measured inside the anode chamber during the SU-D0 and SU-D1 treatment periods, respectively. Kim et al. proposed 7.0 as the optimal pH and -250 mV as the minimum ORP level for aerobic denitrification [25]. In comparison to the suggested condition [25], this result suggested the possibility of denitrification within the anode chambers.

COD removal was observed in all MFC reactors, as shown in Figure 2. During the SU-D0 treatment period, COD removal efficiencies ranged from 6.3 to 64.3%, with average values of 30.6±25.0%, 36.8±17.4%, and 46.3±13.9% for MFC1, MFC2, and MFC3, respectively. For SU-D1 treatment, the COD removal efficiencies ranged from -28.6 to 76.4% with the average values of 12.5±30.1%, 30.5±16.4%, and 46.1±13.2% for MFC1, MFC2, MFC3, respectively. The negative removal efficiencies were driven by greater

COD concentration in MFC1 effluents on days 3 (1,627 mg/L) and 5 (1,831 mg/L) than in the influent (1,424 mg/L). This outcome might have been produced by the medium's discharge of microbial biofilm on those days. The removal efficiency of MFC3 (HRT = 3h) appeared to be higher than that of the other two reactors (MFC1, HRT = 6h; MFC2, HRT = 4h). This trend, however, was not statistically supported (paired t-test, 0.05 significance level). The fluctuation in influent concentration (Figure 2-7) in both SU-D0 and SU-D1 conditions may be caused by microbial digestion inside each tank and precipitation, particularly precipitation in the form of struvite.

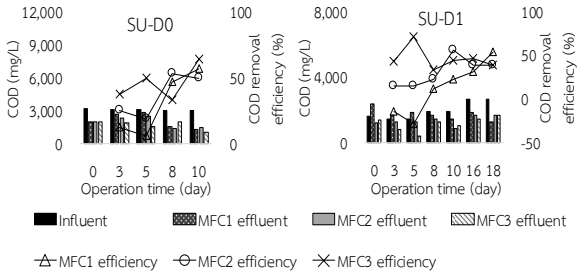

Figure 2 COD removal during the treatment of synthetic urine by MFCs

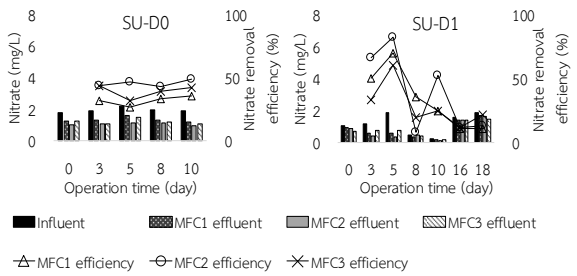

Figure 3 Nitrate and removal during the treatment of synthetic urine by MFCs

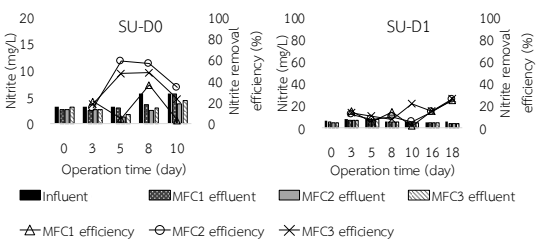

Figure 4 Nitrite removal during the treatment of synthetic urine by MFCs

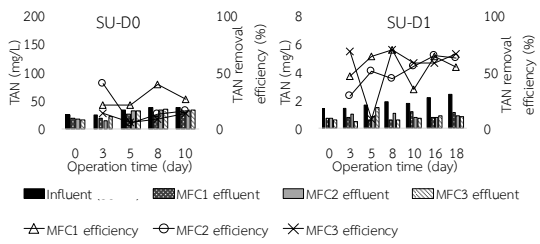

Figure 5 Total amonia nitrogen removal during the treatment of synthetic urine by MFCs

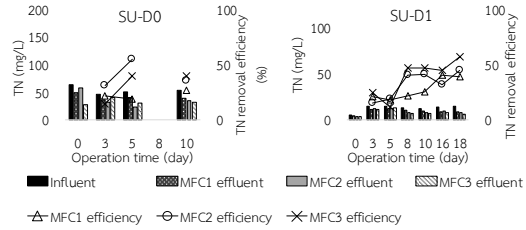

Figure 6 Total nitrogen removal during the treatment of synthetic urine by MFCs

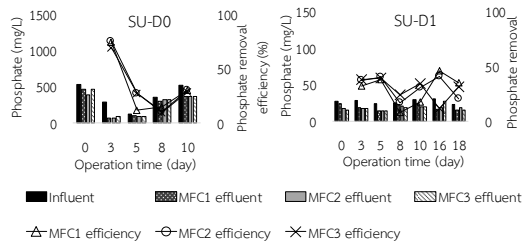

Figure 7 Phosphate removal during the treatment of synthetic urine by MFCs

Concentrations and removal efficiencies of nitrogen compounds and phosphate during the treatment period were shown in Figure 3-7. During SU-D0 treatment period, NO_3^- removal efficiencies ranged from 26.5 to 48.8% with the average values of 32.0±4.0% (MFC1), 45.6±2.8% (MFC2), and 39.2±5.4% (MFC3); NO_2^- removal efficiencies ranged from 3.4 to 58.8% with the average values of 16.5±15.7% (MFC1), 41.2±20.0% (MFC2), and 34.3±15.8% (MFC3); TAN removal efficiencies ranged from 4.9 to 40.2% with the average values of 26.6±8.5% (MFC1), 18.5±15.2% (MFC2), and 10.3±3.9% (MFC3); TN removal efficiencies ranged from 14.6 to 55.1% with the average values of 26.6±8.5% (MFC1), 40.6±12.8% (MFC2), and 31.3±14.4% (MFC3); PO_4^{3-}

removal efficiencies ranged from 10.1 to 75.4% with the average values of 33.2±29.3% (MFC1), 36.1±27.7% (MFC2), and 34.2±25.1% (MFC3).

For SU-D1 treatment, NO_3^- removal efficiencies ranged from 7.7 to 70.2% with the average values of 33.8±23.4% (MFC1), 39.0±32.4% (MFC2), and 28.6±14.4% (MFC3); NO_2^- removal efficiencies ranged from 5.3 to 26.1% with the average values of 12.7±8.4% (MFC1), 12.4±7.1% (MFC2), and 15.9±7.0% (MFC3); TAN removal efficiencies from between 8.2 to 70.0% with the average values of 55.4±13.2% (MFC1), 50.9±13.3% (MFC2), and 54.7±23.3% (MFC3); TN removal efficiencies ranged from 15.0 to 45.0% with the average values of 27.4±9.7% (MFC1), 31.9±12.6% (MFC2), and 38.6±17.0% (MFC3); PO_4^{3-} removal efficiencies ranged from 17.2 to 46.2% with the average values of 29.8±14.1% (MFC1), 31.4±10.3% (MFC2), and 30.2±10.4% (MFC3).

In terms of removal rates, COD and PO_4^{3-} average removal rates increased as influent flow rate (MFC1<MFC2<MFC3) and substrate initial concentration (SU-D1<SU-D0) doubled (see Figure 8). The positive correlation trend between the removal rate and the influent flow rate is consistent with the findings of Mongkulphit et al., who found that higher flow rates resulted in higher pollutant removal rates and higher power densities under linear regression equations with determination coefficients (R^2) of 0.81-0.99 [26].The concordance between increasing substrate initial concentration and increasing removal rate in this study corresponds to the theory of Michaelis-Menten equation [27]. The initial concentration of substrates may provide high enzyme concentration, resulting in high enzyme reaction rates [27]. However, excessive substrate concentrations may cause substrate inhibition, which significantly reduces the hydrolysis rate [28]. This could be one of the reasons why the average removal rates of TAN, NO_3^-, and NO_2^- at SU-D0 were lower than at SU-D1. If the data were individually analyzed in SU-D0 and SU-D1 scenarios, it was discovered that the increase in flow rate caused an increase in the removal rates of NO_3^- and PO_4^{3-}. In the case of low substrate concentration (SU-D1), the TAN removal rate also showed a similar pattern. The previous researches [14, 26] are compatible with this finding as well. The improving mixing condition, which is associated with increasing flow rate, might be the key to higher NO_3^- and PO_4^{3-} removal rates, as well as TAN removal rates under low substrate conditions. Nevertheless, when the flow rate rose, the TAN and NO_2^- removal rates in the SU-D0 condition declined. Sufficient HRT appeared to be the critical factor in achieving high TAN and NO_2^- removal rates in the high substrate condition.

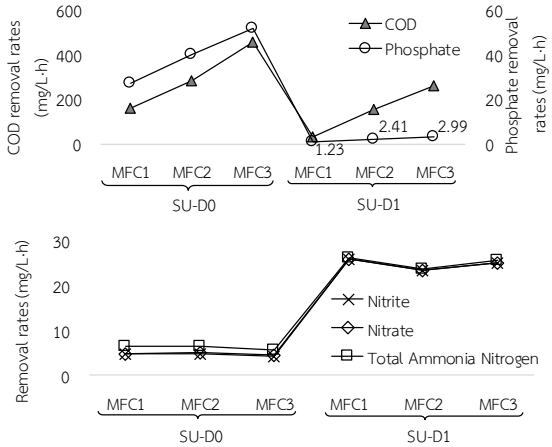

Figure 8 Average removal rates during the treatment of synthetic urine by MFCs

According to MFC literature, nitrogen removal in MFC may occur as a result of 1) the nitrification process at the cathode compartment, in which oxygen gas is used as an electron acceptor in the nitrification process to convert ammonium to nitrite and nitrate, and 2) the electricity generation process, in which both nitrate and nitrite can serve as cathode electron acceptors [29], 3) volatilization of ammonia [30]. Furthermore, the studies indicated that phosphorus could be removed up to 82% by microbial absorption in MFC systems, with 40% recovered by chemical precipitation as struvite at the cathodes [29]. Struvite precipitation [31] is thought to improve electron acceptation at the cathode compartment.

The negative association between NO_2^- and the other pollutants, such as NO_3^-, PO_4^{3-}, and TAN, was revealed by the relationship

between the rates of nutrient removal in Figure 9. Because NO_2^-, NO_3^-, and PO_4^{3-} are cathode electron acceptors and are thought to be largely removed at the cathode surface, they competed with one another. Furthermore, since it was believed that some TAN would be removed through volatilization, a high TAN removal rate would lower the rate at which NO_2^- is produced, which might slow down the process that removes NO_2^-. In order to validate these explanations, additional research is necessary.

Kinetic analysis for COD and nutrient removal

Figure 10 depicts the fitting of our experimental data into the modified Lineweaver-Burk model (= 0.922 and 0.975). The model suggested that a higher substrate loading rate would resulted in a faster removal rate. The equations derived here are helpful in the design of MFCs for treating urine. However, as the components in actual human urine may be 3-4 times greater than those of synthetic urine, further experiments at extremely high substrate concentrations are required before applying the modified Lineweaver-Burk model to develop the human urine treatment process.

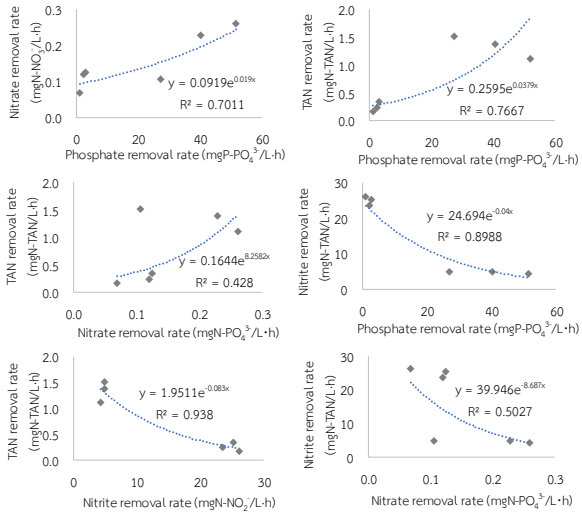

Figure 9 Relationship between average removal rates of each component during the treatment of synthetic urine by MFCs

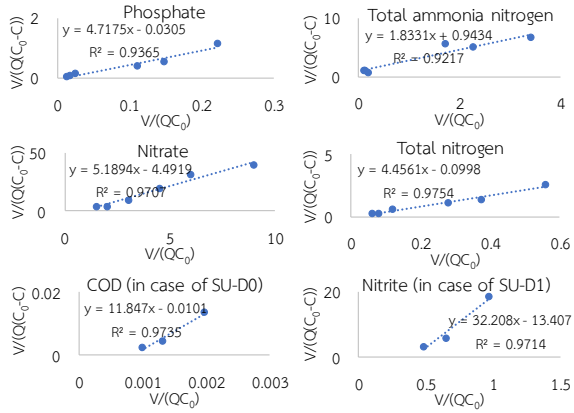

Figure 10 Modified Lineweaver-Burk plot of the synthetic urine treatment using MFCs

Electricity generation Capability

MFCs were operated in an open circuit condition for the first 129 hours of the SU-D0 treatment period. The OCV of 3 MFCs increased from 0.196 to 0.46 V at 24th h to 0.786 to 0.838 V and nearly remained steady from 72nd to 120th h (Figure 11a). A resistor of 10,000 ohms, 1,000 ohms, and 680 ohms was chosen and applied to MFC1, MFC2, and MFC3, respectively, from 130th h to 344th h, based on the results of the first polarization experiment. Throughout the experiment, one side of each resistor was connected to the anode and the other edge to the cathode of each MFC. Figure 11b displays the CCV data obtained during the SU-D0 treatment. The maximum CCV for MFC1 (0.137 V), MFC2 (0.183 V), and MFC3 (0.101 V) appeared at 130th h and 285th h, respectively. In MFC2 and MFC3, the CCV trend was pendulous, whereas in MFC1, it was fairly stable. Due to the suggestion given by the result of the second polarization experiment, 10,000-ohm resistors were added to all MFCs during the SU-D1 treatment period. Figure 11c showed CCV generated by the MFCs during the SU-D1 treatment. When compared to the CCV trends during the SU-D0 treatment period, all MFCs showed considerably lower and more steady trends.

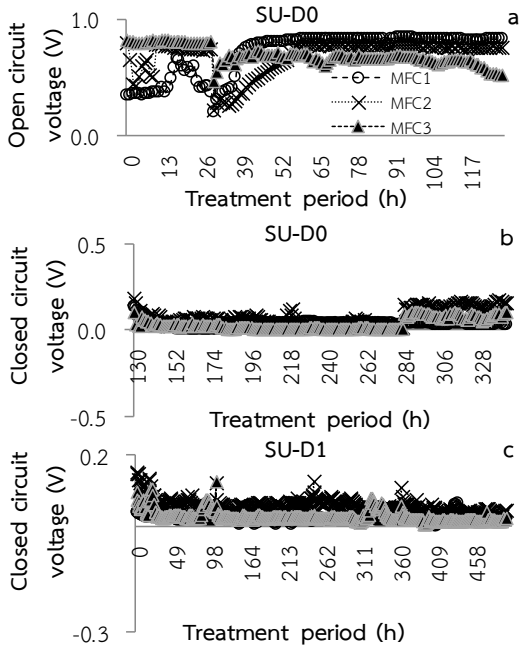

Figure 11 Voltage data collected during the treatment of synthetic urine by MFCs

PD data during the treatment period were displayed in Figure 12. The most powerful generator of electricity was MFC2 (PD = 1.221±1.579 mW/m^2 for SU-D0, 0.153 ±0.133 mW/m^2 for SU-D1), followed by MFC3 (PD = 0.262 ±0.576 mW/m^2 for SU-D0, 0.041 ±0.071 mW/m^2 for SU-D1), and MFC1 (PD = 0.079 ±0.101 mW/m^2 for SU-D0, 0.019 ±0.020 mW/m^2 for SU-D1).

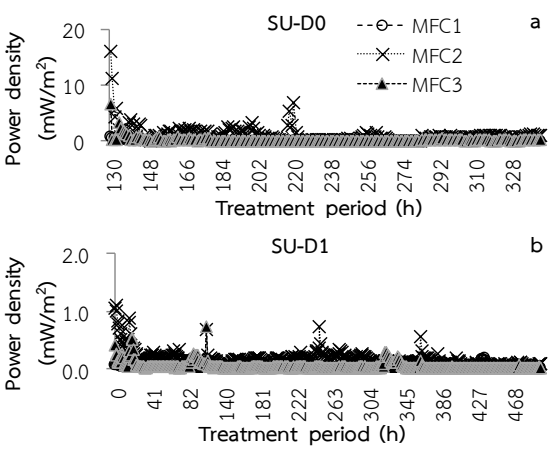

Figure 12 Power density data collected during the treatment of synthetic urine by MFCs

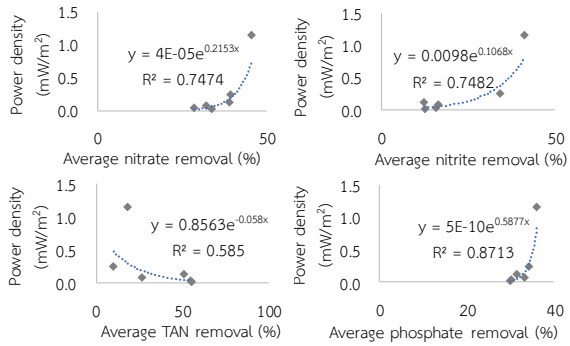

Figure 13 Relationship between power density and removal efficiencies during the treatment of synthetic urine by MFCs

The relationship between PD and the nutrient removal efficiency was explored to provide more understanding. According to the result presented in Figure 13, high power density occurred under the circumstances of high NO_3^-, NO_2^-, and PO_4^{3-} removal efficiencies. One possibility could be that some of their removal processes improved the flow of electrons from the anode to the cathode of MFCs. For instance, NO_3^- and NO_2^- can both serve as cathode electron acceptors [29] and be removed from the influent. Furthermore, electron transport at the cathode surface might be improved by the PO_4^{3-} struvite precipitation reaction [31].

Conclusion

When synthetic human urine was applied to 3 MFCs at 2 levels of substrate concentration and 3 different flow rates, the MFC with the medium level of flow rate (MFC2, 30 L/d, HRT=4h) demonstrated the best performance in both the energy production and nutrient removal aspects. The modified Lineweaver-Burk plot's showed that the substrate loading rate varied in accordance with the nutrient removal rate. As high power density was observed in the condition of high NO_3^-, NO_2^-, and PO_4^{3-} removal efficiencies, the electricity generated by MFCs in this study was considered beneficial for NO_3^-, NO_2^-, and PO_4^{3-}removal.

Acknowledgment

We truly appreciate everyone who has given us the opportunity to perform this research. We were grateful for the insightful guidance provided by Associate Professor Dr. Kanyarat Holasut and Associate Professor Dr. Nattawoot Suwant tota. Finally, we would like to express our gratitude to Mahasarakham University for funding this research project.

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Important Factors Analysis Toward Land Use Development Surrounding the Public Sky Train Station: A case study of the Dark Green Line, Bangkok Metropolitan Administration (BMA)

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Abstract

The area surrounding the public sky train station, in Bangkok is highly dynamic, has many complicated and important factors to response land development according to the sky train lines of urban development, so the study objectives are 1) to study the important factors toward land use development surrounding the public sky train stations in urban and suburb areas, and 2) to study the trend of land use change surrounding the public sky train stations in urban and suburb areas. Asoke and Udomsuk stations represented the urban and suburban areas, respectively. The researchers collected data by field study to survey the physical characteristics of the area around both train stations, following the concept of Transit-Oriented Development (TOD) and using the Multiple Criteria Analysis (MCA) for interviewing 12 experts to assess 10 important factors toward the development of land use around the Dark Green Line stations (BTS). The study results indicated that there were 2 groups of important factors toward land use development around Asoke Station (urban area) and Udomsuk Station (suburb area). For Asoke Station; The main factors were: Factor 9: Criteria announced in the Town Planning Law, Factor 2: Connectivity to housing, workplaces, and other mass transits; Factor 10: The importance of business and trade in the area, and Factor 7: Land and housing prices surrounding the train stations, respectively. Likewise, for Udomsuk Station; The main factors included Factor 9: Criteria according to the Town Planning Law, Factor 10: The importance of business and trade in the area, Factor 2: Connection with housing and workplaces and other mass transits, and Factor 4: The distance to the train station, respectively. The important factor has to be in conformance with town planning clarification. The area surrounding the Asoke station could be a big business development because it is an urban area with high land and house prices and it is the economic center of Bangkok. For the area around Udomsuk station, it could be a small business development as it is a suburban area focused on living and convenience /safety distance travel to the station.

