Interdisciplinary Research Review

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Editorial Note

The Interdisciplinary Research Review (IRR) was established with academic cooperation by the Nakhon Pathom Rajabhat University, The Royal Society of Thailand Committee of Interdisciplinary Research and Development, and Rajabhat University (Western Group). This Issue, Volume 14 Number 6 (November – December 2019). This issue contains of ten articles in diverse fields: (1) Effective behavioral interventions for smoking cessation in the primary care setting: A meta-analysis, (2) Assessment methodologies of groundwater redevelopment considering sustainable utilization: a case study in central Taiwan, (3) Efficiency of activated carbon and white charcoal from textile dyeing industry in synthetic wastewater, (4) Counting gibbons: The evolution of sample methods, (5) Iterative receiver design for indoor wireless visible light communication system, (6) Event marketing as an appropriately integrated marketing communication for promoting tourism of Ko Lad E-Tan, Nakhon Pathom Province, Thailand, (7) Rehabilitation guidelines for children with cerebral palsy, (8) Standard development of rehabilitation services for cerebral palsy children in disability services center and their networks, (9) Interfacial improvement of hole transporting layer using graphene quantum dots for efficiency enhancement of organic photovoltaics, and (10) Application of response surface method (RSM) and central composite design (CCD) for optimization of cassava yield.

The Editorial Board of the IRR encourages anyone to submit articles for evaluation and review. The processes of submission, review and publication of articles are described on the journal's website, https://www.tci-thaijo.org/index.php/jtir. The Editorial Board and Committees of the IRR sincerely thank all peer reviewers who have sacrificed their time to help us produce a better journal, and also wish to thank all teachers, researchers and other academicians for submitting their valuable research to this journal. Finally, we thank readers of our journal who help to spread the knowledge and benefits gained to others. With your feedback and suggestions, we will strive to improve the quality and relevance of the IRR.

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Yongyudh Vajaradul
Editor
Interdisciplinary Research Review

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Effective behavioral interventions for smoking cessation in the primary care setting: A meta-analysis

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Abstract

There are a number of smoking cessation strategies offered by healthcare providers in Thailand. Despite this, the number of Thai smokers have stopped smoking permanently as a result of the strategies is still far less than the expectation of the National Strategic Plan for Tobacco Control. It feels that this is a reflection of the fact that there are a lot of delicate issues around use of the tobacco cessation service system. This research aimed to investigate the effectiveness of strategies for smoking cessation intervention among smokers in the primary care setting on point prevalence abstinence (PPA) basis. English and Thai language articles from 1993 to 2018 available from six databases were used as data sources. Two independent reviewers assessed articles against the following eligibility criteria: experimental study, adult smokers ≥ 18 years of age, studies comparing the effectiveness of a smoking cessation intervention with no treatment or wait-list control, or usual care. Study quality was critically appraised by two reviewers using established criteria; Review Manager 5.1 was used for meta-analyses. Of the 77 eligible studies that were found, 15 had complete data for meta-analysis on PPA and/or wait-list control, or usual care. The meta-analyses indicated that smoking cessation counseling using quitline telephone counseling was the most effective strategy for smoking cessation on PPA when compared with no treatment or usual care. Conversely, other interventions resulted in nonsignificant differences between the experimental and control groups. In summary telephone counseling was found to be the most appropriate approach for facilitating smoking cessation in adult smokers in the primary healthcare setting. Further research is needed to compare the optimal course length, intensity, and long-term effectiveness for helping smokers quit in the primary healthcare setting.

Keywords: Smoking cessation, intervention, smokers, primary care setting

1. Introduction

Smoking cessation conducted by healthcare providers is considered as health benefits both smokers, and others who live closely. It is due to of the fact that tobacco use remains a very crucial leading cause of non-communicable disease globally [1]. Smoking cessation interventions undertaken by healthcare professionals have encouraged smokers to stop smoking permanently [2] –it was measured by point prevalence abstinence (PPA) [3, 4], and/or continuous abstinence rate (CAR) [4 – 6]. Evidently, behavioral counseling for facilitating smoking cessation, especially in the primary healthcare setting has been demonstrated that it is the most significantly effective smoking cessation intervention [6-13]. For offering smoking cessation in the primary healthcare setting, nurses play crucial roles involving identifying smokers, finding out the most suitable strategies for each smoker, as well as monitoring the expected outcomes in order to look after closely [14, 15]. Moreover, they usually appraise and comprehend the context facilitating smoking cessation accurately. However, there are a number of behavioral counseling characteristics for smoking cessation conducted for offering smokers to quit smoking constantly.

With reference to the prior studies, behavioral counseling intervention undertaken to enhance smoking cessation has been pointed out into diverse features. It can be divided into two main attributes in accordance with policy of the WHO Framework Convention on Tobacco Control (WHO FCTC) [16] comprising face to face counseling [4, 9, 10, 13, 17 – 19] and counseling via electronic devices, namely, cessation aid video [9], telephone counseling [6, 7, 10, 17, 20, 21]. text messenger [20], quit line website [4, 12, 18], and multicomponent electronic devices [22, 23]. In short, a variety of behavioral counseling interventions can be

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applied in particular contexts.

Even though, there are various methods to facilitate smokers quitting smoking in Thailand, the number of Thai smokers who can stop smoking permanently is still less than the expectation of the National Strategic Plan for Tobacco Control [24]. It has been illustrated that there was a significant decrease in smoking rate by 11% from 32.0% in 1991 to 21.9% in 2006, in contrast, it was a slight decrease by 0.5% from 21.9% in 2006 to 21.4% in 2013 [25]. It is reflected that there are a lot of delicate issues of smoking cessation system among Thai smokers needed to develop. According to the former studies stated that behavioral interventions in particular behavioral counseling can be used as standard smoking cessation intervention in every area, especially primary care setting. Moreover, smokers in the primary care setting cannot access cessation drug. Therefore, this paper aimed to investigate the effectiveness of behavioral interventions for smoking cessation among smokers in the primary care setting on point PPA. The meta-analysis was performed so as to strengthen the scientific evidences for smoking cessation strategies with a high statistical power and more robust point estimate from any existing studies. The finding of this study can be used as an empirical evidence for developing the behavioral intervention for smoking cessation in the primary care setting appropriately.

2. Methodology

This paper is a meta-analysis of the experimental research following Cochrane methodological guidline [26]. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist and flow diagram were used to be a guideline for reporting the systematic review paper [27] .

2.1. Eligibility criteria

Eligible studies were experimental studies behavioral interventions for smoking cessation provided by healthcare providers among smokers aged over 12 years old. The selected studies intended to compare the effectiveness of smoking cessation intervention with no treatment or wait-list control, or usual care. Furthermore, the studies reported abstinence from smoking with at least a 1-month follow-up-30-day point prevalence abstinence, and/or continuous abstinence as the primary outcome were included. Report characteristics and study design: English and Thai-language quantitative studies employed an experimental design published since 1993 were included. Qualitative studies, editorials, letters, and commentaries, studies which could not be identified a full text, and articles that did not report the minimum information required were excluded.

2.2. Information sources and search strategy

Mixed automated and manual search strategy were employed. The databases from January 1993 to June 2018 were used to conduct comprising: PubMed, CINAHL Plus with full text, Cochrane Library, Web of Science, PUBMED, and SpringerLink. A combination of the constructs "smoking cessation", "tobacco control", "tobacco cessation", "intervention", "counseling", "motivational interviewing", "quit", "stop", "abstinence" and related keywords were searched in order to ensure broad coverage of published studies. Search terms were purposefully broad to ensure that all relevant articles would be captured.

2.3. Data collection process and data items

Eligible studies were coded to capture both substantive and methodological characteristics. The coding focused on the following features of the studies: identifying information, funding source, design, aims and objectives, variables related to the characteristics of participants, the nature of the intervention and its implementation, the nature of the comparison condition(s) and their implementation, analytical methods, follow-up duration and rates, and outcome measurements.

2.4. Risk of bias in individual studies

The Cochrane Collaboration tool for assessing the risk of bias [26] was used to investigate the quality of the selected papers.

2.5. Data synthesis:

Findings from systematic reviews were summarized and compared with findings from original research published beyond date ranges included in the reviews. Strength of evidence was used to assess the body of evidence. Moreover, Review Manager (RevMan5.3, The Cochrane Collaboration, Oxford, England) was used for meta-analyses. All the outcomes in this review were diclotomous outcomes and a weighted odd ratio was calculated if the same measurement scale was used. Heterogeneity was assessed by I^2 statistics. Heterogeneity is considered to be low if I^2 is $\leq 75\%$, and high if I^2 is $> 75\%$ [26]. A fixed effects model for meta-analysis was used. It is due to of the fact that the intervention effect was homogeneous ($I^2 < 75\%$). For forest plots with sufficient studies included (> 10), funnel plots were generated to examine for the publication bias.

3. Results

3.1. Study selection

A total of 77 records were reviewed for eligibility, and 62 were excluded for the following reasons: full text was not available (n = 32), intervention did not meet the definition of "counseling" (n = 17), record
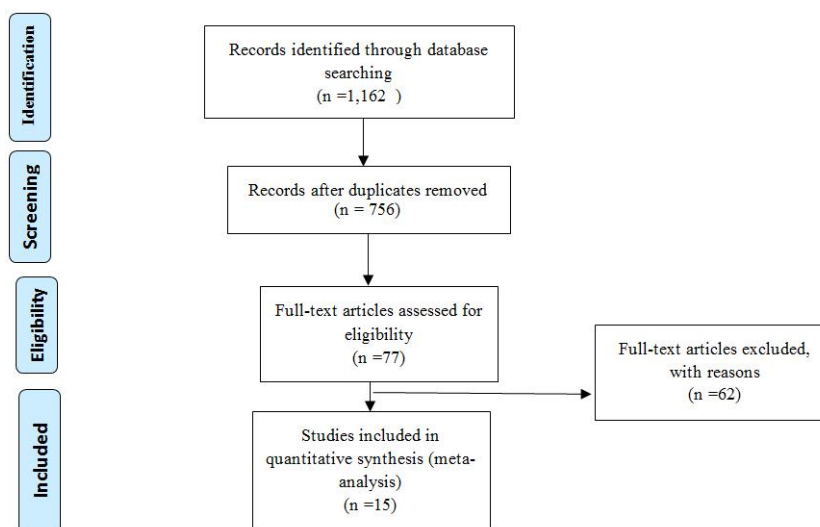
Figure 1: PRISMA flow diagram.

Abbreviation: PRISMA, Preferred Reporting items for Systematic Reviews and Meta-Analyses.

was not a published study (n = 3), smoking outcomes not reported (n = 7), and unable to calculate abstinence rates using available data (n = 3). (see Fig. 1)

3.2. Risk of bias within and across studies

Overall, the studies included in this review had a low risk of bias in most or all areas assessed.

Selection bias: Most studies used an automated randomization strategy that was considered low risk. Allocation concealment was not often described, but when studies were automated, allocation concealment bias risk was judged as low. For example, the study by McGrath, Zak [6] was judged to be at low risk since participants were not blinded.

Performance and detection bias: Performance and detection biases were evaluated the included studies with regard to personnel and their ability to influence outcomes and found most studies to be at low risk for performance bias. Most studies were conducted by personnel involvement in the delivery of the intervention. Therefore, some trials in which performance bias was judged as high risk. For instance, the study counselors giving motivational interviewing program were not blind to condition but interacted with all participants.

3.3. Participants

Participants participated in most of selected studies were in adult age group-average age was mid-30s to late 40s. The majority of studies enrolled a higher proportion of men (67.72%). Unless, some studies, namely, the study by Hollis, Lichtenstein [9] that 68% of participants were female with low socioeconomic status.

3.4. Intervention elements

This study reports 15 studies which were divided in according with The U.S. Treating Tobacco Use and Dependence Clinical Practice Guideline [28] (See Supplementary 1 https://goo.gl/5drQeh), including self-help, and counseling. However, all of selected interventions were counseling in a variety of characteristics as follows:

3.4.1. Face-to-face counseling

Five studies aimed to investigate the effects of counseling by providing information associated with cessation approaches using face-to-face counseling [11, 13, 17 – 19], two studies of the brief intervention using motivational interviewing by nurse [19, 29]. All interventions included nursing counseling, self-help materials, and follow-up contact either in person or by telephone; all were compared with usual care by health care providers, particular nurses, and physicians (brief advice to quit smoking, related self-help materials, or both).

3.4.2. Counseling via electronic devices

Seven studies intended to explore the effectiveness of counseling trough electronic devices as follows:

Telephone counseling–five studies of nurse counseling by quit line telephone [6, 7, 10, 13, 17, 20, 21] Participants were offered multisession telephone counseling, both reactive telephone couseling and proactive telephone counseling, lasting approximately 15 minute in the first time in order to provide intensive counseling. Then, they were arranged follow-up 3 – 4 times roughly 5 minutes after starting quit smoking until 6-12 months so as to prevent smoking relapse.

Self-help materials–three studies offered cessation technique by self-help materials [12, 17, 30],

Text messanger–two studies provided cessation technique via text messanger [20, 23],

Video–two studies delivered cessation technique via text messanger [9, 23].

All interventions included brief and intensive counseling, self-help materials, and follow-up contact either in person or by telephone; all were compared with usual care by health care providers (brief advice to quit smoking, related self-help materials, or both). For smoking cessation providers could be divided in two features including, 1) smoking cessation the primary care service system, the smokers were offered smoking cessation smoking system by health care professionals-most of them were nurses who experienced providing smoking cessation service and 2) smoking cessation by telephone couseling, participants in selected studies were delivered smoking cessation service by quitline counselors trained for providing intensive smoking cessation counseling followed by the gold standard of telephone counseling for quitting smoking.

3.5. Comparison arms

This paper reports characteristics of comparison arms with reference to the features of intervention as follows:

3.5.1. Effects of counseling compared with no treatment or wait-listed control

Only one study [20] that intended to investigate the effectiveness, PPA between counseling by delivering the smoking cessation information via SMS text messaging intervention. However, both of the 1-wk PPA and 1-mo PPA were not significantly different among the study participants.

3.5.2. Effects of smoking cessation counseling compared with usual care or minimal intervention

14 studies [6-13, 17, 18, 30, 31] aimed to investigate the effectiveness-measured by PPA between a variety of counseling interventions and usual care or minimal intervention. Four studies [6, 7, 13, 31] using counseling by telephone comparing with control group. Overall, the findings illustrated that the quitline telephone could assist smokers to stop smoking permanently better than usual care-standard advice, standard counseling, the self-help booklet, particularly proactive telephone [31]. Meanwhile, two studies–Ridner et al. [13], and Etter [11] provided motivational interviewing compared with usual care. The findings illustrated that only study of Ridner et al. [13] could enhance smoker to stop smoking rather than the control group. Moreover, web-based for quitting smoking was used to compare between experimental and control group in the studies of Clark, Cox [12], Brendryen and Kraft [8], Stanczyk, de Vries [23], and Skov-Ettrup, Dalum [31]. The findings revealed that only two studies [8, 12] that counseling through web-based

or internet devices could help the study participants to quit smoking effectively. The comparison of effects of smoking cessation counseling-measured by PPA compared with usual care or minimal intervention is shown as Fig. 2.

3.6. Outcome measures

The outcome varied widely among the studies, which could be divided into characteristics including abstinence self-report and biological verification. Most studies used self-reported abstinence measures (i.e., 7-day, 30-day abstinence) as the primary outcome abstinence measure, ranging from 1 to 24 months after finishing intervention [6 – 13, 17 – 20, 30, 31]. Moreover, biological verifications were used to measure in some studies, namely expired-air carbon monoxide (CO) [12, 19, 30] and saliva cotinine [18].

4. Conclusion

This study reviewed intervention evaluating the efficacy of previous smoking cessation strategies in primary health care that reviews had not covered. This study assessed the body of evidence based on the strength smoking cessation interventions provided for smokers by healthcare providers. This paper summarizes whether the evidence assembled would change recommendations in previous authoritative publications and guidelines.

5. Discussion and Recommendations

The findings of this study can be compared and contrasted witn the former studies as follows:

Firstly, previous studies indicated that brief individual cessation counseling was efficacious [29]. Moreover, the review of counseling yielded mixed results. This study reports the increased abstinence with counseling treatment.

Secondly, the results are consistent with recent reviews [6, 7, 10, 18] showing that self-help, especially by multimedia or modern technology device has more effect when combined with other methods such as person-to-person intervention or mobile phone quit line.

Finally, telephone counselling–a very crucial tobacco cessation service, using multisession telephone counselling [32, 33] has been the most effective kind of behavioral intervention for smoking cessation service. This is because telephone counselling center has delivered information, advice, support, and referrals to tobacco users-regardless of their economic status, geographic location including the primary healthcare setting. Furthermore, the telephone counselling has been staffed by counselors trained specifically to assist smokers quit, also followed by the gold standard protocol [34]. Moreover, telephone counseling for smoking cessation has usually had not only low cost,
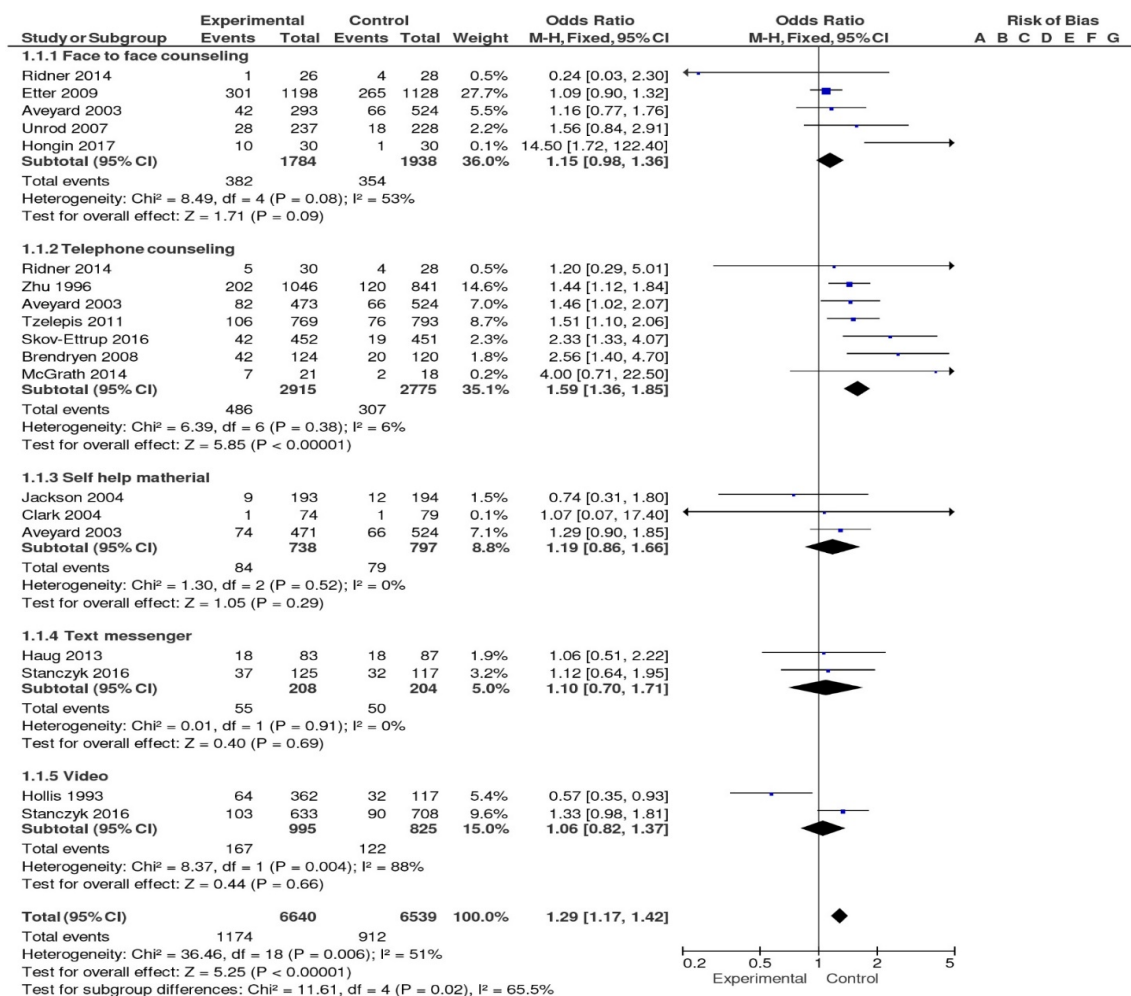
Figure 2: Meta-analysis studies comparing behavioral intervention to usual care or minimal intervention conditions.

but also facilitated smokers in the primary care setting quit conveniently [35]. A good illustration of this is that Quitline for smoking cessation service in New Zealand has promoted health gain, addressed health inequalities among smokers in the primary care setting as well as saved health system costs [36, 37]. However, the telephone counselling service, particularly the Thailand National Quitline (TNQ) should be integrated with other existing smoking cessation services in order to increase the accessibility as well as efficacy of the expected outcome. All thing considered, smoking cessation service system should be provided into primary healthcare service system, also the TNQ should be integrated with other smoking cessation services.

Recommendation for further studies, very few studies explore the effectiveness of an integrated behavioral interventions for smoking cessation using proactive multisession telephone counseling and building capacity the social capitals in the community i.e. Village Health Volunteers (VHVs) or family members because these can help the smoker to stop smoking closely. Especially, community health care service team can facilitate something to assist smoker to quit tobacco use effectively. It is due to of the fact that humans' behaviors, particularly smoking behavior, are caused by complicated factors which include internal and internal factors.

6. Acknowledgments

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Assessment methodologies of groundwater redevelopment considering sustainable utilization: a case study in central Taiwan

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Abstract

Before a groundwater source is redeveloped, many factors determining the groundwater resources should be analysed. As a minimum these should include natural recharge rate, current pumping rate, downstream reserves and reduction factors. Considering the difficulties with actual measurement of groundwater recharge, a method for estimating the rate must be adopted. A complete assessment methodology should be used based on the downstream reserve water of the groundwater area, the rights of users, environmental utilization and the groundwater recharge sources of target area. This approach is necessary in order to help numerical convergence and ensure the sustainability of groundwater resources. This paper uses the groundwater basin of Puli in central Taiwan as an example. It proposes a sound and simple assessment methodology that can be used by the government water resource management teams and development projects to estimate reasonable and sustainable groundwater redevelopment.

Keywords: Groundwater, sustainable development, water resource management

1. Introduction

In the early 20th century Safe Yield was proposed as the assessment foundation for groundwater availability, while the definition of Safe Yield being: "The limit to the quantity of water which can be withdrawn regularly and permanently without dangerous depletion of the storage reserve" (Lee, 1915) [1]. Though it described Safe Yield as hydrogeological observation, no clarification was made regarding dangerous depletion of the storage reserve and regular withdrawal. Later research indicated that the natural recharge of groundwater can be seen as Safe Yield. Since 1950 US Geological Survey discarded such term due to inexplicit definition of Safe Yield, and adopted Sustainable Yield as the basis for evaluation for groundwater availability. However, the definition of Sustainable Yield is even less clear than Safe Yield, while most definitions generally indicated the negative impact to economy, community and environment when groundwater development is based on Sustainable Yield. Although the definition of Sustainable Yield was lack of clear statement, it mostly indicated that Sustainable Yield must be less than Safe Yield, i.e. recharge on the groundwater zone (Kalf and Woolley, 2005) [2].

This paper adopted the EU's Water Framework Directive [3] and believed that most drain of groundwater is surface water within the area; and if there is no human development or utilization, the groundwater discharge should equal to groundwater recharge in the long term. The base flow of surface water discharged from groundwater is restricted by ecological needs for surface water. Therefore it should not regard the total drain of groundwater as Sustainable Yield. Considering the surface water conservation for ecology needs, the maximum rate of Sustainable Yield of groundwater area should exclude necessary ecological base flow from surface water within catchment area from the natural recharge (CIS, 2009)[3]. Previously mentioned Sustainable Yield should be the maximum availability in a groundwater area, however an Aquifer Sustainability Factor must be given to represent the hydrogeological characteristics, groundwater environment status, economic development and other characteristics of project area, so as to define groundwater availability (Smith et al., 2010; Moltz et al., 2013; Henriksen and Refsgaard, 2013) [4 – 6].

As a result, the availability for groundwater redevelopment can be shown as follows:

$$Q_r = Q_a - P \qquad (1)$$

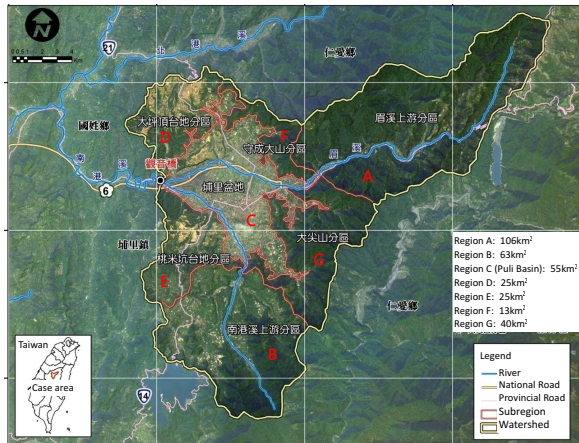*Corresponding author; email:msyang@mail.sinotech.com.tw

Figure 1: Project area and it's sub region of water budget.

Figure 2: Estimated results of water consumption within case area.

$$Q_a = (R - D) \times F \qquad (2)$$

In which: Q_r being the availability for groundwater redevelopment; Q_a being groundwater availability; P being current pumping; R being groundwater recharge; D being downstream reserve, which consists of existing surface water usage of downstream river, scheduled withdrawal for water resource engineering under development, downstream groundwater recharge, and ecological base flow; F being Aquifer Sustainability Factor. As result from Smith et al. (2010) [4], the factor is from 15% to 85%.

In Equation (1) the estimation of actual pumping is required, however in reality it is impossible to conduct investigation on each and every well within the area, therefore here we assessed with officially-declared unit withdrawal and land cover. In Equation (2), complicated groundwater flow simulation is involved. To reflect actual status and provide essential reference for water resource management decision making, relevant research and analysis is critical prior to groundwater simulation. So far the water usage of each objective in Taiwan is not yet fully comprehended; meanwhile, it merely focuses on the research over groundwater flow and the surface water is omitted on groundwater resource studies; parameter setting based on such notion may lead to deviation from reality and cause numerical operation fail to converge, or simulation result inconsistent with reality.

There is a lack of documents recording the relevant details of assessment before numerical simulation of groundwater flow, such as proper method for estimating the groundwater withdrawal, recharge and natural discharge, as well as how to assess proper surface groundwater distribution with simple water budget. To achieve an appropriate estimate of groundwater redevelopment, this paper chose Puli Basin, central Taiwan, to establish estimation equation and its procedure by taking into account of the coverage of surface and groundwater, region from upstream to downstream, the rainfall, evaporation, runoff, recharge, groundwa-

ter drain, etc. in the hydrological cycle, as well as withdrawal, pumping, transbasin diversion, irrigation return flows, etc. of water resource. Furthermore, the above total estimates can be adopted in simulation of time and space domain as initial conditions and parameters for numerical operation, so as to minimize speculation and unreasonable input of parameter adjustment while calculating proper groundwater redevelopment amount. The study area shows the differences between empirical and simulation results of water budget are about 5% to 20%, and the reasonable groundwater redevelopment is 39.26 million m^3 per year.
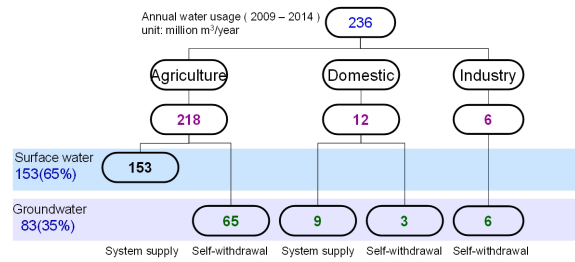
2. Study Area

The genesis of the basin is assumed to be caused by the crustal tension and extrusion. Water accumulated and formed lake, sediment at the bottom of the lake, river eroded towards the source and drained out the lake, alternate deposition and alluvial formed groundwater aquifer. Consolidated formation border on east side of Puli Basin can be seen as zero-flow boundary. On the west side, the high level thick gravel platform recharge groundwater from the side (Fig. 1). Thick at the center and shallow on the rim, the aquifer of Puli Basin is an inverted cone. Pumping wells located mostly at 200 m thick sand-contained gravel zone recharged by surface water, hence is chosen as study target.