Keywords : land use; sky train; urban; suburban; Transit-Oriented Development (TOD)

Introduction

Bangkok Metropolitan Administration (BMA) is the most populous city in Thailand [1], in 2019 found Bangkok has a population 5,701,394 person [2] because it is the capital, administrative center, education, transportation, banking, commerce, business, various communications, causing people relocate to live in Bangkok. Due to congestion and traffic jams and in the year 1999, the dark green line sky train started to service. As a result, the area surrounding the station must be developed according to the concept of Transit-Oriented Development (TOD) Land development consists of many factors that are important and complex to make the right development decisions. TOD means integrated urban places designed to bring people, activities, buildings, and public space together, with easy walking and cycling connection between them and near-excellent transit service to the rest of the city. It means inclusive access for all to local and citywide opportunities and resources by the most efficient and healthful combination of mobility modes, at the lowest financial and environmental cost, and with the highest resilience to disruptive events. Inclusive TOD is a necessary foundation for long-term sustainability, equity, shared prosperity, and civil peace in cities. [3] Therefore, there has been a study on this issue. By choosing to study the development of land use around 2 stations, represent of urban and suburb area. It has two main objectives: 1) to study the important factors toward land use development surrounding the public sky train stations in urban and suburb areas, and 2) to study the trend of land use change surrounding the public sky train stations in urban and suburb areas. Asoke and Udomsuk stations represented the urban and suburban areas, respectively.

The concept of this study is to developing the area around the mass transit station, Peter Calthorpe, who initiated this idea, said that the concept of developing the area around the transit station means developing the area to mixed use of land with high density and promoting the use of mass transit systems, create a variety of activities in the areas surrounding mass transit stations. There are residences, commercial buildings, offices, and other types of utilization, and designed to support mass transit users, and environment conductive to walking, bicycle lane to have a variety of travel options and reduce private car used [4]. Thanyalak Srirattanachot [5] found that the development of the area around the station according to the concept TOD in the area of 96,000 sq.m. of the Treasury Department of Thailand will develop building connections by designing footpath and bicycle lane for travel. Supachara Jingjit [6] found that the proportion management according to the TOD concept and the analysis of demand, it is a design to promotes easy access with convenient to all activities. Witthaya Duangthima and Chakarin Petcharanon [7] found that the concept of developing the area around the rail mass transit station is an application of TOD's concept to urban areas by promoting stronger land use that leads to the development of public spaces to support future activities as well as increasing the livability in the area, which must consider the factors that will affect residential development, such as density, diversity utilization, design of space conditions, distances to train stations, etc. TOD around the stations e.g. the use of car parking management, bus and traffic management, placemaking of each station, and the appropriate use of land related to people's lives affected to the decision making process for Metropolitan Rapid Transit [8-10]. Atchara Limmonthon [11] study of mass transit development in 4 provinces, Chiang Mai, Phuket, Nakhon Ratchasima, and Phitsanulok, found that the projects have low rate of return on investment because the regional cities are the under developing. Although the cities growth and population have increased continuously. The impacts of the public transport projects are both positive and negative and have the influence of the mass transit station to the change of land use in its surrounding area. According to the result, there was an increase of the residential and large commercial building spaces around the station [12, 13]. Roger & Marion [14] found that there is increasing concern about dependence on the car and the need to improve

the environment in many cities. One approach is to construct new public transport systems. Many of these are being planned and constructed in cities around the world. Oliver & Milan [15] found that Public transport is a key element in cities to meet the transport needs of the population. The current trend in Slovakia shows the preference of individual transport over public transport. However, cities are limited by the possibility of constantly building transport infrastructure. The trend towards building smart cities can positively affect different areas of the city, including transport.

Therefore, this study will select only Asoke station and Udomsuk Station, both of which are located in different areas in the context of urban and suburban areas, but both stations are meaningful stations in the area and it is a station that is very important to the area. The Asok station is in the economic district consisting of shopping malls, large stores, workplaces and investments. For Udomsuk Station in a residential area, small shops.

Methodology

The researcher chose to use urban and suburban areas, with urban areas referring to urban area defined by an area with a population of 10,000 or more, or an area where people gather, houses and important places of that city. In this case, it means the surrounding area around Asoke Station and suburban referring to a residential area that is either a part of a city or an urban area or a residential community that is not very far apart from each other. In this case, it means the surrounding area Udom Suk Station [16].

For this study, the researcher synthesized the factors obtained from the literature review from the TOD concept, Urban resilience Principle concept, case studies from Osaka Station, Shin-Imamiya Station and related research review work makes it possible to determine alternatives for making a choice critical factors analysis toward land use development surrounding the public sky train station: a case study of the Dark Green Line, BMA 10 Factors.

The researchers used the Multiple Criteria Analysis (MCA) for city planners, land developers, socialists, environmentalists, economists, and lawyers to decision making and priotize of land use development issues surrounding Asoke and Udomsuk stations because it is a suitable way to compare factors in such a way that any factor is better than any other. It will inspect 10 factors. Factor 1: Parking area around the station, Factor 2: Connection to residence, workplace and other mass transit, Factor 3: Pedestrian and bicycle land, Factor 4: Distance to the station, Factor 5: Population Density, Factor 6: Housing Density, Factor 7: Land and housing price surrounding stations, Factor 8: Diversity to development for various activities, Factor 9: Criteria according to the announcement of the Town Planning Law, and Factor 10: Importance of business and trade in the area. The evaluation criteria are as follows:

0 point means the same factors do not affect the comparison.

1 point means the factor is less important than the comparative factor.

2 points mean that the two comparable factors are of equal importance.

3 points mean that the factor is more important than the comparative factor.

After that, the total score of each factor were summed and divided into groups which are more than 80% and less than 80%.

For research tools, including an MCA assessment form for an interview with a sample of 12 people and surveying the physical characteristics of the two areas within a radius of 800 meters around Asoke and Udomsuk stations.

Result and Discussion

Physical characteristics of the area

1. Asoke station

The area surrounding the station is for parking. There are many Park and Ride near Asoke station which hourly, daily and monthly [17]. Because of connected to housing, workplace, and other public transportation between condominium, hotels, workplaces, department stores, shops, restaurant, sky train stations, bus stops and Sukhumvit Line MRT

(subway) [18]. But have no bicycle lane which in the future may need because it one of the important thoroughfares according to the concept of developing the area around the mass transit station, including the TOD concept, has set a development area of about 800 meters for the city around the mass transit station as a high-density area. There is a mixed use of the building. and encourage traveling on foot. From survey, it found that throughout the distance traveling to the Asoke station within 800 meters, there was a mixed use of buildings, including commercial buildings, and residential buildings. shopping malls, schools, shops, and restaurants, make the traffic comfortable. For population density and the density of housing and workplaces was found to be very dense around Asoke Station.

Because of Central Business District (CBD) of Bangkok. make both Thai people and foreign residents or activities in this area continuously. The area along Sukhumvit Road is one of the areas with the highest of foreign residents in Bangkok. Employed at September 2020 about 80,991 foreigners who come to work and live in the Asoke area. For this reason, the land and housing price around the sky train station is rising accordingly. The various development of the area to be various activities, as well as the increase of business and trade. The various development can be shown in Figure 1.

In addition, from the map showing land utilization around Asok Station, 3.50 square kilometers, it was found that land use was used for residential purposes such as condominiums, detached houses, and apartments, represented in yellow, the total area is 1.59 square kilometers, representing 45.47 percent of the total area, followed by the use of land for other activities instead of white, using an area of 0.63 square kilometers, representing 18.07 percent of the total floor use the land for commerce, represented in red, using an area of 0.60 square kilometers, representing 17.09 percent of the total area It can be noticed that commerce exists in almost every alley of the area, because Asoke is an area with office buildings, large shopping center and diverse sources of work. Later, the use of land for government institutions and other public facilities was represented in blue, taking up an area of 0.22 square kilometers, representing 6.39 percent of the total area mixed use of land, represented by red and yellow occupying an area of 0.18 square kilometers, representing 5.22 percent of the total area use of land for educational institutions such as Wattana Wittayalai School, etc., is replaced by dark green, occupying 0.15 square kilometers of land, representing 4.41 percent of the total floor use of land for recreation, such as Benjakiti Forest Park, etc., is represented by light green, occupying 0.08 square kilometers of land, representing 2.40 percent of the total area land use for religious institutions, such as temples, Christian churches, are represented in gray, taking up an area of 0.02 square kilometers, representing 0.61 percent of the total area and land use for public utilities represented by blue and red, using an area of 0.01 square kilometers, representing 0.3 percent of the total area. (Figure 2)

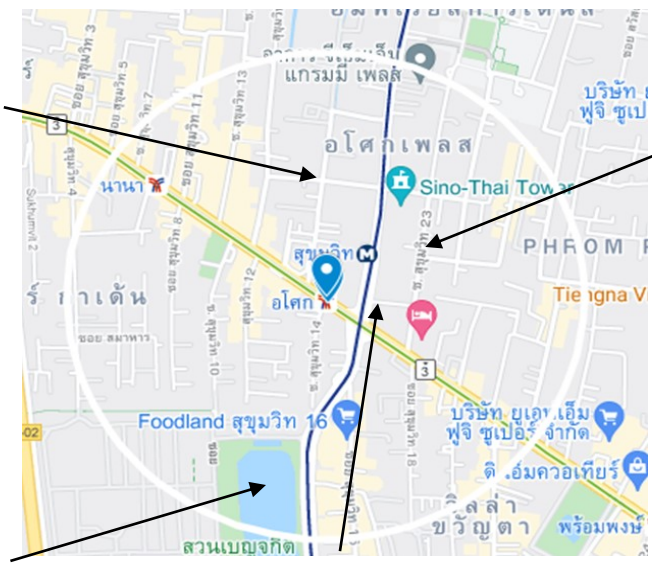
2. Udomsuk Station

The area surrounding the station is space for parking both cars and motorcycles. As well as being connected to housing, workplace and other public transportation. A type of mass transit that found in the suburbs but not found in the urban area is a small minibus. Travel to Udomsuk station it more difficult than Asoke area because the traffic not comfortable. Especially along the alleys in the community, it was found that there were no sidewalks or bicycle lane, therefore, it is necessary to use a motorcycle, taxi to other public transportation. It was found housing density denser than workplace, because around Udomsuk Station is a residential area with detached houses, townhouses, condominium, dormitories, apartments, include many communities such as Mahasin Market Community, Thanin factory. The land and housing price around Udomsuk station is not high compared to the Asoke area. There is also various to activities develop. Due to it a residential area, there are shops, markets, gold shops, pawnshops, and department stores. The variety of development in the Udomsuk area can be shown in Figure 3.

In addition, from the map showing land use around Udom Suk Station. There are a total of 7,407 buildings, consisting of land use for

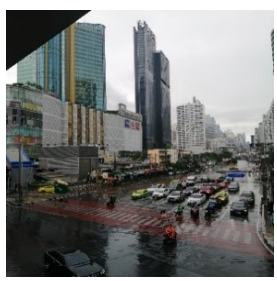
residential purposes the most, represented by yellow, 5,664 houses, accounting for 76.47 percent of the total building utilization, represented by red and yellow, 839 houses, accounting for 11.33 percent of all building utilization. Commercial building utilization, represented by red color, amounting to 431 units, accounting for 5.82% of the total building utilization. industrial use of buildings Represented by purple, 120 houses, accounting for 1.62 percent of all building utilization. Utilization of buildings for educational institutions Represented by dark green, 107 houses, accounting for 1.44 percent of all building utilization. Utilization of buildings for warehouses, represented by pink, 74 houses, accounting for 1.00 percent of all building utilization. Building use for other purposes is represented by white, accounting for 0.99 percent of the total building use. Utilization of buildings for religious institutions, represented by 51 units in gray, representing 0.69 percent. Utilization of buildings for government institutions and other public facilities, represented by blue, amounting to 38 units, representing 0.51 percent of all building utilization. Utilization of buildings for public utilities Represented by blue and red, 6 houses, accounting for 0.08 percent of all building utilization. and the use of buildings for recreation, represented by 4 light green houses, accounting for 0.05 percent of all building utilization. (Figure 4)

Sukhumvit 19
- Entrance to Terminal 21
- Near Sky Train station
- Many entrance and exit, including Soi Nana, Phetchaburi, and Sukhumvit 19



Sukhumvit 23
- Near Srinakharinwirot University and Demonstration School, Srinakharinwirot University
- There are many restaurants and accommodation.
- 2-lane road.

Benchakitti Park



Sukhumvit 21
4 – 7 lanes of road, a lot of office buildings and exit to Kamphaeng Phet Road

Figure 1 Areas around Asoke Sky Train Station

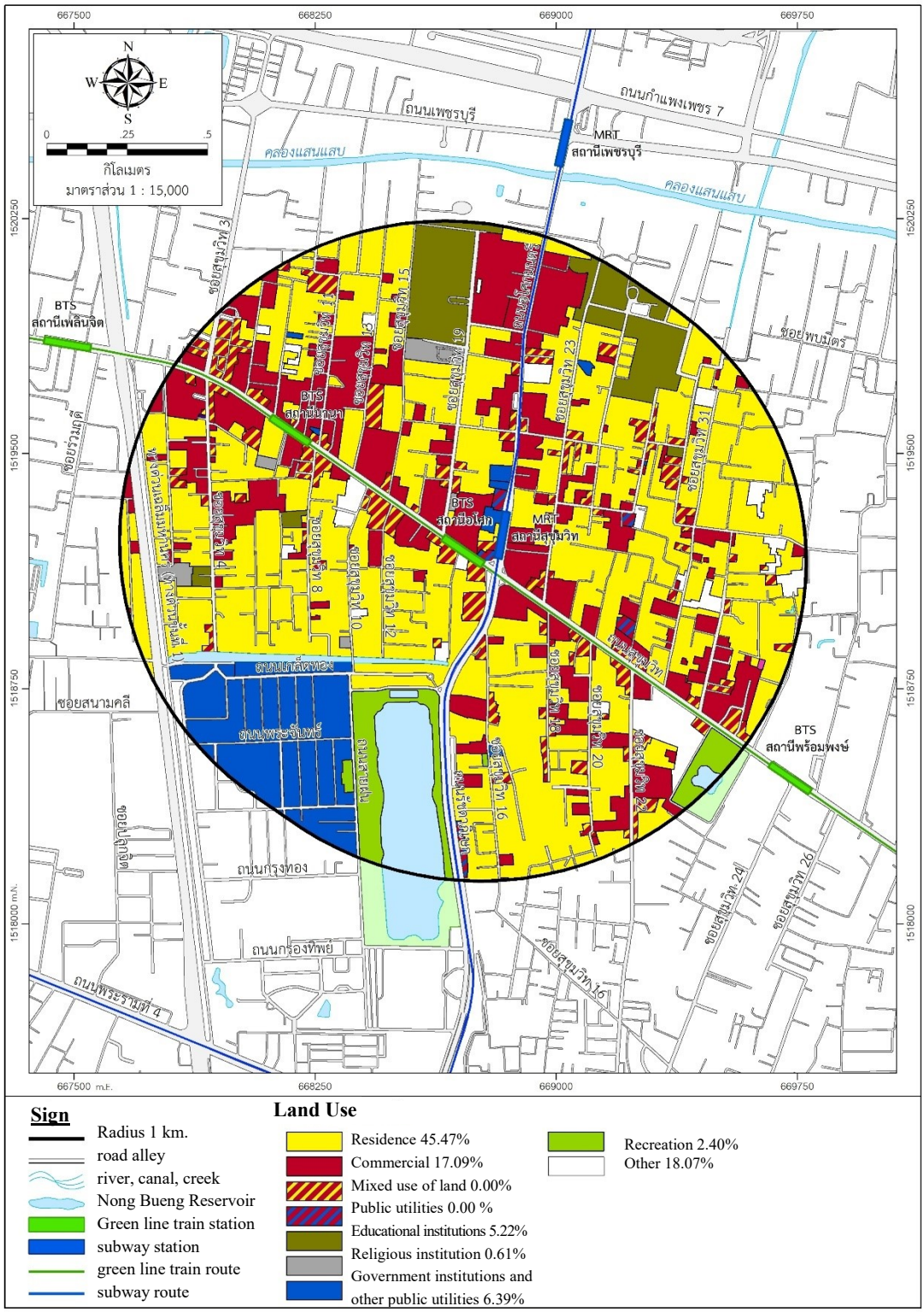


Figure 2 Map of building utilization around Asoke Sky Train station, scale 1 : 15,000 in 2020
Source: Huai Khwang District Office, 2020

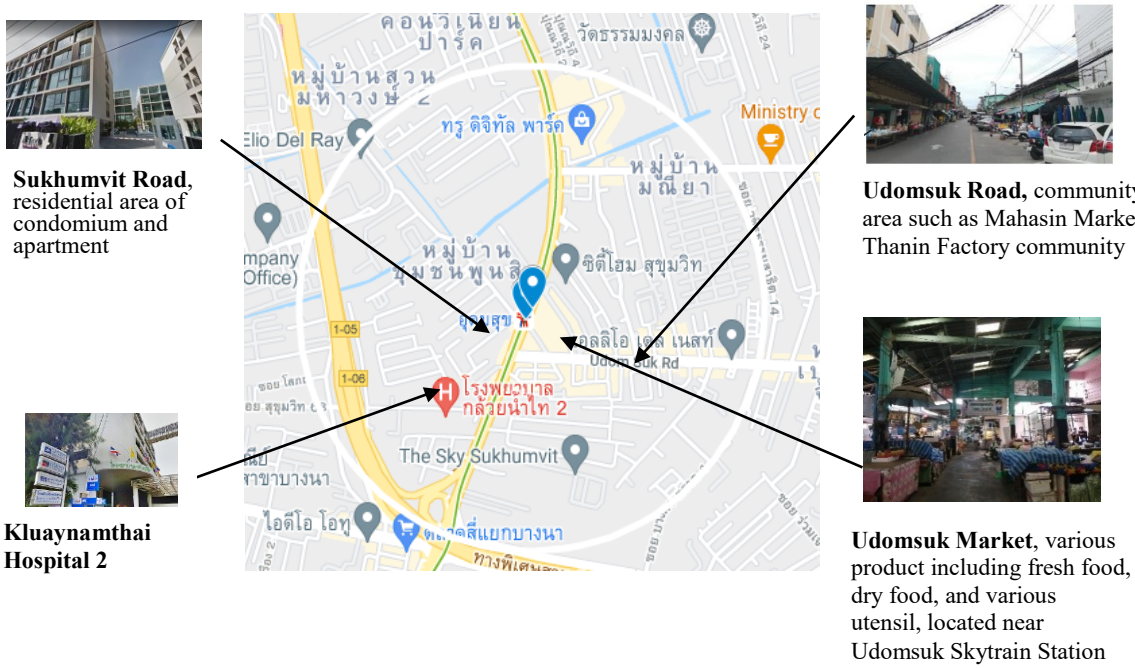


Figure 3 Areas around Udomsuk Sky Train Station

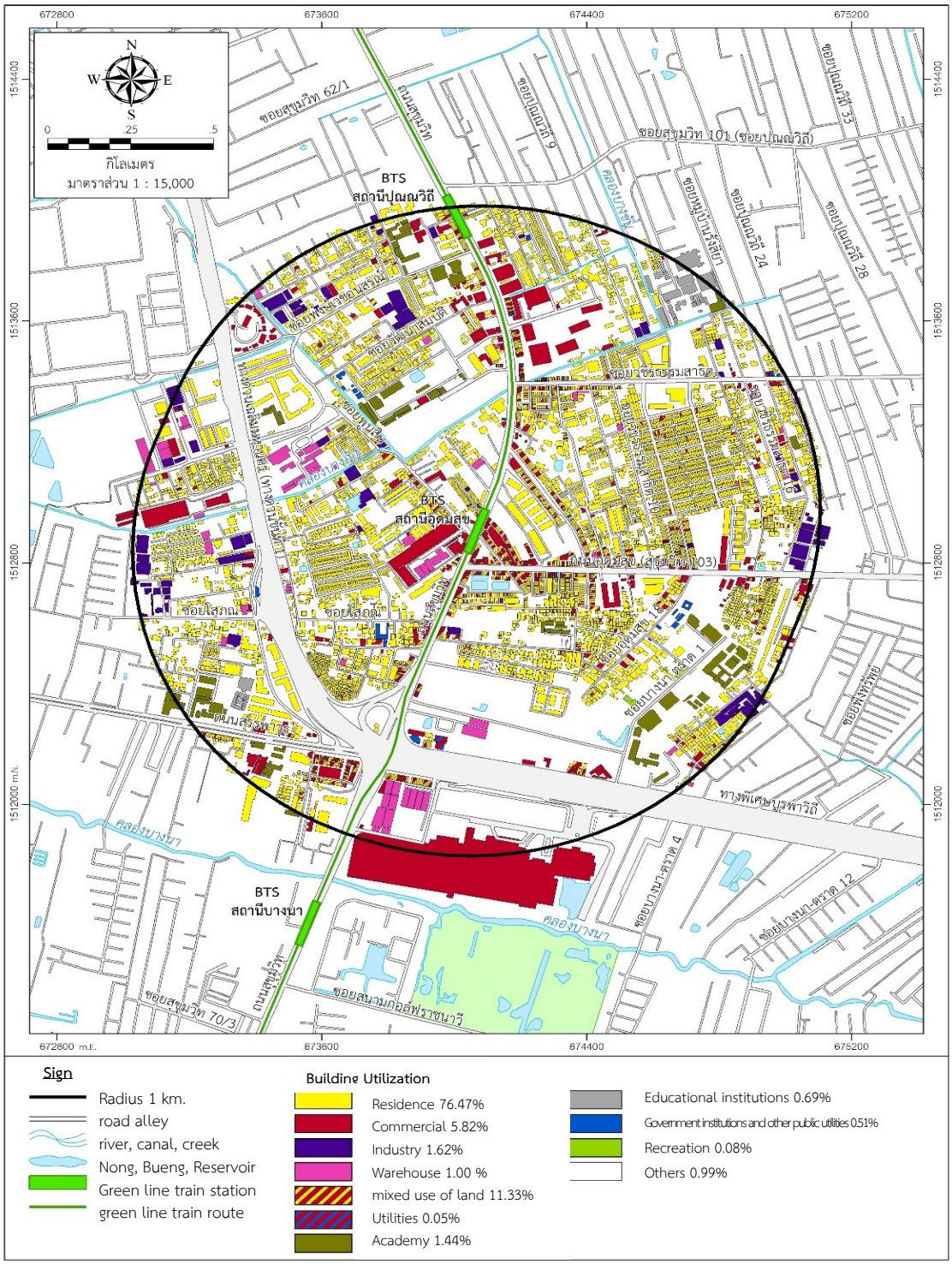


Figure 4 Map of building utilization around Udomsuk Sky Train Station, scale 1 : 15,000 in 2020
Source: Bagna District Office, 2020

Multiple Criteria Analysis (MCA) results by experts

Asoke Station

The study found that the important factors for land use development surrounding the urban dark green line station were divided into 2 groups, which the study used the expert assessment scores compared with total score. Factors with and average more than 80% of the total score is the main factor contributing to the development and the factor with an average of less than 80 percent of the total score is minor factors to development are as follows:

1) The main factors to development are the Factor 9: Criteria announced by the town planning law (95.19 percent of the total score), Factor 2: Connection to housing, work sources, and other mass transit and Factor 10: Business and trade importance in the area (83.70 percent of the total score equal), and Factor 7: Land and housing price surrounding the station (81.48 percent of the total score)

2) Minor factors to development, Factor 3: Footpaths and bicycle lane and Factor 4: The distance to the train station (77.78 percent of the total score equal), Factor 5: Population density and Factor 6: Housing density and workplace (77.04 percent of the total score equal), Factor 8: Diversity to development the area for various activities (76.30 percent of the total score) and Factor 1: Parking area around the station (72.22 percent of the total score), respectively, as shown in Table 1.