In wet season, the groundwater level at the west basin is about 4-6 m and gradually decreases towards the west until meeting the river level as part of surface water; on east side, the depth reaches at least 10 m. Suggest east side irrigation system taking from groundwater, plus no recharge from east consolidated formation, hence leads to deeper groundwater level. The depth during dry season can go 1–4 m deeper than high flow season. While the level of groundwater on the west doesn't change much from wet to dry season, the east varies greater relatively.

2.1. Behavior of water consumption

Case groundwater area located at Puli Basin, central Taiwan, where 75% of 76,000 population depends on Taiwan Water Corporation (TWC)'s water supply

Table 1. Setup of recharge and pumping area for hydrogeological conceptual model.

Land use classification	Recharge from river	Recharge from rainfall	Recharge from irrigation	(Area outside of Irrigation Association) Pumping for irrigation
River	YES	NO	NO	NO
Paddy	NO	NO	YES	YES
dry crop	NO	YES	NO	YES
Impermeable	NO	NO	NO	NO
Non-irrigation permeable	NO	YES	NO	NO

Remark: Recharges from river, rainfall, irrigation recharge and irrigation pumping regions are presumed according to land use classifications to estimate reasonable groundwater recharge and withdrawal.

Remark: Background picture taken from internet and does not reflect actual case area facility or topography.

Figure 3: Estimated results using empirical water budget method on case area.

Remark: No calibration or verification was made to simulation parameters. The values are given based on reference and supplement investigation; due to the difficulty retrieving the actual pumping volume of year 2009-2014, therefore there is difference between simulation and observation value. While partial records are to be confirmed, overall trend is consistent.

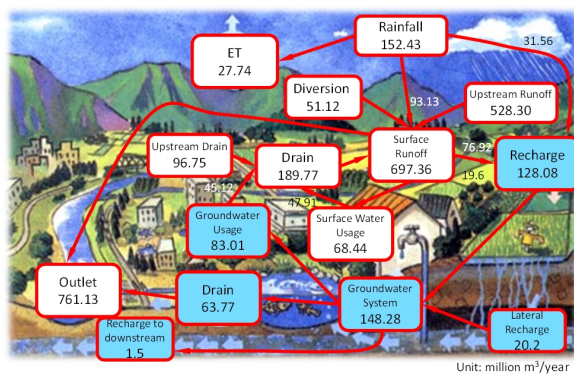**Figure 4**: Simulation result of groundwater level.

from groundwater pumping well, while non-supplied (self-withdrawal) area pump groundwater for own utilization.

The main supply for industrial use comes from groundwater. Most factories are located on the southeast side of the basin. The estimated water amount is 6.42 million m^3, with 84 companies mostly being beverage and pulp and paper based industry.

Irrigation is the main utilization of agriculture use within the basin. Of which, Irrigation Association's consumption is based on surface water, with groundwater as alternative backup source; outside Irrigation Association's business area of non-system supplied, groundwater well is remain in use as main source.

So far, other than TWC and Irrigation Association's records of actual withdrawal and self-withdrawal outside supply system, there are no actual water usage records.

2.2. Estimation of water consumption

Agriculture water use is based on actual surface water usage provided by Irrigation Association (IA) at 153 million m^3 per year; the usage of groundwater is calculated at the irrigation area outside IA business zone multiplied by irrigation depth by IA (excluded conveyance loss), plus livestock water usage; water for

livestock is calculated at the unit usage of Agricultural unit multiplied by the number of livestock. For domestic water supply, the actual groundwater supply provided by TWC is adopted at 9 million m^3 per year. For self-withdrawal, it is calculated by non-TWC-supplied population multiplied by unit quantity of water consumed. Industrial usage is calculated by the amount of authorized water right at 6.42 million m^3 due to TWC does not supply for the use of process. Total annual usage of each purpose is calculated, as shown in Fig. 2, at an average of 236 million m^3.

3. Methodology

From the aspect of groundwater recharge and drain, this paper suggests using groundwater recharge amount for groundwater resource estimation, and empirical water budget method and numerical modeling for analysis. In this paper the empirical water budget method considers the factors of hydrological cycle, groundwater abstraction, irrigation return flows, and possible groundwater recharge. Actual surface water flow amount is recorded at the exit of the basin, cross checked and calculated possible groundwater flow amount. Through the calculation and analysis, feasibility of water quantity in each link is considered, so as to provide groundwater flow numerical simulation's initial input and to compare and verify the two as well as adjust mutual parameters. For empirical water budget method, it is difficult to give precise calculation to groundwater flow and surface water river recharge,

Table 2. Calculation table of water budget on case area by using empirical method.

Source	Direction	Inflow term (million m³/year)		Outflow term (million m³/year)	
Surface Water	Top	Rainfall	152.43[C-1]	Evapotranspiration	27.74[C-6]
		Transbasin Diversion	51.14[C-2]	Surface Intake	68.44[C-7]
	bottom	Drain	-[C-3]	Groundwater Recharge	128.08[C-8]
	Lateral	Upstream Runoff	528.3[C-4]	Surface Runoff	697.38[C-9]
		Irrigation Return Flows	189.77[C-5]	(Surface Discharge Observation of Basin Outlet)	761.13[C-10]
Groundwater	Top	Vertical Recharge	128.08[C-11]	Drain of Groundwater	63.75[C-14]
				Pumping	83.03[C-15]
	bottom	Deep Aquifer	0[C-12]	Deep Recharge	0[C-16]
	Lateral	Lateral Recharge	20.2[C-13]	Recharge to Downstream Basin	1.5[C-17]

Remark: estimated from 2009 to 2014, demonstrated on region C (55.06 km²). Values defined as follows.
C-1: Referred to contour distribution of annual average rainfall. Annual average rainfall (2,768 mm) × the area of Region C;
C-2: Irrigation Association Water Withdrawal Annual Report, average actual withdrawal is adopted;
C-3: Groundwater drain not included in surface runoff to examine surface runoff only from surface source.
C-4: The sum of surface runoff of all regions excluding region C;
C-5: The ratio of return flows is 70% based on Reference [7], the large amount of temperature-controlled water used before discharge in planting white bamboo shoots; irrigation return flows = (surface withdrawal + irrigation pumping) × 70%
C-6: Evapotranspiration is estimated to be 70% of the evaporation from meteorological observation stations, and is calculated as the annual average (720 mm) × the area of this region × 70%;
C-7: Surface withdrawal of this region (canals within Puli Basin) in the Statistical Yearbook of actual withdrawal declared by Irrigation Association;
C-8: The sum of rainfall recharge (31.56 million m³), irrigation recharge (19.6 million m³), river recharge (76.92 million m³); in which river recharge = surface runoff × recharge rate. Recharge rate 10% is based on Reference [8];
C-9: Surface Runoff = Rainfall (C-1) + Transbasin Diversion (C-2) + Upstream runoff (C-4) + Irrigation return flows (C-5) − Evapotranspiration (C-6) − Surface intake (C-7) − Groundwater recharge (C-8). This value is smaller than the record of surface flow existing from watershed outlet. Hence groundwater drain should exist;
C-10: Records of surface flow existing from catchment area for comparison with groundwater drain;
C-11: Come from surface water recharge as C-8;
C-12: Material underneath region C consists of fine aggregate and consolidated bed. Assume no groundwater flowing in from under, therefore zero is adopted;
C-13: Lateral recharge from upstream groundwater;
C-14: Determined by groundwater inflows deducting outflows; groundwater drain = vertical recharge (C-11) + lateral recharge (C-13) − pumping (C-15) − Recharge to Downstream Basin (C-17); Consistency after comparing the result with surface water flow record of basin outlet (C-10) deducting surface runoff (C-9);
C-15: Estimation of water consumption by this paper;
C-16: Material underneath region C consists of fine aggregate and consolidated bed. Assume no groundwater flowing in from under, therefore zero is adopted;
C-17: With Darcy formula, groundwater area (2,665 m²), hydraulic conductivity (0.0018 m/s) and hydraulic gradient (0.01 m/m) are determined by results of references and geologic map.

Table 3. Results of water budget by using two methods.

Method term	Empirical water budget (million m³/year)	Numerical simulation (million m³/year)	Remark
Rainfall and irrigation Recharge (Vertical Recharge)	51.16	48.85	Empirical water budget assessment is based on experience. Numerical simulation takes rainfall, irrigation, river depth and river bed (surface) hydraulic conductivity into consideration and calculates with MODFLOW River Package. Recharge of the latter is related to the change of groundwater level, and it is more able to reflect the actual characteristics.
River recharge	76.92	92.70	
lateral recharge	18.7	16.07	
Pumping (wells)	83.01	83.01	Annual average volume calculated with empirical water budget method and changed into pumping volume by ten-days of each year. The value is then substituted into numerical simulation method.
Drain	63.77	75.48	Groundwater outflow changes due to different recharge assessment method. With empirical method the result is acquired by deducting each volume, and with numerical simulation it is calculated based on groundwater level, elevation, surface hydraulic conductivity, and with MODFLOW Drain Package. With this method it clarifies the time and space distribution of each volume. The latter is suggested to be the principal basis of this paper.

thus empiric value is substituted instead for calculation. MODFLOW (a groundwater modeling simulator) is then adopted for further numerical simulation.

3.1. Assumptions

According to current observation data of groundwater level of Puli Basin, long term groundwater level remains leveled-off. From equilibrium point of view, when there is little change of reserve of groundwater along timeline, the total inflow of groundwater system equals to the outflow of it. Considering the collectability of data sources and the hydrology characteristics of high and low season of recent years, the data of 2009 to 2014 on hydrology and water withdrawal are adopted for analysis basis.

In special characteristics, 7 regions are divided on entire watershed (Fig. 1): Mei River upper stream, Nangang River upper stream, Puli Basin, Dapingding Platform, Taomikeng Platform, Shoucheng Mountain, and Dajian Mountain, marked as A-G. Of which, Mei River upper stream (Region A) and Nangang River upper stream (Region B) have similar characteristics: the surface and groundwater enter from Mei River and Nangang River's pass into Puli Basin; Dapingding Platform (Region D) and Taomikeng Platform (Region E) are non-consolidated formation where surface water recharges groundwater, and recharges from the side of the interface with Puli Basin; Shoucheng Mountain (Region F) and Dajian Mountain (Region G) are consolidated formation, little habitants or agricultural movement. Presume no withdrawal from or exchange between surface or groundwater, and no water recharge to Puli Basin groundwater but surface water into basin as surface runoff.

Estimated by annual average, calculated items include: Rainfall, evapotranspiration, surface runoff, vertical and lateral groundwater recharge, surface water intake, transbasin diversion, irrigation return flows, groundwater withdrawal, and groundwater drain. The total surface runoff are then compared and checked with actual observation at watershed outlet.

3.2. Analysis of water budget

From the previous analysis, when there is very little variation of the storage, inflow equals to outflow according to the empirical water budget analysis, with separated estimation of surface water and groundwater. Each item is estimated as close to reality, however due to the locations of groundwater level measurement station, it is difficult to surmise complete groundwater level from 2009 to 2014 for the estimation of groundwater drain. Therefore, the groundwater drain of Puli Basin, together with the calculated result for each item in equilibrium analyzing chart, is the result of the difference between inflow and outflow. Each region is calculated individually before consolidation. In this paper only Puli Basin (Region C) is demonstrated, as shown in the following calculation:

1. Average rainfall estimate for each region is based on annual average rainfall contour, and is calculated as the annual average rainfall multiplied by the area of surface region;

2. Evapotranspiration is estimated as 70% of the evaporation from meteorological observation stations, and is calculated as the annual average × the area of the surface × 70%;

3. As mentioned previously, most surface withdrawal is for IA's farming purpose, and other target area is supplied by groundwater. Therefore surface withdrawal is calculated based on IA's annual withdrawal report;

4. As mentioned above, the amount of withdrawal takes from each groundwater pumping usage;

5. The estimation for each recharge of Puli Basin and the lateral pathway interfaced with boundaries are based on reference and 2D geologic map. Groundwater section, hydraulic conductivity and hydraulic gradient are determined and calculated using Darcy law.

6. irrigation return flows = (surface withdrawal + irrigation pumping) × 70%; the ratio of return flows 70% is based on Reference [7], the large amount of temperature-controlled water used before discharge in planting white bamboo shoots;

7. Vertical groundwater recharge is the sum of rainfall recharge, irrigation recharge and rive recharge; of which, river recharge = surface water runoff × recharge rate. Recharge rate is adopted as 10% based on reference [8].

8. Rainfall recharge = total rainfall recharge depth × rainfall recharge area; total rainfall recharge depth is determined by the characteristics of non-saturated layer from the result of boring particle size analysis and 15mm/day recharge is adopted based on reference [9]. When rainfall is more than recharge base, 15mm/day recharge depth is adopted, and when less, actual rainfall is adopted and the sum of two equals to total rainfall recharge depth; rainfall recharge area 25.3 km^2 is calculated by excluding impervious area and crop harvest area from Puli Basin;

9. Irrigation recharge = total irrigation recharge depth × irrigation recharge area; total irrigation recharge depth is based on the irrigation time determined by IA report. Irrigation depth 2 mm/day is based on IA report and reference [9]; irrigation recharge area 32.24 km^2 is based on rice field irrigation area.

10. Net surface runoff excluding groundwater drain; Puli Basin surface runoff = rainfall + transbasin diversion volume + upstream runoff + irrigation return water − evapotranspiration − surface withdrawal − vertical groundwater recharge;

11. Puli Basin groundwater drain is estimated by deducting groundwater outflow items from inflow items; groundwater drain = vertical recharge + upstream lateral recharge − pumping − groundwater outlet lateral recharge to downstream basin; watershed outlet record
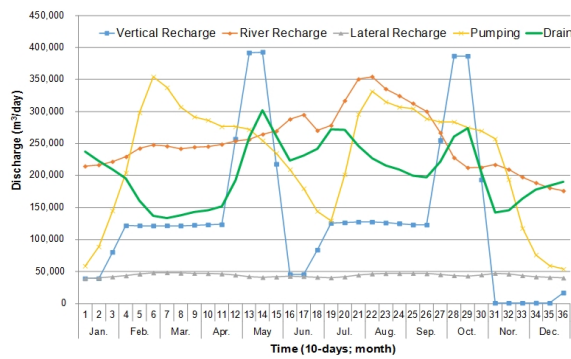
Remark: average result of 2009 till 2014 based on groundwater numerical simulation.

Figure 5: Quantity of water budget using simulation method on case area.

of surface water flow deducting surface runoff is applied for reasonable checking.

4. Study Result

4.1. Results of empirical estimation

From the water budget output of each divided region of Puli Basin watershed, there exist similarity between Region A & B, Region D & E, Region F & G. Region C, the Puli Basin, bears more calculation item resulting from receiving both upstream surface water and groundwater, as well as the irrigation return flows and transbasin diversion.

From Table 1, the result of calculated groundwater drain (66.05 million m^3) plus surface runoff (695.08 million m^3) under respective calculation items matches the record of surface runoff from the watershed outlet (761.13 million m^3). No obvious infeasible phenomena are observed through the inspection of each estimate. Therefore, the empirical water budget method based vertical recharge, lateral recharge and pumping will be used for initial input for future groundwater numerical modeling to simulate and verify the validity of groundwater drain and each item within the hydrogeological conceptual model.

The water budget analysis based on the result of Puli Basin (Region C) is shown as Fig. 3. Of 148 million m^3 annual Puli Basin groundwater recharge, 31.56 million m^3 rainfall of Puli Basin makes up 21%, irrigation recharge 19.6 million m^3 makes up 13%, river recharge 76.67 million m^3 at 52%, basin lateral recharge 20.2 million m^3 at 14%. Of total Puli Basin groundwater outflow, 54% pumping at 80.48 million m^3, 45% drain from surface at 66.05 million m^3, and recharging downstream groundwater from Basin exit make up 1%, at 1.5 million m^3.

4.2. Numerical simulation & recharge estimation

Due to the difficulty of tracing back the actual pumping of 2009-2014 based on the setting methods described hereinbefore, reasonable hydrogeological parameters and pumping are given. Of which, groundwater pumping and recharge areas are given by land use survey result, as shown in Table 2. Current land use status is sorted and summed through high-resolution Remote Sensing Image, cadastral map, e-map and other reference and field survey, so as to present reasonable land use status.

The groundwater hydrograph resulted from 2009 to 2014 of numerical simulation is shown as Fig. 4. No calibration or verification was made in simulation parameters. The values are given based on reference and supplement investigation; due to the difficulty retrieving the actual pumping volume of year 2009–2014, therefore there is difference between simulation and observation value. While partial records need to be confirmed, overall trend is consistent. From here, the numerical model has reflected the proper Puli Basin groundwater characteristics. More precise numerical modeling results can be achieved when large scale water census could be proceeded in the future. Individual volume analysis result of water budget is shown in Table 3 and Fig. 5.

Groundwater recharge of study area includes: rainfall and irrigation recharge, river recharge, and net lateral recharge. The total annual recharge is 157.62 million m^3. According to Equation (1) & (2), groundwater redevelopment of case area (shown as Table 4) is 39.26 million m^3, based on current annual groundwater pumping 83 million m^3.

5. Conclusion

Pre-processing analysis for numerical simulation of groundwater conceptual model helps clarify surface flow and groundwater usage, examine each volume in the hydrological cycle and clarify the time and space distribution characteristics of groundwater pumping and recharge. It also helps numerical convergence, as well as providing reasonable groundwater redevelopment suggestion. In this case, through empirical estimation and numerical simulation, during 2009 to 2014, each item of water budget of Puli Basin (55.06 km^2) is acquired by cross certification. Total groundwater recharge at 158 million m^3 per year, pumping at 83.01 million m^3 per year, groundwater drain to surface by natural force at 75.48 million m^3. Of which, 48.85 million m^3 rainfall and irrigation recharge takes up 31%, 92.7 million river recharge takes 59%, 16.07 million m^3 lateral recharge to basin periphery takes 10%. Natural flow of groundwater to surface occurs at an average of each ten-days, from 0.13 to 0.3 million m^3 daily. The differences between empirical and simulation results of water budget are about 5% to 20%. The yearly reasonable groundwater redevelopment is 39.26 million m^3.

Table 4. Calculation table of groundwater redevelopment on study area.

Term	Estimated method	Value (million m^3/year)
Groundwater Recharge (R)	Result integrated from empirical method & numerical model method	157.62
Downstream Reserve (D)	Existing downstream surface water usage, water withdrawal amount from water source facility in development, downstream groundwater recharge, ecological base flow	13.77
Aquifer Sustainability Factor (F)	Greatest value applies from literature summarized value 15 to 85%	85%
Groundwater availability (Q_a)	Equation (2)	122.27
Existing pumping (P)	Authority Statistical Yearbook & estimated unit pumping volume	83.01
Groundwater redevelopment (Q_r)	Equation (1)	39.26

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Efficiency of activated carbon and white charcoal from textile dyeing industry in synthetic wastewater

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Abstract

The experiment aimed on the treatment of synthetic wastewater of disperse dye and reactive dye with activated carbon and white charcoal by wastewater shell that flow through the column. It contained small pellet of charcoal, having thickness 20, 40 and 60 cm, respectively and measured the treatment efficiency of dye color every hours and chemical oxygen demand (COD) before and after treatment. The study observed the efficiency of white charcoal treatment through that synthetic wastewater treatment of disperse dye having thickness of 20, 40 and 60 cm. The efficiency was 62.97%, 50.18% and 89.22%, respectively and activated carbon was 36.88%, 40.77% and 62.38%, respectively. While in case of reactive dye the efficiency of white charcoal was 14.85%, 42.47% and 99.94%, respectively and activated carbon was 13.12%, 35.46% and 53.78%, respectively. The treatment of COD found that white charcoal and activated carbon were 71.09% and 58.79%, respectively. Efficiency of both dye color and COD treatment increased with increase in the thickness of charcoal. The thickness of 60 cm was better than 40 and 20 cm.

Keywords: Adsorption, activated carbon, white charcoal, disperse dye, reactive dye

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1. Introduction

The textile industry plays a significant role in Thailand's economic development. It is an industry with an export value of 3.40% of total domestic products. The average amount obtained from textile and garment exports is more than 150,000 million baht per year and employ more than 1 million people, accounting about 20% of all employment in the manufacturing sector in Thailand [1]. The process of dyeing is an important step in the textile industry and it is important to make the fabric and yarn colorful, durable to the environment and should be comfortable to the wearers. Therefore, it is important to examine the dyeing process of textile industry. The dyeing industry use chemicals and dyes to alter the properties of fibers in the dyeing process and these processes often rely on water as an intermediary for almost every step. Tanning industry is an industry that requires large amounts of water. In addition, wastewater after dyeing process will be contaminated by chemicals since manufacturing process use chemicals, such as cleaning agents,

dyes, dyestuffs. The properties of wastewater generated by each dyeing industry, or even the same type of dyeing, differ at different stages. There are many differences in the characteristics of waste water depending on the type of production and selection of chemicals [2]. Most of the effluent is composed of colored-organic matter with variety of pH value, thereby affecting the organism in natural water sources. It also destroyed the scenic beauty and is offensive to the environment. Some dyes cannot be treated by physical and chemical methods such as reactive dye, acid dye, basic dye and direct dye. Therefore, wastewater treatment from the textile industry is adopted as a means to meet the effluent standards and to prevent pollution problem [3]. There are many ways to remove colorants in industrial wastewater, including membrane filtration treatment, coagulation and flocculation process with alum and calcium hydroxide and ozone treatment. This method is a highly effective method of treatment. However, there are limitation on the flow rate, pH and water temperature [4]. The adsorption method is simple and can be used in a variety of ways. Materials used are silica gel, activates - alumina, zeolite, activated carbon and white char-

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coal [5]. Activated carbon and white charcoal are suitable materials for wastewater treatment from dye, due to the very porous surface (300-700 m^2/g). The adsorbent commonly used is activated carbon, a form of raw materials consisting of carbon-based organic substance. This carbon is activated by heating or burning in a confined furnace at a high temperature so as to create porosity. Then, it is compressed with steam to increase the absorbent surface area. White charcoal is a charcoal with a production process, very different from general black charcoal production, having luster and it looks like metal. White charcoal are denser than other charcoal. It can also be reused after treatment through a regeneration process. Therefore, the efficiency of activated carbon and white activated carbon should be studied in color treatment in synthetic wastewater as well as studying the appropriate thickness of the charcoal layer. This increases the choice of using absorbent materials in the textile dyeing industry so as to be able to treat color in wastewater efficiently and suitable for wastewater.

Sun et al. [6] studied three types of reactive dyestuffs such as Reactive Red 23, Reactive Blue 171 and Reactive Blue 4, with activated carbon being produced from green algae. The study found that activated carbon has a dye adsorption capacity of 59.88, 71.94 and 131.93 mg/g, respectively. Similarly, Palanisamy et al. [7] found the activated carbon that is made from *Euphorbia tirucalli Linn.* has a dye adsorption capacity of Reactive Red and Reactive Blue, 217.39 and 200 mg/g, respectively. While El-Sayed et al. [8] found adsorbed dyestuffs with activated carbon that is made from sugar cane stalks can remove more than 50% in an hour.

2. Research Objectives

This research aimed at studying the synthetic wastewater treatment of disperse dye and reactive dye with activated carbon and white charcoal using a Column Adsorption Process. It also discusses the factors influencing the adsorption process. The following are the objectives:
- To study the efficiency of dye treatment from synthetic wastewater by activated carbon and white charcoal
- To find out the efficiency of the COD treatment
- To analyze the life cycle of charcoal

3. Methodology

3.1. Preparation of materials and synthetic wastewater

Synthetic wastewater was prepared from Red Disperse and Red Reactive dye as shown in Fig. 1. The adsorbents used were activated carbon obtained from C. Gigantic Carbon Co., Ltd. and white charcoal from Charcoal Home Co., Ltd.. The two types of charcoals
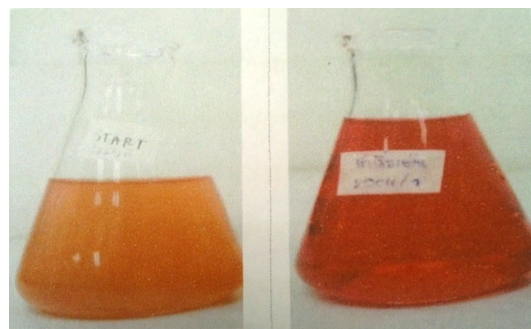
Figure 1: Synthetic wastewater, Red Disperse and Red Reactive dye.

Figure 2: The column with 20 cm. of charcoal.

were used to grind and separate through a sieve having a size of 0.85-2 mm, then it was washed with distilled water to remove debris and contaminants. After that, it was dried in the sun and stored for experimental use.

3.2. Study on dye and COD efficiency with activated carbon and white charcoal

Activated carbon and white charcoal were placed in columns with a diameter of 4.30 cm, giving the charcoal layer a thickness of 20 cm, as shown in Fig. 2, and feeding the disposable and disposable synthetic wastewater. Column analysis of synthetic wastewater concentration before and after it passes column each hour with UV-VIS Spectrophotometer at the maximum wavelength of synthetic wastewater. The reflux method was used to determine the COD value by using the method of Standard Methods for the Examination of Water and Wastewater [9]. The experiment was repeated but the thickness of charcoal was changed to 40 and 60 cm order.

3.3. Study on the efficiency of dye treatment and COD from synthetic wastewater by activated carbon and white charcoal

Filled activated carbon and white charcoal in a column with a diameter of 4.30 cm, the charcoal layer

Figure 3: The efficiency of dye treatment by activated carbon and white charcoal; (A) is disperse dye and (B) is reactive dye.

is 20 cm thick as shown in Fig. 2 and filled with disperse wastewater and reactive wastewater in column and analysis were done s of the concentration of synthetic wastewater before column and after column passes every 1 hour with UV-VIS Spectrophotometer at the maximum wavelength of synthetic wastewater. Used the Close reflux method to determine the COD value by using the method of Standard Methods for the Examination of Water and Wastewater [9]. Then, the experiment was repeated with the thickness of the charcoal layer of 40 and 60 cm, respectively.

3.4. Study of life cycle of activated carbon and white charcoal

Life cycle is the lifetime of the activated carbon and white charcoal until eventually the activated carbon must be replaced. Activated carbon and white charcoal were added in the column to a thickness of 20 cm. Thereafter, the synthetic wastewater was filled into the column and the concentration of synthetic wastewater that passed through the column were analyzed every 1 to 6 hours, followed by every 2 to 12 hours and consequently analyzed every 4 hours until the synthetic wastewater that passed through the column was similar to the wastewater before passing to the column.

4. Results and Discussion

4.1. The efficiency of dye treatment from synthetic wastewater by activated carbon and white charcoal

The results of dye treatment from synthetic wastewater have shown that: the efficiency of Red disperse of activated carbon was at 20, 40 and 60 cm. A high proportion, of 36.98%, 40.77%, and 62.38%, respectively was found to be having efficiencies in white charcoal with thickness of 20, 40 and 60 cm, respectively. Similarly, in the case of 62.97%, 50.18% and 89.22%, respectively, the efficiency was decreased in the 1st hour and increased at 4th hour and remained constant until the 6th hour as shown in Fig. 3(A). While in the case of Red Reactive activated carbon, the efficiency was at 20, 40 and 60 cm thickness with proportion. Another 13.12%, 35.46%, and 53.78%, respectively were having efficiencies. Similarly, another 14.85%, 42.47% and 99.94%, respectively white charcoal were having efficiencies with thicknesses of 20, 40 and 60 cm, respectively. The efficiency of the two types of charcoal was the highest in the first hour and gradually decreased over the time period as shown in Fig. 3(B). It can be seen that the Red Disperse dye tends to increase the efficiency of dye treatment when the system duration increases. This is because the rate of water flowing out of the system is less, synthetic wastewater has a longer contact with charcoal and the property factor of the dye with large particles, dissolve into colloidal particles causing more clogging in the space between the charcoal particles, making the space smaller
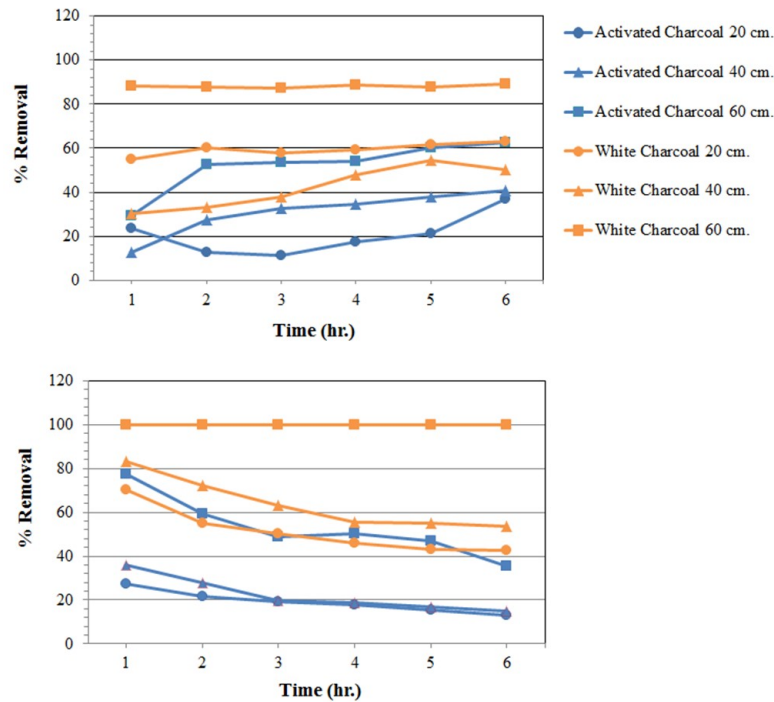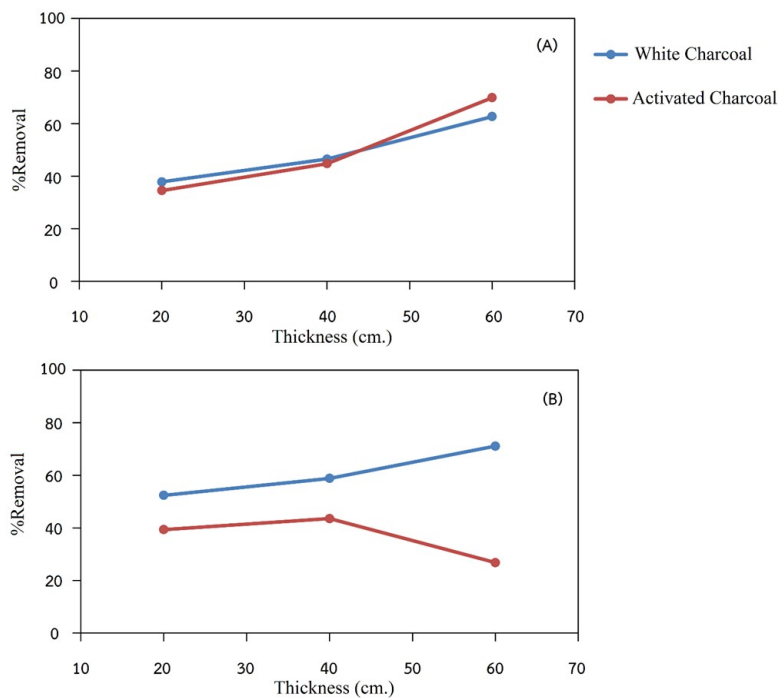
Figure 4: The efficiency of COD treatment by activated carbon and white charcoal; (A) is disperse dye and (B) is reactive dye.
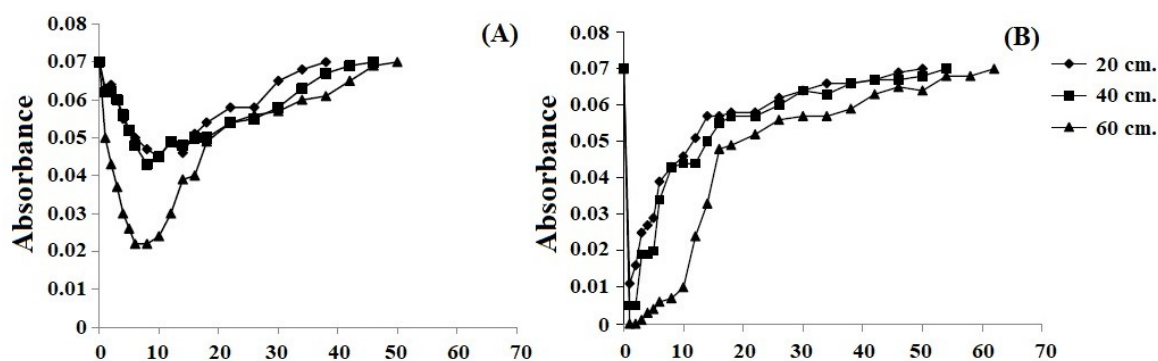
Figure 5: The life cycle of both types of charcoal; (A) is activated carbon and (B) is white charcoal.

Less passed synthetic wastewater. Therefore, increasing the resistance time is a factor that makes the treated wastewater to have better efficiency. In part of Red Reactive, it can be seen that there is a tendency for the effectiveness of dye treatment to decrease when the system duration increases. Due to the qualification factors of this type of dye, it has a fine texture and dissolves well. Resulting in waste water in the form of a solution, and over time the solution particles are absorbed more on the charcoal particles. Causing the surface area of the charcoal to be less adsorbed and the treatment efficiency in the later hours tends to decrease from the first hour.

Furthermore, Sinsangkaew et al. [10] found powdered soybean meal that pretreatment by washing with distilled water, dried at 90 °C for 2 hours, sift through the sieve 30-40 mesh, 1 hour in adjusted with 0.5 M

NaOH, washing with distilled water then dried at 60 °C for 24 hours. The adsorption of reactive dye and basic of cationic dye was 100%, and 67.5%, respectively. However, findings of Ahmad and Hameed [11] who found active carbon prepared form bamboo waste by chemical activation method can reduce color of 91.84%.

From the Table 1, it was found that $F_1 = 44.844$. It can be concluded that the average of thickness with each level were different at P-value < 0.0009. Pairwise comparisons revealed that: the average of absorbance of thickness of 60 cm was lower than the thickness of 20 and 40 cm while the average of absorbance of thickness of 20 and 40 cm was not different.

For $F_2 = 88.067$, it can be concluded that the average of each type of charcoal were different at P-value < 0.0009. It was found the average of activated carbon

Table 1. Results of Analysis of Variance of removing disperse dye.

Data Sources	Sum of Squares	df	Mean of Squares	F	P-value
Thickness level	0.010	2	0.005	44.844	< 0.0009
Type of charcoal	0.010	1	0.010	88.067	< 0.0009
Thickness * type of charcoal	0.002	2	0.001	8.956	< 0.0009
Deviations	0.011	102	0.00001078		
Total	**0.033**	**107**			

Table 2. Results of Analysis of Variance of removing reactive dye.

Data Sources	Sum of Squares	df	Mean of Squares	F	P-value
Thickness level	20.505	2	10.253	107.793	< 0.0009
Type of charcoal	1.071	1	1.071	11.256	0.001
Thickness * type of charcoal	1.966	2	0.983	10.335	< 0.0009
Deviations	9.702	102	0.095		
Total	**0.033**	**107**			

was higher than white charcoal. And $F_3 = 8.956$, it can be concluded that there is a relationship between the thickness level and type of charcoal at P-value < 0.0009. While lower average absorbance values indicate high performance of removing dye.

From the Table 2, it was found that $F_1 = 107.793$. It can be concluded that the average of thickness with each level was different at P-value < 0.0009. Pairwise comparisons revealed that: the average of absorbance of thickness of 60 cm was lower than the thickness of 20 and 40 cm while the average of absorbance of thickness of 20 cm was higher than thickness of 40 cm.

For $F_2 = 11.256$, it can be concluded that the average of each type of charcoal was different at P-value < 0.0009. It was found the average of activated carbon was higher than white charcoal. And $F_3 = 11.335$, it can be concluded that there is a relationship between the thickness level and type of charcoal at P-value < 0.0009. While lower average absorbance values indicate high performance of removing dye.

4.2. The efficiency of dye treatment from synthetic wastewater by activated carbon and white charcoal

The results of COD treatment from synthetic wastewater have shown that a high proportion of 34.54%, 44.77% and 69.87%, respectively were having efficiency of disperse dye of activated carbon at 20, 40 and 60 cm thickness respectively. Similarly, 37.83%, 46.51% and 62.69%, respectively were having maximum COD treatment efficiency. The efficiency was increased by thicknesses as shown in Fig. 4(A). While the efficiency of reactive dye of activated carbon varies at 20, 40 and 60 cm thickness having COD treatment efficiency with a large proportion of 39.33%, 43.53% and 58.79%, respectively. And

the COD treatment efficiency of White Charcoal was found to be increased with thickness (52.38%, 58.82% and 71.09%, respectively) as shown in Fig. 4(B). It can be seen that the trend of COD treatment efficiency increases when the thickness of the charcoal layer increases. Because there is more charcoal taken in the treatment and the water flowing out from the system has a longer time to contact the charcoal. While Jain and Sikarwar [12] investigated adsorption methods from waste material sawdust as adsorbent, it can reduce COD of 73.5 mg/L when the particle size is not over than 106 BSS mesh. Furthermore, Ahmad and Hameed [11] found active carbon that prepared form bamboo waste by chemical activation method. It can reduce COD of 75.21%.

From the Table 3, it was found that $F_1 = 43.583$. It can be concluded that the average of thickness with each level was different at P-value < 0.0009. Pairwise comparisons revealed that: the average of %removing COD of thickness of 60 cm was higher than the thickness of 20 and 40 cm while the average of absorbance of thickness of 20 and 40 cm was not different.

For $F_2 = 79.668$, it can be concluded that the average of each type of charcoal was different at P-value < 0.0009. It was found the average of white charcoal was higher than activated carbon. And $F_3 = 7.351$, it can be concluded that there is a relationship between the thickness level and type of charcoal at P-value < 0.0009.

From the Table 4, it was found that F1 = 104.330. It can be concluded that the average of thickness with each level was different at P-value < 0.0009. Pairwise comparisons revealed that: the average of absorbance of thickness of 60 cm was lower than the thickness of 20 and 40 cm while the average of absorbance of thickness of 20 cm was lower than thickness of 40 cm.

For $F_2 = 13.021$, it can be concluded that the aver-

Table 3. Results of Analysis of Variance of COD treatment from synthetic wastewater of disperse dye.

Data Sources	Sum of Squares	df	Mean of Squares	F	P-value
Thickness level	24,447.419	2	12,223.710	43.583	< 0.0009
Type of charcoal	22,344.508	1	22,344.508	79.668	< 0.0009
Thickness * type of charcoal	4,123.381	2	2,061.691	7.51	0.001
Deviations	28,608.093	102	280.472		
Total	**79,523.402**	**107**			

Table 4. Results of Analysis of Variance of removing reactive dye.

Data Sources	Sum of Squares	df	Mean of Squares	F	P-value
Thickness level	67,384.293	2	33,692.147	104.330	< 0.0009
Type of charcoal	4,204.886	1	4,204.886	13.021	< 0.0009
Thickness * type of charcoal	7,612.885	2	3,806.442	11.787	< 0.0009
Deviations	32,939.589	102	322.937		
Total	**112,141.653**	**107**			

age of each type of charcoal was different at P-value < 0.0009. It was found the average of white charcoal was higher than activated carbon. And $F_3 = 11.787$, it can be concluded that there is a relationship between the thickness level and type of charcoal at P-value < 0.0009.

4.3. Life cycle analysis of Charcoal

At the start of the system, the absorbance of synthetic wastewater was reduced rapidly. Until the saturation point, the absorbance value was increased. Demonstrated reduced efficacy or the end of life cycle. In this study, the charcoal layer a thickness of 20, 40 and 60 cm in length, respectively. It was found the life cycle of a white charcoal was 50, 54 and 60 hours, respectively. While the life cycle of an activated carbon was 38 and 40 and 48 hours, respectively. The life cycle of both types of charcoal. It showed that the life cycle is longer than the use of charcoal in the treatment of synthetic wastewater. So, both types of charcoal can be reused in the experiment as shown in Fig. 5.

5. Conclusions

It can be concluded that the treatment synthetic wastewater of disperse dye and reactive dye, white charcoals had treatment efficiency of dye color and COD higher than activated carbon. The production process of the white charcoal produced by using high temperature, it made white charcoal to have more porous than activated carbon. It caused the white charcoal to have more area to absorb. The efficiency of dye treatment from synthetic wastewater by activated carbon and white charcoal varies with thickness. The higher the thickness is, the higher the proportion of efficiency of disperse dye treatment of activated carbon and white charcoal treatment. Setha [13] and Iampee [14] found that activated carbon can be used to remove color, suspend solids, BOD and COD. Furthermore, the increased thickness of the charcoal layer increases the efficiency of the treatment.

This research is to use white charcoal as an alternative absorbent. At present, there are no white charcoal that has appropriate appearance and has not been sold widely in the market. White charcoal is more effective adsorption than activated carbon. And with price per unit of charcoal is high, it should be used to treat or absorb important pollutants in order to be more economical

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Counting gibbons: The evolution of sample methods

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Abstract

Estimating the population sizes of endangered species in the natural environment is a major activity of conservationists. Different types of animals require different methods of population census and sampling. Statistical standards of sampling populations have increased and new analytical software has reduced the time needed for manual computation, but increased the need for standardized data collection methods. Here I discuss the methodology used in gibbon population sampling and current discussions regarding the best method of data analysis. Gibbons are most efficiently sampled by listening for their duetted songs given by mated reproductive pairs in small territorial groups. Several problems have to be overcome in field data collection and analysis: the decline in sound detection with distance, the possibility of groups singing more than once in a day, the probability of a group singing (or not singing) on a given day, and determination of the total area that the audible groups are occupying. The traditional way of dealing with these problems is by triangulating on singing groups from several simultaneous listening posts, and carefully mapping the locations of groups. There are biases present in most methods and ways overcoming bias using newer methods are discussed. Survey of gibbons and other animals is a constantly evolving process, and there is still no universally accepted methodology.

Keywords: Auditory survey, census methods, gibbons, population sampling, wildlife survey

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1. Introduction

Conservation of endangered species of plants and animals requires methods for estimating population sizes, and also the probability of survival of the species or continued decline [1]. Complete census of individuals is usually only possible for a few Critically Endangered species that have declined to very low numbers; other species require methods of sampling large populations often distributed patchily over the landscape. Cryptic or secretive habits, wide-ranging movements and difficulty of identification make statistical sampling very difficult for most species. Tracks, signs and vocal cues are important aids in sampling animals and studying population structure and movements [2].

The naturalists who initially observed, described and mapped animal populations were not concerned with estimating the sizes of populations, and did not have the methods for doing so. Modern conservation biologists now are concerned with studying population demographic and genetic structure and estimating population size for a variety of reasons, and have a growing statistical toolbox for doing so. The particular methods used for sampling gibbon populations

have gone through an evolution that is still continuing and improving; as a participant in this evolutionary development I wish to outline it and present my ideas on what is being done and what might still need to be improved.

Gibbons make loud noises, including duets performed by male-female pairs, with other members of the group sometimes participating [3, 4]. Ellefson (1974) [5] may have been the first person to describe a gibbon duet, consisting of the female's great-call and male's hoot series, as the loud songs signaling the presence of a mated pair on its territory. The adult pair are the central component of a small territorial group that occupies a permanent range, usually around 15 – 50 ha in area, depending on species. These characteristics make gibbons relatively easy animals to census through direct observation, but such census is time-consuming and cannot be applied to large populations. The availability of gibbon duets as auditory cues that indicate the presence of breeding pairs make auditory sampling the method of choice in gibbon surveys.

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2. Auditory Sampling

By listening for the loud calls or songs of gibbon groups we can estimate the density of groups in an area, and by replicating sample areas we can then estimate the density of the population within a large sampled area such as a national park. Before attempting to do this we must be familiar with all the call types that gibbons make, and the structure of the duet bout. The duet consists of repeated great-call sequences given by the pair at intervals of 1 to 2 min, and lasting as long as 10 to 20 min. The duet structure varies somewhat between the species of gibbons. Haimoff (1984) [6] has described these duet patterns and attempted to standardize their terminology. Distinctive solos are also given by the males of all species. These are easily recognizable but both mated and not-yet-mated males may give solo calls in most species. Special alarm hoots and inter-group conflict hoots are also given by gibbons which are important to behavioral researchers but not of much use in sampling a population.

2.1. Triangulation from listening posts and mapping

Auditory sampling of gibbons can enable us to determine the locations of singing groups by recording the compass direction of each group duet heard and estimating its distance away. Gibbon duetted songs can be heard from as far away as 2 km, but estimating the distance is very difficult, although accuracy improves with experience. In order to map the groups in an area, three or four "listening posts" (LPs) are established on nearby hilltops or ridges and the groups heard from each LP are noted down over a period of several days (usually four days). In order to map the locations of groups, listeners on different LPs several hundred meters apart take compass readings simultaneously which can be used to determine the location through "triangulation", mapping the intersections of the compass directions from two or more LPs. (Fig. 1). The exact times of all the bouts heard from all LPs must be noted down so that it can be assured that calls that are triangulated from different LPs emanate from the same group. Songs that are too far away to be heard by listeners from at least two LPs are usually not included in population estimates.

There are additional problems in mapping and identifying groups for density estimation. The major problem is that gibbon pairs may duet more than once during a day, or not at all. There are several procedures and rules-of-thumb that allow the reasonable determination of the number of groups singing. Sometimes particular features of the duet pattern such as sound frequency allow us to identify individual groups [7, 8]. Otherwise, it is usually assumed that if song locations map within 500 m of each other, they are from the same group unless proven otherwise. The most important condition that determines that singing locations are from different groups is their singing at the same time, or in bouts that are too close in time to be

from the same group. During a 4-day period of listening, it is possible to separate most groups that occupy adjacent territories and map the approximate location of the boundary that separates them (Fig. 2). At the end of the listening period, there are still likely to be a few groups that cannot be diagnosed as separate from other nearby groups, which will result in some underestimation of population density. With four days of listening, this is not likely to be more than about ten percent of the population (see Equation 2 below). Increasing the number of days of listening from each array of points would help reduce this problem, but this would demand more time and manpower and might reduce the number of arrays or sample areas that can be surveyed; this involves a trade-off between quality of data and quantity of data.

2.2. Listening area

The density (D) of groups within an area is calculated from

$$D = N/Ap \qquad (1)$$

where N is the number of groups heard and mapped, A is the "listening are" and p represents a correction factor to compensate for groups that were present but did not happen to duet during the period of survey. The estimation of p will be described in the next section.

There are several ways of determining the listening area (LA), and most have the potential for introducing bias. Two ways were proposed by Brockelman and Ali (1977) [7]: the fixed radius method which assumes that all groups can be heard a fixed distance from the LP, and the terrain-limited method which uses a map of the terrain to determine how far groups can be heard around an array of carefully placed LPs. The fixed radius method has been used where there are no terrain features that limit the listening area, or where suitable topographic maps (preferably 1:50,000 UTM maps that also show forest cover) are not available. The fixed radius method has been used by many surveyors, usually assuming reliable detection within a radius of 1 km [8 – 13]. An example of a manual plot of gibbon singing data from four listening posts is shown in Fig. 1. In this survey, five days of listening were conducted per array of LPs. At the end of the survey, the mapped groups' singing locations for all five days are all plotted on a single map, color coded by day. The challenge is then to determine the number of groups from this map (Fig. 2). The main device is to determine the locations that must be from different groups by identifying those that were heard during overlapping times; territorial boundaries must exist between these locations.

The fixed radius method always underestimates gibbon density unless the radius is made so small (< ca. 600 m) that most groups heard lie outside the listening area, which wastes much of the data. Several surveys have shown that a fixed radius of 600 m generally gives a significantly higher density than use of a
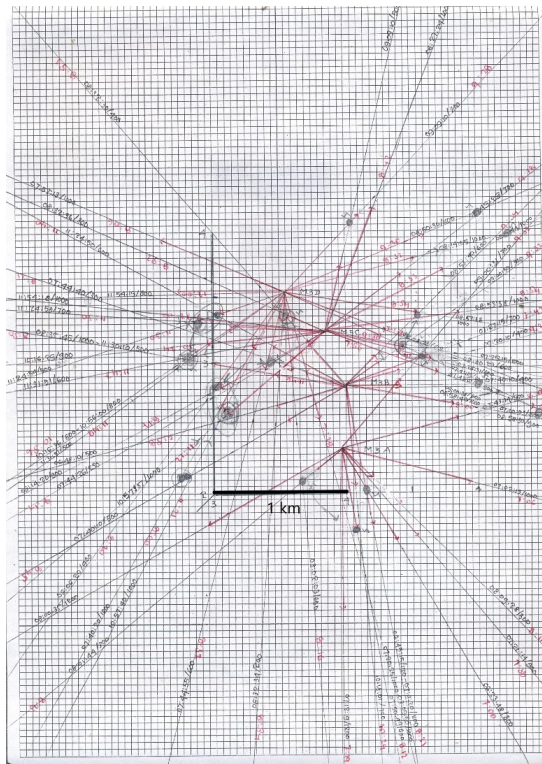
Figure 1: Map showing how groups are triangulated from 4 listening posts on a single day of listening. Singing times are written on the sighting lines to facilitate identification of groups, which here are marked by penciled points at the intersections of the lines. The red segments of the lines represent the crude estimates of distance from the listening posts. (Data from the Mahamyaing survey in Myanmar [8]).

Figure 2: A plot of all singing locations triangulated on the 1-day singing data maps, color-coded by day (same array as in Fig. 1). Listening posts are marked by X. Groups heard singing at overlapping times are connected with lines (most too faint to see). Locations assumed to be of the same group are circled. The circles represent fixed radii of 1.0 and 0.6 km around each LP.

radius of 1000 m [8, 13, and unpublished data], which indicates that many groups between 600 and 1000 m were not heard. These groups were located behind unseen hills or in valleys where sound transmission was blocked by the terrain.

The terrain-limited method of listening area estimation involves selecting a large valley from the map where sound transmission is not likely to be obstructed by terrain features. The method requires that four LPs be carefully selected so that all parts of the valley are within hearing range of at least two LPs. Often it can be assumed that any group heard from any LP must be in the valley. Often most parts of the valley are visible from the LPs so that it can be seen that sound transmission passes through open space over the forest canopy: this makes it possible to hear groups from distances of 2 km or so, provided that the air is still and not breezy. In the terrain-limited method, it is assumed that the all the groups heard represent a complete census of those that sang in the listening area.

One criticism sometimes heard of this method is that the habitat within the listening area may not be representative of the entire range of slope and elevation in the total area sampled. Usually the listening area encompasses all terrain types and elevations, although it is difficult to demonstrate this or convince a statistician that there is no possible bias. Nevertheless, this method yields the highest estimates of gibbon density of all methods commonly in use [14 – 16].

The solution to the problem of eliminating bias in the determination of the listening area lies in the use of the Distance method for the analysis of line transect and point transect data [17]. Distance methods are now widely used in wildlife sampling and software is readily available on the R platform. The Distance program does not require estimation of a listening area, but determines the density of groups as the area under a detection function extending from the line or point, outward to some truncation distance. The main assumption of the Distance program is that the probability of detection is 1 if the group is directly over the transect line or point.

In the case of gibbons, auditory sampling uses the *point transect method* where distances of all singing groups are measured to a single sample point. However, distances all must be determined as accurately as possible using triangulation from multiple LPs. I believe that the best method of achieving this is to initially select the sample points for Distance on a map, and then arrange arrays of LPs around the sample points such that there is no possibility of missing any group singing near the sample point. Each array will consist of four LPs in a 4-sided polygon around the point, each LP approximately 300-500 m from the

point. It is not necessary that the LPs are in a regular polygon or square, as long as their locations are precisely known and mapped. The LPs are placed on elevated points of terrain selected from a topographic map, and explored on foot before the survey so that no unseen obstructions to sound are present. Prior to analysis, all distances of gibbon groups are remeasured on a map to the sample point. It is not necessary, or even desirable, to place an LP on or even near the sample point; doing so might spook or scare any groups that might be in the area.

A final requirement of Distance methods is that the sample points (or transects) are randomly selected within the whole sample area, or superimposed on a regular grid over the area. Most early surveys of gibbon populations have not properly randomized the sample procedure, but have rather carried out what may be considered to be representative area surveys. Proper means with confidence intervals cannot be placed around most such estimates.

A survey of white-handed gibbons in Huai Kha Khaeng Wildlife Sanctuary in western Thailand is now being completed by Wildlife Conservation Society–Thailand using triangulation from LPs and the point-transect Distance program described above. Preliminary (unpublished) results show that estimated densities of gibbon groups around the randomly selected sample points average >4 groups km^{-2}, rather higher than expected, which is a tribute to the quality of protection of the sanctuary by the Dept. of Parks, Wildlife and Plant Conservation, as well as to the efficacy of the survey methods used.