Udomsuk station

Factors that are important to the development of land use around dark green line suburbs stations was divided into 2 groups based on the same criteria as the urban dark green line station (Asoke Station) are as follows:

1) The main factors to development are the Factor 9: Criteria announced by the town planning law (97.41 percent of the total score), Factor 10: Business and trade importance in the area (86.67 percent of the total score), Factor 2: Connection to housing, work sources, and other mass transit (83.33 percent of the total score), and Factor 4: The distance to the train station (81.85 percent of the total score), respectively.

2) Minor factors to development, Factor 8: Diversity to development the area for various activities (78.52 percent of the total score), Factor 3: Footpaths and bicycle lane and Factor 6: Housing density and workplace (77.41 percent of the total score equal), Factor 7: Land and housing price surrounding the station (75.19 percent of the total score), Factor 1: Parking area around the station (73.33 percent of the total score), and Factor 5: Population density (70.37 percent of the total score) respectively, as shown in Table 2.

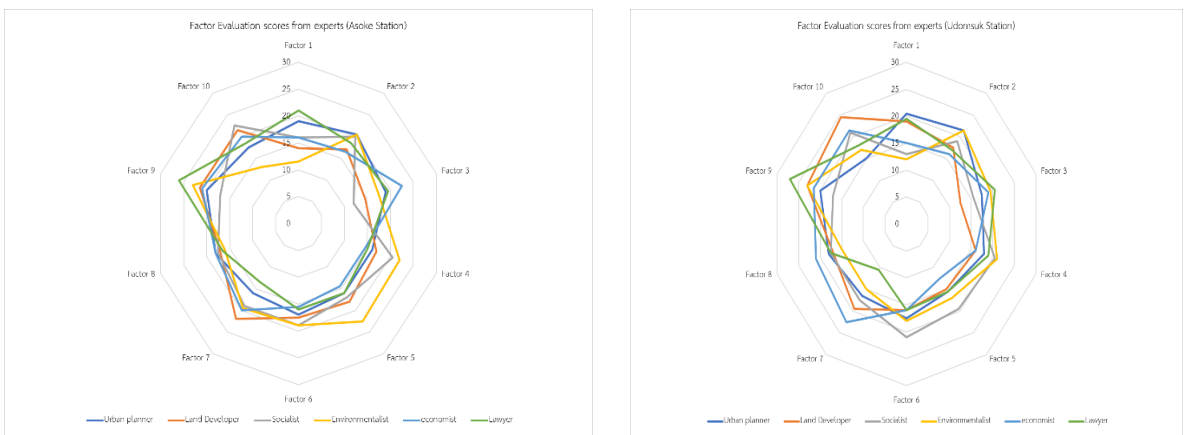
Table 1 Scores of factors that important to land use development surrounding Asoke station

NO.	Experts	Factors									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Urban planner (1)	14	25	22	17	21	19	18	17	16	11
2	Urban planner (2)	24	16	16	15	11	15	14	19	24	24
3	Land Developer (1)	11	17	11	17	16	17	21	18	26	26
4	Land Developer (2)	17	17	18	17	20	18	23	16	17	17
5	Socialist (1)	16	17	14	18	17	20	19	20	19	20
6	Socialist (2)	16	23	10	23	17	18	19	15	15	25
7	Environmentalist (1)	12	17	22	21	22	19	21	22	21	12
8	Environmentalist (2)	11	24	13	23	23	19	18	10	25	14
9	economist (1)	23	13	24	10	17	18	18	15	21	21
10	economist (2)	9	20	21	19	12	13	22	21	21	19
11	Lawyer (1)	19	19	18	12	18	18	13	18	27	18
12	Lawyer (2)	23	18	21	18	14	14	14	15	25	19
Total		**195**	**226**	**210**	**210**	**208**	**208**	**220**	**206**	**257**	**226**
Percentage of total score		**72.22**	**83.70**	**77.78**	**77.78**	**77.04**	**77.04**	**81.48**	**76.30**	**95.19**	**83.70**

Table 2 Scores of factors that important to land use development surrounding Udomsuk station

NO.	Experts	Factors									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	Urban planner (1)	26	23	23	17	19	17	17	14	15	9
2	Urban planner (2)	15	20	12	19	12	18	16	22	25	21
3	Land Developer (1)	22	17	12	15	14	18	17	18	23	24
4	Land Developer (2)	16	18	13	17	16	14	22	16	23	25
5	Socialist (1)	17	17	19	17	17	23	21	14	18	20
6	Socialist (2)	9	21	12	24	22	19	14	21	16	22
7	Environmentalist (1)	13	21	19	20	21	19	15	16	19	15
8	Environmentalist (2)	11	22	20	22	13	17	15	14	27	19
9	economist (1)	13	13	17	13	14	17	24	23	23	23
10	economist (2)	17	19	21	19	11	15	21	19	20	20
11	Lawyer (1)	15	19	18	18	17	17	12	18	27	19
12	Lawyer (2)	24	15	23	20	14	15	9	17	27	17
	Total	**198**	**225**	**209**	**211**	**190**	**209**	**203**	**212**	**263**	**234**
	Percentage of total score	**73.33**	**83.33**	**77.41**	**81.85**	**70.37**	**77.41**	**75.19**	**78.52**	**97.41**	**86.67**

The scores to be displayed with a Radar Chart to showing the views of experts in each field on what factors are important to the development of the areas surrounding the 2 stations. The results showed that Asoke station, the graphs are skewed towards Factor 9: Criteria announced by the town planning law, Factor 2: Connection to housing, work sources, and other mass transit, Factor 10: Business and trade importance in the area, and Factor 7: Land and housing price surrounding the station, respectively. For the area around Udomsuk Station, curves that are skewed towards Factor 9: Criteria announced by the town planning law, Factor 2: Connection to housing, work sources, and other mass transit, Factor 10: Business and trade importance in the area, and Factor 4: The distance to the train station, respectively, as shown in Figure 5.



(a) Asoke station (b) Udomsuk station

Figure 5 Scores of key factors affecting land use development surrounding (a) Asoke station and (b) Udomsuk station

It found that the factors that experts give priority to the land use development around the 2 stations accordance with the concept of TOD that wants to promote the connection of various modes of transportation. In order to have a quick and comfortable travel. As well as the distance to the station is also important to the development of the area. It accordance with Chookiat Salakkham [19] or the use of transportation as a catalyst for new development by placemaking around the station [20]. Importantly, the area development around the mass transit station needs consider to the criteria announced by the town planning law, accordance with Sarit Tiyawongsuwan [21] who has studied the Criticizing transit oriented development patterns between original concept and Khon Kaen comprehensive plan act found that the determination of land use in the Ministerial Regulations of Town Planning all affects the conditions for design and development of the town plan. In addition, Area around Asoke Station, which is representative of the urban area, experts focus on land and housing prices around the station accordance with the Charoensuk Wannapha [22] who said that the changes in the city parallel the Bangkok Mass Rapid Transit Green Line, Asoke section, are housing price and land price and the distance to the stations. Therefore, the main difference of the two stations is the price of land, especially stations in urban areas. The land price has a greater effect on the area development than suburban stations.

Therefore, from the expert assessment, the trend of land use around the Asoke station would be for business purposes in the area as a large business suitable for investors. Because the price of land and housing in this areas are high, taking into account the connection between housing, workplace and various of public transportation. Most importantly, it must comply with the criteria according to the town planning law announcement. For the trend of land use around Udomsuk stations will be for doing business and various trades, but as a small business to suit the physical characteristics and the role of the area that is a residential area taking into account the connection between residence, workplace and various of public transportation, as well as the distance to the station will be more convenient and safer Most importantly, it must comply with the criteria announced by the town planning law.

Conclusion

Important factors analysis toward land use development surrounding the public sky train stations: A case study of the Dark Green Line, Asoke and Udomsuk station in expert opinions that are according with TOD concept and the physical characteristics obtained from the survey are Factor 9: Criteria announced by the town planning law, Factor 2: Connection to housing, work sources, and other mass transit, and Factor 10: Business and trade importance in the area. Therefore, the trend of changing land use around the 2 stations is expected around the Asoke station, it will be developing the area to connections between residences, workplace and other public transportation. Asoke is an important economic area of Bangkok suitable for investing in real estate, including condominium, offices, shops, as well as doing business because of the land and housing prices are high. For the trend of land use around Udomsuk station, developing the area to have a connection between residences, small shops, markets and local public transportation such as such as minibuses in the form of small minibuses. Including the distance to the station must be convenient and safe must strictly comply with the town planning law in order to develop correctly and continue to be appropriate.

This study is a study by integrating spatial data, theories, concepts, and opinions of experts in various fields. In addition, additional information is also needed in order to maximize the efficiency of urban development, such as comparing and extracting lessons from case studies, public hearings study of government area development policies, etc.

So, the benefits of this study are the key factors in the development of land use around the Dark Green Line stations in urban and suburban areas can be used as data for potential land use development and use the results from this study to be used as information or guidelines for the development of other areas

of the mass transit system in Bangkok or other provinces.

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Application of Analysis of Variance for Vitamin B Injection Solution Defectives Reduction in the Pharmaceutical Industry

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Abstract

The objective of this research was to study the defectives reduction in the aseptic filling process in the pharmaceutical industry. The major nonconforming problem was the soot particles on the inner surface of vitamin B injection solution tube in the aseptic filling process. Analysis of Variance (ANOVA) was applied to determine factors, which had a significant effect on defectives percentage and the optimal levels of the factors to reduce defectives percentage. For experimental design, a Completely Randomized Design (CRD) was generated with 3 factors as follows: 1) needle type 2) needle position and 3) machine speed. According to the Analysis of Variance (ANOVA), needle type factor had a significant effect on defectives percentage. From the interval plot, the 95% confidence intervals of defectives percentage of vitamin B injection solution aseptic filling problem occurred by the two needle types were not overlapped. Therefore, the mean defectives percentage produced by the proposed type 1 needles was significantly less than the mean defectives percentage produced by the type 2 needles of the case study. Additionally, it was found that when the proposed type 1 needles were used, the mean defectives percentage was 4.25%. The mean defectives percentage of the current process using the type 2 needles was 15.90%. It can be concluded that when the proposed type 1 needles were used after the improvement, the mean defectives percentage decreased by 11.65%.

Keywords : Analysis of Variance; Design of Experiments; Defectives Reduction; Pharmaceutical Industry

Introduction

Waste management is a concept that focuses on the waste problems and includes different strategies to manage sustainably waste. These sustainable solutions include Refuse, Reduce, Reuse, Repurpose and Recycle. The 5R's Concept (Refuse-Reduce-Reuse-Repurpose - Recycle) is a sequence of steps on how to manage waste properly. **Refuse** can be explained as deny what is not needed, **reduce** refers to the reduction of wasteful and non-recyclable materials, and by reducing waste, we reduce production costs and avoid the unnecessary use of the resources such as materials, energy and water, **reuse** is about using again what is consumed, **repurpose** involves taking items that were meant for one purpose but can be used for other ones, and **recycle** is about turning something to a new product that might suffer a decrease in quality [1]. Refuse is the first step of the 5R process. It is the leading principle that urges us to refuse anything we don't really need; however, in this case study of a pharmaceutical company, vitamin B injection solution is the important product and it is necessary to treat a vitamin B deficiency. A deficiency in vitamin B can lead to various health problems, ranging from fatigue to permanent neurological problems. The top priority is Reduce, which is to reduce waste generation from the production process. Most of the production of waste should be reduced from the beginning. The main priority is always to reduce and prevent the waste generation from the manufacturing process (Reduce) [2]. The

objective of this research is to prevent the waste generation and reduce the percentage of defectives from aseptic filling process in the pharmaceutical industry. Vitamin B injection solution is the important product of the case study pharmaceutical company. Vitamin B helps our body use fat and carbohydrates for energy and make new protein. It is also important for normal blood, cells, and nerves. Most people get enough vitamin B in their diet, but a vitamin B deficiency may occur in certain health conditions such as poor nutrition, stomach/ intestinal problems, infection and cancer. Serious vitamin B deficiency may result in anemia, stomach problems, and nerve damage [3]. The nonconforming products data of the aseptic filling of vitamin B injection solution was collected and analyzed. It was found that the soot particles on the inner surface of vitamin B injection solution tube problem was the most important defectives problem.

According to the aseptic filling process of vitamin B injection solution, the Pareto chart was used to analyze and display in Figure 1 [4]. The most important nonconforming problem was the soot particles on the inner surface of vitamin B injection solution tube problem (90,879 tubes or 58.7%). The second major problem was the aseptic filling process contamination (39,069 tubes or 25.2%). There were 10,403 nonconforming tubes (6.7%) and 8,032 tubes (5.2%) occurred from vitamin B tube crack and seal leakage problems. Other defectives are 6,350 tubes (4.1%). According to the most important problem which was soot particles on the inner surface of vitamin B injection solution tube, the root cause was the inappropriate aseptic filling machine setup. Design of Experiments (DOE) was applied to the pharmaceutical industry in many case studies [5]. DOE was used to determine the optimal level of machine setup [6]. Analysis of Variance (ANOVA) was used for the study of the aseptic filling machine setup effects on the mean defectives percentage from the vitamin B injection solution aseptic filling process.

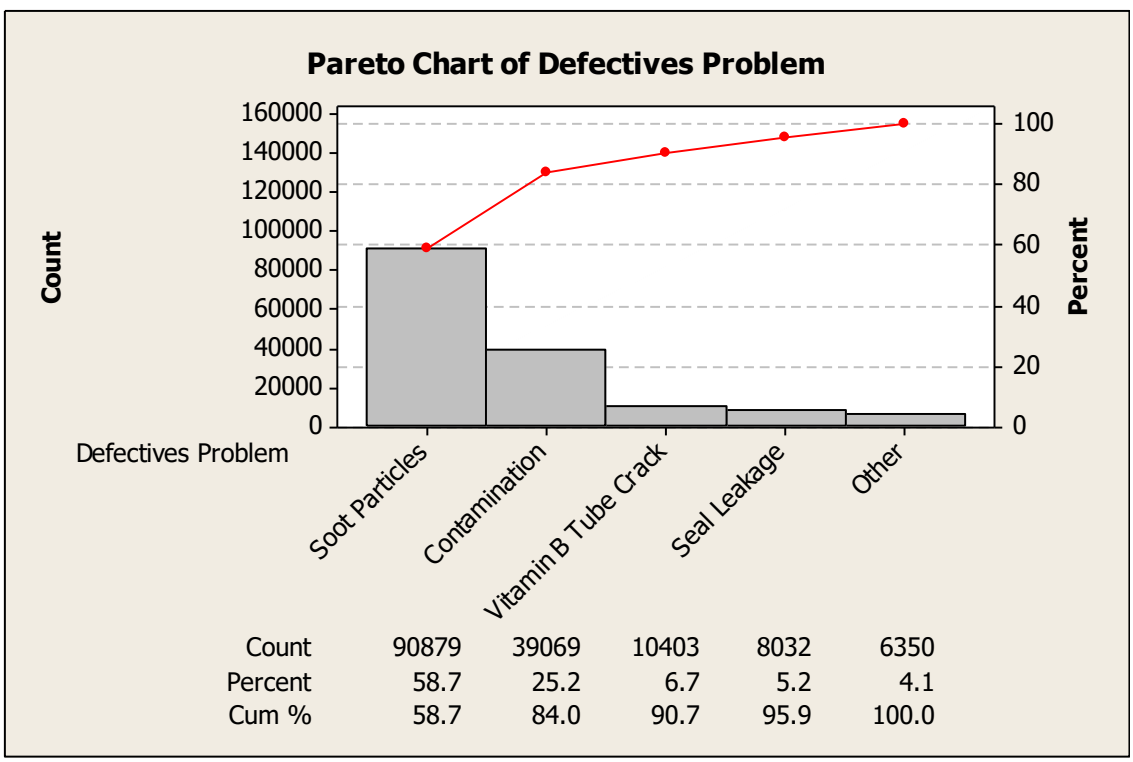

Figure 1 Pareto chart for nonconforming parts of the aseptic filling process in the case study pharmaceutical company

Methods

Design of Experiments (DOE) mathematical methodology used for planning and conducting experiments as well as analyzing and interpreting data was obtained from the experiments [7]. It was used for conducting scientific studies of a system, process or product in which input variables (Xs) were manipulated to investigate its effects on measured response variable (Y) [8]. Design of Experiments is statistical tool deployed in various types of system, process and product design, development and optimization. It has been a very useful tool traditionally used to improve product quality and reliability [9]. The usage of DOE has been expanded across many industries as part of decision making process along with a new product development, manufacturing process and improvement. It is not used only in engineering areas but it has also been used in administration, marketing, hospitals, plastic parts, food, pharmaceutical industry [10], energy, and architecture [11, 12]. Research work flow can be classified as follows:

1. State the objectives – it is a list of problems that are going to be investigated. In this research, Analysis of Variance (ANOVA) was used to study of aseptic filling machine setup effects on the mean defectives percentage of vitamin B injection solution in the aseptic filling process. The optimal level of machine speed, needle type, and needle position was analyzed and experimented.
2. Response variable definition – this is measurable outcome of the experiment that is based on defined objectives. The percentage of defectives from the vitamin B aseptic filling process was the response variable.
3. Determine factors and levels – selection of independent factors that have a significant effect on the response variable. To identify factors (machine speed, needle type, and needle position) that may affect the response variable (defectives percentage).
4. Determine Experimental Design type – a completely randomized design (CRD) was applied and planned.
5. Perform experiment using design matrix.
6. Analyze data - using the Analysis of Variance (ANOVA) statistical method.
7. Make conclusions and recommendations - using graphical representation of the results.