2.3. Singing probability

The final challenge to accurate estimation of gibbon groups is the estimation of the probability that an average group will duet on any particular day of the survey, defined as $p(1)$. From this can be estimated the probability that a group will duet at least once over a period of n days, $p(n)$, which will become the correction factor in the above Equation (1). The sequence of singing or not singing over a period of n days is treated as a binomial process where p and $(1 - p)$ are the probabilities of the two alternatives. The model assumes that p on successive days is independent. The probability of singing at least once in n days is predictable from $p(1)$, as

$$p(n) = 1 - [1 - p(1)]^n \qquad (2)$$

This formula was devised, or reinvented and applied to gibbon calling, by Brockelman and Srikosamatara (1993) [14]. While it allowed us to determine the probability of missing groups that did not sing after n days knowing the value of $p(1)$, it did not allow accurate estimation of $p(1)$. That is, there was no simple way of estimating the number of silent groups—the groups that did not sing at least once during the survey. Members of the Gibbon Subgroup of the IUCN Primate Specialist Group, assigned with preparing "Best

practice guidelines for surveying and monitoring gibbons", have recently figured out how to estimate $p(1)$ from data on the frequencies of groups singing on n numbers of days out of the total number of days of survey per array of LPs (usually 4 days). A maximum likelihood estimator has been developed by David Borchers (personal communication) for estimation of $p(1)$ and $p(n)$ with confidence limits. The basic data for this estimation consist of the numbers of groups that sang on increasing numbers of days out of n. First, we need to tabulate the singing record of each group over the n days. For example, if $n = 4$, we need the number that sang on only one day out of four, on any two days out of four, any three days out of four, and on all four days. This is simply the frequency distribution of the total number of days on which each group sang.

For most gibbon species and sites, the probability of singing on a single day $p(1)$ varies from about 0.20 (for some western hoolock populations) to about 0.70 (for some *Hylobates lar* populations). For a $p(1)$ well below 0.5, the correction factor in equation (1) will make a sizable difference to the estimation of density.

2.4. Capture-recapture method for density estimation

A number of statistical methods have been developed for sampling wildlife populations that can be applied to the use of data consisting of cues such as songs and calls detected by listeners. Some methods require the ability to identify individual callers or groups (such as capture–recapture methods) and others do not. A method that is now receiving much attention is the Spatially Explicit Capture-Recapture (SECR) method that uses auditory data [18, 19]. It involves analysis of the probability that a group is heard calling from two LPs (as opposed to just one LP) a known distance apart. Data on joint detection frequency of groups at various distances from the listeners allow determination of a detection function and also group density. The method is touted to require no mapping of groups and, potentially, require less time and manpower than more traditional methods that involve detailed mapping. The claim that no mapping is required, however, is suspect.

An issue that "remains to be resolved" for the SECR method is how to deal with uncertain recapture identification [18]. Ascertaining that the same group has been detected from two LPs on a single occasion depends primarily on matching the times of the bouts heard, and verifying that the listening angles intersect at a plausible distance away. Greater difficulty is encountered in determining if another duet heard later in the day is given by a group heard earlier, or represents a new group, because groups can duet more than once during a morning, and usually move between singing locations. Matching bouts heard on successive days presents further challenges. The SECR software requires users to input the "capture histories" of all groups, but no instructions are provided for how to

determine group histories. In relatively dense populations (> 2 groups km^{-2}), where group ranges often border one another or even overlap slightly, allocating singing events to different groups requires detailed mapping of singing locations from data collected over at least 4 days, as explained in the above sections. Such determination and mapping of groups is required for estimation of singing probability as well as for verifying recapture identifications. Borchers et al. [18] state that "we expect that methods that use location data to quantify the probability that detections are recaptures will be useful." I agree with this admission and am hopeful that such a process, which we now carry out on paper maps or with the help of GIS, can be automated.

2.5. N-mixture models

Among the methods that do not require identifying or marking individuals is a class called N-mixture models for estimating populations using call count data [20]. Spatially replicated point counts are made for calling or singing species without identifying individuals, or measuring distances to all groups heard. Estimation of density involves a maximum likelihood procedure that makes assumptions about the spatial distribution of the callers (Poisson) and calling probability (modeled as a binomial process). The method has been tested on bird data and can produce population size estimates from simple and easy-to-collect field data. However, the method has been criticized for reliance on assumptions (random distribution of groups and binomial singing frequencies) which may be inappropriate in some cases, resulting in poor estimation of detection probability [21]. The method needs to be tested further against other more data-intensive methods.

3. Methods Using Visual Detection

3.1. Population census

Seeing gibbons is much more difficult that hearing them. Because gibbon pairs of nearly all species duet on most days of good weather, and no groups have been found that do not duet (even after many years of research on well-known study populations), auditory location is the standard in gibbon survey and study. Observation of groups, however, is necessary when we wish to conduct a *census*, which is an inventory of *all* groups and individuals residing in a defined area. A census involves approaching each group and observing its size, age composition, color morphs and any other features that distinguish it from other groups in the neighborhood. Approaching wild groups for close observation requires skill and practice. One technique that is useful is to approach while the group is duetting, when its attention to what is on the ground is relaxed. When duetting stops, one must take cover and move extremely quietly. Census is best done in

wet weather; when the leaves and sticks are dry and crackle underfoot, approaching wild gibbons is almost impossible. A thorough census requires at least one day per group in the area, and hence only relatively small areas (a few square km) can realistically be censused.

An auditory/visual census is required in several situations, including (1) site preparation for a long term study, (2) preparation of an educational or tourism area featuring gibbons, (3) replicated, long term monitoring of the demography or density of a population, and (4) monitoring of a critically endangered species such as the Hainan black-crested gibbon.

3.2. Line transect method

Line transect methods in the standard Distance software package have a relatively long history of development [17] and require little explanation here. They use visual detection of social groups or individuals, and have been widely employed in primate surveys [7, 22 – 24]. The Distance line transect method evolved from the older "strip transect" methods of Kelker, Hayne, and others [22]. Debate has continued regarding which is the least biased method [25, 26]. Such methods seldom give very accurate estimates of primate density because of frequent failure to satisfy the required assumptions: probability of detecting animals over the transect line = 1, detection of animals before significant movement away, failure to determine group center, lack of sufficient observations, etc. Lack of sufficient replicated transects is almost always a problem because of the heavy work involved. For gibbons, the problem of groups fleeing before detection can be very serious. In areas where gibbons have been habituated to humans, however, overestimation of density rather than underestimation may result due to differences caused in the detection function [25].

4. Discussion

The estimation of the population sizes of gibbons in the natural environment depends on accurate methods for estimation of density of breeding groups in the forest. The behavioral and ecological characteristics of gibbons make population survey of gibbons easier than for other types of primates: relatively stable, sedentary groups, and loud singing by mated pairs. The genetic effective population size of gibbon populations is roughly twice the number of groups.

The two major issues in the estimation of gibbon group density have been the estimation of the number of groups in a given area from the songs or duets heard, and the estimation of the area that they occupy, Interpreting the auditory data requires information on the singing frequency of groups (probability of singing per day), the number of songs given per day. Estimation of the area requires knowing how detectability (chance of hearing a group that sings) decreases

with distance from listeners. This will depend very much on selection of listening posts and the terrain roughness, as well as factors such as weather and season. Distance software analysis is now the preferred method for modeling detectability, and does not require prior determination of the "listening area". But it does require careful selection of listening posts using a topographic map, and careful mapping of groups.

The newer SECR method models detectability using auditory data from two or more listening posts and does not require measurement of distances to groups. However, there appear to be a few issues that have not been fully dealt with in the SECR method. The software does not contain methods for verifying recapture identification from multiple calls (songs) within days and between days. This is left to the users' ingenuity, and normally such verification requires detailed mapping exercises. The software also does not estimate the probability of calling. Because of these problems the SECR method may require further development, or specification of how these problems are to be solved. In spite of these problems, the SECR method is ingenious and promises to become a useful method for density estimation. It is still being improved and testing it against other methods such as the point transect is highly desirable. This has not progressed very far because the point transect Distance method itself is also still in the process of being refined and tested for use in gibbon survey.

Auditory methods probably give more reliable estimates of gibbon density than visual line transect methods, partly because they allow for coverage of much more sample area than is normally the case in line transect surveys. The preparation of transects in dense tropical forests, especially over difficult terrain, is laborious (in some areas impossible) and hence under-sampling usually results. Gibbons can be heard singing from distances greater than 1 km away, but can be seen reliably only 20–30 meters away in evergreen forest (provided they don't see you first).

5. Conclusions

The methods of survey and sampling of wildlife populations have evolved in spurts of research activity and they continue their transition into the modern age of improved statistical estimation and computer modeling. The development of better methods of gibbon sampling must continue as there is at present no unanimous agreement as to the best or most promising method. The most modern methods will employ more advanced detection technology such as acoustical analysis and recording equipment, as well as field data input methods. But as better methodology is being developed, gibbon populations are becoming more fragmented and are declining in numbers. As populations decline in numbers it becomes more critical that we know how many there are left.

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Iterative receiver design for indoor wireless visible light communication system

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Abstract

White LED will be a dominant device for lighting in the near future through which we can have the luminance and data transmission simultaneously. An indoor wireless visible light communication system (IWVLC) describes the communication during the indoor applications. This paper presents an iterative receiver design for the IWVLC system and proposes the Soft-Output-Viterbi algorithm to equalize and detect the signal at the receiver of the IWVLC system which is based on the numerical simulation. The performance of the proposed algorithm is better than the conventional Viterbi algorithm in terms of the bit error rate. The simulation results unveil the performance of the proposed iterative algorithm where it can be seen that the BER comes out to be less at the same SNR (dB) as compared to the conventional ones even when the data rate is very high.

1. Introduction

LED is light emitting diode that a semiconductor device can produce a light where LEDs obtain more energy. In the near future, LED will replace a conventional lamp because there are many benefits such as power consumption, life time, cooling operating system, small size, and high frequency response etc. Additionally, it can be used for communications system which is white LEDs. A higher power LED can produce 130 lumens per a single LED, so not sufficient for a typical room that requires luminance of 300 to 1,500 lx. Therefore, the lamp is made to be array LEDs. VLC system has many benefits compared to radio frequency system (RF). Since the radio frequency (RF) spectrum is so crowded, and the data transmission rate of RF communications cannot satisfy the great demand for huge data transmission, visible light communication (VLC) has proceeded as a possible state of the art for next generation communications. VLC systems in which white light emitting diodes (LEDs) are used as transmitters for communications. They can become the dominant indoor communication method.Their advantages are high speed, no electromagnetic interference and environmental protection. Also, they show potential prospects in hospital, indoor and outdoor

short-distance communications, intelligent transportation and other areas. The interest in VLC system has rapidly increased due to it can combine the high speed communication and a luminance system at the same time by using an LED as a lighting source.

A basic model was first introduced by Toshihiko et al. [1] as the indoor wireless visible light communication link, used white LEDs arrays transmitter and illumination in a typical room. The photodetector used in the receiver to receive light from the transmitter and to convert the light to be electric signals. The light path divided into two parts which are the direct path and the diffusion path. Toshihiko et al. [1] found that the power distribution covered the typical room and the numerical result calculated average power of 2.5 dBm. However, when the data rate is sent with high speed, the signal to noise ratio will be low. The main effect of this system is the reflectivity of another path in the typical room and ambient light has been an inter-symbol interference (ISI). The suggestion to reduce ISI effect is using an equalizer before decoding the original data at the receiver. Lubin et al. [2] proposed a transmission in VLC system, found that it can improve a data rate from 16 Mbps to 30 Mbps by using a filter design. Nguyen et al. [3], a modulation technique was used as the same as configuring system such as the room dimension, and a parameter setting was as [1-2], the data modulation by NRZ-OOK schematic can improve

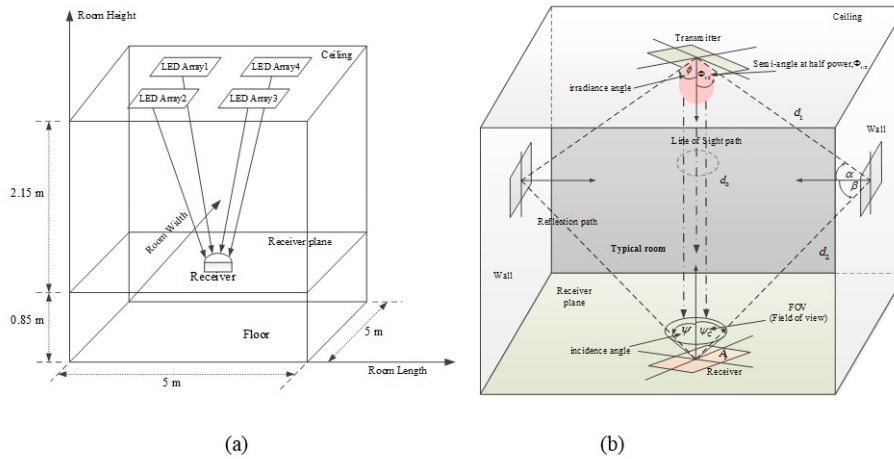[*]Corresponding author; email: adisorn@npru.ac.th

Figure 1: (a) a visible light using LEDs lamp in a typical room, (b) the position of light source related with the receiver LOS and Diffuse Path.

the bit error rate as the result shown in [3]. In their study, Kwonhyung et al. [4] studied a characteristic of the indoor wireless VLC channel of white LEDs shown wide bandwidth for the transmission in optical wireless communication compared with infrared channel. Brief of this paper was the bandwidth of channel which depends on LED lamp used and the coefficient reflection of materials in a typical room. Yan et al. [5] proposed a combination VLC and WiFi based indoor wireless network architecture which supports bidirectional high-speed data transmission, and a demo system was designed and implemented. Feng et al. [6] investigated on two recent indoor channels in future 5G networks based on mmWave and VLC, in their results showed that VLC and mmWave channels share some common characteristics while differing in others, which makes them appealing in different application scenarios. Adisorn et al. [7] proposed the receiver design based on a partial-response maximum-likelihood technique for the indoor wireless visible light communication system, where a transmitter is placed on the ceiling, a receiver is on the table, and the signal transmission is based on the on-off keying (OOK) intensity modulation. The result compared the performance between a conventional receiver design and the proposed, the receiver design based on PRML technique improved bit error rate for indoor wireless VLC system.

In this paper, we proposed an iterative receiver design for indoor wireless visible light communication system, organized as follows. In section 2, a model an indoor wireless VLC system is discussed and included to describe a light propagation and a received power distribution in the typical room. In section 3, iterative receiver design for indoor wireless VLC system is described. Then, in section 4, the results and discussion are described. Finally, the conclusion is given in section 5.

2. Indoor Wireless VLC System Modeling

Indoor wireless visible light communication system using arrays LED lamps is shown in Fig. 1 [1], so each array LED lamp is on the ceiling of the room, including a dimension of the room, a receiver, and a transmitter. All the parameters of typical system model are shown in the Table 1. The VLC system is shown on a Fig. 1 as four sets of LED arrays are on the ceiling. The receiver is placed on the receiver plane above the floor. The room size is $5.0 \text{ m} \times 5.0 \text{ m} \times 3.0 \text{ m}$., the distance between transmitter and receiver plane is 2.15 m. A coordinate system is set as following the Fig. 1, x and y - axis are the floor plane, the height direction is a z - axis. The illuminance expresses the brightness of an illuminate surface. The LED has an illuminous $I(0)$ on the optical axis and Lambertian distribution is assumed as its light distribution $I(\phi)$ spread around the typical room, the light distribution depends on the function of cosine and the irradiance angle of LEDs [1 − 3].

$$I(\phi) = I(0) \cos^m(\phi) \quad (1)$$

where $I(0)$ is the center illuminous intensity of the group LEDs, m is the order of Lambertian emission, which is relative to the semi-angle at half power of the LED denoted as , and is defined as (2).

$$m = \frac{-\ln(2)}{\ln(\cos \Phi_{1/2})} \quad (2)$$

A horizontal illuminance E_{hor} is given by [1], represented as the Eq. (3), where $I(\phi)$ is the illuminous intensity in angle ϕ, and as Eq. (3) is divided by $\cos(\psi)$ is the cosine function of angle ψ.

$$E_{hor} = \frac{I(\phi)}{d^2 \cos(\psi)} \quad (3)$$

where ϕ is the irradiance angle of LEDs, a transmitter in VLC system, ψ is the incidence angle of photodetector that a receiver in the system and d is the

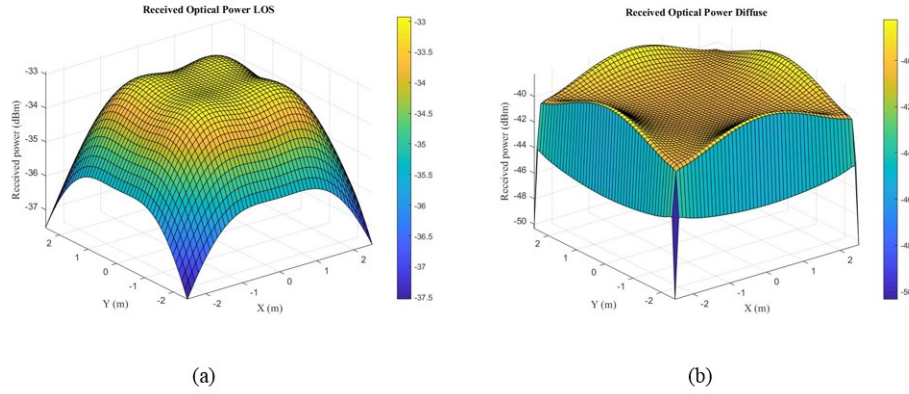(a)   (b)

Figure 2: Optical power distribution in received optical plane for a semi-angle at half power 70°, (a) the distribution of direct lights received optical power (Ave. -34.0925 dBm) and (b) the distribution of reflective lights received optical power (Ave. -40.0851 dBm).
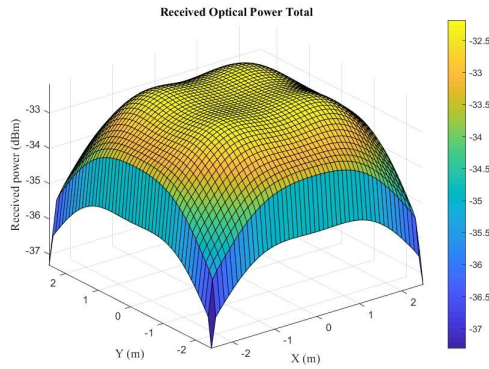

Figure 3: Total optical power including reflections distribution in received optical plane for a semi-angle at half power 70° (Avg. -33.0747 dBm).

distance between an LEDs and a photodetector. The illuminance of light is considered due to the lighting is required to standardize in office room.

The received optical power from a transmitter to a receiver is divided two paths, firstly, the channel DC gain of Light of sight path (LOS) given by [1 – 3] as Eq. (4)

$$H_d(0) = \begin{cases} \frac{(m+1)A}{2\pi d^2}\cos(\phi)\,T_s(\psi)\,g(\psi)\cos(\psi), \\ 0 \leq \psi \leq \Psi_c \\ 0, \psi > \Psi_c \end{cases} \quad (4)$$

where A is the physical area of the detector in a PD, d is the distance between a transmitter and a receiver, ψ is the angle of incidence, ϕ is the angle of irradiance, $T_s(\psi)$ is the gain of an optical filter, and $g(\psi)$ is the gain of an optical concentrator. Ψ_c denotes the width of the field of view of photodetector. The optical concentrator $g(\psi)$ can be given as:

$$g(\psi) = \begin{cases} \frac{n^2}{\sin^2(\Psi_c)}, 0 \leq \psi \leq \Psi_c \\ 0, \psi > \Psi_c \end{cases} \quad (5)$$

where n is the reflective index, and the received optical power P_r is derived by the transmitted optical power P_t multiplied by the channel DC gain $H_d(0)$ as shown in Eq. (6).

$$P_r = H(0)\,P_t \quad (6)$$

In this paper, the all parameters are shown in the Table 1. A semi-angle at half power (FOV) of the receiver is 70.0 deg., and the detector physical area is 1.0 cm². The gain optical filter is 1.0, and the reflective index of an optical concentrator lens is 1.5. Fig. 2 shows the distribution of received power of direct light from the LEDs to the receiver plane, Fig. 2 (a) and (b) depicted the received optical power of LOS and diffuse link, respectively. In Fig. 2 (a) and (b), the received optical power is -37.5328 to -32.9261 dBm and -50.3478 to -38.2263 dBm respectively, in all the places of the room.

We consider the effect of reflective light by walls. The received optical power is given by the channel DC gain on directed path $H_d(0)$ and reflected path $H_{ref}(0)$.

$$P_r = \sum^{LEDs}\left[P_tH_d(0) + \int_{walls} P_t dH_{ref}(0)\right] \quad (7)$$

The channel DC gain on the first reflection is [1]:

$$dH_{ref}(0) = \begin{cases} \frac{(m+1)A}{2\pi d_1^2 d_2^2}\rho dA_{wall}\cos^m(\phi)\cos(\alpha)\cos(\beta) \\ \times\,T_s(\psi)\,g(\psi)\cos(\psi), 0 \leq \psi \leq \Psi_c \\ 0, \psi > \Psi_c \end{cases}$$

$$(8)$$

where d_1 is the distance between an LED on the ceiling and a reflective point at the walls, d_2 is the distance between a reflective point and a receiver, ρ is the reflectance factor, dA_{wall} is a reflective area of small region, ϕ is the irradiance angle at LEDs, α is the irradiance angle to a reflective point, β is the irradiance angle to the receiver, psi is the incidence angle at the receiver as Fig. 1 (b).

Fig. 3 shows the distribution of received optical power including the reflection. In all the places of

Table 1. All parameters for setting in the simulation.

Parameters	Values	Parameters	Values
Room size	5 x 5 x 3 m^3	Wall reflectivity	0.7
Desk height from the ceiling	2.15 m	FOV at the receiver	120°
Single LED power PLED	30 mW	Detector physical area of PD	1.0 cm^2
LED response time	150 ns	Transmission coefficient of optical filter	1.0
Semi-angle at half power	70°	Refractive index of lens at PD	1.5
Number of LEDs arrays	4	Photodiode responsivity (R)	0.4 A/W
Number of LEDs per array	25 (5 x 5)	Turning Parameter (P)	2
LED pitch	1 cm	Amplifier noise density	5 pA
Floor reflectivity	0.15	Ambient light photocurrent	5840 uA
Ceiling reflectivity	0.8	Noise-bandwidth factor (I_2)	0.562

(a)   (b)
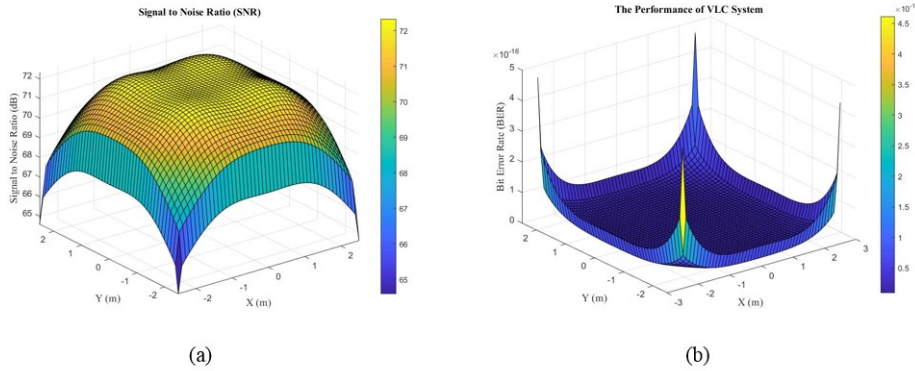
Figure 4: (a) The signal to noise ratio distribution for a semi-angle at half power 70°, (b) bit error rate distributions.

the room the received optical power is -37.3114 to -32.1806 dBm. The received maximum and average power are -32.1806 dBm. and -33.0747 dBm. respectively. The photodiode is used to convert the received optical power into the electrical current, and the output current is $i = P_r * R$ where R is the photodiode responsibility (denotes 0.4 A/W as Table 1). The SNR is given by [2]:

$$SNR(dB) = 10\log_{10}\left(\frac{P_r R}{\sigma_{total}^2}\right) \qquad (9)$$

where σ_{total}^2 is total noise variance and it is given by [2] $\sigma_{total}^2 = \sigma_{shot}^2 + \sigma_{amplifier}^2$, and the shot noise variance σ_{shot}^2 is given by $\sigma_{shot}^2 = 2qRB_n(P_r + P_n)$ where B_n is the noise bandwidth, P_n is the noise power of ambient light around the room, $B_n = I_2 R_b$, where R_b is the data rate and I_2 is the noise bandwidth factor. The amplifier noise variance is given by $\sigma_{amplifier}^2 = i_{amplifier}^2 B_a$, where B_a is noise amplifier bandwidth. The bit error rate is calculated as:

$$BER = Q\sqrt{(SNR)} \qquad (10)$$

where $Q(x) = \frac{1}{\sqrt{2\pi}}\int_x^\infty e^{-y^2/2} dy$. AS followed the signal to noise ratio distribution in Fig. 4 (a) and the Fig. 4 (b) shows the performance of the IWVLC system. The

bit error rate calculated from the signal to noise ratio (SNR). At all corners of the room, it can be seen that the bit error rate raised more than the other place of the receiver plane as shown in Fig. 4 (b) bit error rate distribution. The low BER area is increased by at the corners of the room that is low illuminance.

All the parameters are mentioned in Table 1, where the LED response is a function of exponential as described in [2], and can be written as: $h_{LED}(t) = e^{-\omega_c t}$ where $\omega_c = p/(T_r + T_f)$. p is an experiment tuning function. T_r is the rise time and T_f is a the fall time, there is defined to 20 nsce and 130 nsec. [2] respectively as shown in Fig. 5 (d). Fig. 5 shows the normalized impulse response at corner of the typical room (x, y, z)=(0.5, 1.0, 0.85). From Fig. 5 (a), (b), and (c), it can be seen that the different of impulse response in each path of optical channel that included LOS path, diffuse path and total impulse response as respectively. The optical wireless channel model is expressed as follows [1]:

$$y(t) = Rx(t) \otimes h(t) + n(t) \qquad (11)$$

where $y(t)$ represents the received signal current that is converted by the PIN photodetector, is the detector responsivity of the photodiode, $x(t)$ represents the transmitted optical pulse that is a digital signal input convolution with the LED response base on a simulation model, $h(t)$ is the optical impulse response, $n(t)$
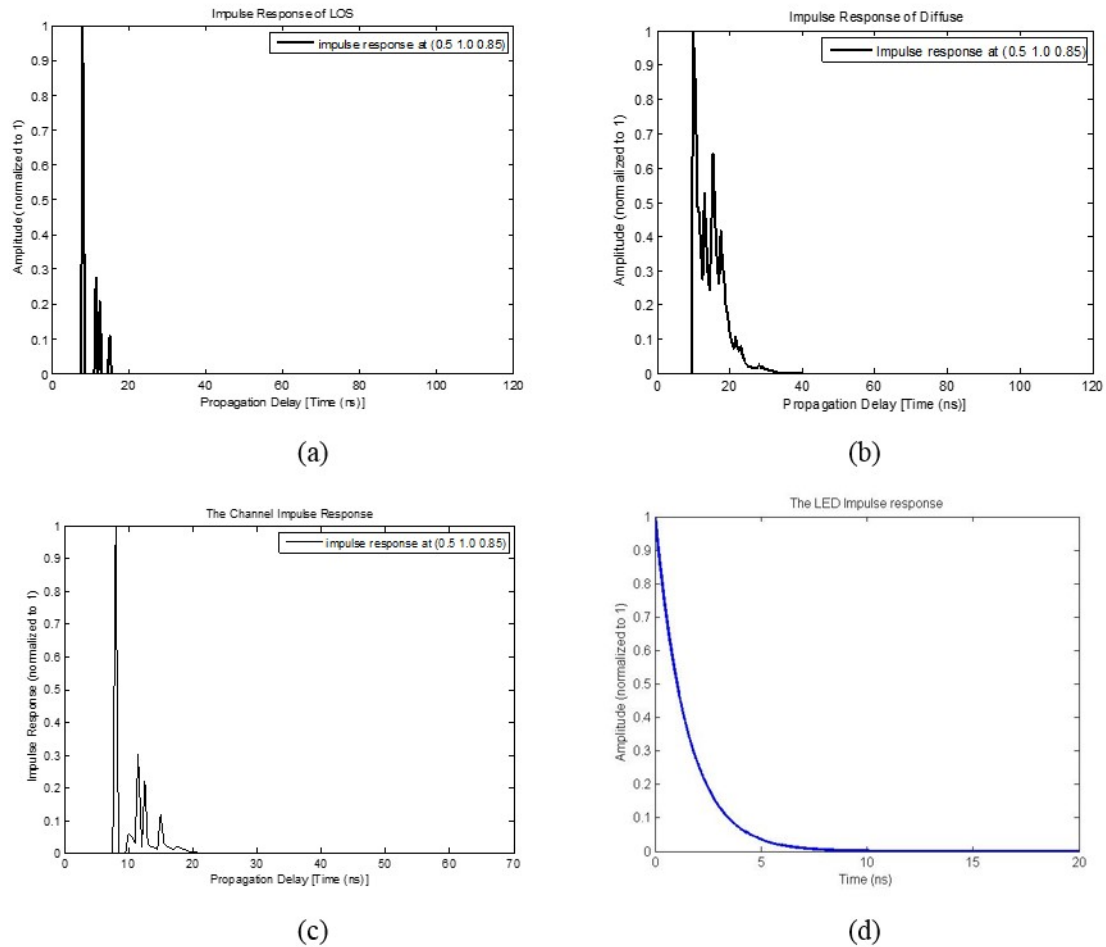
Figure 5: Impulse response of the typical room IWVLC system at (0.5, 1.0, 0.85) (a) impulse response of LOS path (b) impulse response of diffuse path (c) the total channel impulse response and (d) the LED impulse response.

represents the AWGN, and the symbol $\otimes$ denotes convolution.