A Completely Randomized Design (CRD) of three factors experiment was applied for the optimization experiment. ANOVA was used for the analysis of factors (machine speed, needle type and needle position) affecting on the percentage of defectives. The type 2 needles were used before this research was conducted. Therefore, the unsuitable type of needles caused the soot particles on the inner surface of vitamin B injection solution tube problem. There were three machine speed levels, which were 8 pieces per minute, 10 pieces per minute, and 12 pieces per minute. There were two needle types including type 1 and type 2. The two needle position levels which were 0 mm and 3 mm above the vitamin B level in the vitamin B injection solution tubes were tested.

Results and Discussion

The experimenter should carefully choose a model before collecting data. The assumptions of ANOVA including normality, constant variance, and independence assumptions should be checked before the ANOVA is applied [13]. This is typically done by residual plots. Plots of residuals typically show trends more readily than plots of the response values [14]. Therefore, normality, constant variance, and independent assumptions were tested in the model adequacy checking as shown in Figure 2, Figure 3, and Figure 4.

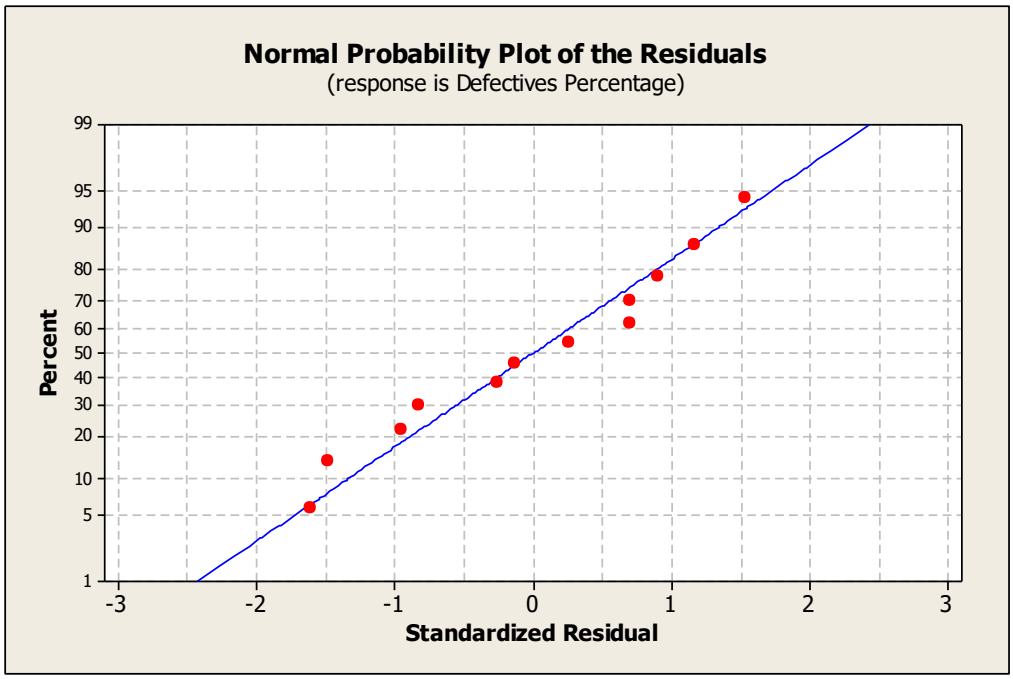

Figure 2 Normal probability plot of the residuals

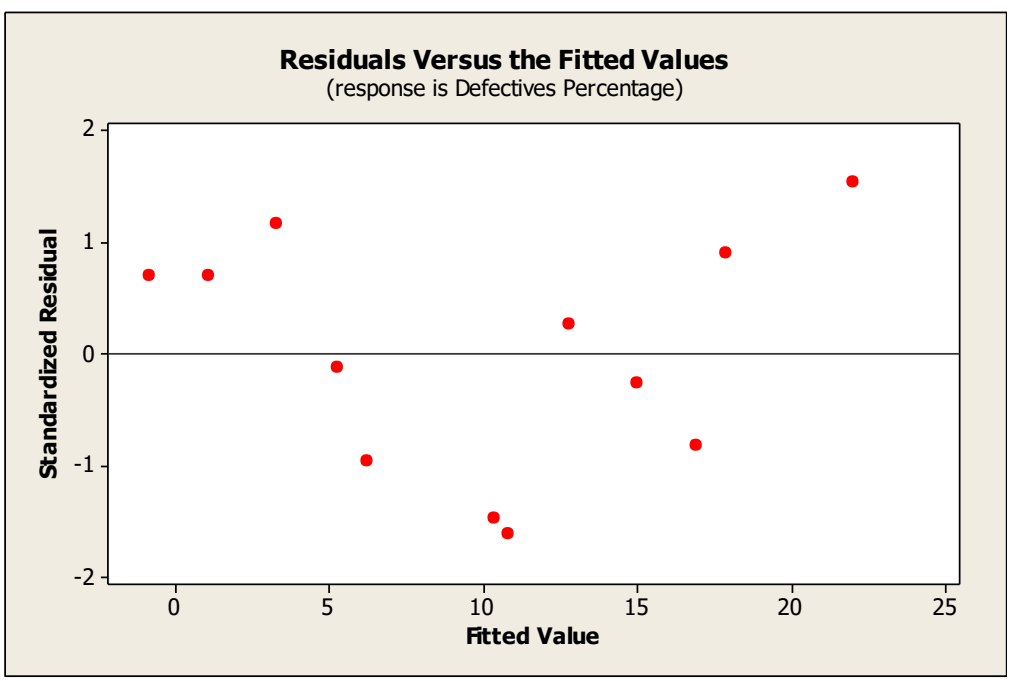

Figure 3 Constant variance assumption checking

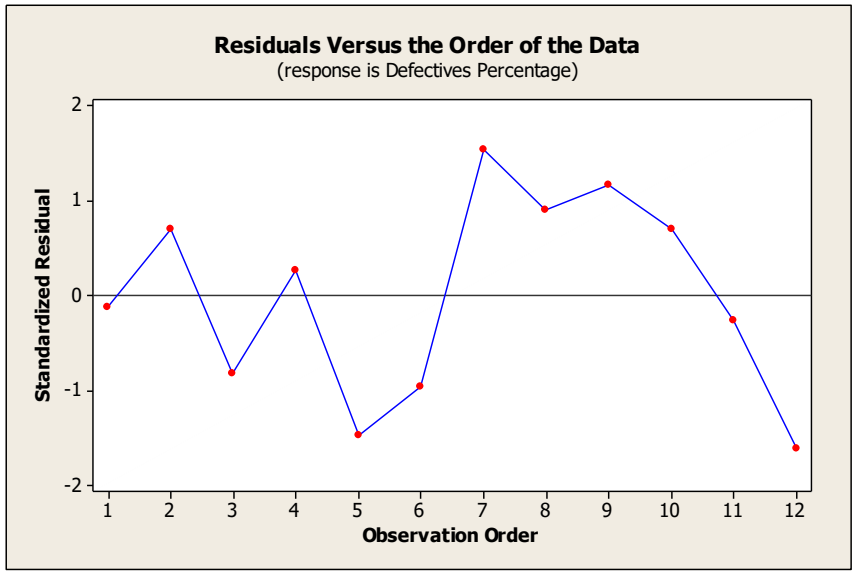

Figure 4 Residuals versus the order of the data (independence assumption)

According to the model adequacy checking [15], it was found that residuals were normally distributed. The variance of residuals was constant and the independence assumption was checked. Therefore, the ANOVA was suitable for the analysis of the three factors affecting on the mean percentage of defectives.

The needle type factor had a significant effect on the vitamin B injection solution aseptic filling mean defectives percentage since the p-value was 0.01, which was less than 0.05 significant level. The machine speed and needle position factors had no significant effects on the mean percentage of vitamin B injection solution nonconforming products as shown in Table 1.

Table 1 The ANOVA table for the experiment which defectives percentage was the response variable

General Linear Model: Defectives Percentage versus
Machine Speed, Needle Type, and Needle Position

Factor	Type	Levels	Values
Machine Speed	fixed	3	8, 10, 12
Needle Type	fixed	2	1, 2
Needle Position	fixed	2	0, 3

Analysis of Variance for Defectives Percentage, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Machine Speed	2	106.41	106.41	53.21	1.61	0.266
Needle Type	1	407.03	407.03	407.03	12.30	0.010
Needle Position	1	51.34	51.34	51.34	1.55	0.253
Error	7	231.56	231.56	33.08		
Total	11	796.34				

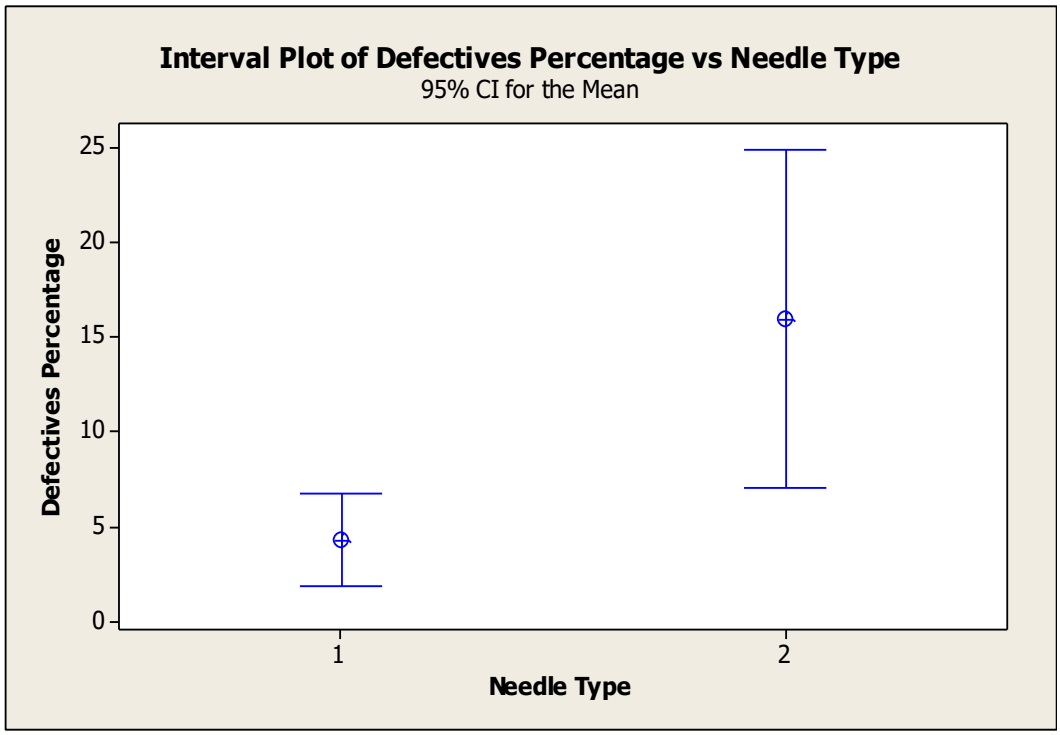

Figure 5 Interval plot of defectives percentage

Figure 5 displayed the interval plot of defectives percentage. From the interval plot, the lower and upper bounds of the 95% confidence interval for defectives percentage were 1.84% and 6.67% using the proposed type 1 needles. When the type 2 needles were used, the lower and upper bounds of the 95% confidence interval for defectives percentage were 6.96% and 24.84%. The two 95% confidence intervals for defectives percentage were not overlapped. Therefore, the mean defectives percentage produced by the proposed type 1 needles was significantly less than the mean defectives percentage produced by the type 2 needles of the case study.

Conclusions

The study of the defectives reduction in the aseptic filling process of the case study pharmaceutical company was conducted. Vitamin B injection solution tubes are the important products of the case study. The major nonconforming problem was the soot particles on the inner surface of vitamin B injection solution tube in the aseptic filling process. Experimental design was applied to determine the optimal level of aseptic filling machine setup for minimization of the mean percentage of defectives. The model adequacy checking was tested with the three assumptions, which are normality, equal variance, and independence assumptions. Analysis of Variance (ANOVA) was the appropriate statistical technique. For experimental design, a three-factor Completely Randomized Design (CRD) was generated and the ANOVA was carried out. According to the ANOVA table, it was found that the needle type had a statistically significant effect on the mean defective percentage. The appropriate needle type with the smaller value of the mean defective percentage was the type 1 needle. It was found that when the proposed type 1 needles were used, the mean defectives percentage was 4.25%. The mean defectives percentage using the type 2 needles was 15.90%. It can be concluded that when the proposed type 1 needles were used in the aseptic filling process of vitamin B injection solution after the improvement, the mean defectives percentage decreased by 11.65%. Further study about the inner diameter of tubes of vitamin B injection solution can provide the

opportunity to explore the vitamin B injection solution defectives reduction in the case study pharmaceutical company. The wide inner diameter tubes should be used to avoid the nonconforming problem in the aseptic filling process since the probability of the soot particles occurrence on the inner surface of vitamin B injection solution tube will be reduced significantly.

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Effect of Negative Aeration Rates on Water Balance in Biodrying of Wet-Refuse-Derived Fuel

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Abstract

Biodrying as a part of mechanic biological treatment (MBT) is a wide application method to reduce the excess moisture content in the substance and to improve the combustible materials as refuse-derived fuel (RDF) production process. The moisture content is reduced by evaporation and leachate generation during the biodrying process. To minimize the leachate generation due to it being more harmful to the environment, the optimization of the aeration rate should be assessed. Therefore, this study investigated the water balance under the variation of continuous negative aeration. The experiment set aeration rates of 0.4, 0.5, and 0.6 m^3/kg/day. The operation time of each experiment was set to five days. This study was performed with a lysimeter scale using wet-RDF as a feedstock. The initial weight of wet RDF was 70.0 kg. At the end of the operation, the comparison of moisture content change in the feedstock and biodried products from evaporation and leachate generation was analyzed. The study illustrated that the highest moisture content reduction by evaporation was obtained from 0.4 m^3/kg/day, followed by 0.5 m^3/kg/day and 0.6 m^3/kg/day, respectively. The highest water reduction by leachate generation was obtained at 0.6 m^3/kg/day, followed by 0.4 m^3/kg/day and 0.5 m^3/kg/day, respectively. The final moisture content in the biodried product was 20.27 kg, 23.03 kg, and 23.47 kg from the negative aeration rates of 0.4, 0.5, and 0.6 m^3/kg/day, respectively. Also, the moisture reduction of each experiment was 35%, 27%, and 26% that corresponding to weight reduction at 18%, 17%, and 15% of 0.4, 0.5, and 0.6 m^3/kg/day, respectively.

Keywords : Biodrying; Wet-RDF; Water balance; Moisture removal

Introduction

Waste generation is steadily increasing in developing countries, especially Thailand, due to the growth of industrialization and urbanization. However, mismanagement of municipal solid waste (MSW) not only severely impacts the environment but also puts the public's health at risk and raises several other socioeconomic issues that need to be addressed [1]. Thailand's Pollution Control Department estimates a nationwide total of 26.9 Mt of MSW, of which 16% was produced alone in Bangkok [2]. The composition of MSW in Thailand varies depending on urbanization, population density, and income in various regions, but it usually comprises roughly 51% organic waste, 22% plastic, 13% paper, and 3% glass. The whole MSW was appropriately managed by 47%, disposed of by 27%, and reused/ recycled by 20%; the rest was incinerated [2, 3].

Waste-to-energy conversion is now a kind of renewable energy that can benefit both

the environment and the global economy. However, a waste-to-energy solution through thermal waste treatment, such as incineration, is inappropriate in Thailand due to the higher proportion of organic fractions in their MSW composition [4]. In Bangkok, Thailand, at On-Nut waste transfer station is receiving more than 45% of the whole MSW generated from Bangkok and the metropolitan area, mechanical biological treatment (MBT) is used to separate the MSW for converting into various applications, i.e., recycling, composting, refuse-derived fuel (RDF) production, incineration, and landfilling. After MSW passes through the MBT process, the remaining material can be transferred to the RDF production due to comprising more than 50% non-degradable material, less than 30% biodegradable material, and recycling material. The chemical composition was analyzed to characterize the RDF production potential. The chemical composition has been measured the moisture content and heating value for more than 40% and less than 3,000 kcal/kg, respectively. Therefore, this object has been named wet-RDF [5, 6].

The viability of MBT is a comprehensive application method related to MSW management. Biodrying is a part of the MBT operation that generally to be able to enhance the combustion quality of waste in terms of increased Heating Value and reduced moisture content [7, 8]. Heat is produced by the degradable material, which accelerates the evaporation of water. In the biodrying process, biological heat is incorporated to diminish the excessive moisture content, together with forced aeration, to almost totally accomplish the drying process. There are three types of water in mixed substances, i.e., water components in the feedstock, water vapor associated with the air input, and water generated during organic degradation [4]. In the biodrying process, the biodried product is influenced by two primary steps; 1) The evaporation process changes water-vapor molecules from liquid to gaseous and emits them into the surrounding air; 2) airflow moves the evaporated water-vapor through the matrix and removes it with the exhaust gases. The aeration rate influences the water removal activity produced by these two processes. Zhou et al. [9] executed the airflow rate at 0.088 $m^3/kg_{TS}/h$ and modified the air pump's on-off duration by supplying air for 6 minutes before turning it off for 34 minutes. They observed that water removal was highest removed for sewage sludge biodrying. Zhao et al. [10] found that a high airflow rate of 0.3 $m^3/kg_{TS}/h$ improved heat generation more than a low one of 0.15 $m^3/kg_{TS}/h$) and effect to the loss of moisture content in the sewage sludge biodrying. In light of the above, the study of the effect of aeration rate on the biodrying of wet-RDF in water removal performance has not been widespread. Therefore, this work investigates the aeration rate's interactive influence on water balance.

Materials and Methods

Feedstock analysis

First, the MBT plant in the On-Nut waste transfer station produces the wet-RDF, referred to as feedstock. It is then transported to waste-to-energy plant in Thailand's Saraburi province. Wet-RDF samples for 20 kg were randomly collected from different locations in stockpiles in the waste-to-energy plant for composition analysis. Another 20 kg was also collected and quartered to remain 1.5 kg for measuring their chemical properties before biodrying process. The wet-RDF is depicted as having an observed values composition made up of 8.72% packaging and plastic tube, 13.08% cloth and napkins, 46.33% plastic bags, 22.98% degradable materials (food, garden, and paper trash), 1.43% rubber, and 5.09% other/separated waste. Second, the wet-RDF stockpile was randomly sampled for this study before being put into the biodrying lysimeters. The content of the wet-RDF feedstock and bio-dried product was examined using the quartering method following ASTM D5231-92. Finally, the degradable material was separated to measure the moisture content from the feedstock and biodried product. The average weight of the feedstock in the lysimeters was 70.0 kg with 232 kg/m^3 of bulk density, and it was equally loaded to a height of 1.2 m. By ASTM D7582, a thermogravimetric analyzer was used to

measure the moisture content accumulation in the feedstock and biodried product. The initial moisture content of the wet-RDF was 46%.

Investigation of biodrying system

The feedstock material was loaded into a square lysimeter made of stainless with 2 m of height and 0.5 width. The outer wall was covered in 2.5-cm-thick polyurethane foam for thermal insulation. The perforated metal plate was positioned at the lysimeter's bottom to support the waste material and air ventilation. A ventilation pipe, condensation pipe, and blower are parts of the ventilation component system established at the bottom of the lysimeter to provide airflow. The U-trap pipe, which has a 5.08 cm diameter, was connected to the ventilation pipe to collect condensation. Leachate was collected using the 5.08 cm diameter U-trap pipe that was placed at the lysimeter's bottom. A process flow diagram of the investigated biodrying of the wet-RDF system is shown in Figure 1A.

The biodrying is the purpose of utilizing the exothermal bacterial oxidation of organic matter to evaporate the excess moisture contained in the waste. A process flow diagram of the investigated biodrying system showing the thermodynamic system boundary and primary process inputs and outputs is shown in Figure 1b. The thermodynamic system represents the energy transformed due to biological activity within released heat to the surroundings. Major input is the feedstock, aeration feeds, and its associated water vapor. The biodried product, dry exhaust gases, and exited water vapor are major outputs. The heat input and output represent ambient air and exhaust temperature, respectively.

The wet-RDF is usually desirable to evaporate water and generate leachate during biodrying for producing a relatively biodried product.