3. Iterative Receiver Design for the IWVLC System

A conventional receiver for the IWVLC system [2], the received signal from a PIN photodetector is filtered by a low pass filter that is an analog filter to equalize the received signal, then [2] decided by a threshold detector to recover a data. However, in [7] used Partial-response maximum-likelihood (PRML) combined with a Viterbi detector to improve the performance of the IWVLC system at a receiver. Additionally, in this paper proposed a new approach for IWVLC receiver. As Fig. 6 shows a block diagram of an iterative receiver for IWVLC system. Low density parity check (LDPC) codes proposed by Gallager in 1962 [8], there are many communication technologies that have been used LDPC algorithm to improve the performance of their system. Yishuo et al. [9] proposed to use the LDPC code for the VLC system to

study a performance of VLC based on LDPC code. In [9], found that the QC-LDPC code is suitable channel code for VLC, and to reduce a complexity to a large extent on covering the BER performance of the VLC system. In [10] studied run-length code for VLC system to improve many performance factors, including spectral efficiency, power efficiency, DC balance and flicker avoidance, and the results confirm the superb performance of the RS-eMiller schemes. However, this work is continued from [7] and the diagram that a new receiver is proposed as shown in Fig. 6.

According in the Fig. 6, the data from equalizer is a digital input y_k through the soft output Viterbi algorithm (SOVA) detector that is a Viterbi detection. The output of SOVA detector transfers the data iteratively with LDPC decoder until the iteration finished. Equalizer taps can be expressed as Eq. (12) in the domain D. The equalizer target is designed by using the Eq. (12) and (13) based on the minimum mean squared er-
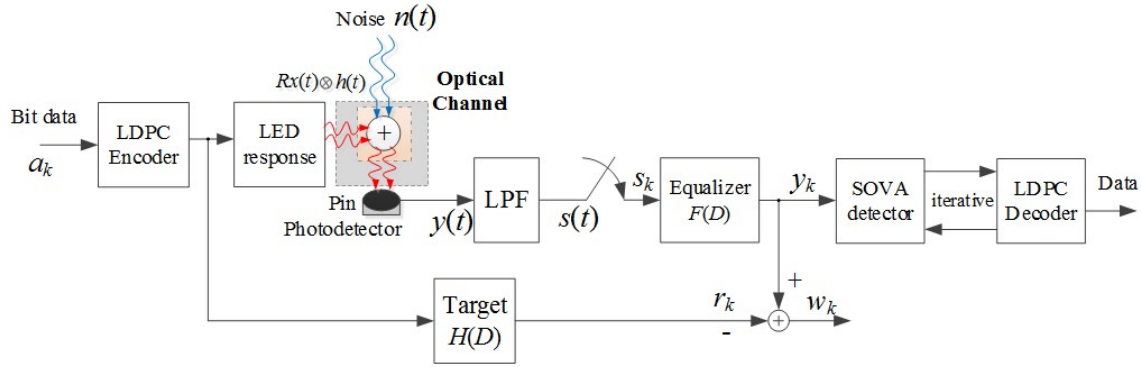
Figure 6: Iterative receiver block diagram for the IWVLC system.

ror (MMSE) [11].

$$F(D) = \sum_{k=-K}^{K} f_k D^k \qquad (12)$$

where D is the delay operator unit, f_k is the filter coefficient of equalizer $F(D)$, h_k is the filter coefficient of target $H(D)$ as Eq. (12) and (13) respectively.

$$H(D) = \sum_{k=0}^{L-1} h_k D^k \qquad (13)$$

$F(D)$ and $H(D)$ are vectors that K and $L-1$ are lengths of the filter coefficient of equalizer and the filter coefficient of target, respectively. In simulations, the values of K and L are set to be 5 and 3 respectively, to determine the minimum mean square error $E\left[\omega_k^2\right]$ in the (14) [11-16], where $\otimes$ is the convolution operator, $E[.]$ is the expectation operator.

$$E\left[w_k^2\right] = E\left[\{(s_k \otimes f_k) - (a_k \otimes h_k)\}^2\right] \qquad (14)$$

Following the Fig. 6, a_k , bit data is created randomly from the simulation program. A sequence of bit data is encoded by the LDPC encoder. Parity check matrix H is created in [8-9] and [16] by based a quasi-cyclic (QC-LDPC). A log-likelihood ratio based propagation (LLR) decoding algorithm of LDPC code proposed to use include with SOVA detector in IWVLC system. The input sequence of SOVA detector is denoted by y_k. Detailed decoding steps of LLR BP (Belief Propagation) algorithm are as follows [8-9] and [16]. Assume that the prior probability of the information is given:

$$L^{(0)}\left(q_{ij}\right) = L(P_i) = \ln\left(\frac{1 + \exp\left(2y_i/\sigma^2\right)}{1 + \exp\left(-2y_i/\sigma^2\right)}\right) = \frac{2y_i}{\sigma^2} \qquad (15)$$

where y_i is the output sequences from SOVA detector, σ^2 is the total noise variance. Check nodes updating. Calculate the information of check nodes received form variable nodes as Eq. (16), [8-9] and [16] where

the Tanner Graph and Trellis of SOVA diagram are described, respectively.

$$L^{(l)}\left(r_{ji}\right) = 2\tanh^{-1}\left(\prod_{i' \in R_j/i} \tanh\left(\frac{1}{2}L^{(l-1)}\left(q_{i'j}\right)\right)\right) \qquad (16)$$

The variable nodes updating, to calculate the information of variable nodes received form check nodes:

$$L^{(l)}\left(q_{ij}\right) = \frac{2y_i}{\sigma^2} + \prod_{j' \in C_i/j} L^{(l)}\left(r_{j'i}\right) \qquad (17)$$

Then, the information of variable nodes is decoded as follows:

$$L^{(l)}(q_i) = L(P_i) + \prod_{j \in C_i} L^{(l)}\left(r_{ji}\right) \qquad (18)$$

when reach the maximum iterating time the bit data is 1 if $L^{(l)}(q_i) \geq 0$ and is 0 if $L^{(l)}(q_i) < 0$ .The simulation parameters for iterative receiver of the IWVLC system which the size of LDPC code parity check matrix is denoted by 445 x 4095, code length is 4095 and the code rate is 8/9.

4. Results and Discussion

In Fig. 7 illustrates the BER performance between the Viterbi detector and SOVA detector at the different data rate 50, 100, 150, and 200 Mbps. It can be seen that a new approach receiver gave the better BER performance more than 10^{-4} at the same data rate and SNR (dB). An iterative receiver at all data rate, it can accept BER 10^{-5} as differences the signal to noise ratio (SNR) about 6, 10, 12, and 15 dB., respectively, as shown in Fig. 7.

Fig. 8 shows the performance of bit error rate of the IWVLC system by comparison with a different iteration 5, 10, 20, and 30, it can be seen that the more iteration the bit error rate is low as SNR 4 dB and at 30 iterations the BER performance is lower than 10^{-5} as well. According to Fig. 8, the SNR is low, the iteration of decoding hardly improved decoding LDPC
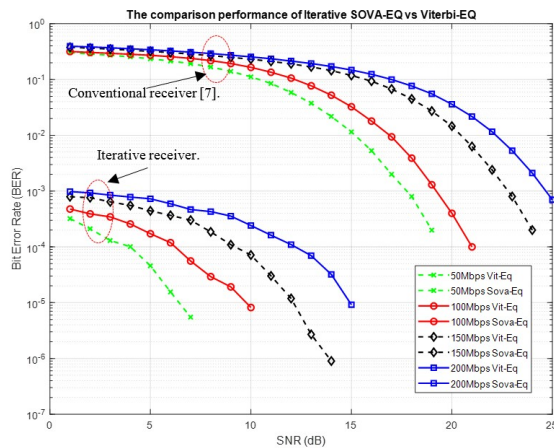
Figure 7: The performance of the IWVLC system comparison between LDPC and Viterbi detector.
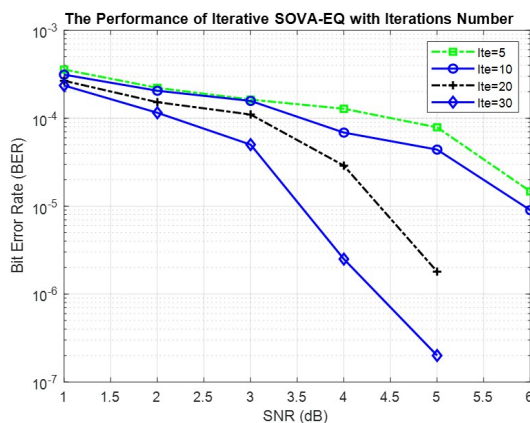
Figure 8: The performance of the IWVLC system comparison between a different iteration.

algorithm. When the SNR is 2 dB, the BER performance is higher than 10^{-4} of all the iteration. And when the SNR is 5 dB, the iteration of decoding can improve the bit error rate of the IWVLC system significantly. Moreover, there is a large difference between 30 and 5 iterations.

Fig. 9 shows the BER performance of the IWVLC system when the data rate is high. As Fig. 9, the bit rate 200 Mbps and 500 Mbps gave the bit error rate that can accept at 10^{-4} by SNR(dB) at 12 and 14 dB, respectively. However, as the bit rate is over up to 1 Gbps and 2 Gbps, the IWVLC system needs alternative techniques to support and that is the challenge to the next work.

VLC technology has advantages which make it a good candidate solution for indoor wireless access network, and it can combine the RF with the Wi-fi network for indoor at the specific places. Recently, VLC technology is one of complementary technology for future 6G network [17] that is to exploit the visi-
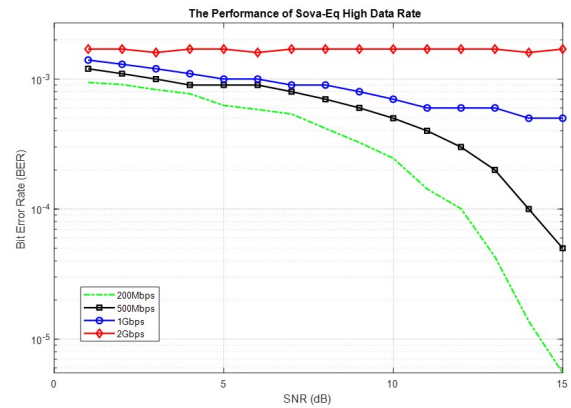
Figure 9: The performance of the IWVLC system comparison between a different high data rate.

ble spectrum with visible light communication (VLC) techniques for short range (up to few meters) links, which compared to classically adopted RF bands offers ultra-high bandwidth (THz), zero electromagnetic interference, free unlicensed abundant spectrum, very high frequency reuse [18]. Therefore, researchers keeping on VLC technology will have opportunities to investigate in the future 6G network area.

5. Conclusions

This paper proposes a receiver design for indoor wireless visible light communication system. This work has reported an investigation of the performance of the schemes LDPC coding and the detector SOVA equalize of the IWVLC transmission system by combining both techniques. The performance shows the bit error rate of new schemes better than the conventional schemes. In addition, the more iteration number used its BER performance improved. The proposed method is useful and suitable for the IWVLC system. But, at high data rate needs a new approach to improve the performance of the IWVLC system.

Acknowledgements

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Event marketing as an appropriately integrated marketing communication for promoting tourism of Ko Lad E-Tan, Nakhon Pathom Province, Thailand

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Abstract

The aim of this research was to create a model of integrated marketing communication for supporting community tourism in Ko Lad E-Tan, Nakhon Pathom Province. Grounded theory was used to collect the data from two sample groups. The first group consisted of stakeholders and locals. The second sample group was tourists. It was found that a wide variety of integrated marketing communication types were not run by government offices. All marketing and communication plans were based on previous plans which were thought to be ineffective. This research found that the local population in the sample group were interested in the use of integrated marketing communications. This study explains the potential of the local population for carrying out integrated marketing communications. These resources consisted of local human resources, local stories, communication channels and tourists. Moreover, this research has shown that event marketing is an appropriate model of integrated marketing communication which can be used effectively to support community based tourism. This is because it can respond the needs of the local population and it can solve tourism problems in this area. At the same time, the model can be used to communicate directly with tourists. This model can be used to boost the image of tourism and create loyal, revisiting, tourists. Finally, the research identified key factors for the success of community-based integrated marketing communication management in long term. It found that communications should be based on the local uniqueness as well as responding to needs and potentials of the local population. Importantly, it should also be focused on local budget, local human resources and should respond to tourists' needs.

Keywords: Event marketing, integrated marketing communication, agro tourism, Nakhon Pathom Province

1. Introduction

One of the challenges for community-based tourism management in Thailand is its marketing communication [1]. In the study of Srisawang and Buaban [1], it was found that local people in community based tourism projects often lacked the knowledge and experience required to do marketing communication effectively. They particularly had problems with creating interesting marketing tools and how to reach the target tourist groups. Moreover, local people also faced a lack of budget and staff to adequately promote tourism in the long term. Marketing and communication through local participation was found to be incapable of presenting the destinations' true and authentic image. Moreover, the information provided about the destination did not meet the needs of tourists.

Pongsthapon [2] studied the growth of information technology and its effect on the marketing and communication in tourism. They found both positive and negative impacts from tourist receiving a variety of information from different sources. Receiving information from a variety of information sources was also found to confuse tourists. They were found to find it difficult to identify which information they can be confident in before they decide to travel. Government organizations have funding available to carry out marketing communication programs for supporting community-based tourism in Thailand but many projects are not innovative and are simply a replication of the previous program. There is often no local participation process in developing such projects. For these reasons these projects do not adequately respond the needs of the local population in the tourism areas and tourists. This has a direct impact on the num-

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ber of tourists in the community tourism destinations. Keller [3] indicated the importance of carrying out a participatory process when carrying out a marketing and communication project. This participatory process should include experts in the tourism products, customers and all relevant stakeholders so that it leads to the development of an adequate marketing and communication plan.

Integrated communication marketing is one solution for accessing and responding to the direct need of customers. It also responds to the needs of locals to promote destinations based on authenticity. It ensures that tools of communications and the message delivered are linked together. Keller [3] discovered that there is a positive relationship between the tools of marketing communications and organizations' success. Integrated communication marketing can be used to deliver huge benefits. At the same time, it can help tourists by giving reminders, information which can be updated in real time and special offers. Moreover, it can differentiate tourism products from others by adding value and supporting the participation process for all [4]. Srisawang and Buaban [1] found that integrated communication marketing is important for the long-term marketing of community-based tourism. They found that this was because communities often lack the money, staff and knowledge to do the marketing themselves. Integrated marketing communication provides many appropriate tools for the local population and can response the needs of tourists. It is important to note that, in a truly authentic destination, the local population will have their own occupations and so do not have adequate time to promote tourism themselves. It is, however, easy for them to collaborate with other stakeholders or organizations which support tourism to carry out integrated marketing communications.

The community of Ko Lad E-tan, in Nakhon Pathom Province, Thailand has promoted agro tourism for more than 10 years. It has a variety of tourism resources such as an outstanding green environment, agriculture and local wisdom. There are other traditional tourism destinations near to the area which is situated around one hour from Bangkok. Local people have needed the additional income from tourism due to the extensive flooding in 2011 which destroyed their main income. The core products the area produced were; pomelos, bananas, jack fruits and local fruits. Many of these trees were destroyed by the flooding. The trees have since been replanted but took time to recover. During this period tourism provided a much needed second income source for the community. Tourists visit the area and pay for tourism activities such as cooking classes, field trips, tram rides around the community, boat trips, cycling and creative activities which focus on co-creation processes. Four years later, tourism has become one of the main routes to market for their agricultural prod-

ucts which are bought directly from the community by the tourists. Despite this the community have not received the economic benefits from tourism that they anticipated. Buaban and Srisawang [5] found that the number of tourists has actually decreased over the last two years. One of the reasons that was identified for this was that tourists did not feel receive what they expected from their visit based on the information they obtained prior to their visit. The area has a low tourist revisit rate. Meanwhile, marketing communication tools developed by local government offices do not appear to be reaching new tourists. Buaban and Srisawang [5] also found that locals do not want to do marketing communication for community-based tourism because they think it is not their work. Importantly, they also do not have time to do it because they have own occupations. At the same, there are local conflicts among stakeholders who work more directly relates to tourism. Some of them say they cannot participate with the tourism route because they do not have enough time to welcome tourists at their tourism point. Meanwhile, there are many tourism sites for welcoming tourists and their marketing communication is done in different ways. The information about tourism in the area therefore does not work together in harmony. This makes tourists' confused with the information when they would like to visit this area. Finally, the information that is provided often not up to date and consistent. One of reasons for this is a lack of community expertise in marketing communication. Buaban and Srisawang [5] concluded that this area requires an appropriate use of integrated communication for long-term marketing to sustain tourism in the area and to support its economic growth.

Until now, there has not been a study that has presented the appropriate use of integrated communication through local participation for long-term marketing in community-based tourism sites. The aim of this research was therefore to study and develop a model of integrated marketing communication for promoting tourism in Ko Lad E-Tan, Nakhon Pathom province, Thailand. Grounded theory was used in this research because it is a strong interpretive tool for in-depth understanding of quantitative data. It can be used to focus on people's experiences and interpret the active roles of actors [6]. The research results developed could improve the attraction by developing a model of integrated marketing communication which will be used to promote community-based tourism management in the long term.

2. Research Objective

To study and develop event marketing as appropriate use of integrated marketing communication model for promoting community based tourism in Ko Lad E-Tan, Nakhon Pathom province, Thailand

3. Literature Review

3.1. Integrated marketing communication

Belch and Belch [7] defines integrated marketing communication as: "the process develops and sustains brand identity and brand equity, and also increases long-term customer relationships". Some organizations use only marketing strategies to promote their products or their organization's image. Typically their methods include as public relations exercises, special events and advertisements. Integrated marketing communication requires a unified strategic plan with an expert working under a single strategic planner. Integrated marketing communications are thought to be essential for use in businesses due to the complex needs of today's customers. In addition to other complexities, today's customers have access to far more knowledge about the product or service they are interested in purchasing. For these reasons it is necessary to find new methods and tools for communication, as well as to combine new and existing tools and methods. Integrated marketing communication leads to the delivery of consistent news and provide a high sales impact. It also requires the creation of a product image. It can increase the company's ability to communicate to the right news to the right customers at the right time and place. When choosing the tools and methods to be used for an integrated marketing communication several considerations must be made. These relate to the specific situation, which methods of communication are most relevant to the product, service or customer group, which messages should be sent, or which groups of consumers should be targeted. It should use the most appropriate communication methods rather than those that are just most familiar to the project's manager.

Keller [8] explained that integrated marketing communications first involves determining the target audience. It then formulates a combination of marketing promotion programs to match the needs and responses of the target audience. Today, most marketing professionals turn their attention to communication as a tool for managing customer relationships. They pay attention to a specific target group as a small group of customers with similar needs or individually, identifying the needs of each specific customer.

Concluding, integrated marketing communication is a concept of creating a marketing communication plan in order to increase the overall value of the plan. It includes the planning and evaluation of strategies of various types of communication which in turn creates clarity reliability and the most effective from communication integration [9].

3.2. Tourist behavior

Cohen et al [10] stated that tourist behavior refers to all actions of tourists, regardless of whether they are aware or unaware of it. Nobody may notice their actions that they themselves are unaware of however people can easily observe tourist's overt behavior. On the other hand, tourist 'covert' or non visible behavior is more difficult to observe. Non visible behaviors include the thoughts and emotions that are held within. These are often interrelated with overt behavior in which internal behavior determines the external behavior of tourists. It is therefore possible to find a solution to change the tourist's behavior for buying services. Importantly, it can help to develop the market and develop tourism products continuously. This behavior that is shown by tourists is their reflection to the environment they find themselves within. Because of this it is important to understand the feeling, knowledge and understanding of tourists in order to meet their needs and to satisfy their demands. Moreover, tourists' behavior means that people who seek to buy, use, and evaluate tourism products or services are expected to meet their needs. Therefore, studying the behavior of tourists can lead to a deeper understanding of their decision making patterns. It can help to understand what travel services they would like to buy, why they choose to buy the services they do, when they like to buy services, where they like to buy services and how often they buy services. In addition to this tourist's behavior allows an understanding of how they evaluate those services that they have purchased. This is one issue that that is critical for businesses to know about in order to satisfy their customer's needs. The service provider must learn everything related to their target tourists, such as studying their needs, ideas and how they work, and spend their leisure time. It is important to understand both personal factors and group factors that affect tourists' decision to buy services.

Reanthong [11] studied about tourist behavior. Some behavior is easily observable such as the words they use, their actions, facial expressions, or gestures while visiting tourist spots. Taking pictures, eating food and purchasing items are also behavior characteristics that can be used to indicate a tourist's inner thoughts. These behaviors may be based on individual characteristics or needs or may be similar for groups with similar needs. They also may depend on the environment or experience of the individual tourists themselves.

It can be concluded that tourist behavior acts that expresses the inner thoughts and feelings of tourists, whether or not they are conscious or not. Expressions while traveling may be delivered through speech, actions, facial expressions or gestures. The expressions of tourists can be divided into two key types. These are external and internal behaviors. The external behavior is that which others can easily notice while internal behavior is more difficult to understand. Internal and external behaviors are interrelated and can be used to determine the overall external behavior of tourists. Therefore, to study the tourists' behavior is so important for develop or create integrated marketing com-

munication. It is one of factors to create interesting tools for attract tourists or customers.

3.3. Event marketing

Miyazaki and Morgan [12] suggests that event marketing is marketing activities that involve the use of special activities or events. Belch and Belch [7] explained that marketing activities or activity marketing is a way to let consumers know about their products and allow them to appreciate their products though activities involving the product. The overall aim of this is to increase sales of the company's products. In recent years event marketing has become more popular. Marketing communication can motivate consumers to participate in the activities themselves. Success can be measured by the number of people who attend the activity and are interested in the company's products following the activity.

Companies arrange special events to create a good image for the company or reinforce the selling point of specific products. Companies can also be a sponsor of special events held by others if they fit in with their brand image. They can gain the interest of target consumers through sponsoring sporting events, exhibitions or concerts. There are also ways of getting involved with activities that others have already done. This can be particularly successful if the activity is already popular with consumers. Supporting special activities may be done on a daily, weekly, monthly, yearly or ongoing basis. This creates more opportunities for customers to become familiar with products and can help to emphasize the key selling points of products [13].

Therefore, one of the key factors when arranging event marketing is to understand the objectives which emphasize the relationship between activities and product benefits. Marketing activities must be clear and meaningful. All activities should convince, attract and stimulate the interest of target customers.

4. Method

The purpose of this research was to study and develop the appropriate integrated marketing communication model for promoting tourism in Ko Lad E-Tan, Nakhon Pathom Province, Thailand. This area was chosen for the study because at the time of the study they were experiencing marketing communication problems. The area has a variety of tourism resources such as outstanding green areas and engaging local wisdom. As well as this it has a strong and structured community who are cooperative with research projects of this nature.

Grounded theory was applied to collate information obtained during the study. It was applied by constructing and interpreting empirical material through in-depth interviews. Charmaz [13] and Lindroth et al

[14] found that grounded theory is an effective methods in obtaining detailed information from participants and a deep understanding of the subjectivity and diversity of a community. This method is suitable for this research which focuses on the people's social experiences, especially in the tourism industry that needs an understanding of subjective variations of tourists and stakeholders.

Meeting with various stakeholder groups can lead to obtaining in-depth data [15]. The participants in this research were stakeholder groups who were related to tourism management and local residents. As part of this study, 40 participants were interviewed. These were from public organizations or were government officials, private organizations/entrepreneurs and local residents. They were chosen based on their knowledge, roles, experience and influence in tourism. Interviews and focus groups were carried out over a period of three months.

Data analysis was conducted using a systematic data coding process. Coding processes are the key to analysis in grounded theory, however, it is also necessary to compare themes with extant literature to validate the theory for development. Stern [16] explained that the process does not strictly follow a fixed step by step process from open coding through axial coding to selective coding. It depends on what actually takes place during the fieldwork. Questions or new issues are identified during the course of the research which can change its direction. This often requires researchers to go back to the field to collect further data from other participants. The process is continued until it is considered that data saturation is reached. The answers from participants lead to the construction of the concept. Finally, the concept would also compare with extant literature to validate theory.

5. Results and Discussions

This research found that event marketing is an appropriately integrated marketing communication strategy for promoting tourism in Ko Lad E-Tan in the long-term. It was found to be able to deal with the present challenges in the area. At the same time, it was identified that the community has the potential to develop various tools for carrying out integrated marketing communication and which could reach a wide variety of tourists. The model of event marketing through local participations that was developed can integrate various tools of marketing communication which are based on local authenticity.

5.1. The situation of marketing communication of Ko Lad E-Tan

At the time of the research there were marketing communication projects in place for promoting Ko Lad E-Tan tourism. It was found, however, that all tools were not aligned to the same objectives and were
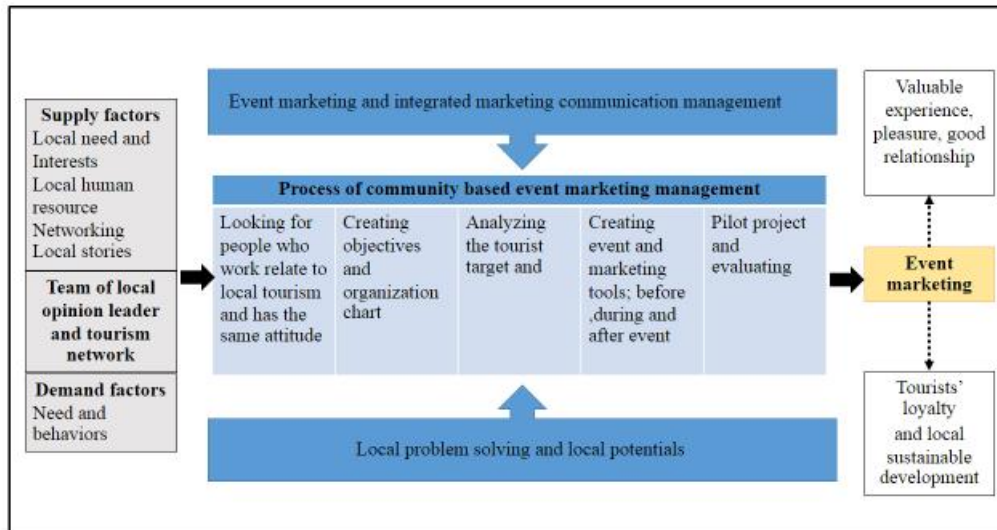
Figure 1: A model of event marketing based on local participation (Author, 2019)

inconsistent. The local government offices or private stakeholders were found to be the key people for carrying out marketing communication projects. Historically these had been carried out as public relations exercises using staff or through the villagers who take care of the various tourism spots in the area and various signs produced by organizations such as Nakhon Pathom Rajabhat University. The community also has a website which is run by Ko Lad E-Tan community group.

The marketing communications challenge in this area is one that relates to the development plans of local government organizations. It was found that there was no clear marketing communication plan to promote tourism in Ko Lad E-Tan. Most of the plans that were identified focused on tourism resource development such as creating tourism routes and activities and developing tour guides. Any marketing communication projects that were undertaken were similar to the ones that preceded them. None of the plans studied the demands of the tourists who visited Ko Lad E-Tan. Meanwhile, the private stakeholders focused only on promoting their individual products rather than promoting the area as a tourism destination as well. Consequently, the marketing communication tools that have been used to promote tourism have not been able to achieve their goals. In fact, the number of tourists of Ko Lad E-Tan has actually decreased over the past 2 years.

5.2. The community potentials to develop an integrated marketing communication

In the focus groups, the participants brainstormed about the potential of the local community to do integrated marketing communication for supporting tourism management in the long term. They identified

four key areas which they believed could be used to develop the appropriately integrated marketing communication in Ko Lad E-Tan.

1) The community has local human resources who are able to tell the story of the community to tourists. The local human resources should be local experts with good standing in the community, have main occupations in this area and be interested in tourism management. Importantly, these people should be interested in marketing communication for tourism.

2) Local authenticity and stories which can attract tourists can be developed by the community. Ko Lad E-Tan has a distinctive identity with regards to it being one of the best areas for fruit farming in Thailand. Pomelo which are grown in the area has been registered as Geographical Indication, GI products in Thailand. Moreover, there is a large amount of local wisdom in agriculture in the area. It has a distinctive topography that looks like a horseshoe shaped island and is surrounded by river. It is for this reason that it is known as 'Ko' or Island in English.

3) The community has a network of communication channels through which they can reach their target audience. The area has tourism infrastructure that could be used to promote the community. This includes tour companies, hotels and agencies. In addition to these communication channels the community has existing customers or tourists and local government offices including academic organizations which could help to promote it.

4) The target groups for the communication are people who receive the information about the community and decide to visit Ko Lad E-Tan. This research found that Ko Lad E-Tan has key tourist groups which it is keen to attract. If the community clearly specifies its target groups, it will lead to visits from tourists with

the correct interests for the destination. Tourists who visited Ko Lad E-Tan were interviewed as part of the research. In their responses, they focused on tourism according to specific interests in agricultural tourism. They stated that they were seeking meaningful experiences, pleasure and fun. They also wanted to have good relationship with the local people they met during their visit.

5.3. Event marketing: the integrated marketing communication for promoting tourism in the long term

This research found that the event marketing is a suitable form of integrated marketing communication for Ko Lad E-tan. It can directly communicate with consumers. The community agreed that this approach would reduce the marketing communication problems that it faced at the time of the research. In particular problems relating to a lack of budget and human resources in marketing communication. This research showed that a model of event marketing should be based on local participation. It should focus on the need and behavior of tourists, their demands and what the community can supply. Firstly, identifying people whose work relates to local tourism and people who have the same attitude is the first key step. Secondly, all actors must learn and share knowledge together in order to create objectives and an organization chart. Thirdly, the tourist target market must be analyzed and an appropriate group or groups of tourists must be selected. Fourthly, an event must be created which should be based on local authenticity. In this step the various marketing communication tools should be used to promote the event. Finally, a pilot project should be carried out and thoroughly evaluated. It is hoped that this model can help build the tourists' loyalty and enhance the local economy in a sustainable way.

This research identified key benefits of integrated marketing communication through event marketing. These were: low cost budget, up increasing sales of local products, reaching tourists directly and increasing tourist loyalty. The community is able to obtain income from arranging the event. They should not need to spend a large amount of money to do the marketing communication as they can promote it through their existing network. During the event they can also promote their tourism or products and create a "tourism image" for memorizing though suitable activities during the event. The local community believed that regular events will grow organically and steadily. During the events tourists can test the products or communicate with the product owner, it will lead to build the loyalty tourists and consumers. In this research, it was found that the process for doing the marketing communication had three key phases. These were; before event, during event and after event. Importantly, event

marketing can integrate various marketing communication tools and can reach to the target tourists.

From the analysis of the potential of the community of Ko Lad E-Tan, the participants created the "Wan Chiva Event". This presented local stories and responded the needs of the community and the present tourists of Ko Lad E-Tan. This research found that tourists wanted to have a holiday break with a feeling of pleasure, that they desire green space for relaxing and like to look for and purchase organic products. They focus on healthy tourism styles and appreciate a positive relationship with the local population they meet. The name of the event was derived from these needs "Wan" is the distinctive flavors of fruit which has a good taste (Many fruits from the area have won the national flavor awards in Thailand.) and "Chiva" meaning of the local way of life that is both physically and mentally happy.

The schedule for the event responded to the needs of the community and the tourists. It gave a chance for the community to bring their products to show to tourists through friendship and smiles. As well as, tourists have the opportunity to get involved the production process through creative tourism activities. The event was divided into 3 zones.

Zone 1: Local food and beverage service area. 90% of the products were from Ko Lad E-Tan community and the 10% of products were from outside the area in Nakhon Pathom Province. This zone promoted local food and beverages. Zone 2, Creative activity area. This area provided workshops for tourist who desired a valuable creative experience. All of the activities were co-creation workshops and provided inspiration.

Zone 3, Guest Speaker area. Community invited guest speakers for sharing, discussing about around a monthly theme. The guest speaker area provided informative views and interesting insights for the tourists and local community alike.

The local community in Ko Lad E-tan designed three tools for promoting their event. All of these tools were based on local potentials and were present in the same event theme.

1) Advertising via media at the tourist information points in the Rai Khing Temple and Don Wai Floating Market. The challenge with this type of advertising was to create interesting media such as images, text or video clips for attracting tourist decision to visit Ko Lad E-Tan. Timing is also important to make tourists interested and decide to travel at a time when they can.

2) Public relations and news through local media such as radio, newspaper and travel books. The local community used their network to promote the event with local organizations relate to tourism in the area. All if these tools can present tourism image, news, information of Ko Lad E-Than Event. In the future, there will also be long-term marketing communications.

3) Direct marketing through the internet. This was

used to directly communicate with specific groups of tourists. Most of the target population are people who are already interested in the area so the goal of this is to persuade them to participate the event.

This research found the similar result of the study's Belch and Belch [7] that the event marketing is a way to let consumers know about their products and allow them to appreciate their products though activities involving the product. This study found more information that integrated marketing communication in long-term through event marketing of the Ko Lad E-Tan community should be based on local human resources, their authenticity and should respond to the needs of tourists. Various local people and organizations are important for the long term management of such projects. These include students in local schools, government officers and all stakeholders. In addition, this work has to consider the return on investment from different marketing strategies. The community does not currently have sufficient funds to set up marketing communications to reach the target tourists. Networking is important for success in integrated marketing communication and particularly vital for this community.

6. Conclusion

Event marketing was found to be an appropriately integrated marketing communication model for Ko Lad E-Tan. The local community believes it can promote tourism and solve community problems. Event marketing can communicate directly with consumers by arranging special events and using them as a platform to promote tourist destinations and community products. At the same time, it can enhance the tourism image of Ko Lad E-Tan, Nakhon Pathom Province. Moreover it can create strong emotions and memories in tourists about agro tourism which focuses on health. Importantly, this model is able to integrate a variety marketing communication tools. It does not require a large amount of funds and also brings various groups who work in tourism together. This study found that the local community should have strong potential for skills which could be used for event marketing. These are local human resources, local stories and communication networks. Moreover, the needs and behaviors of tourists are important for choosing the most appropriate communication tools. Advertisements through media are likely to attract some groups of tourist whereas

using the internet is likely to attract others. In this project, the stakeholders and locals organizations were encouraged to work together. This included the temple, school, local community and government officers. It can be concluded that integrated marketing communication through event marketing requires careful planning and a long-term plan in order for it to be successful. Training local human resources in event marketing is important for it to have maximum benefit.

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Rehabilitation guidelines for children with cerebral palsy

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Abstract

Cerebral palsy (CP) is a group of physical and movement disorders in children, which is formed due to damage to a part of the brain that controls movements and gestures. Children affected have trouble moving and balancing. They cannot control the movement of their arms, legs and bodies like normal people, so they tend to face developmental delays. As a result, children with cerebral palsy must have a correct and appropriate rehabilitation program. Each patient has different symptoms, so there is no standard program that can treat all patients. A good rehabilitation plan must be an individualized plan approved by an interdisciplinary team who work with the patient, his/her family, teacher and caretaker.

Keywords: Children with cerebral palsy, rehabilitation

1. Introduction

Cerebral palsy is not a specific disease, but a group of symptoms caused by permanent brain disabilities in child patients. These disabilities are stable and do not expand but they will affect the part of the brain that controls or coordinates movements of muscles. As a result, patients will have abnormal movements and balance such as contraction of the facial muscles, tongue, body, arms and legs, and balancing difficulties, or they may not be able to position themselves to sit, stand or walk, depending on the damage to the brain or severity of the disability. We can conclude that cerebral palsy is a type of motion disability.

Cerebral palsy was first described in 1843 by Dr. William Little, an English surgeon who specialized in osteoarthropathy. He noted that cerebral palsy was caused by brain damage due to birth trauma. At that time, Dr. Little explained only one type of cerebral palsy which was spastic diplegia cerebral palsy. [1]

Later in 1889, Sir William Osler became an iconic researcher who first started to do a research on cerebral palsy, and wrote a book entitled "The Cerebral Palsies of Children" It was the first book that explained cerebral palsy. Also, Sir Osler was the first person to coin the term "cerebral palsy" to help people understand this type of disorder - a term accepted and recognized widely to this today.

Sir Osler researched cerebral palsy in more detail and found many more different types of brain abnormalities which corresponded with the findings of Dr. Little. Moreover, Sir Osler explained to the public the fact that if children with cerebral palsy are correctly and appropriately treated and rehabilitated, they are able to develop and have a better quality of life. This clearly supported the establishment of a rehabilitation program for children with cerebral palsy. [2]

2. Background of Cerebral Palsy

Cerebral palsy is a group of symptoms caused by brain abnormalities while the children's brains are developing. Normally, it happens in children of up to six to seven years old. It results in disabilities in terms of movements, balance and gestures. The mentioned brain abnormalities will be stable, not worsening or recovering. In other words, cerebral palsy is an abnormality to the part of the brain that controls the organ functions, not to the nerves, arms, legs or body, and it is not a contagious disease. Signs of cerebral palsy can often occur or be noticed before the child turns three years old. The main symptom that can be seen is developmental delays such as in rolling, sitting, crawling, walking, writing and using scissors. In some cases, there may be other coexisting signs such as seizures and intellectual disabilities.

A definition of "cerebral palsy" has been proposed by many researchers and scholars, but the most ac-

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cepted and recognized as the most comprehensive and referenced is that by Peter Rosenbaum (2006). He defines cerebral palsy as "a group of permanent disorders of the development of movement and posture, causing activity limitation that are attributed to non-progressive disturbances which occurred in the developing-fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication, and behavior; by epilepsy, and by secondary musculoskeletal problems" [3].

Although there is more than one definition among scholars, all definitions go the same way. So, it can be summarized that children with cerebral palsy are children who have motion abnormalities which are caused by damage or disease to the part of the brain that controls body movement. Patients will have movement and gesture abnormalities which can occur while the brain is developing or not fully developed. They will not be able to control movement of their arms, legs and body. Damage to the brain is permanent and it will not properly develop, and the muscles can be weakened if the patients do not have a correct and continuous rehabilitation in time.

The causes of cerebral palsy can occur in three stages, all during the period when the brain is developing and deprived of oxygen for four minutes or more. (1) Prenatal causes are the most common accounting for about 75-80% of the total cases and arise from the start of pregnancy up to six months. Examples of prenatal cause include: maternal infection during pregnancy that deprives oxygen from the baby's brain; chronic health problems in the mother such as diabetes or hypertension; genetic disorders; chromosome abnormalities and congenital brain defects such as intracranial water congestion; underdeveloped brain; and brain atrophy. (2) Perinatal causes account for about 10% and can occur during the last three months of pregnancy up to the first week after birth. These are examples of perinatal causes: premature birth, delivery complications such as nuchal cord, newborn choking on amniotic fluid and delivery that requires extra equipment such as forceps and vacuum. (3) Postnatal causes are about 12-21% and may arise from the first week after birth up to the child reaching seven years old. The causes mostly consist of complications that affect the child's brain or deprive him or her of oxygen for four minutes or more such as drowning, seizures and choking, infections such as meningitis, encephalitis and rubella, and accidents that affect the brain such as skull fracture causing brain hemorrhage. [4]

Parents often notice such abnormalities before the child turns one year old. They tend to sleep in an abnormal position due to weak or contracted muscles. For children older than five months old, they are likely to clench their fists rather than extend their hands and children over two years old show signs of not being able to balance themselves properly while walking. Once the parents notice such abnormalities, they should bring their children to be treated immediately. Children with cerebral palsy cannot be completely cured but therapy and rehabilitation are very important tools for them as they can still develop their capacity and skills. Many patients can be happy and live a normal life like other children if they receive correct and appropriate rehabilitation, but there is no standard or ideal program for all patients - it depends on the determination of the physician who must identify the specific disabilities and needs of each patient. Progressive, efficient development and rehabilitation of each child depend on the design of each individualized rehabilitation plan, and caregivers/family members are the most important supportive factors for children with cerebral palsy.

3. Situation of Children with Cerebral Palsy

In terms of epidemiology of people with brain disabilities globally, the ratio of children with cerebral palsy is around 2.0 – 2.5 to 1,000 newborns. Also, cerebral palsy is found in premature babies more than normal ones. [5] A study in Europe found that this disorder is 70 times more likely in infants whose birth weight is below 1,500 grams than those who weight more than 2,500 grams at birth. In Sweden, the prevalence of cerebral palsy is 1.4, 14, 68 and 57 in infants who weight more than 2,500 grams, 1,500-2,499 grams, 1,000 – 1,499 grams and less than 1,000 grams at birth, respectively. (ratio 1: 1,000) [6]

In the United States, the Cerebral Palsy International Research Foundation of USA is a private, non-profit organization whose mission is to conduct research and studies to promote and support the development of quality of life for children with cerebral palsy in the United States. It has determined that the average number of newborns with cerebral palsy in USA is 8,000 per year - in 2014 there were 1.5 – 2 million adult and child sufferers of CP while in 2017 the number had decreased to one million. Statistically, the number of patients is tending to decrease. [7] Also, the annual report of the Cerebral Palsy Alliance in Australia in 2013 showed that there were about 17 million CP patients around the world with 34,000 (0.2%) of them living in Australia. [8]

Meanwhile, in Thailand there is little information on children with cerebral palsy. From a survey done by the National Statistical Office in 2007, the number of children who require special needs from birth until the age of 24 was 182,599 or 9.75% of disabled citizens. Among them, 13,309 were children with cerebral palsy, or 7.29% of the total number of children with special needs, which can be categorized into three age ranges as shown in Table 1.

4. Rehabilitation Guidelines for Children with Cerebral Palsy

According to the rehabilitation guidelines of the World Health Organization (WHO, 2011), they set five goals for rehabilitation services: to protect, to decelerate, to improve or restore, to compensate losses and to treat malfunctions of different body systems. To make the guidelines of rehabilitation for children with cerebral palsy most effective, WHO recommends starting the rehabilitation before the babies turn six months old and/or starting the process as soon as possible. [10]

The rehabilitation guidelines for children with cerebral palsy put forward by Somnath Chatterji (2015), a researcher at WHO, recommends that a good rehabilitation principle should include an opportunity for the patients and caregivers/family members to take part in defining goals and a rehabilitation program that consider the context of their familial environment. This is to increase the patients' capacity to rehabilitate and develop to the fullest by working together with a multidisciplinary team. [11] Somnath (2015) and Tieman (2004) have presented study results that suggest the same. The rehabilitation of children with cerebral palsy should consider the familial environment as a main factor as they must deal with this constantly in their daily lives all the time. And whenever they feel safe and trusted, there will be a more positive impact to the rehabilitation process.

Christine Thorogood (2013), Associate Professor specializing in rehabilitation of children with cerebral palsy at Jacksonville University, Florida, USA, recommends a rehabilitation program that includes four main therapies [12]

4.1. Physical therapy

This therapy stimulates the patient to learn and control the movement of each joint that is essential to the body movement and prevent abnormalities of the bone and muscle systems that may come from unnatural movements. It can help prevent or decrease convulsion and maintain flexibility of joints and soft tissue. Stretching for exercises can strengthen muscles and it should be practiced according to the child's development. It should start with control of head and neck then continue to the body and self-help skills in daily living afterwards. Moreover, the physical therapy includes horseback-riding therapy (treating children with cerebral palsy by having them riding a horse). The Physical Therapy Student Union of Thailand (PT-SUT) has reported research results regarding the latter. It has certified that horseback-riding therapy is beneficial to the physical development of patients in terms of positioning, balancing and moving, and this also includes mental development. Most importantly, this type of therapy can be combined with a physiotherapy because the mechanism of horse-riding is a three-dimensional movement which is similar to the way humans walk. When the child patients sit on a horse, they have to try to balance themselves, especially when the horse is walking. The horse's walking rhythm will teach them about balancing, positioning, weight unloading, righting and equilibrium reaction. Hence, it can be concluded that horseback-riding therapy is beneficial to the patient's muscles – it helps decease contraction and facilitate better body movement.

4.2. Speech and language therapy

Children with cerebral palsy usually have dysarthria which affects the control of muscles on the face, neck, throat and head. This can lead to problems when speaking, chewing and swallowing. Also, the majority of cerebral palsy patients have drooling problems which are caused by abnormalities of the mouth's muscles that control how we swallow, so they have difficulties swallowing their saliva, drool and have articulation problems. Although children with fewer severe symptoms can speak and communicate, speech abnormalities can still be found such as speaking slowly and not clearly, or pronouncing words incorrectly and not clearly. Therefore, patients need to rehabilitate themselves by joining a speech training program to correct the way they speak and stimulate language and communication development. Each child must be assessed in order to define and design an appropriate individualized rehabilitation program.

4.3. Occupational therapy

This therapy is designed to promote and rehabilitate the capacity of children with cerebral palsy by aiming to train the control of fine motor skills, for example, grabbing things by the hands and using the eyes and hands at the same time. The therapy should focus on daily life skills training such as eating, getting dressed, showering and using the toilet, including skills relating to hygiene of both men and women. Moreover, it should also include rehabilitation and development of language such as learning, knowing, hearing and understanding. This can be simply done by training the child patient to do the things that the caregivers say and to appropriately express their feelings through actions, postures and facial expressions without trying to speak. Next, the child should be trained to adapt themself, interact with others and make friends. They should also learn daily life skills to take care of themselves such as getting dressed, eating and using the toilet. Each activity must be preceded by an occupational therapist's recommendation, by taking into account the development and capacity of the patient.

4.4. Recreational therapy

A rehabilitation or relaxation plan integrates social, emotional and mental aspects. Its aims are to encourage children with cerebral palsy to join recreational activities and to adapt to their capacity, interests and development in daily life. Moreover, it enhances their skills and experiences on interacting

Table 1. Statistics of children with cerebral palsy

Age range	Number of children with special needs	Number of children with cerebral palsy	percentage
0-6 years old	17,640	1,349	7.64
7-14 years old	50,874	4,357	8.56
15-24 years old	114,085	7,603	6.66
Total	182,599	13,309	7.29

Source: National Statistical Office,(2008), Disability survey in 2007. [9]

with others within the environment around them. Examples of recreational therapy are arts, crafts, sports, games and dances. Apart from the benefits to the body, mind, emotions and socializing skills of the patients, it has been found that recreational therapy can reduce stress, depression and worries. Most children with cerebral palsy face stress and worries when they step into teenagehood. This type of therapy can develop their emotional intelligence quotient (EQ), make them happy and realize their own feelings and those of others. It can also develop their social intelligence quotient (SQ). Social intelligence is the capacity to adapt, accept and face the truths in life. It explains the capacity of patients to efficiently adapt themselves in society. The challenge for recreational therapists of cerebral palsy patients is to design an activity that matches the symptoms and degree of severity. They need to focus on the child's participation and can use supplementary equipment to help the patient move around, such as a wheelchair, iBOT wheelchair and walker rollator. Furthermore, modern recreational therapy includes activities to develop independent living skills (IL). Independent living is an idea to train children with cerebral palsy to live independently like others regardless of how severe their condition is. It aims to teach the patients to help themselves to the highest degree and to depend less on others. The main principal of this training is self-determination. The child has all rights and opportunities to live independently, the same as other people. This is a new approach to rehabilitation that emphasizes on changes to the patient themself by boosting their self-independence and reducing their dependence on others.

Christine Thorogood rehabilitation program for cerebral palsy mentioned above, has been found to be consistent with the concept of Professor Fehlings (Darcy Fehlings, 2015), who is a professor at the Department of Pediatrics, Toronto University, the President of the American Academy for Cerebral Palsy and Developmental Medicine and chairperson of The Cerebral Palsy Foundation (CPF). Professor Fehlings states that the international rehabilitation program for children with cerebral palsy consists of four standard programs: physical, occupational, recreational and speed and language therapies. There is no single standard program that suits all patients. Each child must

be diagnosed to identify the type of symptoms they have by a specialized interdisciplinary team that will define therapeutic options and an individualized rehabilitation plan for cerebral palsy. Most importantly, the rehabilitation should be conducted as soon as the abnormalities are diagnosed and/or during the second and third years after birth. This is the most appropriate period in which to commerce rehabilitation. [13]

In addition, the United Cerebral Palsy Association (UCP) also presents four types of rehabilitation for children with cerebral palsy. This program also correlates with concepts of Christine Thorogood and Darcy Fehlings, and emphasizes that the best way to rehabilitate afflicted children is to design an individualized rehabilitation plan. Most importantly, an interdisciplinary team needs to work with the patient, their family, teacher and caregiver. UCP also offers a fifth treatment, namely drug therapy. General drugs to treat cerebral palsy are muscle relaxants and can be categorized into three groups: Diazepam, Baclofen and Dantrolene Diazepam, commonly known as Valium. These drugs can only be prescribed by a specialized physician. [14]

Children with CP suffer from multiple problems and potential disabilities such as mental retardation, epilepsy, feeding difficulties, vision, and hearing impairments. Screening for these conditions should be part of the initial assessment. The child with CP needs an individualized treatment plan. Management is not curative; however, it can improve the quality of life of these children and their families. Physicians, in cooperation with the child, family, and members of a multidisciplinary team, can coordinate a complex care system to the maximal benefit of each child. [15]

A 2013 systematic review of Cochrane found that the treatments with the best evidence are medications (Anticonvulsants, Botulinum Toxin, Diazepam), therapy (Bimanual Training, constraint-induced movement therapy, context-focused therapy, fitness training, goal-directed training, home programmes, occupational therapy, pressure care) and surgery. [16]

5. Conclusions

From global epidemiology data on people with cerebral palsy, it has been found that 2.0-2.5 out of

1,000 newborns will have cerebral palsy. However, statistics also show a decline in the number of children in the newborn to seven years age group suffering from this disability. The most common causes of cerebral palsy are accidents, damage to the brain or deprivation of oxygen to the brain for four minutes or longer. There are many types of cerebral palsy namely: spastic CP which is the most common; athetoid CP, which is the second most common; and ataxia CP.

Cerebral palsy is not a disease or sickness but a disability which cannot be cured. All children with cerebral palsy must be treated correctly and rehabilitated appropriately. The treatment should start before the children turns six months old and/or immediately after noticing any sign to ensure maximum benefit of treatment. There are four main rehabilitation therapies.

Rehabilitation is very important and vital for patients. They should follow the rehabilitation program provided by a specialized interdisciplinary team and appropriate home programs are highly recommended in some cases. Christy et al. (2010) explains that the most effective and appropriate period for rehabilitation is four hours a day and it should be done continually five days a week for three weeks. These numbers ensure the maximum benefit for children, family and caregiver need to possess knowledge and understanding of the issue concerned to make the rehabilitation program fully effective.

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Standard development of rehabilitation services for cerebral palsy children in disability services center and their networks

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Abstract

This qualitative research aimed to study the situations of rehabilitation services given to cerebral palsy children in disability services center and networks for physically challenged children and to develop the standard of rehabilitation services for Cerebral Palsy. Fieldwork was conducted along with in-depth interviews of a sampling group comprising management levels, heads of the service team, service providers and clients, totaling 37 people. All are from disability services center and service networks for physically challenged children, which provide rehabilitation services for cerebral palsy children. The results can be summarized into a standard of rehabilitation services for cerebral palsy children in disability services center and networks. There are 8 components, 25 indicators and 65 diagnosis guidelines. The total score is 325 points. The 8 components are 1) Qualifications of the service providers 2) Location, facilities and equipment 3) Access to services 4) Privileges of a child patients; 5) Rehabilitation services 6) Database system 7) Coordination system and 8) Evaluation and assessment of service quality.

Keywords: Cerebral palsy children, standard development of rehabilitation services, disability services center

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1. Introduction

According to the Empowerment of Persons With Disabilities Act, B.E. 2550 [1] and its amendment (second edition), B.E. 2556 [1], Sections 20/3 and 20/4, states that there shall be service center for physically challenged people to thoroughly and fairly support and develop their quality of life. The act specifies two types of service center: 1) Disability Services Center and 2) provincial service center. The first type can be founded by an organization for physically challenged people or other organizations that provide services to them. They must be certified by standards listed in Section 6(10) and provide services based on the zone, type of disability or specific needs. The second type is founded by the Department of Empowerment of Persons with Disabilities to support and coordinate the services of Disability Services Center and other matters. It aims to develop the quality of life for physically challenged people in all 77 provinces in Thailand. [2]

The general service centers have five duties: 1) Provide information and updates relating the rights, welfare and assistance as requested by the Cerebral Palsy 2) Demand the rights and benefits of physically challenged people or elimination of all forms of discrimination to them on their behalf 3) Provide assistance in terms of basic living skills, rehabilitation, occupation including recruitment for physically challenged people 4) Assist physically challenged people or those who risk having disabilities to receive healthcare and rehabilitation or specific tools according to their needs, and 5) Coordinate with authorized government agencies to assist physical challenged people according to their needs.[3]

The service center for physically challenged people policy began in 2014 and has been in effect for more than five years. A statistical report from the Department of Empowerment of Persons with Disabilities shows that as of 16 December 2016, a total of 1,173 service centers are divided into 1,096 general service centers and 77 provincial centers. Among these numbers, in the fiscal year 2016, there were 64 general centers all across Thailand that are registered and certified under organizations for physically challenged people or the ones that provide services to them (including both organizations of and for physically challenged people).[4]

From the statistics above, it is found that only 64 general service center are registered as formal center.