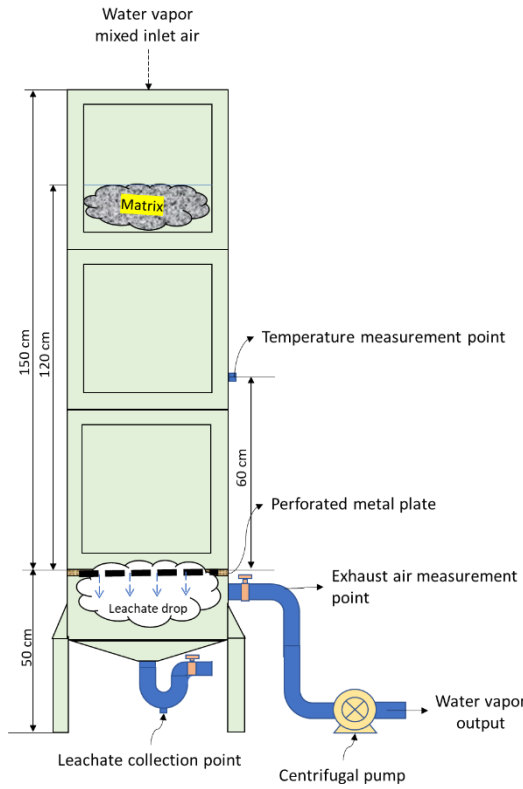

Figure 1 Description of the wet-RDF biodrying system; a) schematic diagram of process layout and b) process flow boundary of this study

The overall airflow through the lysimeter is the mixture of fresh air (dry air mixed water vapor) used to provide the oxygen consumption of the microorganism activity and evacuate evaporated moisture. This study operated three experiments in different conditions based on aeration rate, i.e., 0.4, 0.5, and 0.6 m^3/kg/day. Therefore, the negative ventilation can be distributed down-flow from the top to the bottom of the lysimeter. The following aeration rate set in this study was base on the 1) stoichiometric air demand for the compositing process [11], the stoichiometric air demand for biodrying process [6, 8], and the literature review of the appropriate aeration rate for biodrying process [9, 12-19]. The appropriate aeration rate was assumed the oxygen consumption while minimize the energy consumption for aeration supplied in the biodrying process.

The main mechanisms for moisture movement in the matrix are air convection and molecular diffusion. Removal of water content from the wet-RDF matrix during the biodrying process by convective evaporation is determined by the thermodynamic equilibrium between the solid and gas phases. The water balance was contained for two terms; 1) two-stream for gas (water vapor) and solid (wet-RDF) for the inlet, and 2) two-stream for gas (water vapor) and solid (biodried product) for the outlet. There is a general equation (1) to describe the water balance as follows;

$$W_{inlet} - W_{outlet} + W_{matabolic} = W_{accumulation} \quad (1)$$

$$W_{inlet}\ (g) = W_{feedstock} + W_{vapor\ inlet} \quad (2)$$

$$W_{outlet}\ (g) = L_{generation} + W_{vapor\ outlet} \quad (3)$$

$$W_{vapor\ inlet/outlet}\ (g/h) = F\ (m^3/h) * \left[\frac{217 * p_v}{237.15 * p_{vs}}\right] \quad (4)$$

$$p_v\ (Pa) = RH\ (\%) * p_{vs} \quad (5)$$

$$p_{vs}\ (Pa) = 6.1078 * 10^{\left[\frac{7.5 * Temperature\ (°C)}{Temperature\ (°C) * 237.3}\right]} \quad (6)$$

$$W_{vapor\ air\ flow}\ (g/h) = W_{vapor\ outlet} - W_{vapor\ inlet} \quad (7)$$

$$W_{matabolic}\ (kg/h) = \frac{16.3}{21} * \Delta C_{gen} * \frac{18\ kg}{1 kmol} \quad (8)$$

$$\Delta C_{gen}(kmol/h) = [(F * CO_2)_{out}] * \frac{1\ mol\ CO_2}{100 * 22.4 m^3} \quad (9)$$

$$W_{vapor\ evaporation} = W_{outlet} - (W_{inlet} + W_{matabolic}) \quad (10)$$

when; W_{inlet} is water inlet, W_{outlet} is water outlet, $W_{accumulation}$ is water accumulation, $W_{feedstock}$ is water in feedstock, $L_{generation}$ is leachate generation, $W_{vapor\ inlet/outlet}$ is water-vapor inlet or outlet, RH is relative humidity, p_v is water vapor pressure, p_{vs} is saturated water vapor pressure, $W_{vapor\ air\ flow}$ is water-vapor mixed airflow, ΔC_{gen} is CO_2 generation rate, F is airfow rate, and $W_{vapor\ evaporation}$ is water-vapor evaporation.

The water inlet (2) represents the water mixed in feedstock and water vapor mixed inlet air (4). The water outlet (3) represents the leachate and water vapor in the outlet air (4). The metabolic water generation (8) is water mass produced from bioactivity organic digestion. The water accumulation represents the moisture in the biodrired product (1). Finally, water vapor evaporation (10) is represented the whole water vapor in the biodrying system that is evaporated into the surrounding [20, 21].

In addition, this study focused on water balance, the unit of gases and leachate output corresponding to the production of microorganism digestion, i.e., carbon dioxide and methane, and other organic fractions, was not accounted for in this study.

Experimental monitoring

The temperature was measured using thermocouples type K, which have a temperature range of -270 °C to 1,327 °C. These sensors were positioned in the center and exhaust air measurement point of lysimeters, while a third sensor for monitoring ambient temperature was positioned outside the lysimeter. The midi Logger recorded all temperature measurements hourly (Graphtec GL220). Daily measurements of the CO_2 concentration in percent by volume during the biodrying process were conducted with Biogas 5000 (Geotech, UK) at the lysimeter's exhaust air sampling location. Daily weight measurements of the feedstock in the lysimeter were performed using a push gantry hoist and digital crane scales. The relative humidity was

measured for the ambient and exhaust air measurement point.

Results and Discussion

Water balance before and after the biodrying process

Table 1 summarizes the results of the three experiments on water balances between input and output of the biodrying process of wet-RDF. It was observed that the aeration rate influenced water removal and water generation. The AR 0.4 showed the highest water removal by evaporation (9.98 kg), followed by AR 0.5 and AR 0.6 at 8.26 kg and 6.72 kg, respectively. The water vapor air flow was water removal due to air force without considering the metabolic water generation. The highest water vapor air flow was AR 0.4 at 24.04 kg, followed by AR 0.5 and AR 0.6 at 21.70 and 18.71 kg, respectively. The highest leachate generation was obtained from AR 0.6 at 1.6 kg, followed by AR 0.4 and AR 0.5 at 1.04 kg and 0.5 kg, respectively. Finally, metabolic water generation is the production of organic digestion by bioactivity. The highest generation was from AR 0.4 at 14.05 kg, followed by AR 0.5 and AR 0.6 at 13.44 kg and 11.99 kg, respectively.

Table 1 Balance of water during the biodrying process

Condition	AR 0.4	AR 0.5	AR 0.6
Water vapor evaporation (kg)	9.98	8.26	6.72
Water vapor air flow (kg)	24.04	21.70	18.71
Water in feedstock (kg)	31.79	31.79	31.79
Leachate generation (kg)	1.04	0.50	1.60
Metabolic water generation (kg)	14.05	13.44	11.99
Water accumulation (kg)	20.27	23.03	23.47

The overall water balance during the biodrying process of wet-RDF is shown in Figure 2. The proportion of water in feedstock was the highest in the system, followed by the difference between the water outlet and water inlet due to vapor carried in the air flow without considering the water generation by metabolic activity (water vapor airflow). The lower water vapor air flow is represented by the lower remaining water in the system. On the other hand, the air force represents the higher removal. The lowest water vapor air flow was AR 0.6 at 26.42%, followed by AR 0.5 and AR 0.4 at 28.67% and 29.71%. This is because a high aeration rate drives the water vapors out of the system more than a low aeration rate. This was confirmed by Yang et al. [22], who summarized the relationship between aerations and water vapor removal. They reported that the inlet air increase could transport the vapor out from the system due to the increase in water holding capacity. The metabolic water generation is the third proportion of water in the system; AR 0.5 was the highest, accounting for 17.75%, and the lowest was AR 0.6, accounting for 16.93%. This can be summarized that; AR 0.5 was the optimum aeration rate for bioactivity due to the appropriate oxygen consumption.

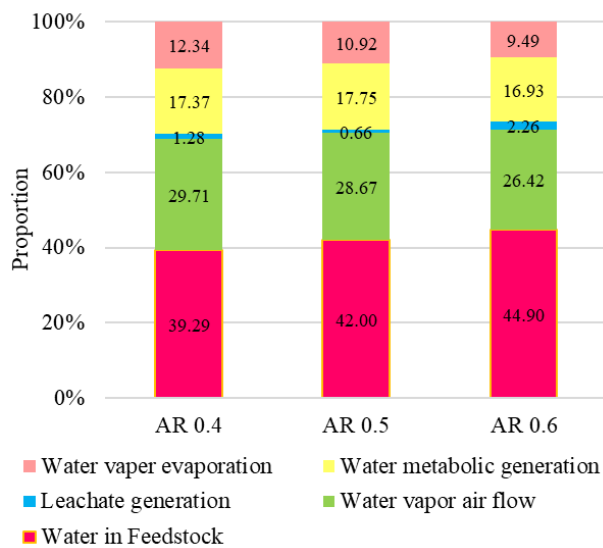

Figure 2 The proportion of water balance during the biodrying process

On the other hand, AR 0.6 was the higher aeration for the biodrying system of wet-RDF. Water vapor evaporation is related to

water removal within bioactivity because it accounts for the removal from metabolic water generation. The leachate generation was the nominal proportion of the water balance system because of less removal. Although, this study was performed under a negative ventilation system that allows for a higher excretion of leachate than positive ventilation. However, the amount of leachate removal was still low. Tom et al. [23] operate the MSW biodrying under a positive ventilation system. They observed no leachate production during the entire reaction period, although the feedstock condition reported the potential for leachate generation, i.e., % organic substance and moisture content. The leachate reduction mechanism of the biodrying system is an effective waste management operation in reducing environmental pollution.

Daily metabolic water generation

The water produced from organic digestion by microorganisms is presented by metabolic water generation, as shown in Figure 3. This result was obtained from the balancing process using equation 8. The daily carbon dioxide concentration is the bioproduction converted into a mass of water under aerobic digestion [24].

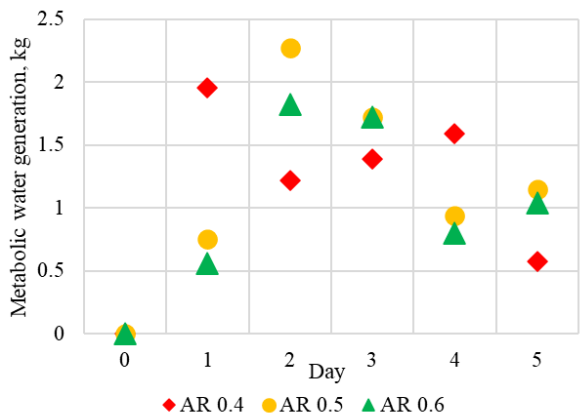

Figure 3 Daily metabolic water generation of each experiment

The highest metabolic water generation was obtained from AR 0.5 for 2.27 kg on day 2, followed by AR 0.4 for 1.90 kg on day 1, while AR 0.6 had the maximum for 1.82 kg on day 2. The metabolic water generation trend of AR 0.4 rapidly increased to its peak on day 2 and then decreased to its minimum on day 5. Notably, AR 0.5 and AR 0.6 were slightly increased to their peak on day 2, then slightly decreased to their minimum on day 4. Ham et al. [21] reported that the effect of metabolic water generation on the variation of airflow rates was not changed throughout the time for the biodrying process. In contrast, this study showed a different generation rate trend because of the difference in feedstock and operations.

Effect of aeration rate on total water removal

Referring to equation (1), the balancing process, the difference between water input and water output, the water accumulation is the remaining water in the biodried product compared to the feedstock. Figure 4 shows the comparison of water accumulation in each experiment's balance process and measurement.

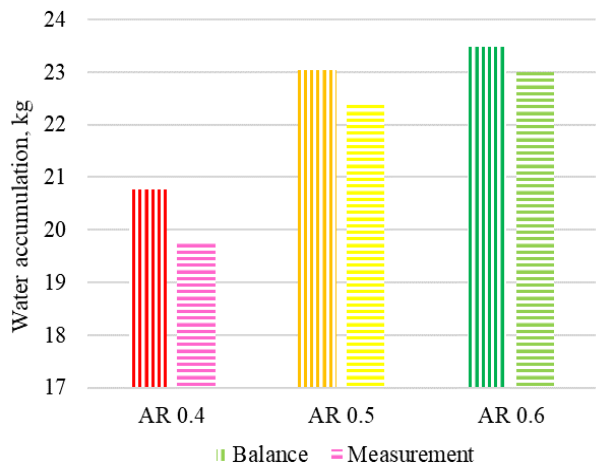

Figure 4 Water accumulation of each experiment

The lowest water accumulation from the balancing process was AR 0.4 at 20.77 kg, followed by AR 0.5 and AR 0.6 at 23.03 kg and 23.47 kg, respectively. The lowest water accumulation from measurement in the laboratory was AR 0.4 at 19.97 kg, followed by AR 0.5 and AR 0.6 at 22.42 kg and 23.23 kg, respectively. Therefore, the average water accumulation of AR 0.4, AR 0.5, and AR 0.6 at 20.37 kg, 22.72 kg, and 23.35 kg, respectively.

The lowest aeration rate at 0.4 m^3/kg/day can drive water removal by evaporation for the biodrying of wet-RDF operation. This aeration rate was better for producing gases, water, and heat, allowing the evaporation of water vapor to the surrounding.

Furthermore, this study more effectively removes water by transforming it into vapor than by disposing of leachate. According to the findings, a high aeration rate produced less water vapor and more leachate than low aeration rates, with a higher elimination of water vapor. Wang et al. [16] and Zhou et al. [9] provided similar explanations, confirming that a lesser amount of water is transferred by air because of a higher aeration rate.

Daily water accumulation and temperature profile

The daily amount of water accumulated in the matrix of each experiment is shown in Figure 5.

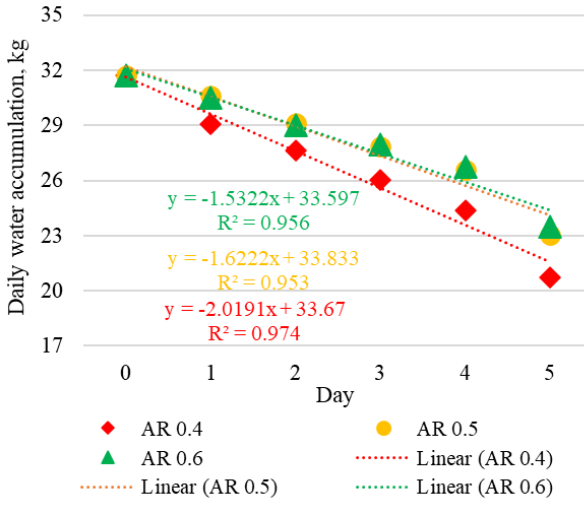

Figure 5 Decrease of daily water accumulation in each experiment

The initial water content of all experiments was 46%, measured at 31.74 kg. However, the water accumulation was slightly decreased from the beginning until the end of the process. AR 0.4 was the highest reduction rate of water accumulation at 2.01 kg/day, followed by AR 0.5 and AR 0.6 at 1.66 kg/day, and 1.53 kg/day, respectively.

The matrix water accumulation change was related to matrix temperature and aeration rate. The matrix temperature of each experiment is shown in Figure 6. In this study, the biodrying of wet-RDF was rapidly increased in matrix temperature from the beginning to day 1, then slightly increased to the end of the process. The highest temperature was obtained from AR 0.4, which reached the peak on day 4 at 64.4 °C, followed by the maximum temperature of AR 0.6 and AR 0.5, which peaked on day 4 at 57.1 °C and 52.4 °C, respectively.

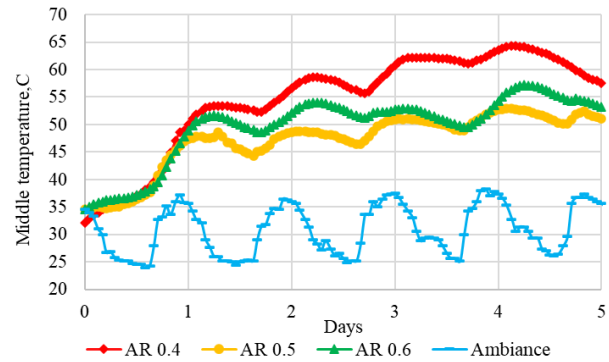

Figure 6 Daily temperature in the matrix of each experiment

The matrix temperature of this study was higher than in the previous study. However, the feedstock condition was unfavorable for reaching the higher temperature generation compared to those studies, i.e., the amount of degradable material and moisture content [21, 23, 25]. According to Ham et al. [21], when the aeration rate increased from 0.60 to 2.50 m^3/kg/day, the highest matrix temperature reduced from 58 to 49.9 °C, while the moisture reduction increased by 2.3 times. Compared to the results of the experiment by Tom et. al. [23], this study provided the maximum water reduction only 1.5 times, but it was found that the maximum temperature was higher.

Conclusions

To investigate water balance, this study performed a biodrying of wet-RDF on the lysimeter scale. The water balance was estimated within the variation of the aeration rate. The water inlet was from water in

feedstock and water vapor mixed inlet air. The water outlet was from evaporation and leachate generation. The remained water was the water accumulation in the biodrired product. This study reported that minimizing leachate generation and water accumulation was the optimum water balance influenced aeration rate. Less leachate generation and water accumulation were obtained from the biodrying operation of wet-RDF with 0.4 m^3/kg/day because it maximizes water evaporation. Moreover, the phenomenon findings in this study are the low aeration rate (0.4 m^3/kg/day) resulted in maintaining the system temperature to enhance the water evaporation. In comparison, the high aeration rate (0.5 m^3/kg/day) resulted in a force of leachate dropdown in the negative ventilation system.

Acknowledgement

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Factors Affecting Decision-Making to Use Feeder Bus Services and Air-Conditioned Buses in Salaya Subdistrict Towards A Sustainable Transport Policy

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Abstract

This research aims to study the factors affecting the public transport travel behavior of people in the community around Salaya station area. We distributed 375 questionnaires to examine the behavior of people in Salaya subdistrict municipality area and its environs. To promote sustainable transport, it is important to consider policy interventions that encourage the use of public transport and reduce dependence on private cars. Therefore, the study area has been chosen in order to give an insight into feeder bus planning will supports the commuter railway line that is to be developed in the near future. This study focuses on two research questions necessary for the feeder transport planning as factors that affect the choice of a feeder system to travel in the area and the factors that affect the choice of using the air-conditioned feeder bus. The behavior of the samples was analyzed by binary logistic regression in two steps: first, to predict the factors that affect the probability that people will use the feeder bus service that picks up passengers between destinations in SALAYA and between SALAYA and Bangkok. Second, to predict the factors that affect the probability of choosing an air-conditioned bus service. As a result, the demographic factors that appeared to affect the decision of choosing a feeder bus were income and the number of vehicles owned. Furthermore, the factors affecting the decision to use air-conditioned buses are age, education, and income. Understanding these factors can help local transport authorities for designing more effective shift-mode strategies.

Keywords : Public Transportation; User Perception; Feeder Bus; Logistic Regression; Mode Choice

Introduction

Bangkok Metropolitan Region (BMR) is the largest urban area in Thailand and has struggled with problems in travel management. The cities, which are part of BMR, failed to promote high quality bus transport which is one of the major causes of severe traffic congestion as well as increasing air pollution problems. In many agencies that are ranked, the factors that result in traffic jams are composed of the factors mentioned above. Many studies by experts mentioned that a key to solving this problem is to use public transport. Therefore, many agencies are trying to support public transport in the main transport system and secondary travel to encourage more people to use public transport services. This can be observed from the number of electric train projects increasing in order to meet the needs of people who want to travel from more places [1].

According to the research from the National Research Institute [2], Thailand has been facing air pollution problems, and many agencies are interested in solving or reducing them. This research found that land transport contributes the most to the occurrence of the PM 2.5 problem, accounting for about 31 percent. There are many ways to reduce this problem, such as by supporting the use of electric vehicles, reducing the consumption of

diesel, and shifting from private vehicles to public transport.

This research, therefore aims to study the behavior of people living in the Salaya area to identify factors that affect their decision-making when choosing a bus service for traveling around the Salaya area. The study focuses on identifying the factors related to the decision-making process between selecting air-conditioned buses or ordinary buses. The findings of this study provide an insight into information that supports a sustainable transport policy by examining people's preferences for using public buses.

The study area is the Salaya subdistrict municipality, which is the major town of Phutthamonthon district, Nakhon Pathom province. It is located to the west of Bangkok, the capital of Thailand. It is also considered as the part of BMR area. We used Salaya subdistrict as a study area due to the future plan of commuter rail development which needs feeder transport planning to help connecting to places near the station. Also, Salaya subdistrict is highly populated because of the aggregated government offices, schools and universities, as well as the rapid growth of communities which is reflected in the glowing public transport travel demand.