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When compared with 157 certified organizations for physically challenged people (including both organizations of and for physically challenged people) under Section 6(10), the registered center are equivalent to only 40.76% of the total numbers. The percentage is barely sufficient for the 1.7 million physically challenged people in Thailand.[5]

In the past, only a few organizations for physically challenged people tried to study and process the registration to be a formal general service center. Each organization may have had its own reasons or limitations such as knowledge and understanding about the operation, concepts and readiness of the management team or head of the organization, readiness of staff, tools and facilities for activities of each target group according to the regulations. For another thing, the service center for physically challenged people is a new policy and mechanism of Thai society. It is also a new mission of the Department of Empowerment of Persons with Disabilities. As a result, it issued the Act Empowerment of Persons with Disabilities Regulations Concerning Principles, Methodology and Conditions of Service Center for Persons with Disabilities B.E. 2556 [6]. This law authorized a working committee to establish a service system for service center and determine the plan, format, guidelines, establishment rules and operation of each type of service center. Especially in Section 4, which describes the operational standards and service provisions to people with disabilities, Rule No.20 states that all service centres must have an operation and service standard as the criteria announced by the department. However, this is merely a rule that is written conceptually. Practically, there is no determined standard that can be used as a guideline for general service center for physically challenged people. To this day, there is still no standard that acts like a framework to control, monitor and evaluate the operation of each service center. In my opinion, the service standard of general service center is very important and necessary for the quality of the center' operation and efficiency of service activities for a specific symptom. It is also crucial in terms of responding to specific needs and service arrangements under the concept of rights for people with disabilities as a mechanism and "make the right real".

Cerebral palsy, or CP is a group of physical and movement disorders in children. Cerebral Palsy children are classified as a type of children with special needs. Their disabilities are formed due to damage to a part of the brain that controls movements and gestures, so the affected children will have difficulties to move and balance themselves. They will not be able to control the movement of their arms, legs and body and tend to face developmental delays. They have a slow progress in terms of movement development and usually have limited development in other aspects as well such as physicality, emotion, socialization, fundamental learning and self-assistance [7].

From a survey done by the National Statistical Office in 2007, the number of children who require special needs from birth until the age of 24 is 182, 599, or 9.75% of the citizens with disabilities. Among them, 13,309 are children with cerebral palsy, which is 7.29% of the total number of children with special needs [8]. Cerebral Palsy children are classified as an important target group of service center. The centers have to arrange a service package for the Cerebral Palsy children and their caregivers as required by the regulations to enhance rehabilitation services. The physical rehabilitation package consists of four main activities: 1) Physiotherapy, 2) Speed-language pathology, 3) Occupational therapy and 4) Recreational therapy [9], and other activities that help to rehabilitate, stimulate and support the learning of the patients. The caregivers also need to be provided with necessary knowledge to be able to take care of and rehabilitate the children correctly. These packages conform with the intention of the Empowerment of Persons with Disabilities Act, B.E. 2550 and its amendment (second edition), B.E. 2556.

I am interested in the research of standard development of rehabilitation services for cerebral palsy children in general service center for persons with disabilities and their networks. This research aimed to study the situations of rehabilitation services given to cerebral palsy children in general healthcare centers and service networks for physically challenged people and to develop the rehabilitation service standards for Cerebral Palsy in these centers. The results from this study will provide guidelines to support and develop the capacity of the service system of the service center as formal and standardized center and guide the service providers to offer high-quality service packages. Moreover, the results can yield recommendations to the responsible government agencies and national organizations for people with disabilities. They can use this information as guidelines to track, inspect and support the general service centers to follow the approved standard rehabilitation model.

This research is also beneficial to the organizations for people with disabilities that are certified under Section 6(10). They can study the results and use them to develop their capacity and standardize their service system until they can register as a formal Disability Services Center for people with disabilities. This can increase the numbers of general service center and open more channels for children and people with disabilities and the caregivers to gain access to the welfare, benefits and services. The overall quality of the lives of Thai people with disabilities will be developed according to the social model that emphasizes the basic rights of people with disabilities and as a mechanism to "make the right real".

2. Research Objectives

This research aimed to:

2.1 Study the situations of the rehabilitation services given to Cerebral Palsy children in disability services center and service networks for physically challenged people.

2.2 Develop the rehabilitation service standards for Cerebral Palsy in those center.

3. Research Methodology

This research is a qualitative research using field research and in-depth interviews.

3.1 In terms of the study of the situations of rehabilitation services given to cerebral palsy children in general healthcare centers and service networks for physically challenged people, in-depth interviews were conducted and the data were synthesized to compose the draft standards.

1. Interviewee group - All interviewees were selected specifically by purposive sampling method from the general service center and service networks for physically challenged people in Bangkok. Only five centers that provide rehabilitation services for Cerebral Palsy children were selected, namely the healthcare center for people with general disabilities of the Foundation for Children with Disabilities and another four Learning and Rehabilitation Center for Children with Disabilities by Families (Minburi, Udomsuk, Nongkaem and Wangthonglang districts) which belong to the service network. I conducted in-depth interviews with management levels, heads of the service teams, service providers and clients, totaling 37 interviewees.

2. Research tool - I conducted the in-depth interview by using open questions about the service situations, contexts, providers' qualifications, problems, obstacles, satisfaction, strengths and weaknesses of the services, capital, suggestions and support towards the development of rehabilitation service standards given to cerebral palsy children in general healthcare center and service networks for physically challenged people. The questions were reviewed for accuracy by three experts in children and people with disabilities, medicine for children with disabilities and special education. The final index of item-objective congruence or IOC is 1.0. Some word choices and content have been amended according to their recommendations. As a pilot group I tried out the questions with five interviewees who faced a similar situation and analyzed the results to improve all questions again before starting the study interviews.

3. Data collection - Data were collected personally by the researcher using semi-structured or guided interviews with one interviewee at a time. I used the in-depth interview method as specified in 1) Data analysis - I performed a content analysis of the collected data which related to the subject matter and focus on the reasons behind it. Then, I presented the main ideas in writings to link to the draft standards, components and measurement indicators. This draft can be developed to service standards for Cerebral Palsy children in general service center and service networks for physically challenged people, as planned in the objectives.

3.2 In terms of the development of rehabilitation service standards for Cerebral Palsy children in general service center and service networks for physically challenged people, I synthesized the data collected from the in-depth interview in 1.4 and proposed the draft standards, components and measurement indicators for the rehabilitation services given to Cerebral Palsy children in general service center and service networks for physically challenged people. The procedures of this process are described below.

1. Finished drafting the standards for the rehabilitation services given to Cerebral Palsy children in general service center and service networks for physically challenged people.

2. Called for a meeting with experts to receive their suggestions on the draft. All of the five experts who were involved have expertise and experiences working with Cerebral Palsy children and/or the caregivers of this group of children. They also have at least 5-year experiences in terms of the measurement and evaluation on the subject matters.

3. Developed the draft standards according to the recommendations from the experts.

4. Tested the amended standards by using an external evaluation by myself. I sought comments and suggestions from related parties including management levels, service providers and clients of the service center and networks. The draft standards were tested with a purposive sampling group at four facilities. Two of them were registered as formal service center for people with disabilities and provide rehabilitation services for Cerebral Palsy children. Another two are the centers that provide rehabilitation services for Cerebral Palsy children but have not been registered as formal service center. After that the test results were summarized into two points: evaluation results and comments of the stakeholders.

5. Concluded the final draft standards for the rehabilitation services given to Cerebral Palsy children in general service center and service networks for physically challenged people. The test results and stakeholders' comments were applied to improve the final draft.

4. Results and Discussion

The research results can be summarized as follows:

4.1 The situations of the rehabilitation services given to cerebral palsy children in general healthcare center and service networks for physically challenged

people can be summed up into eight important aspects as follows:

1. Rehabilitation services for Cerebral Palsy children in general service center for physically challenged people - From the research, I have found four types of service. The first type is the information and knowledge service. The service providers provide information, knowledge, rights and privileges for the affected children and their caregivers. It is found that this is the most important and necessary service that conforms to the duties and mission of the general service center for physically challenged people as specified by the Act's policy. The second type of service is also related to knowledge and skills in terms of Cerebral Palsy children's rehabilitation. It is the service that provides service packages such as physiotherapy treatment, Thai massage, movement training, occupational therapy or learning activity, and recreational therapy. The third service provides social skills to the Cerebral Palsy children and their families. This is the activity some people call "learning activity for a wide world". It helps teach life experiences and social skills to the affected children and their caregivers. The last service is the power boosting service in the form of a self-help group, or commonly known as "friend for friend group".

2. Cerebral Palsy Children families' contexts relating to the rehabilitation - There are many problems concerning this aspect. First of all, the families have to face an attitude issue. The families of the affected children have troubles overcoming the physical challenge. Next, some caregivers do not have knowledge to take care of and rehabilitate the Cerebral Palsy children, so they need to search for a relevant knowledge source. Lastly, there is a problem about responsibility sharing among the family members. The affected children have to be taken care of closely all the time.

3. Strengths and weaknesses of the provided services in the targeted five service centers - One of the strengths is the concept to strengthen the Cerebral Palsy children's families and to have qualified and experienced service providers who have appropriate knowledge. All five service centers also have fully integrated services, and they act as a ground to let the Cerebral Palsy children befriend and socialize with others. Moreover, they provide additional services to the families. There is another outstanding strength unlike other service centers, which comes in the form of a self-help group or "friend for friend group". In terms of weaknesses, findings show that the four center in the network have small facilities and no specific training rooms. The center's buildings are either rented houses or townhouses with limited space. Their training materials are not various and sufficient for all clients. I have also found the weakness in terms of the document system used to collect forms, registrations, profiles, statistics and other data. The system is not very effective. For the last point, the centers do not re-

ceive sufficient funds as they have not been certified as a formal service center according to the government's law, and they do not have sources of funds to support the operation.

4. Qualifications of the service providers to Cerebral Palsy children in general healthcare center and service networks for physically challenged people - All centers are well aware of the importance to have qualified service providers. The first qualification upon which all interviewees agree is that the service providers must have specific capacity, experiences and skills that match with the services they give. And when they need to service a patient with specific needs, they must use a specific expert who really specializes in that disability. From the interviews, I can conclude that there are four main qualifications of the service providers for Cerebral Palsy children. First, the service provider must specifically take care of this group of children. Second, he/she must have knowledge relating the rehabilitation of Cerebral Palsy children. The knowledge can be divided into two levels: basic knowledge and specific knowledge. Third, he/she must have skills and expertise in the rehabilitation of Cerebral Palsy children. Fourth, he/she must be able to train his/her own child and other children with various disabilities. If all four qualifications are met, the client will be very confident in the quality of service.

5. Suggestions for the development of general healthcare center and service networks for physically challenged people - Overall, the interviewees were satisfied with the rehabilitation services for Cerebral Palsy children of the five center because they responded to the needs of the children and the families. Although there were problems and obstacles sometimes, the clients usually can accept them as they understand the center' limitations, and the problems were minor and did not affect the rehabilitation. The clients in the target group have suggested that they wanted the center to arrange some occupational training for the caregivers after finishing the rehabilitation training and service hours.

6. Service system for the rehabilitation of Cerebral Palsy children in general healthcare center and service networks for physically challenged people - I have interviewed the officers who are responsible for the policy of the Department of Empowerment of Persons with Disabilities. They stated that the system must follow the Empowerment of Persons with Disabilities Regulations Concerning Principles, Methodology and Conditions of Service Center for Persons with Disabilities B.E. 2556, especially Section 3 which mentions the service provisions and service system for the rehabilitation of physically challenged people. The main content of this section is to organize a committee to assess the children's ability, to assess the children's ability and to plan individual education programs (IEP). Each service center must arrange an appropriate service that matches with each patient's needs. If any

Table 1. Draft service standards for Cerebral Palsy children in general service center and the service networks (1st edition)

Component	Number of indicators (indicators)	Evaluation Guidelines*	Weight of scores (scores)
1. Service quality	8	27	135
2. Service providers' qualification	4	15	75
3. Location	4	10	50
4. Tools and facilities	2	7	35
5. Evaluation / measurement	2	6	30
6. Data recording system	3	12	60
7. Coordination system	2	5	25
Total	25	82	410

Remark: *means the evaluation guideline of each indicator. Each one has 5 scores.

Table 2. Draft service standards for Cerebral Palsy children in general service center and the service networks (2nd edition)

Component	Number of indicators (indicators)	Evaluation Guidelines*	Weight of scores (scores)
1. Service providers' qualification	4	13	65
2. Location, tools and facilities	5	12	60
3. Access to service	3	6	30
4. Privileges for children with disabilities	2	6	30
5. Rehabilitation service	3	7	35
6. Data recording system	3	7	35
7. Coordination system	2	5	25
8. Evaluation / measurement	3	9	45
Total	25	65	45

Remark:*means the evaluation guideline of each indicator. Each one has 5 scores.

Disability Services Center can operate as specified by the regulations, they can be entitled to receive support from the government.

7. Per-unit capital of the rehabilitation services for Cerebral Palsy children in general healthcare center and service networks for physically challenged people - It is found that the budget policy of the Department of Empowerment of Persons with Disabilities to support the general service center for physically challenged people conforms to the framework of the Empowerment of Persons With Disabilities Regulations Concerning Principles, Methodology and Conditions of Service Center for Persons With Disabilities B.E. 2556. The ratio of supporting funds in Section 3 which mentions service arrangements following the mission of general service center for physically challenged people refers to the expense management principles for medical rehabilitation services of the National Health Security Office Fund. This government agency has duties regulating the list of treatment and cost of each medical rehabilitation treatment for hospitals and healthcare service centers [10]. The pricing scheme is per-unit capital. For example, a physiotherapy session is 150 Baht/person/time. An occupational therapy session costs 150 Baht/person/time or 75 Baht/person/time for a group therapy. The Depart-

ment of Empowerment of Persons with Disabilities applies this expense management framework to define the cost scheme in Section 3 and uses it as a credit limit of supporting funds for general service center for physically challenged people. From the interview, I have found a weakness in the expense recording system as there were no expense records, and the income and expense account system was not effective enough. I also focused on the approved per-unit budget of the service center for physically challenged people, which are 150 Baht/person/time/activity. The management levels have agreed that this amount was enough and appropriate. However, each agency should have an opportunity to be considered first because this is a channel that can help each provider arrange high-quality and efficient services.

8. Support to build standards of the rehabilitation services for Cerebral Palsy children in general healthcare center and service networks for physically challenged people - I focused on the support from the Department of Empowerment of Persons with Disabilities which is a main policy maker in this matter. The strength of this point is the mechanism of the Department of Empowerment of Persons with Disabilities' committees. There is a main committee for national operations and provincial subcommittees

Table 3. The test results of the draft rehabilitation service standards for Cerebral Palsy children in general service center and the service networks (2nd edition), divided into each component.

Component	Scores (percentage)			
	Agency 1	**Agency 2**	**Agency 3**	**Agency 4**
1. Service providers' qualification (Total score: 65)	65 (100)	60 (92.31)	40 (61.54)	30 (46.15)
2. Location, tools and facilities (Total score: 60)	60 (100)	60 (100)	45 (75)	40 (66.67)
3. Access to service (Total score: 30)	30 (100)	30 (100)	25 (83.34)	20 (66.67)
4. Privileges for children with disabilities (Total score: 30)	30 (100)	30 (100)	25 (83.34)	25 (83.34)
5. Rehabilitation service (Total score: 35)	35 (100)	35 (100)	25 (71.43)	25 (71.43)
6. Data recording system (Total score: 35)	35 (100)	35 (100)	15 (42.86)	5 (14.29)
7. Coordination system (Total score: 25)	25 (100)	25 (100)	0 (0)	0 (0)
8. Evaluation / measurement (Total score: 45)	45 (100)	45 (100)	25 (55.56)	0 (0)
Average total score	325 (100)	320 (98.46)	200 (61.54)	145 (44.62)
Standard quality	Very good	Very good	Acceptable	Failed

for each province. However, there is a weakness in terms of specific standards of general service center for physically challenged people. Now, the regulations of general center establishments are tied to the standards of organizations for physically challenged people. If the service standards are developed in the future, it will help control the quality of the operations and service arrangements of the center with the Department of Empowerment of Persons with Disabilities controlling and supporting them.

4.2 Rehabilitation service standards for Cerebral Palsy children in general service center and the service networks

1. Drafted the rehabilitation service standards for Cerebral Palsy children in general service center and the service networks - I used data in Item1 to draft the first edition of the standards. It comprises 7 components, 25 indicators and 82 evaluation guidelines. The total scores are 325 as seen in Table 1.

2. Called for a meeting with experts to receive suggestions for the draft standards - The experts have suggested revising the draft according to the authority and mission of the general service center for physically challenged people as approved by the government's policy [11]. They also pointed out the amendment in evaluation guidelines as there was some redundancy in word choices, and some statements were not clear. For another thing, the scoring criteria needed to be revised to follow the common standard, which uses 100% as the total score. Each center must get no less than 60% to pass the evaluation in that certain aspect (out of 8 aspects). The evaluation scores can be divided into three levels: very good (81-100%), good (71-80%), and acceptable (60-70%). If the score is below 60%, it means that aspect does not pass the standard.

3. Developed the draft rehabilitation service standards for Cerebral Palsy children in general service center and the service networks - After reviewing the suggestions from the experts and applying to the draft, I have finished the second edition. It is composed of 8 components, 25 indicators and 65 evaluation guide-

lines. The total scores are 325 as seen in Table 2. The evaluation scores can be divided into three levels: very good (81-100%), good (71-80%), and acceptable (60-70%). If the score is below 60% (0-59%), it means that aspect does not pass the standard.

4. Tested the draft standards - I used an external evaluation method and conducted the evaluation myself. The test results are shown in Table 3.

From Table 3, we can see that Agency 1 has an average total score of 325 (or 100%), so it receives a very good ranking and passes the standards of all 8 components. Agency 2 has an average total score of 320 (or 98.46%), so it also receives a very good ranking and passes the standards of all 8 components. Agency 3 has an average total score of 200 (or 61.54%), so it receives an acceptable ranking. This agency does not pass the tests of the 6th (data recording system) and 7th (coordination system) components. Agency 4 has an average total score of 145 (or 44.62%), so it does not pass the standards. It can be concluded that Agencies 1 and 2, which are the certified service center for people with disabilities and have been in service for at least three years, have passed the standard tests. However, the other two agencies are two of the centers in the service networks. They have not been certified and registered as formal service center. The results show that Agency 3 still has acceptable standards while Agency 4 does not pass the standard tests.

I have asked the opinions of the stakeholders about the draft standards. They totally agreed on having the service standards as they are important tools to measure the service quality of each center, and the interviewees agreed that this draft is appropriate. The first two agencies have experiences on the quality assessment before they were certified as formal service center, so the tests were not new to them. They even helped them keep their quality standards. The other two agencies have never had experience with the standards assessment. This was the first time for them, so they found the tests to be very challenging, and they were motivated to develop their operations to meet the

standards. The test results can be guidelines to develop their operations, and they have learned their strengths and weaknesses of each component as the tests specify the indicators clearly. There is also a suggestion to the Department of Empowerment of Persons with Disabilities and/or other expert or authorized agencies. These organizations should provide coaching to any centers that want to standardize their practice and process the registration to be a certified Disability Services Center for people with disabilities.

5. Conclusion of the standards - In Item 2.3, there are 8 components, 25 indicators and 65 evaluation guidelines. The total score is 325 (as shown in Table 2). The table consists of (1) service providers' qualifications with 4 indicators and 65 points, (2) location, tools and facilities with 5 indicators and 60 points, (3) access to service with 3 indicators and 30 points, (4) privileges for children with disabilities with 2 indicators and 30 points, (5) rehabilitation service with 3 indicators and 35 points, (6) data recording system with 3 indicators and 35 points, (7) coordination system with 2 indicators and 25 points, and (8) evaluation and measurement with 3 indicators and 45 points. The evaluation of the total average score can be divided into 3 levels: Very good (81-100%), good (71-80%) and acceptable (60-70%). If the total average score is below 60%, it means that the center does not pass the test.

5. Discussion

In this research, I focused on 2 issues: 1) The situations of the rehabilitation services given to Cerebral Palsy children in general healthcare center and service networks for physically challenged people, and 2) the development of rehabilitation service standards for Cerebral Palsy in those center.

5.1 Situations of the rehabilitation services given to Cerebral Palsy children in general healthcare center and service networks for physically challenged people - I have found four main services concerning the rehabilitation of Cerebral Palsy children in general service center for people with disabilities. They are to 1) provide information and updates relating the rights and welfare, 2) provide knowledge and skills for the rehabilitation, 3) provide social skills to Cerebral Palsy children and their families, and 4) empower the children with a self-help group. The services conform to the Empowerment of Persons with Disabilities Regulations Concerning Principles, Methodology and Conditions of Service Center for Persons with Disabilities, B.E. 2556. This announcement specifies five duties of service center for people with disabilities. The first out of five duties specified in this announcement is to provide information, updates, privileges and welfare as requested by people with disabilities. In terms of the activities for the rehabilitation of Cerebral Palsy children in general service center for people with disabili-

ties, the centers arrange integration activities including physiotherapy (big muscle training), traditional Thai massage, movement training, occupational therapy or learning activities and recreational therapy for Cerebral Palsy children and their families. They assess the development and disabilities of each child to design an individual education program (IEP) that conforms to the rehabilitation program for Cerebral Palsy of Christine Thorogood (2556) [12]. She has studied Cerebral Palsy and designed a rehabilitation program comprising four main activities: physical therapy, speech and language therapy, occupational therapy, and recreational therapy. The program should consider the differences of each patient and specific need of his/her family. It should be supported by people who are close to the children, especially the guardians (the caregivers). They should take part in the designed rehabilitation program. Moreover, the operation model and principles that the general healthcare center and service networks for physically challenged people use pay attention to the guardians (the caregivers). This conforms to the research of Bennett (2012) [13] which is a qualitative research concerning the guardians' participation in an assistance program in the first stage of development of children with disabilities. The research shows that continual participation of the parents and regular rehabilitation sessions at home are beneficial to the children. The results show visible improvement in their development.

5.2 Development of rehabilitation service standards for Cerebral Palsy children in general healthcare center and service networks for physically challenged people - From the research results, I can conclude 8 components, 25 indicators and 65 evaluation guidelines as presented in Table 3, Items 2.4 and 2.5. If we compare this conclusion to the concept of rehabilitation service standards of Cerebral Palsy Association of Tasmania, Australia, which mentions 12 components, we can find some similarities such as access to services, privacy and confidentiality and protection of benefits. However, the essence of the standards depends on context, conditions and regulations of each task and/or operation. This research emphasizes the operational standards which are in accordance with the concept of Meesuttha and Sachukorn (1999) [14]. They explained the benefits of the operational standards which can lead to more visible results from the operations and guide the service providers to operate correctly. The management levels can use the standards to evaluate the staff's performance with clear purposes and criteria, and the staff will be able to accept the evaluation better.

In addition, this research has found that there was no formal service standards for the rehabilitation of Cerebral Palsy children in general healthcare center and service networks for physically challenged people; even the Empowerment of Persons With Disabilities Regulations Concerning Principles, Methodology

and Conditions of Service for Persons With Disabilities B.E. 2556 specifies that there must be a working committee to design a service system for service center for people with disabilities and define mission and duties on planning, operational model, guidelines, establishment method and operation of the center, especially in Section 4 - Operation and service standards of service center for people with disabilities. Item 20 specifies that each service center must have operations and service standards for people with disabilities as specified by the regulations of the department. Item 21 specifies that the department must support each center in terms of academic matters, budget, staff, and other necessary and appropriate matters. And it must have a process to track, verify and control each center's operation and ensure it meets the standards. From the data collected from the interviewees, it was found that they agreed on having specific service standards for specific disabilities. The results are similar to the stakeholders who also agreed that the standards are necessary. But each agency must study and develop its operations to meet standards, and it has to understand that the standards are important tools to measure the service quality. This opinion aligns with the research of Methawikul et al. (2014) [15], who studied the development of operational models and guidelines of service center for people with disabilities. They found that in the Empowerment of Persons with Disabilities Regulations Concerning Principles, Methodology and Conditions of Service Center for Persons With Disabilities B.E. 2556, Item 20 specifies that each service center must have operations and service standards for people with disabilities as specified by the regulations of the department. And they proposed to the policy makers of the Department of Empowerment of Persons with Disabilities that there should be regulated criteria to measure specific service standards of general center for people with disabilities.

For another thing, the sampling stakeholders suggested that the Department of Empowerment of Persons with Disabilities and/or expert agencies should provide coaching to any centers that are trying to standardize the practice to register as a certified service center. This aligns with the research of Sukonthawit et al. (2016) [16], who studied the developmental guidelines for center for independent living to upgrade to be certified service center for people with disabilities. The research has found that:

The qualifications of the service providers are the main feature that can upgrade each service center to be a certified one. The service providers must be committed and keep developing their capacity to maintain basic knowledge and skills as a service provider. The management of the organization, staff, work plan, budget and service standards is also the key. Sukonthawit et al. (2016) even suggest that the Department of Empowerment of Persons with Disabilities, as a directly responsible government agency, should provide

coaching to any agencies or organizations wishing to develop themselves to be certified as a formal service center for people with disabilities and standardize their practice.

6. Conclusions

This research is a qualitative research aiming to study the situation of rehabilitation services given to cerebral palsy children in general healthcare center and service networks for physically challenged people and to develop the rehabilitation service standards for Cerebral Palsy.

I used field research to study the situation of rehabilitation services given to cerebral palsy children in general healthcare center and service networks for physically challenged people. An in-depth interview was used with a purposive sampling group selected from 5 general service center and service networks for physically challenged people in Bangkok that provide rehabilitation services for Cerebral Palsy children. I conducted interviews with management levels, heads of the service teams, service providers and clients, totaling 37 interviewees. Eight important aspects have been identified: 1) Rehabilitation services for Cerebral Palsy children in general service center for physically challenged people, 2) Cerebral Palsy Children families' contexts relating to the rehabilitation, 3) Strengths and weaknesses of the provided services in the five targeted service center, 4) Qualifications of the service providers to Cerebral Palsy children in general healthcare center and service networks for physically challenged people, 5) Suggestions for the development of general healthcare center and service networks for physically challenged people, 6) Service system for the rehabilitation of Cerebral Palsy children in general healthcare center and service networks for physically challenged people, 7) Per-unit capital of the rehabilitation services for Cerebral Palsy children in general healthcare center and service networks for physically challenged people, and 8) Support to build standards of the rehabilitation services for Cerebral Palsy children in general healthcare center and service networks for physically challenged people. These 8 aspects were applied to the analysis, and the first edition of the rehabilitation service standards for Cerebral Palsy children in general service center and the networks is drafted. Next, I called for a meeting with an expert team to review the draft and apply the recommendations to the second edition of the standards. The next step was the test of the draft standards and data collection for synthesis. Lastly, I concluded the results into the final draft of rehabilitation service standards for Cerebral Palsy children in general service center as shown in 2.3. There are 8 components, 25 indicators and 65 evaluation guidelines. The total score is 325 points (Table 2). The 8 components are 1) service providers' qualifications with

4 indicators and 65 points; 2) location, tools and facilities with 5 indicators and 60 points; 3) access to service with 3 indicators and 30 points; 4) privileges for children with disabilities with 2 indicators and 30 points; 5) rehabilitation service with 3 indicators and 35 points; 6) data recording system with 3 indicators and 35 points; 7) coordination system with 2 indicators and 25 points; and 8) evaluation and measurement with 3 indicators and 45 points. The evaluation of the total average score can be divided into 3 levels: very good (81-100%), good (71-80%) and acceptable (60-70%). If the total average score is below 60%, it means that center does not pass the test.