The factor that will make public transport most efficient is connectivity between nodes and places. Feeder bus service is often planned along with metro expansion to encourage connections between railway stations and their destinations.

Therefore, this study investigats factors that influenced their decisions on mode-shift to use the feeder bus service by investigate the factors affecting people's decisions to use feeder bus service and the decisions to choose the air-conditioned bus for their feeder bus trip. This study provides a research method for consequential decisions on using public transport to help local transport authorities determine the type of feeder bus service which will encourage the mode-shifting in station premises which would help them achieve the sustainable transport policy advocacy.

The objectives of this study focus on the decisions to use public transport in tropical countries. The literature on factors affecting the decision to use public transport and the factors affecting the use of air-conditioned buses has therefore been reviewed. There are various studies related to these topics that can help develop the research methodology for this study. The literature reviews can be summarized as follows:

Factors affecting the decision to use public transport

According to research, the factors for public bus service users' decision-making include gender, age, education, income, occupation, and educational background [3-5]. Other personal factors that affect the willingness to use public transport include the number of vehicles possessed, and ability to drive different types of cars [3, 6, 7], but some studies have also questioned the ability to drive and possession of vehicles such as the studies of [6, 8-10].

The factors that will affect the trip can be generally classified into two groups: the travel cost and the total travel time including the time spent on the journey and the waiting time that occurs at the time of deciding to travel by public transport. A number of studies have shown that travel time affects travel decisions [3, 7, 11-13, 10]. Many studies specify that the travel time is directly related to the decision to use public transport [3, 7, 10-13].

Service reliability has a huge impact on decisions to use public transport [2-4, 6, 10, 13, 14, 17] The service frequency has generally been mentioned as a major cause of the reliability [8, 11, 12, 15, 16], followed by safety, which usually includes safety at bus stops or terminals and onboard safety [14, 17]

Another factor of service reliability is service quality, which was mentioned in the research of [9-11, 13, 14] who stated that the customer services provided by public transport operators are related to the willingness to use public transport. The better a user's satisfaction, the more attractive using public transport is in other words, passengers expect a good experience during a trip. This also includes the information provided by the transit operators. The passengers want to know information about various aspects of the service in order to make a decision to use it.

The cleanliness aspect is also considered as a factor of service quality. Cleanliness affects the decision to use public transport because passengers prefer travel in clean bus [10, 12-14]. Cleanliness refers to the hygiene and comfort of the service [11-13, 17, 18] which make passengers feel safe and comfortable during the trip.

The surge in environmental concerns also affects the intention to use public transport. Nowadays, many people pay more attention to transport activities that harm the environment. These may be considered as unsustainable activities such as car dependency or overuse of fuel in transport activities. Various studies have confirmed that those activities caused a negative environmental impact. This evidence affects the increase in use public transport worldwide both with regard to individual decisions and urban policy [6, 11, 14, 13, 17].

Factors affecting air-conditioned bus users

Thailand is located in a tropical zone near the equator. Throughout the country, the average temperature is between 18 - 38 degrees Celsius. The summer lasts about 3 months. The hottest weather is in mid-April. After that, under the influence of the monsoon winds, Thailand enters the rainy season for 6 months and the winter for 3 months respectively [19].

Generally, buses in BMR provide two types of service: regular buses and air-conditioned buses. Several bus lines have both services operating on the same route to let passengers choose the service they prefer. The fares for both services are approximately 50% different. On this sensitivity of mode choice, there are limited studies that focus on the decision to use air-conditioned bus services. This research reported that the comfortable temperatures on the paratransit are significant for the intention to use public transport [13]. Another study conducted in Delhi, India, applied multi-criteria decision-making to observe travel mode shifts to use public transport and considered 4 groups of factors: reliability, comfort, safety and cost. The results of the study suggested that the comfort factor which consists of the air-conditioned vehicles affected 16% of intentions to use public transport. However, the most influential factor was safety which accounted for 27% followed by the fare at 21% [12].

The limitations of the study about decisions to use air-conditioned public transport services brought us to explore the factors that influenced people to use the air-conditioned feeder bus service. The results of this analysis could explain more about the sensitivity between cost and time for using public transport in Salaya City.

Methodology

This study focuses on factors that affect the decisions about using feeder transport by investigating the factors and the probability that passengers decide to use feeder bus services in the study area. The present bus operation in BMR has both air-conditioned and non-air-conditioned bus services. We also investigated the major causes of selecting air-conditioned feeder bus services for short trips within the study area. These objectives are fruitful for the feeder bus operation especially in tropical countries as the area of this study has an average maximum temperature of 32-34 degrees Celsius throughout the year [20].

Data collection was done by questionnaire surveys distributed to people who live or have experience of traveling to Salaya area. A total of 375 samples were collected. The questionnaire was endorsed with MU-CIRB project code 2021/483.2211. The questionnaire focuses on the decision to use a bus service to transport passengers between places within the study area. The logic of the questionnaire survey is illustrated in Figure 1.

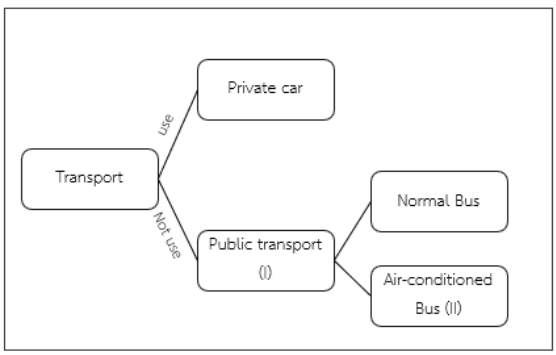

Figure 1 The logical of questionnaire survey

From the distribution of all questionnaires, there were a total of 409 questionnaires, 29 samples were excluded due to no experience of visiting Salaya area and another 5 people refused to answer the questionnaire. Therefore, 375 samples were used in this analysis.

We use statistical analysis to explain the factors affecting the mode choice of the sample. The analytical method is adopted from the study of [20] which used a logic tree binary logistic regression for making a logic of public transport users' decisions. The binary logistic regression model is therefore used in this study for predicting decisions to use feeder bus services and air-conditioned buses in Salaya subdistrict. The study predicts the consequential decisions related to the use of feeder bus services including two research questions: first, to predict factors affecting the probability that people will use the feeder transport service; and second, to predict the factors that affect the chances of using an ordinary bus (non-air-conditioned) or the air-conditioned bus. The data was analyzed using the binary logistic regression model which is described in **Equation 1.** The descriptive statistics are shown in Table 1.

$$\rho_{(x)} = \frac{1}{\left(1+e^{-(\alpha+\Sigma\beta_i x_i)}\right)} \qquad \textbf{Equation 1}$$

Table 1 Descriptive Statistic

Characteristics		Frequency	Percentage
Sex			
	Male	180	48%
	Female	190	50.70%
	LGBTQ+	5	1.30%
Age			
	Less than 20 years	89	23.70%
	21-30 years	142	37.90%
	31-40 years	79	21.10%
	41-50 years	43	11.50%
	More than 50 years	22	5.90%
Education			
	Primary	46	12.30%
	Secondary	76	20.30%
	Non-Formal Education	3	0.80%
	Vocational Certificate	84	22.40%
	High Vocational Certificate	32	8.50%
	Bachelor Degree	86	22.90%
	Master Degree	35	9.30%
	Doctor Degree	13	3.50%
Occupation			
	Student	75	20%
	Government career	35	9.30%
	Company employee	215	57.30%
	Freelance	26	6.90%
	Business owner	12	3.20%
	Retired	6	1.60%
	Other	6	1.60%
Personal Income			
	Less than 9,000 baht	221	58.90%
	9,001-15,000 baht	35	9.30%
	15,001-30,000 baht	63	16.80%
	30,001-50,000 baht	34	9.10%
	50,001-100,000 baht	16	4.30%
	More than 100,000 baht	6	1.60%

Characteristics	Frequency	Percentage
Number of vehicles in owner		
0	45	12%
1-2	146	38.90%
3-4	163	43.50%
4-5	18	4.80%
more than 5	3	0.80%
Total	375	100

Results and Discussion

Decision to use feeder bus service

The results of binary logistic regression analysis on the effect of personal factors in the decisions to use the feeder bus service in Salaya found that the inclusion of the explanatory variables reported predictive value of 91.2%. The results shown in Table 2 suggest that income and the number of vehicle owners are strongly related to the willingness to use the feeder bus service. Results of the analysis indicated that the model fit the data as Hosmer-Lemeshow's test was 0.691.

Equation 2 examines the binary logistic regression equation for the decision to use feeder bus service. As a result, only the income factor and the number of vehicles owned correlated with the tendency of using feeder bus services. The interpretation of the logit was the lower numbers of vehicles owned and lower income led a higher possibility to use feeder bus service. When comparing decisions to use feeder buses with different income ranges, the lower income group has a probability of decision to use feeder buses 0.529 times higher than the higher income group. The comparison among the different numbers of vehicle ownership, the lower numbers of vehicle owned has a probability of decision to use feeder buses 0.568 times higher than vehicle ownership.

$$Logit\ (Decision) = 4.173 - 0.565v\,\text{eh} - 0.637income$$

Equation 2

Table 2 Explanatory variables for probability of using feeder bus service

Explanatory variables	B	Wald	df	Sig.	Odd ratio	95% C.I. for Odd ratio	
						Lower	Upper
Income	-.637	7.446	1	.006	.529	.334	.836
Number of vehicle owned (vehicle)	-.565	3.512	1	.061	.568	.315	1.026
Constant	4.173	11.645	1	<.001	64.932		

Using air-conditioning bus service (II)

The results of binary logistic regression analysis on the effect of personal factors on the decision to use the feeder bus service in Salaya found that the inclusion of the explanatory variables reported the predictive value as 77.6%. The results shown in Table 3 suggest that age, education and income are strongly related to the willingness to use air-conditioned bus services. Results of the analysis indicated that the model fit the data as Hosmer-Lemeshow's test was 0.675.

Equation 2 examines the binary logistic regression equation for the decision to use feeder bus services. As a result, only age, education and income correlated with the tendency to use air-conditioned bus services. The interpretation of the logit was that the lower age, lower income and lower education led to higher possibility of using air-conditioned bus services. When comparing the decisions to use air-conditioned bus services using different age ranges, the lower age group has 1.309 times higher probability of deciding

to use air-conditioned bus services than the higher age group. The comparison among different education determined that the lower education level has a 1.228 times higher probability of making a decision to use air-conditioned bus services. The comparison between the different levels of income determined that the lower income group has 1.608 times higher probability of deciding to use air-conditioned bus services than the higher income group.

The Probability Prediction Equation that People Choose Air-conditioned Bus Services can be shown as follows **Equation 3**.

$$Logit\ (Air - condition) = -3.943 + 0.269age + 0.206edu + 0.475income$$

Equation 3

Table 3 Explanatory variables for probability of using air-conditioned feeder transport

Explanatory variables	B	Wald	df	Sig.	Odd ratio	95% C.I. for Odd ratio	
						Lower	Upper
Age	.269	3.069	1	.080	1.309	.969	1.768
Education	.206	5.179	1	.023	1.228	1.029	1.466
Income	.475	9.687	1	.002	1.608	1.192	2.168
Constant	-3.943	33.956	1	<.001	.019		

Conclusions

This study predicted the decisions to use feeder bus services and air-conditioned buses in Salaya subdistrict, Thailand, using a binary logistic regression model. The model gave an insight of the factors that influenced the samples decision making which benefited the transit authority's plan for public transport services in Salaya subdistrict. This plan assists the metro rail expansion project called the Red-line extension in terms of the connectivity which has a huge impact on mode shift.

The prediction is based on the binary logistic regression logit on two consequential decisions for using feeder bus services in the study area including factors affecting the decision to use feeder bus services and the decision to use air-conditioned bus services. The air-conditioned bus service became the subject of this study as the current operation of buses in Bangkok has two types of bus service including air-conditioned bus and non-air-conditioned bus. These two types are operating on the same routes in some areas to provide users a choice of travel.

From the findings of this study, it can be concluded that income and the number of vehicles owned are the variables that significantly correlated with the tendency to use feeder bus services as the inclusion of the explanatory variables reported predictive value of 91.2%. Odd ratios of the income variable and the numbers of vehicles owned indicated 0.529 and 0.568, respectively. While age, education and income are strongly related to the willingness to use air-conditioned bus service the inclusion of the explanatory variables reported predictive value of 77.6%. Odd ratios of age, education, and income are shown as 1.309, 1.228, and 1.608, respectively. In contrast, sex and occupation are not significant to the tendency to use feeder bus services or air-conditioned bus services. The income variable is correlated in both observed decisions as it illustrated a strong correlation. This indicates that feeder bus service users vary with the level of income. Although income and occupation seem to correlate, we discuss that this study did not establish the relationship between occupation and income due to the lack of justification for the level of occupation. Thus, we cannot determine whether there is a correlation between occupation and income based on the findings of this study. Additionally, the relationship between occupation and income is redundancy.

Also, the lower income group prefers air-conditioned bus service and this group basically has a higher tendency to use public transport than other groups. In our discussion, we consider that having a lower personal income could make it less likely for people to use air-conditioned bus service, as the fare for

these services is typically around 50% higher than that of non-air-conditioned buses. However, it should be noted that the maximum fare for air-conditioned bus services on this particular route is only 30 baht, which falls within the range of what low-income individuals may be willing to pay. Therefore, we recommend that further research be conducted on the willingness to pay for these services in order to effectively encourage the use of public transport.

A limitation of this study was that it only investigates the sampling's decision by using socio-economic factors which excluded the people's attitude for selecting public transport as a daily mode of transport. Even though a large number of people have changed their attitudes to pay more attention to the environmentally friendly activities, the attitude about using public buses in Bangkok has not been identified. We state these aspects because there is an attitude issue of how Thai people receive public transport which is considered as a transport choice for low-income people and also considered as an uncomfortable and old-fashioned mode of transport. A perspective on the service reliability of bus services in Bangkok is that it is perceived as an unreliable mode of transport. We also note that this study is a case study of countries with a tropical climate where the air-conditioner is a crucial factor for any activities in a closed environment. Therefore, the findings of this study may help local transport authorities to understand the socio-economic factors that affect bus service selection, but the implications of a sustainable transport policy may also need to consider the feasibility of future service providers that will be in charge of operating the feeder bus in the Salaya area and the long-term environmental impact of the overall transport activities as well.

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Strategic Environmental Assessment: A Case Study of Mueang Lopburi District, Lopburi Province, Thailand

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Abstract

The objectives of this research were 1) to study and analyze gaps in strategic plans under the Mueang Lopburi District Development Plan (Development Plan) and 2) to evaluate and recommend suitable strategic alternatives for the Development Plan. Alternative 1 defines following the Development Plan (B.E. 2015 - 2017). Alternative 2 applies the strategies set for the Development Plan (B.E. 2018 - 2022). Alternative 3 adopts the results of the strategic environmental assessment or environmental assessment at the strategic development level for Mueang Lopburi District to develop the area. The study found that Alternative 3 was recommended to use for decision-making in the preparation of the next development plan of the Mueang Lopburi District. Interviewing the stakeholders in Mueang Lopburi District was conducted to prioritize the issues to be formulated as strategic issues, which were summarized into five strategic issues environmental quality development, social development, quality of life and equality, economic and tourism development, water resource management, and agricultural development. The assessment of the impact of the implementation of Alternative 3 was as follows: It should focus on measures to promote solid waste segregation at source to reduce the amount of solid waste being discarded to the solid waste disposal process. Furthermore, measures should be established to monitor the quality of effluent at the source. Moreover, soil characteristics and land use should be studied following scientific principles. Finally, a forest fire management plan should be in place to mitigate a forest fire. Air pollution control equipment and air quality monitoring should be installed in the local workplace.

Keywords : Strategic Environmental Assessment (SEA); Strategic Alternatives; Mueang Lopburi District

Introduction

According to the Lopburi Provincial Development Plan, Mueang Lopburi District has the potential for tourism promotion due to its ease of access to various historical assets and resources, including art and archaeological sites, royal palaces as well as diplomatic sites from the early Ayutthaya era. Therefore, harmonizing with its remarkable assets, the Mueang Lopburi District Development Plan 2018 – 2022 [1] highlights key developmental strategies, including promoting tourism, eco-tourism, and attractive historical sites. Such implementation success relies heavily on improving people's health and infrastructure, strictly prohibiting illegal drug use, citizen and property safety, and good quality education systems and environment. Furthermore, the enhancement of agricultural productivity is another important issue for the socioeconomic development of the area. However, Mueang Lopburi District has not yet achieved its goals arising from a lack of comprehensive integration of economy, society, and environment into the development planning process. Hence, this study applied the Strategic Environmental Assessment (SEA) tool to ensure consideration of those three sustainable pillars in the process for long-term sustainability [2].

Materials and Methods

This qualitative research applied SEA to evaluate the impact of strategic alternatives for sustainable development of Mueang Lopburi District, Lopburi province [3]. The step-by-step description is shown below.

Step 1 Identify the strategic issues involved in the study area regarding the 20-year National Strategy (2018 – 2037), the 12th National Economic and Social Development Plan (2017 – 2021), the Regional Development Plan (2018 – 2021) including Chainat, Lopburi, Singburi, Angthong provinces, 4-year [4], Lopburi province Development Plan and 5-year Mueang Lopburi District Development Plan (2018 – 2022) [5]. The latest plan consists of six strategies, improvement of life quality and infrastructure, strict prohibition of illegal drug use, safety in daily life and property, tourism promotion, eco-tourism, and attractive historical sites as learning resources, good quality educational systems and environment, and enhancement of agricultural productivity.

Step 2 Consider and consult with key stakeholders in the study area to determine the strategic issues to be considered in this study by using questionnaire techniques, in-depth interviews, and data collection. The main target stakeholders will be divided into three groups as follows:

1. Representatives of government agencies such as the Lopburi Provincial Office, the Lopburi Provincial Tourism Office, private organizations in tourism management in Lopburi, Mueang Lopburi District, the Office of the Environment Region 7 (Saraburi), the Office of Natural Resources and Environment, the Office of Public Works and Town & Country Planning, and the Water Supply and Maintenance Department at 1 Lopburi Irrigation Project. In this study, a total of 11 people were interviewed.

2. Representatives of local government organizations in Mueang Lopburi District and representatives from higher education institutions by selecting one representative from each agency, totaling 24 persons, to provide information on policies and plans for area development, including development measures, impacts and concerns from the development of Mueang Lopburi District.

3. Representatives of communities in Mueang Lopburi District by selecting one representative from each community. A total of 22 people were selected to provide information on their potential and trends in the area.

Strategic issues of Muang Lopburi District were set up in three dimensions: economic (tourism, agriculture, industry, transportation, and fisheries), social (quality of life and equality, electricity, and urban development), and environmental dimension (climate change, water resources, environmental quality, and biodiversity) [6]. These dimensions and issues are consistent with the work of the Office of the National Economic and Social Development Council, the Asian Development Bank, and the International Center for Environmental Management (2019) under the "SEA of the Rayong Provincial Development Plan" project [7].

Step 3 Prioritize strategic issues by the judgment of 11 representative government agencies and subsequently define sub-topics and indicators under each strategic issue to be further investigated in this study.

Step 4 Utilize the derived data to analyze, synthesize, review, compile, and describe the study and discussion results. Then develop and evaluate strategic options through a public hearing with key target participants to develop and assess the proposed strategic options. Covering measures for preventing or mitigating potential impacts of implementing the strategic alternatives and recommendations on the implementation by the various agencies involved in the Mueang Lopburi district obtained from the study.

Results

1. Development of issues and indicators for the environmental impact assessment at the strategic level and the development of strategic alternatives to be used in the assessment

1.1 Development of issues and indicators for the environmental impact assessment at the strategic level was performed. Issues and indicators used in the strategic impact assessment were based on scoping at the issue level according to the Sustainable Development principle. That is a development creating balance in three aspects: economic, social, and environmental. Up to 12

strategic issues related to the development of Mueang Lopburi District covering all three dimensions were defined. These issues were consistent with the Office of the National Economic and Social Development Council, the Asian Development Bank, and the International Center for Environmental Management (2019). In this regard, this research studied the gaps in the development of Mueang Lopburi District from the implementation of the Mueang Lopburi District Development Plan (2018 – 2022). In the past, some issues had not yet been addressed with respect to the goals of the development plan. The results of the gap analysis are shown in Table 1.

The Mueang Lopburi Development Plan (2018 – 2016) was presented to experts in Mueang Lopburi District and 11 experts. The aim was to prioritize strategic issues by allowing the experts to assess each strategic issue regarding the size of the problem, the difficulty of solving the problem, the severity of the problem, and public interest. The scoring was from 1(least) to 9 (most). The top four results are shown in Table 2.

The results of prioritizing the strategic issues by the expert judgment found that the experts highly impacted four strategic issues: environmental quality, social, quality of life, equality, economy, and tourism and water resources, respectively. It was found that agriculturalists in the area were managing the water and the gap analysis results of the plan. There were still gaps in agriculture gap analysis, including the vision of Mueang Lopburi District. It also highlighted the importance of food security. Therefore, adding another strategic issue, namely, agriculture, was appropriate. The researcher presented five strategic issues to the stakeholders. The stakeholders were comprised of local government organizations and higher education institutions in Mueang Lopburi District representatives, totaling 24, and 22 Mueang Lopburi District community representatives selected by using an interview form to present sub-issues under the strategic issues, indicators, and goals of all five strategic issues, shown in Diagram 1.

Table 1 The results of the gap analysis in the development plan of Mueang Lopburi District (2018-2022)

Strategies	The gaps in the Mueang Lopburi District development plan
Strategy 2 Solving the illegal drug problem and providing people with daily life and property safety.	Lack of cooperation at the local level, such as no power of attorney or village headman not being involved in solving illegal drug problems.
Strategy 3 Promoting and developing prominent tourist attractions, eco-tourism, and history as learning resources.	Promotion of tourism without considering the potential supporting tourists causes the following problems: 1. The amount of waste increases more than the capacity of the waste bins provided by Mueang Lopburi District, generating excess rubbish around the bin area. 2. The ancient site was destroyed due to more tourists than the staff could monitor. Therefore, the supervising was not strict enough to ensure adequate care. 3. Monkeys in Mueang Lopburi District change their eating behaviors because tourists feed them. Moreover, the tourists threaten the monkey's habitat, so the monkeys invade local people's properties, causing conflict between the locals and the monkeys.
Strategy 5 Developing and increasing agricultural productivity to be safe and the development of local products.	Lack of promoting the body of knowledge in the development of new agricultural products and lack of support for innovation in organic farming or non-toxic agriculture.

Table 2 Results of prioritization of strategic issues

No.	Economy and Tourism.				Society quality of life and equality.				Electricity and energy.				Climate change.			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
01	5	5	5	5	7	6	5	4	4	3	5	4	6	5	4	4
02	4	4	4	5	6	5	2	2	3	3	5	3	5	5	4	4
03	2	2	7	3	2	4	7	4	1	1	7	5	4	4	4	2
04	2	2	4	6	4	6	4	3	1	2	4	4	4	3	4	4
05	4	4	5	7	5	5	5	5	3	2	2	5	5	4	4	5
06	4	4	4	4	4	4	5	4	5	5	6	5	4	5	6	3
07	5	4	4	3	5	5	5	5	3	4	5	5	3	4	2	4
08	6	6	6	6	6	6	7	6	3	3	4	4	3	4	5	6
09	5	4	5	6	5	6	6	6	4	3	2	2	5	6	3	4
10	2	2	4	6	4	6	4	3	1	2	4	4	4	3	4	4
11	5	5	5	5	7	6	5	4	4	3	5	4	6	5	4	4
Sum	44	42	53	56	55	59	55	46	32	31	49	45	49	48	44	44
Mean (Sum/11)	4	4	5	5	5	5	5	4	3	3	4	4	4	4	4	4
Positive	18				19				14				16			
Multiply	400				500				144				256			
No.	3				2				6				5			

No.	Water resources.				Agriculture				Industry				Urban development			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
01	4	5	5	5	3	3	5	4	3	3	3	3	3	3	3	3
02	4	4	4	4	3	3	6	4	4	4	5	4	3	3	3	3
03	5	6	4	7	5	4	4	7	2	1	7	4	2	5	4	7
04	4	5	3	6	3	3	4	5	2	2	5	5	4	3	3	4
05	6	3	4	4	2	3	2	3	2	2	2	2	2	3	3	3
06	5	4	6	5	3	3	5	3	2	2	2	2	3	2	2	2
07	4	4	3	3	2	3	4	3	4	3	5	6	1	2	3	2
08	2	3	4	4	3	4	5	4	2	2	2	2	2	2	2	2
09	3	3	4	3	2	1	2	3	3	4	2	3	2	3	4	2
10	4	5	3	6	3	3	4	5	2	2	5	5	4	3	3	4
11	4	5	5	5	3	3	5	4	3	3	3	3	3	3	3	3
Sum	45	47	45	52	32	33	46	45	29	28	41	39	29	32	33	35
Mean (Sum/11)	4	4	4	5	3	3	4	4	2.6	3	2.5	3.5	2.6	2.9	3	3.2
Positive	17				14				11.6				11.7			
Multiply	320				144				68.25				72.38			
No.	4				7				10				9			

No.	Transportation				Fishery and Livestock				Quality of environment.				Diversity Biological.			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
01	3	3	3	3	4	5	5	5	5	6	6	5	1	1	2	5
02	3	3	4	3	4	4	4	4	3	3	4	3	1	1	4	3
03	3	4	6	4	3	2	6	4	3	2	3	6	4	2	6	1
04	1	2	3	4	1	1	2	1	7	7	7	4	1	1	1	1
05	1	2	1	1	1	3	3	5	6	7	4	6	2	2	3	1
06	1	1	3	1	5	2	4	4	4	6	5	7	3	3	6	6
07	1	2	2	2	2	3	2	2	5	6	6	7	3	2	2	2
08	2	2	2	2	2	3	3	2	4	4	4	4	1	2	2	2
09	3	2	3	2	2	4	3	3	6	6	5	6	3	3	2	2
10	1	2	3	4	1	1	2	1	7	7	7	4	1	1	1	1
11	3	3	3	3	4	5	5	5	5	6	6	5	1	1	2	5
Sum	22	26	33	29	29	33	39	36	55	60	57	57	21	19	31	29
Mean (Sum/11)	2	2.4	3	2.6	2.6	3	3.5	3.3	5	5	5.2	5.2	1.9	2	3	2.6
Positive	10				12.4				20.4				9.5			
Multiply	37.44				95.55				676				29.64			
No.	11				8				1				12			

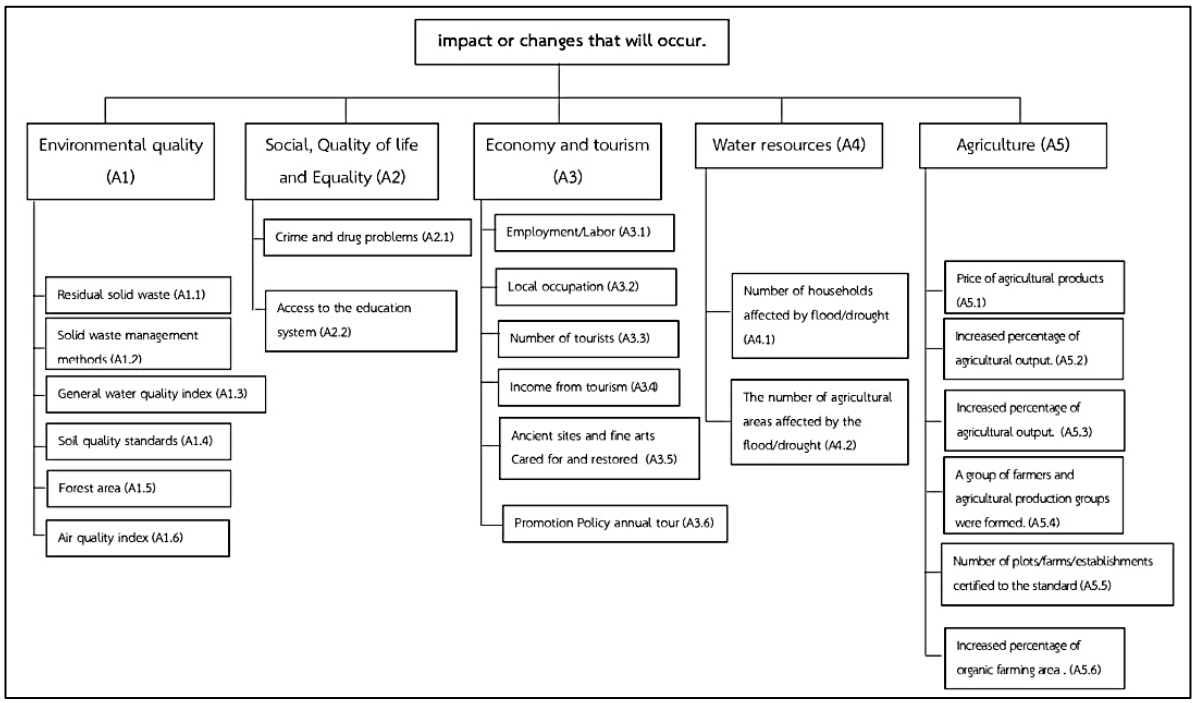

Diagram 1 Effects or changes that may occur as a result of the operation

Eleven experts compared the importance of each strategic issue, then prioritized the issues and indicators by comparing correlations individually. Then compiled the assessments in a matrix table, starting from the top layer of the chart with strategic issues, and the lower level of the chart was the indicator level. It uses the level of importance of all problems with numbers -3 to +3. The results were considered important by the experts. The results are shown in Table 3.

1.2 Determination of strategic alternatives for environmental assessment at the strategic level of Mueang Lopburi District.

The Environmental Impact Assessment at a Strategic Level that may occur from implementing the Mueang Lopburi District Development Plan affects the economy, society, and environment. Mueang Lopburi District has considered the role and vision of Mueang Lopburi District as "*The district is livable, has stability, promotes tourism development, people have knowledge and food safety.*" The main activities were improving the quality of life for people's health and infrastructure education system development for a solution to the illegal drug problem, developing a safe agriculture system, and promoting and developing historical and eco-tourism sites [8].

Strategic issues according to the development plan of Mueang Lopburi District, Lopburi province (2018 - 2022) [9] from the area's potential and the social component of Mueang Lopburi District based on background data, on-site interviews with the stakeholders, and on-site observations. Therefore, there were three important alternatives to be considered in assessing the impact level, namely:

1) Adopting a strategy for the development of Mueang Lopburi District, Lopburi province (2014 - 2017) to undertake development in the area and assess the impact of the operation (Containing, Strategy 1 Creating Value by increasing food safety. Strategy 2 Create added value in tourism and tourism products. Strategy 3 to improve people's quality of life to have good health).

Table 3 Results of priority consideration from experts

No.	A1	Value*						A2	Value*		A3	Value*						A4	Value*		A5	Value*					
		A1.1	A1.2	A1.3	A1.4	A1.5	A1.6		A2.1	A2.2		A3.1	A3.2	A3.3	A3.4	A3.5	A3.6		A4.1	A4.2		A5.1	A5.2	A5.3	A5.4	A5.5	A5.6
1	0.65	0.15	0.05	0.28	0.25	0.11	0.16	0.46	0.53	0.47	23.0	0.09	0.16	0.11	0.41	0.13	0.1	0.26	0.66	0.34	0.25	0.14	0.13	0.38	0.15	0.04	0.16
2	0.25	11.0	15.0	0.29	0.09	0.13	0.23	0.24	0.49	0.51	0.29	0.17	0.06	0.17	0.42	0.08	0.1	0.34	0.69	0.31	0.36	0.14	0.09	0.45	0.12	0.14	0.06
3	0.33	24.0	23.0	0.16	0.06	0.1	0.21	0.27	0.29	0.71	0.95	0.16	0.03	0.13	0.17	0.25	0.26	0.21	0.36	0.64	0.42	0.03	0.17	0.47	0.04	0.26	0.03
4	0.42	19.0	0.17	0.13	0.26	0.14	0.11	0.85	0.31	0.69	0.74	0.14	0.14	0.14	0.11	0.33	0.14	0.23	0.26	0.74	0.12	0.06	0.16	0.15	0.16	0.33	0.14
5	0.26	11.0	0.19	0.14	0.14	0.14	0.28	0.54	0.11	0.89	0.35	0.14	0.14	0.08	0.24	0.28	0.12	0.32	0.65	0.35	0.23	0.12	0.13	0.16	0.14	0.31	0.14
6	0.51	33.0	0.24	0.14	0.07	0.14	0.08	0.26	0.6	0.4	0.38	0.24	0.14	0.16	0.12	0.2	0.14	0.38	0.54	0.46	0.25	0.04	0.08	0.35	0.18	0.21	0.14
7	0.52	17.0	0.26	0.09	0.09	0.14	0.25	0.35	0.2	0.8	0.27	0.18	0.14	0.24	0.05	0.24	0.15	0.44	0.14	0.86	0.64	0.05	0.32	0.23	0.04	0.01	0.35
8	0.26	45.0	19.0	0.03	0.01	0.12	0.2	0.24	0.21	0.79	0.25	0.09	0.14	0.1	0.48	0.07	0.12	0.43	0.3	0.7	0.52	0.03	0.08	0.32	0.14	0.25	0.18
9	0.54	06.0	33.0	0.05	0.31	0.08	0.17	0.69	0.33	0.67	0.24	0.04	0.18	0.25	0.13	0.24	0.16	0.25	0.65	0.35	0.34	0.21	0.17	0.18	0.17	0.15	0.12
10	0.62	09.0	22.0	0.04	0.24	0.12	0.29	0.25	0.79	0.21	0.29	0.16	0.12	0.21	0.21	0.26	0.04	0.32	0.33	0.67	0.23	0.09	0.14	0.07	0.19	0.37	0.14
11	0.37	35.0	15.0	0.14	0.04	0.13	0.19	0.39	0.24	0.76	0.32	0.14	0.14	0.11	0.36	0.16	0.09	0.45	0.05	0.95	0.25	0.14	0.14	0.13	0.17	0.15	0.27
Mean	**0.43**	**0.10**	**0.15**	**0.26**	**0.14**	**0.20**	**0.16**	**0.41**	**0.37**	**0.63**	**0.39**	**0.14**	**0.13**	**0.15**	**0.25**	**0.20**	**0.13**	**0.34**	**0.42**	**0.58**	**0.33**	**0.10**	**0.15**	**0.26**	**0.14**	**0.20**	**0.16**

* Remark:

A1	Environmental Quality
A1.1	The amount of residual solid waste
A1.2	Solid waste management methods
A1.3	General water quality index
A1.4	Soil Quality Standards
A1.5	Forest area
A1.6	Air Quality Index

A2	Social Quality of Life and Equality
A2.1	Crime and illegal drug problems
A2.2	Access to the education system

A3	Economic and Travel
A3.1	Employment/Labor
A3.2	Local Occupation
A3.3	Number of tourists
A3.4	Income generated from tourism
A3.5	Historic Sites and Arts
A3.6	Tourism Promotion Policy

A4	Water Resources
A4.1	Number of households affected by flood/drought
A4.2	Number of agricultural areas damaged by flood or drought

A5	Agriculture
A5.1	Prices of agricultural products
A5.2	Percentage increase in agricultural production
A5.3	Percentage of developed farmers
A5.4	Farmers gatherings
A5.5	Number of plots/farms that have received the standard
A5.6	Percentage increase in organic farming

2) Implement a strategy for the development of Mueang Lopburi District, Lopburi province (2018 – 2022) to undertake development in the area and assess the impact of the operation (Consisting of Strategy 1 Improving the quality of life for people's health and infrastructure. Strategy 2 Solving the illegal drug problem and providing people with safety in life and for property. Strategy 3 Promote and develop important tourist attractions, eco-tourism, and history as learning resources. Strategy 4 Promote quality education systems and learning resources to develop people's education. Strategy 5 To develop and increase agricultural productivity to be safe and develop products.

3) Bring the environmental assessment results at the strategic level of the Mueang Lopburi District development plan, Lopburi province (2018 – 2022), to be used in the decision-making of the next development plan for Mueang Lopburi District. By these, the strategic data is separated according to the specified alternatives into three alternatives [10]. The chart data is shown in Diagram 2.

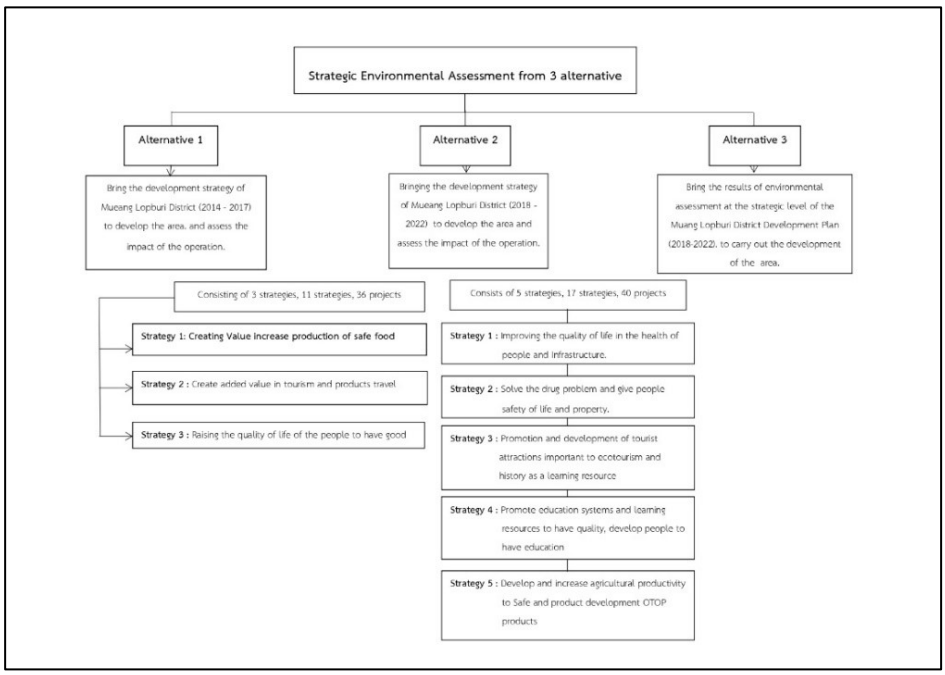

Diagram 2 Strategic Environmental Assessment from 3 alternatives

All three alternatives, according to the Lopburi Provincial Development Plan, the Lopburi District Development Plan, and other related plans, plus field visits to collect data from stakeholders in the area. The results showed that Alternative 3, an alternative proposed to use the results of environmental assessment studies at the strategic level of the development of Mueang Lopburi District, should be used in the decision-making in the preparation of the next Mueang Lopburi District development plan was the alternative with the highest rating score (3.47). Followed by the second option, to adopt the Mueang Lopburi District development strategy, Lopburi province (2018 – 2022) (2.54).

1.3 A study of the stakeholders' opinions on the development of Mueang Lopburi District.

In this part of the study, the stakeholders' opinions were surveyed by using an electronic media system (Video Conference) to assess their opinions on the development of the area according to the development strategy of Mueang Lopburi District. If there was an action to develop Mueang Lopburi District according to the third option, which was the result of the environmental assessment study at

the strategic level, the development of Mueang Lopburi District to be used in decision-making in the preparation of the next development plan for Mueang Lopburi District implementing all 5 strategies [11] by 31 commentators, consisting of

1. Representatives of provincial-level agencies 6 persons
2. Representatives of Mueang Lopburi District 2 persons
3. Representatives of local government organizations in Mueang Lopburi District 8 persons
4. Community leader 15 persons

The results of the opinion study revealed that despite implementing the Mueang Lopburi District development plan (2018 – 2022) in the past, Mueang Lopburi District still faces problems in all dimensions, whether in terms of economy, society, and environment. In terms of economy, as the main income of Lopburi province is from tourism since the Covid-19 epidemic at the beginning of 2020, Mueang Lopburi District has been unable to drive the tourism promotion policy to achieve its full potential. The epidemic situation for the business sector has also slowed down investment and business operations. The aforementioned development plan for Mueang Lopburi District does not specify an action plan for epidemic situations in the social aspect of developing the quality of life in Mueang Lopburi District. The development of quality of life is carried out overall under the government's quality of life improvement policy, focusing on vulnerable groups such as the elderly and the disabled. The welfare state has not yet been promoted to cover all age groups, genders, and the environment. The primary problem is solid waste, and the local government organizations do not have the ability to suitably and entirely dispose of solid waste. Some local government organizations also dispose of solid waste by tipping it outdoors (Open Dump), which is not sanitary. In the study, participants were asked to give their opinions on the issue of the impact that will occur from the development of Mueang Lopburi District. These opinions were separated into positive impacts or expected benefits and negative impacts or issues that stakeholders were worried about if there is a future development of Mueang Lopburi District; the results of comments in the form of positive and negative impacts as shown in Chart 1.

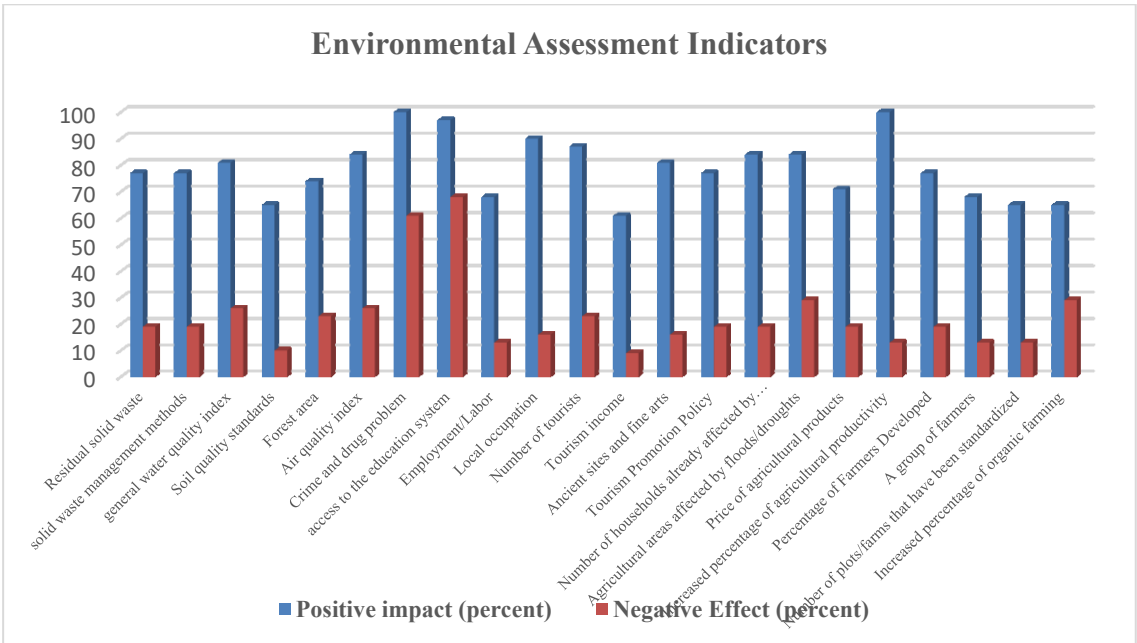

Chart 1 Environmental Assessment Indicators

Strategic Environmental Assessment for Mueang Lopburi District Development, Lopburi Province

The strategic environmental assessment in this study provided a description of the potential impacts in detail on each strategic issue. along with the weight of the score for the assessment to clearly see the impact by dividing the scoring criteria into 7 levels, namely Max Benefit +3 Medium Benefit +2 Minor Benefit +1 No benefits or effects 0 Low Impact -1 Medium impact -2 and Severe Impact -3

First, the impact levels, both strategic issues and indicators of each alternative, were calculated by weighting the priority values of the strategic issues and indicators considered by experts. The experts were representatives of provincial agencies, district agencies, local authorities, and local people, a total of 31. The details of the Strategic Evaluation of the three options for the development of the Mueang Lopburi District were as follows:

1. The Strategic Environmental Assessment for Mueang Lop Buri District Development Lopburi Province According to Option 1, the development strategy of Mueang Lopburi District Lopburi Province (2014 - 2017), three strategies to be implemented in the area of Mueang Lopburi District Lopburi Province as shown in Table 4, 5 and 6.

Table 4 The results of the environmental assessment at the level of strategic development of Mueang Lopburi District, Lopburi Province according to alternative 1

Strategic Issues	Indicators	Impact		
		Score	weight value from experts	weighted score
1. Environmental quality	1. 1The amount of residual solid waste	1	0. 10	0.10
	1. 2Solid waste management methods	1	0. 15	0.15
	1. 3General water quality index	-1	0.26	-0.26
	1. 4Soil Quality Standards	1	0.14	0.14
	1. 5Forest area	1	0.20	0.2
	1. 6Air Quality Index	2	0. 16	0.32
	Total	**5**	**1.00**	**0.65**
2. Social quality of life and equality	2. 1Crime and drug problems	1	0.37	0.37
	2. 2Access to the education system	-2	0.63	-1.26
	Total	**-1**	**1.00**	**-0.89**
3. Economic and travel	3. 1Employment/Labor	1	0. 14	0.14
	3. 2Local Occupation	1	0. 13	0.13
	3. 3Number of tourists	1	0. 15	0.15
	3. 4Income generated from tourism	1	0. 25	0.25
	3. 5Historic Sites and Arts	0	0. 20	0.00
	3. 6Tourism Promotion	0	0. 13	0.00
	Total	**4**	**1.00**	**0.67**
4. Water resources	4. 1Number of households affected by flood/drought	1	0.42	0.42
	4. 2Number of agricultural areas damaged by flood/drought	1	0.58	0.58
	Total	**2**	**1.00**	**1.00**

5. Agriculture	5. 1Prices of agricultural	1	0. 10	0.10
	5. 2Percentage increase in agricultural production	0	0. 15	0.00
	5. 3Percentage of developed farmers	1	0.26	0.26
	5. 4Farmers gathering	1	0. 14	0.14
	5. 5Number of plots/farms that have received the standard	1	0. 20	0.20
	5. 6Percentage increase in organic farming	1	0. 16	0.16
Total		**5**	**1.00**	**0.86**
Impact on environmental quality		0.65	0.43	0.28
Impact on society, quality of life and equality		-0.89	0.41	-0.36
Impact on the economy and tourism		0.67	0.39	0.26
Impact on water resources		1.00	0.34	0.34
Impact on Agriculture		0.86	0.33	0.28
Total		**2.29**	**1.9**	**0.80**
Include the strategic environmental assessment results from alternative 1				**0.80**

Table 5 The results of the environmental assessment at the level of strategic development of Mueang Lopburi District, Lopburi Province according to alternative 2

Strategic Issues	**Indicators**	**Impact**		
		Score	**weight value from experts**	**weighted score**
.1Environmental quality	1.1The amount of residual solid waste	2	0. 10	0.2
	2.1Solid waste management methods	1	0. 15	0.15
	3.1General water quality index	1	0.26	0.26
	4.1Soil Quality Standards	1	0.14	0.14
	5.1Forest area	1	0.20	0.2
	6.1Air Quality Index	2	0. 16	0.32
	Total	**8**	**1.00**	**1.27**
.2Social quality of life and equality	1.2Crime and drug problems	1	0.37	0.37
	2.2Access to the education system	2	0.63	1.26
	Total	**3**	**1.00**	**1.63**
.3Economic and travel	1.3Employment/Labor	2	0. 14	0.28
	2.3Local Occupation	1	0. 13	0.13
	3.3Number of tourists	2	0. 15	0.3
	4.3Income generated from tourism	2	0. 25	0.5
	5.3Historic Sites and Arts	1	0. 20	0.2
	6.3Tourism Promotion	2	0. 13	0.26
	Total	**10**	**1.00**	**1.67**
.4Water resources	1.4Number of households affected by flood/drought	1	0.42	0.42
	2.4Number of agricultural areas damaged by flood/drought	1	0.58	0.58
	Total	**2**	**1.00**	**1**

.5Agriculture	5.1 Prices of agricultural	1	0. 10	0.1
	5.2 Percentage increase in agricultural production	1	0. 15	0.15
	5.3 Percentage of developed farmers	1	0.26	0.26
	5.4 Farmers gathering	1	0. 14	0.14
	5.5 Number of plots/farms that have received the standard	1	0. 20	0.2
	5.6 Percentage increase in organic farming	1	0. 16	0.16
Total		**6**	**1.00**	**1.01**
Impact on environmental quality		1.27	0.43	0.55
Impact on society, quality of life and equality		1.63	0.41	0.67
Impact on the economy and tourism		1.67	0.39	0.65
Impact on water resources		1.00	0.34	0.34
Impact on Agriculture		1.01	0.33	0.33
Total		**6.58**	**1.9**	**2.54**
Include the strategic environmental assessment results from alternative 2				**2.54**

Table 6 The results of the environmental assessment at the level of strategic development of Mueang Lopburi District, Lopburi Province according to alternative 3

Strategic Issues	**Indicators**	**Impact**		
		Score	**weight value from experts**	**weighted score**
.1Environmental quality	1.1The amount of residual solid waste	3	0. 10	0.3
	2.1Solid waste management methods	2	0. 15	0.3
	3.1General water quality index	2	0.26	0.52
	4.1Soil Quality Standards	2	0.14	0.28
	5.1Forest area	1	0.20	0.2
	6.1Air Quality Index	2	0. 16	0.32
Total		**12**	**1.00**	**1.92**
.2Social quality of life and equality	1.2Crime and drug problems	2	0.37	0.74
	2.2Access to the education system	2	0.63	1.26
Total		**4**	**1.00**	**2**
.3Economic and travel	1.3Employment/Labor	2	0. 14	0.28
	2.3Local Occupation	2	0. 13	0.26
	3.3Number of tourists	2	0. 15	0.3
	4.3Income generated from tourism	2	0. 25	0.5
	5.3Historic Sites and Arts	2	0. 20	0.4
	6.3Tourism Promotion	2	0. 13	0.26
Total		**12**	**1.00**	**2**
.4Water resources	1.4Number of households affected by flood/drought	2	0.42	0.84
	2.4Number of agricultural areas damaged by flood/drought	2	0.58	1.16
Total		**4**	**1.00**	**2**

.5Agriculture	1.5Prices of agricultural	2	0. 10	0.2
	2.5Percentage increase in agricultural production	1	0. 15	0.15
	3.5Percentage of developed farmers	1	0.26	0.26
	4.5Farmers gathering	1	0. 14	0.14
	5.5Number of plots/farms that have received the standard	1	0. 20	0.2
	6.5Percentage increase in organic farming	1	0. 16	0.16
Total		**7**	**1.00**	**1.11**
Impact on environmental quality		1.92	0.43	0.83
Impact on society, quality of life and equality		2.00	0.41	0.82
Impact on the economy and tourism		2.00	0.39	0.78
Impact on water resources		2.00	0.34	0.68
Impact on Agriculture		1.11	0.33	0.37
Total		**9.03**	**1.9**	**3.47**
Include the strategic environmental assessment results from alternative 3				**3.47**

According to the environmental assessment at the development strategy level of Mueang Lopburi District, all three alternatives from the information study according to the Mueang Lopburi District Development Plan, other related plans, and field visits to obtain information from stakeholders in the area. It was found that Alternative 3 was proposed to bring the results of the environmental assessment study to the Strategic Development Level of Mueang Lopburi District. To be used for decision-making formatting the next version of the Mueang Lopburi District Development Plan, the option with the highest evaluation score was at the highest level (3.47), followed by the second option to adopt the Mueang Lopburi District Development Strategy. Lopburi Province (2018 - 2022) with strategies to be implemented in the area of Mueang Lopburi District Lopburi Province (2.54).

Discussion

1. Assessment of strategic alternatives for the development of Mueang Lopburi District

According to the assessment of Strategic Alternatives for Development of Mueang Lopburi District, there were 31 stakeholders, consisting of 6 representatives of provincial government agencies, 2 representatives of Mueang Lopburi District, 8 representatives of local government organizations, and 15 representatives of the people. The alternatives were weighted and scored based on the opinions of the stakeholders with a scale to assess the impact weighted to clarify the impact score criteria divided into 7 levels (-3 to 3). The evaluation results for each option were as follows:

1) Alternative 1. Adopting all strategies set out in the Mueang Lopburi District development plan, Lopburi province (2014 - 2017) with three strategies to operate in Mueang Lopburi District scored equal to 0.80.

2) Alternative 2. Adopting all strategies set out in the Mueang Lopburi District development plan, Lopburi province (2018 - 2022) with five strategies to operate in the area of Mueang Lopburi District scored equal to 2.54.

3) Alternative 3. The results of the environmental assessment study at the strategic level of Mueang Lopburi District development to be used in the decision-making in the preparation of the next development plan of Mueang Lopburi District got a score of 3.47.

It was concluded that Alternative 3, an alternative proposed to bring the results of environmental assessment studies at the strategic level of the development of Mueang

Lopburi District, be used in decision-making in preparing the next development plan of Mueang Lopburi District, was preferred. It was the choice with the highest evaluation scores, followed by Alternative 2, implementing all the strategies set out in the Mueang Lopburi District development plan, Lopburi province (2018 - 2022) with five strategies to operate in the area of Mueang Lopburi District. Last was Alternative 1, adopting all strategies set out in the Mueang Lopburi District development plan, Lopburi province (2014 - 2017), with 3 strategies to operate in the area of Mueang Lopburi District.

2. Measures for promoting positive impacts and preventing negative impacts from developing Mueang Lopburi District

1) Measures for promoting and preventing impacts on environmental quality.

Residual solid waste should emphasize the measures to promote solid waste separation at the source to reduce the amount of solid waste that enters the disposal process. Also, to stress the importance of a well-maintenance landfill site for solid waste according to the Pollution Control Department of the Ministry of Natural Resources and Environment measures. It must ensure that it is ready for use and appropriately manage waste landfill sites for the actual amount of solid waste to prevent it from overflowing.

General water quality index measures should be put in place to monitor the quality of effluent, and the source should be established. Additionally, a collective wastewater treatment system in Mueang Lopburi District should also be constructed.

Soil quality standards should consider soil characteristics and land use in the area according to scientific principles, including preparing land use maps that give data on soil fertility and soil type to be used as information in land planning and soil use.

Air quality index air treatment equipment should be installed in an establishment in the area. Also, air quality monitoring should be carried out by installing air quality monitoring stations in Mueang Lopburi districts and nearby at-risk areas, i.e., heavy traffic and air quality displays, along with recommendations, should be made available to residents [12].

2) Measures for promoting and preventing social impacts, quality of life, and equality.

Crime and illegal drug problems in Mueang Lopburi District should resolve by integrating the work of the police and local government officials to take action to prevent potential crime. These crimes may be due to domestic violence, quarrel, mayhem, or snatching. For the problem of illegal drug trafficking in the area, access to the education system and focus on preventing the problem at the grassroots level. To address the lack of educational opportunities for school-age children in Mueang Lopburi District, authorities should work with educational institutions to create a plan to solve the problems of families with a shortage of funds or lack of access to education. This plan shall encompass everyone; all genders of school age should have a good education, equal to those in large cities. Additionally, develop a plan to construct a body of knowledge, especially developing academic knowledge, technology, and innovations.

3) Measures for promoting and preventing impacts on the economy and tourism.

It is important to focus on preventing problems of non-national workers or workers from outside the area. Firstly, supervise and control outside workers and take measures to promote and develop occupations for people in the area. Plus, having an income should be promoted by conserving local occupations or traditional occupations, which represent the identity and background of Mueang Lopburi District or that area. Mueang Lopburi District should be promoted as important tourist attractions, ancient sites, and historical places. Allow the public to easily access open space for organizing activities to attract tourists who want to travel in the area. The tourism income of Mueang Lopburi District should be managed, and the budget should be used for tourism development. It may be hiring tour guides, hiring workers, cleaning tourist attractions, or developing new attractions according to social trends. These investments will generate more tourism revenue for government agencies, including the private

sector. Civil society conservationists join together in the care and maintenance of ancient and art sites to keep them in good condition and take measures to prevent the destruction of ancient sites. It should drive tourism promotion policies according to the development plan and quickly adjust to keep up with social trends, observing what tourists are currently interested in. The relevant agencies should organize activities to fulfill the needs of tourists.

4) Measures to promote and prevent impacts on water resources

By focusing on quantitative water resource management, it should provide water reservoirs to prevent flooding during the rainy season and drought during the dry season. To prevent damage to life and property, buildings, and houses, the District should, as an urgent case, provide water reservoirs to prevent flooding during the rainy season and provide irrigation water during a drought in the dry season because floods or droughts will directly affect the agricultural areas. Mueang Lopburi District should work with relevant agencies on joint ventures related to the issue of dredging canals. To ensure the canals are not clogged or shallow, procure water storage resources, and prescribe measures to financially compensate farmers affected by such disasters to alleviate their suffering. Reference from Department of Environmental Quality Promotion. 2020. Environmental standards [13].

5) Measures for promoting and preventing agricultural impacts

Agricultural production prices should be controlled through economic mechanisms by organizing a forum to exchange farmers' knowledge. And to allow farmers to access new farming information and promote the integration of farmers to strengthen the administration and stability in agricultural operations. Also, to create more bargaining power in the market, encouraging farmers to be aware of and have a shared awareness in using resources in an agricultural occupation. Incentivize farmers to develop their farm plots and farms to meet the standards set by the government referring to the agricultural management guidelines from the Agricultural and Cooperative Development Plan of Lopburi Province (2018 - 2022)

Conclusion

Study on the formulation of the Mueang District development plan with SEA, a Case Study of Mueang Lopburi District had three strategic alternatives identified as follows :

Alternative 1. Implementing all strategies set out in the Mueang Lopburi District development plan, Lopburi province (2014 - 2017) with the strategies to operate in Mueang Lopburi District.

Alternative 2. Adopting all strategies set out in the Mueang Lopburi District development plan, Lopburi province (2018 - 2022) with five strategies to operate in the area of Mueang Lopburi District.

Alternative 3. To bring the results of an environmental assessment study at the strategic level of the development of Mueang Lopburi District.

They were used for decision-making in preparing the development plan for Mueang Lopburi District by using strategic environmental assessment principles, field visits, interviews with stakeholders, and observations in the area. The results of the study can be concluded as follows:

1. Mueang Lopburi District is located in the central region of Thailand. It has an area of approximately 565 square kilometers. It is about 153 kilometers from Bangkok, considered a district not far from the capital. The advantage of Mueang Lopburi District is that there are various transportation routes, whether car via many routes, a railway station, public bus routes (vans), and a service station. Therefore traveling to Mueang Lopburi District is quite convenient. The southern area of the District is a lowland area suitable for farming, and the northern and eastern areas of the District are upland scrubland.

2. Strategic issues and appropriate indicators for the development of Mueang Lopburi District cover all aspects based on the principle of sustainable development. Balanced development of three dimensions: Economic dimension (strategic issues in the economy were tourism and agriculture), Social dimension (strategic issues on social was quality of life), and Environmental dimension (environmental quality strategic issues were

water resources). Based on the priorities of the strategic issues study, Environmental quality strategic issues were the most important in the area's development. This was followed by strategic issues in social, quality of life, the environment, economic, and tourism, strategic issues on water resources, and strategic issues in agriculture. Environmental quality strategic issues were the issues that may be affected first by the area's development. For example, soil resources must be developed by accumulating data and mapping the land use according to the fertility of each soil type to plan for appropriate land use during the construction of roads, buildings, or various development projects. If the soil is used to fill an area, it will be necessary to study the soil data and sources for use in the ecosystem boundaries of the development area. These boundaries should be clearly defined to comply with strict measures to prevent encroachment.

Establish a unit to supervise and regularly monitor solid waste. The potential of local administrative organizations should be developed to effectively manage the waste problem campaign for waste sorting to reduce the amount of waste, providing a reserved area to dispose of solid waste.

Air quality monitoring stations should be installed to cover the area of Mueang Lopburi District. Daily results report instructions on the right actions and measures to reduce activities that may cause air pollution, such as announcing no-burning zones. Control the industrial sector to strictly comply with the pollution prevention measures of the Department of Industrial Works.

3. Environmental Assessment at the strategic level of Mueang Lopburi District development according to Alternative 3 brings the results of an environmental assessment study at the strategic level of Mueang Lopburi District development to be used for decision-making in the preparation of the next development plan of Mueang Lopburi District from the implementation of the aforementioned alternatives. There may be impacts from the implementation of the Muang District Development Plan. However, such impacts are in the executives' plans in every District, and governance is managed following mitigation principles by using the cooperation of the people in the area of Mueang Lopburi District to prevent such negative effects from occurring as little as possible.

4. Based on the stakeholders' opinion of Mueang Lopburi District according to the development strategy of Mueang Lopburi District, the development would be beneficial to the quality of life of the people, mostly from career development opportunities, well-being quality, and access to a sound education system, the standardized public health system, social services, and the welfare state. In addition, they expressed concern about the change in environmental quality. Such development might directly affect the soil, water, and air quality of the ecosytem. Resulting in the development affecting the lifestyles and culture of the people of Mueang Lopburi District. Moreover, the non-registered populations and non-nationals might cause changes to the culture and traditions unique to the Mueang Lopburi District and the safety of people's lives and properties.

5. Development of Mueang Lopburi District could have both positive and negative impacts; it would make Mueang Lopburi District grow and become more competitive but, at the same time, cause negative impacts on various issues such as economic development, and tourism affects the environmental quality and the well-being of society. Therefore, the appropriate development has to be developed on the sustainable development principle.

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[1] Inthorn, D., Sidtitoon, N., Silapanuntakul, S. and Incharoensakdi, A. 2002. Sorption of mercury, cadmium and lead in aqueous solution by the use of microalgae. Science Asia. 28(3): 253-261.

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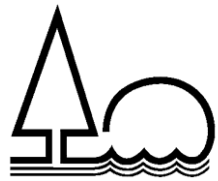

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