Recommendations for future studies

1. There should be a study on per-unit capital of the rehabilitation services for Cerebral Palsy children in general service center and networks for people with disabilities. This is another main issue that requires a specific study and it takes time to collect the data as a system.

2. There should be a study on the development of various service standards to treat other types of disability in children at general service center and networks for people with disabilities. There should be standards for other types of disability as well. ?

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Interfacial improvement of hole transporting layer using graphene quantum dots for efficiency enhancement of organic photovoltaics

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Abstract

Graphene quantum dots (GQDs)/PEDOT:PSS films exhibit the improved interfacial contact with substrate encouraging better charger transport in organic photovoltaics (OPVs). The GQDs/PEDOT:PSS films were successfully prepared by mixing of GQDs and PEDOT:PSS under sonication. The mixtures were deposited on SnO_2:F (FTO) substrate using a convective deposition system and characterized. Optical transmittance of the GQDs/PEDOT:PSS films reveals higher average value than that of the PEDOT:PSS films. Surface contact angles display similar decreasing trends for all films. For OPVs fabrication, GQDs/PEDOT:PSS films were used as a hole transporting layer in the OPV device. Power conversion efficiency (PCE) is enhanced to the maximum value of 1.71% for the GQDs/PEDOT:PSS film-based in comparison to the PEDOT:PSS film-based (1.14%). The enhancement is dominating correlation to the improved short-circuit current density and fill factor due to the high transmittance and the improved interfacial contact, respectively. GQDs are not only improving interfacial contact on the FTO substrate but also full-filling coverage over the substrate. Therefore, GQDs are demonstrated as a potential additive material for PCE enhancement of OPVs.

1. Introduction

Interfacial defect in thin-film based devices is a majoring concern because it directly involves charge carrier transport. The charge carrier transport behavior between interfacial contacts can affect device performance. Organic photovoltaics (OPVs) is one of thin-film based device that has the interfacial defect problem because it consists of multi-layer thin films that easy causes defect between layered interface which affecting the loss of carrier transport efficiency. To solve the problem, interfacial contact between each layer should be improved for better device performance. The addition of proper additives is considered as a facile method for modifying the electronic property of materials. Graphene quantum dots (GQDs) are inter-

estingly investigated for a decade due to unique properties such as good conductivity, high transparency, low heat capacity [1]. It is demonstrated an efficient material for improving several devices such as UV detector, optoelectronic devices, and solar cells [2,3]. Especial to solar cell application, Sharma et. al. [4] demonstrate a theoretical effect of adatoms (nitrogen, boron, and phosphorus) on COOH edge-functionalized GQDs materials for applying in quantum dot solar cells (QDSCs). The improvement of power conversion efficiency (PCE) is found after doping due to the change of electrical and optical properties. The decrease in energy band gap (E_g) and stronger absorption are observed at the same time. The absorption peak shifts to larger wavelength correlating to lower E_g. These changes beneficial result in the raise of short-circuit current density (J_{sc}) which final result a *PCE* enhancement of the QDSCs. Kim
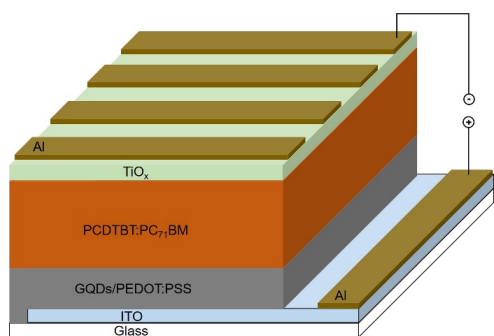
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Figure 1: Schematic structure of OPVs.

Figure 2: Transmittance spectra of PEDOT: PSS films and GQDs/PEDOT: PSS films at different volumetric ratios.

et. al. [1] present the development of dye-sensitized solar cells (DSSCs) by incorporating GQDs into TiO_2 photoelectrode for DSSC application. They found that low GQDs size around 5 nm shows a potential to enhance *PCE* of DSSC device in comparison to larger GQD size (10 nm). The enhancement is examined and revealed the correlation to high incident-photon-to-current conversion efficiency (IPCE). This effect is described that small quantum size offers unique electron energy for generating numerous electrons, which results in high J_{sc} and *PCE*. Moreover, several effective parameters are changed including low recombination, enhanced electron transport, and increased light scattering. The improved IPCE of DSSCs is occurred due to GQDs incorporation which is agreed to a report of Kumar et. al. [5]. They incorporated GQDs with TiO_2 and prepared as photoelectrode for fabricating flexible DSSCs. *PCE* of 5.48% is observed for the GQDs-TiO_2 photoelectrode based DSSCs with J_{sc} and open-circuit voltage (V_{oc}) of 11.54 mA/cm^2 and 0.73 V, respectively. The role of GQDs for increasing charge extraction and reducing recombination is successfully examined. Majumder et. al. [6] modified ZnO photoelectrode using sulfur and nitrogen co-doped GQDs (SNGQDs). The modified photoelectrode affects in high IPCE around 92%. This phenomenon leads the high J_{sc} and V_{oc} which is resulting in higher *PCE* compared with conventional ZnO photoelectrode. Additional to the internal charge mechanism, they found that charge transfer is improved due to the high conductivity of GQDs. In other words, it could interpret that recombination is also reduced due to fast charge carrier separation upon GQDs incorporation. Shin et. al. [7] shows an improved *PCE* of perovskite solar cells (PSCs) after modifying with GQDs. The modification is performed by doping GQDs in phenyl C_{61} butyric acid methyl ester ($PC_{61}BM$) for applying as an electron transport layer (ETL). The modified ETL explores the improvement in conductivity and optical transmittance. Moreover, charge recombination behavior between ETL and perovskite of PSC is reduced. These effects result in *PCE* enhancement. Not only ETL application, but hole transporting layer (HTL) is also modified by GQDs accord-
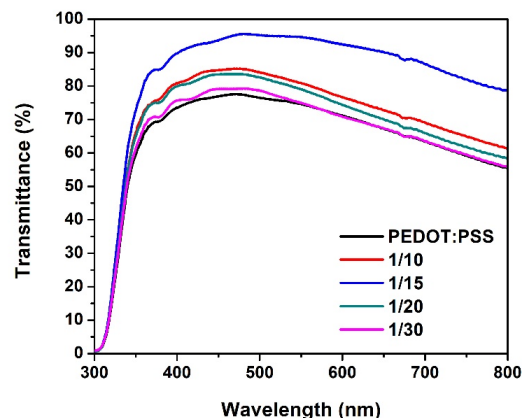
ing to a report of Kang et. al. [3]. They modified poly (3,4-ethylenedioxythiophene)-poly (styrene sulfonate) (PEDOT:PSS) by mixing with nitrogen- and oxygen-doped GQDs (NO-GQDs) for PSC application. *PCE* enhancement has appeared in comparison to pure PEDOT:PSS based PSCs. The occurrence is due to high crystallinity and good electrical properties of NO-GQDs for facilitating internal electrical mechanisms. It should be noted that high quantum yield is also found for the NO-GQDs implying well structural confinement for electrical and optical properties. Due to the successful application of GQDs in several solar cells and the unique property, thus it is a good interesting candidate material that should be considered as a potential functional material for modifying HTL in OPVs.

In this work. GQDs and PEDOT:PSS are mixed and prepared as GQDs/PEDOT:PSS composite films for using as HTL in OPV device. Due to the excellent conductivity and the low dimension of GQDs, it is expected to improve the charge carrier transport and interfacial contact [8]. Thus, incorporation of GQDs could enhance *PCE* of OPVs.

2. Experimental

0.1 M GQD solution was prepared following to a previous report [9]. Briefly, carbon source was performed from citric acid. The citric acid precursor was prepared by dissolving citric acid monohydrate powder in ethanol and carbonized at 250 °C to form as GQDs. The GQDs was mixed with PEDOT:PSS solution under sonication. Volumetric mixtures of GQDs/PEDOT:PSS were varied as 1/10, 1/15, 1/20 and 1/30. Before the HTL deposition, SnO_2:F (FTO) substrate was patterned and then sequentially cleaned with alconox, distilled water, and isopropanol for 30 min each using sonication and dried with N_2 gun, following by surface treatment with oxygen plasma.
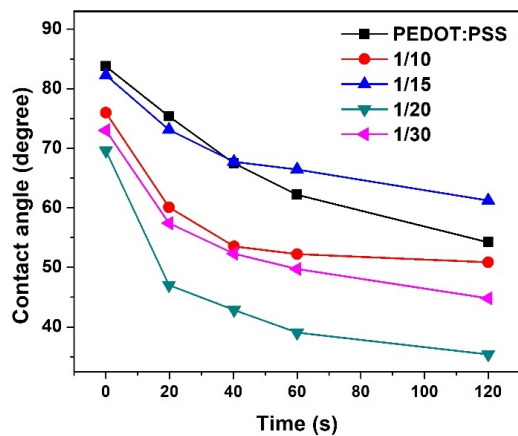
Figure 3: Contact angle of PEDOT:PSS films and GQDs/PEDOT:PSS films at different volumetric ratios.

Figure 4: J-V characteristic curves of OPVs fabricated with PEDOT:PSS films and GQDs/PEDOT:PSS films at different volumetric ratios.

Then, a portion of the mixtures ($20\,\mu L$) were deposited on the FTO substrate using a convective deposition system [10], following by heating at 120 °C for 30 min to form GQDs/PEDOT:PSS films. The films were characterized using several techniques. Optical transmittance was measured using ultraviolet-visible (UV-Vis) spectroscopy. Contact angle was examined using a contact angle measurement system. Functional group was examined using Fourier-transform infrared spectroscopy (FTIR). Cross-sectional image was observed using scanning electron microscopy (SEM). For OPV fabrication, the GQDs/PEDOT:PSS films were used as HTL and it was sequentially deposited by other layers according to previous reports [11]. Brief description, active layer was prepared by mixing of poly [N-9'-heptadecanyl-2,7-carbazole-alt-5,5-(4',7'-di-2-thienyl-2',1',3'-benzothiadiazole)] (PCDTBT) and PC$_{71}$BM and convectively coated on the HTL. Then, the TiO$_x$ solution was coated over the active layer and heated. Finally, the aluminum films were deposited to cover the TiO$_x$ layer using thermal evaporation. After the fabrication, the complete OPV as illustrated in Fig. 1 was moved to measure photovoltaic characteristics under standard irradiation of 100 mW/cm^2 from a solar simulator.

3. Results and Discussion

Optical transmittance spectra of all films are measured as shown in Fig. 2, and average transmittance in the visible region is listed in Table 1. The average transmittance of the GQDs/PEDOT:PSS films reveals higher values than that of the PEDOT:PSS films. The phenomena might be a result of smooth surface formation [12, 13] which could be caused by GQDs assistance. GQDs have a lower dimension that can reduce the thickness and maintain the optoelectronic property of the GQDs/PEDOT:PSS films at the same time.
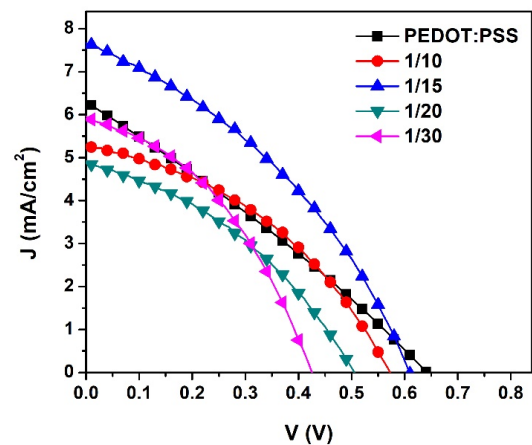
The initial contact angle of GQDs/PEDOT:PSS films show lower values than the PEDOT:PSS films (can see in Table 1) indicating a little hydrophilic surface improvement. However, decreasing trends of contact angle show similarity between the PEDOT:PSS films and the GQDs/PEDOT:PSS films as shown in Fig. 3, indicating the slow spreading of the mixing solution on substrates.

All prepared films were then transferred to use as HTL for OPV fabrication, current density (J) versus voltage (V) curves were measured as shown in Fig. 4. Photovoltaic parameters were calculated using Eq. (1) – (2) [14, 15] as listed in Table 2.

$$PCE = \frac{J_{sc}V_{oc}FF}{P_{in}} \qquad (1)$$

$$FF = \frac{J_{max}V_{max}}{J_{sc}V_{oc}} \qquad (2)$$

where FF is fill factor, P_{in} is a power of incident simulated sunlight, J_{max} and V_{max} are current density and voltage at the maximum power point, respectively. There are varieties in PCE values and maximum PCE is observed for the GQDs/PEDOT:PSS ratio of 1/15. The maximum PCE is enhanced to be 1.71% (50% increase) in comparison to the conventional device (device fabricated with PEDOT:PSS) of 1.14%. Thus, the GQDs/PEDOT:PSS ratio of 1/15 is considered as an optimal condition for OPV application in this case. The PCE enhancement dominating correlates to the increase of J_{sc} and FF. The increased J_{sc} is due to higher electron-hole pair generation corresponding to the highest transmittance. The improved FF is caused by excellent charge carrier transport through external load due to better interfacial contact between FTO substrate and GQDs/PEDOT:PSS films. To investigate the interfacial contact on the substrate, cross-sectional
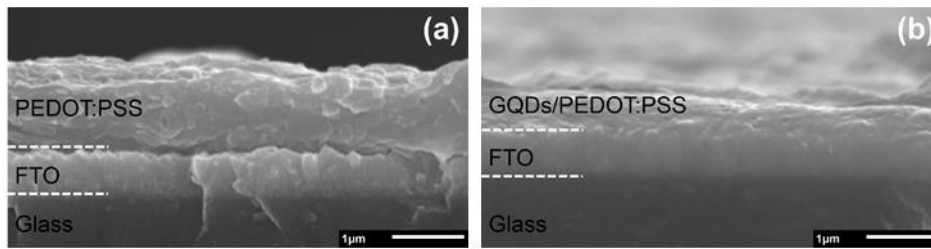
Figure 5: Cross-sectional image of (a) PEDOT:PSS films and (b) GQDs/PEDOT:PSS films.

images of PEDOT:PSS films and GQDs/PEDOT:PSS films at the ratio of 1/15 are observed as shown in Fig. 5. It is found that discontinuation of interfacial contact between substrate and PEDOT:PSS films are found, while better interfacial contact is observed in the case of GQDs/PEDOT:PSS films. Thus, it confirms that the addition of GQDs can improve interfacial contact on FTO substrate. Note that, the films form better coverage and smoother surface. The behavior could describe that GQDs likely act as seeds for distributing PEDOT:PSS on substrate. The appropriate distribution can avoid the accumulation of PEDOT:PSS molecules which resulting in high transmittance and good interfacial contact. The small size of GQDs is also believed that can penetrate to full-fill the void position for uniform film formation during the preparation. Additional to V_{oc}, it is believed that V_{oc} changes due to the change of injected electron density (I_{inj}) which involve J_{sc} as describing in the Eq. (3) [16].

$$V_{oc} = \frac{k_B T}{e} \ln\left(\frac{I_{inj}}{n_{cb}k_r c}\right) \qquad (3)$$

where k_B is the Boltzmann constant, T is the absolute temperature, e is electron charge, n_{cb} is the electron density in the conduction band, k_r is the recombination rate, and c is the charge concentration.

In addition, FTIR of the PEDOT:PSS films and GQDs/PEDOT:PSS films were investigated to characterize functional groups as shown in Fig. 6. Appeared peak at 1556 cm^{-1} attributed to the asymmetric stretching of C = C bonds [17]. The peaks at 1216 cm^{-1} and 1124 cm^{-1} attributed to the stretching vibration of C-O-C bonds [18]. The observation of these peaks implies that interaction between GQDs and PEDOT:PSS has occurred. This interaction is believed as one factor that causing the better interfacial contact.

4. Conclusion

GQDs/PEDOT:PSS films exhibit the improved interfacial contact with substrate encouraging better charger transport in OPVs. The GQDs/PEDOT:PSS was successfully prepared by mixing of GQDs and PEDOT:PSS under sonication. The mixtures were deposited on the FTO substrate using a convective deposition system and characterized. Optical transmit-
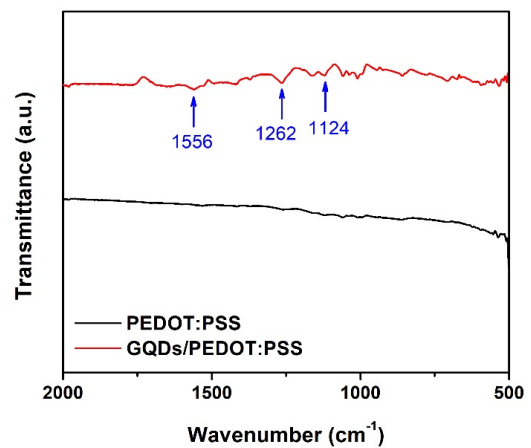
Figure 6: FTIR of PEDOT:PSS films and GQDs/PEDOT:PSS films.

tance of the GQDs/PEDOT:PSS films show higher than that of the PEDOT:PSS films. Surface contact angles reveal similar decreasing trends for all films. For OPVs fabrication, PCE is enhanced to the maximum value of 1.71% for the GQDs/PEDOT:PSS film-based in comparison to the PEDOT:PSS film-based (1.14%). The enhancement is dominating correlation to the improved J_{sc} and FF due to high transmittance and improved interfacial contact, respectively. GQDs are not only improving interfacial contact on the substrate but also full-filling coverage over the substrate. Therefore, GQDs can able be used as a potential additive material for PCE enhancement of OPVs or thin-film based device applications.

5. Acknowledgment

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Application of response surface method (RSM) and central composite design (CCD) for optimization of cassava yield

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Abstract

The decline of agricultural output which has made Nigeria turn from a major agriculture-based exporter to an importing country has prompted us to investigate the effects of Nitrogen, Phosphorus and Potassium (N.P.K) fertilizer on the yield of cassava planted on non-fertile land using the Response Surface Methodology (RSM). A three-factor Central Composite Design (CCD) was applied to determine the effects of the fertilizers on the yield of cassava. The polynomial regression model was developed and validated prior to optimization studies. It was found that the optimum production conditions for the cassava yield were 63.95 kg/ha of nitrogen, 154.35 kg/ha of phosphorus and 45.56 kg/ha of potassium. The 3D response surface plot derived from the Mathematical models was applied to determine the optimal conditions. Under the conditions, the maximum cassava yield was 29.90kg/ha. The Coefficient of determination (R^2) and adjusted R^2 values were 0.9240 and 0.8556 respectively. This showed that the experimental values are in good agreement with the predicted values based on the analysis of variance result. This study proved that Response Surface Methodology can be used effectively to optimize the yield of cassava, and the Central Composite Design is efficient, simple, economical and time-saving which can be adopted for optimizing crop yields.

Keywords: Central composite design, response surface methodology, cassava yield

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1. Introduction

The decline in agricultural production has made Nigeria turn from a major producer of stable foods and cash crops to an importing nation that is dependent on importation for stable food supply [1]. The decline can be attributed to among other factors like planting on over-used land, inadequate fund, non-availability of modern farming tools, machinery and lack of information. These challenges have persistently militated against the growth of agricultural production in Nigeria and even it has led to a rural to urban movement of rural workforce in order to seek for unavailable white-collar jobs [2]. One of the most planted and common agricultural produce is Cassava (*Manihot esculenta Crantz*) which is cultivated mainly in the tropic and sub-tropic regions of the world, over a wide range of environmental and soil conditions. It is very tolerant of drought and heat stress and produces well on marginal soils. It is an important dietary staple in many countries within the tropical regions of the world [3], where it provides food for more than 800

million people [4]. As a subsistence crop, cassava is the third most important carbohydrate food source in the tropics after rice and maize, providing more than 60% of the daily calorific needs of the populations in tropical Africa and Central America [5]. According to [6], cassava plays an important role in alleviating food problems, because it thrives and produces stable yields under conditions in which other crops fail. Cassava is a versatile crop and can be processed into a wide range of products such as starch, flour, tapioca, beverages and cassava chips for animal feed. Cassava is also gaining prominence as an important crop for the emerging biofuel industry and a potential carbohydrate source for ethanol production [7].

Despite the cultivation of Cassava by several farmers, the output is still low. Therefore, in order to boost it, [8] recommended that 60 kg N, 10-20 kg P_2O_5, and 50 kg K_2O ha^{-1} should be applied to the soil for an expected yield of 15 t/ha where all stems and leaves are returned to the soil. On the other hand, [9] emphasized that cassava requires fertilization especially nitrogen, phosphorus and potassium; and even more nitrogen than phosphorus. Also, [10] noted that cassava is known to respond to the application of organic

and inorganic fertilizer while several other types of research like [11 – 13] reported that the crop is responsive to fertilizer usage. But over-application of fertilizer may as well lead to unusually luxuriant vegetative growth at the expense of roots and tubers [14 – 15].

Having discussed this, there is need to attain an optimal production for cassava planted on over-used farmland in this research work, statistical approaches were used to model Cassava yield with respect to level of fertilizer application to varieties of cassava in order to attain cassava production efficiency. Response Surface Methodology (RSM) which is a combination of mathematical and statistical techniques was used. This approach has been used by several researchers to analyze agricultural experiments and these include [16 – 35] but an application to fertilizer application to cassava is not very common. In essence, this research involved the design of a statistical experiments using a central composite design (CCD), development of a mathematical model of the experimental data, representation of the direct and interactive effects of process parameters through two and three-dimensional plots and finding an optimal set of experimental parameters that produce a maximum value of response.

2. Materials and Methods

2.1. Factorial design

A factorial design was used in experiments involving several factors where it was necessary to investigate the joint effects of the factors on a response variable. In this research, Nitrogen, Phosphorus and Potassium fertilizers were used as predictor variables and cassava yield was considered as the dependent variable. Then, the coded values of the variables were determined by

$$X_i = (x_i - x_0)/x \qquad (1)$$

where X_i is a coded variable of the ith variable, X_0 is the average value of the variable in high and low levels, x is (variable at the high level – variable at low level)/2 and X_i is an uncoded value of the ith test variable. The factorial point is defined as ± 1 unit for each factor.

2.2. Response surface methodology

The Response Surface Methodology (RSM) is a collection of Mathematical and Statistical techniques which are useful for the modeling and analysis of problems in which a response variable of interest is influenced by several independent variables. In this research, Cassava yield was the response variable, and it was a function of Nitrogen, Phosphorus and Potassium. This is expressed as

$$y = f(x_1, x_2, x_3) + e \qquad (2)$$

where x_1, x_2, x_3 are predictor variables, y is the response variable and e is the experimental error term. The error term e represents any measurement error on the yield, as well as other types of variations were not counted in the function.

In order to develop a proper approximation for f, a low-order polynomial in some small region was used to define a linear function of independent variables, then the approximating function was a first-order model. A first-order model with k independent variables is expressed as

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + ... + \beta_k x_k \qquad (3)$$

where y is the dependent variable, $\beta_i, i = 0, 1, ..., k$ is the regression coefficients that measure the expected change in the response y per unit change x_k when other predictor variables are held constant. If there is a curvature in the response surface, then a higher degree polynomial should be used.

2.3. Step in response surface methodology

When there is a curvature in the response surface, the first-order model is insufficient. Therefore, the second-order model is useful in approximating a portion of the true response surface with a curvature. The second-order model includes all the terms in the first-order model, and quadratic and cross product terms. It is represented as

$$y_i = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_i x_i^k + \sum_{i=1}^{k} \sum_{j=1}^{i=1} \beta_{ij} x_i x_j \qquad (4)$$

The second-order models illustrate quadratic surfaces such as minimum, maximum, ridge, and saddle. If there exists an optimum, then this point is called stationary point. The stationary point is the combination of design variables where the surface is at either a maximum or a minimum in all directions. If the stationary point is a maximum in some direction and minimum in another direction, then the stationary point is a saddle point

2.4. Designs for fitting the second-order model

The second-order model is fitted using central composite Design (CCD). It consists of a factorial point, central point, and axial points. CCD is developed through sequential experimentation. When the first-order model shows evidence of lack of fit, then axial points can be added to quadratic terms and with more center points to develop CCD. The number of center points m at the origin and the distance α of the axial runs from the design center are two parameters in the CCD design.

2.5. Parameter estimation in second order regression model

The second order model in equation (4) can be written in matrix notation as

$$y = \beta_0 + x'b + x'Bx \qquad (5)$$

where

$$x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_k \end{bmatrix}, \quad b = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_k \end{bmatrix}$$

and

$$B = \begin{bmatrix} \beta_{11} & \beta_{11}/2 & \cdots & \beta_{1k}/2 \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2k}/2 \\ \vdots & \vdots & \cdots & \vdots \\ sym. & \cdots & \cdots & \beta_{ik} \end{bmatrix}$$

2.6. Testing for lack of fit for second-order model

In order to determine the lack of fit of the model, the hypothesis below is considered.

H_0: There is no lack of fit

H_1: There is lack of fit

using $\alpha = 0.05$ as the significance level.

Decision rule: Reject H_0, if the lack of fit p-value is less than the significance level (α) otherwise accept H_1. If the lack of fit attributable to curvature in the response function is not adequately modeled, then in such cases a polynomial of a higher degree must be used sure as third-order.

2.7. Location of the stationary point

Once a second order model is fit to the response but if not locating the stationary point enough, the next step is to locate the point of maximum or minimum response. The point for which the response $\hat{y}$ is optimized is the point at which the partial derivatives, $\frac{\delta\hat{y}}{\delta x_1}, \frac{\delta\hat{y}}{\delta x_2}, ..., \frac{\delta\hat{y}}{\delta x_k}$ are all equal to zero. This point is called the stationary point. The stationary point may be a point of maximum response, minimum response or a saddle point. The stationary point can be determined by firstly differentiating equation (5) with respect to x and this gives

$$\frac{\delta\hat{y}}{\delta x} = b + 2B = 0 \qquad (6)$$

Thus, the stationary point is

$$x_s = -\frac{1}{2}B^{-1}b \qquad (7)$$

The predicted response at the stationary point is

$$\hat{y} = \beta_0 + x'_s b + x'_s B x_s$$

$$\hat{y} = \beta_0 + x'_s b + \left(-\frac{1}{2}b'B^{-1}\right)Bx_s$$
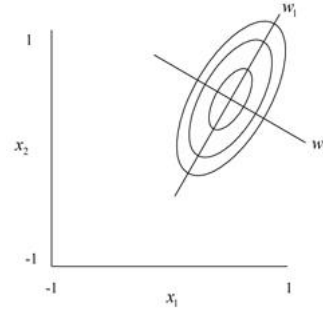

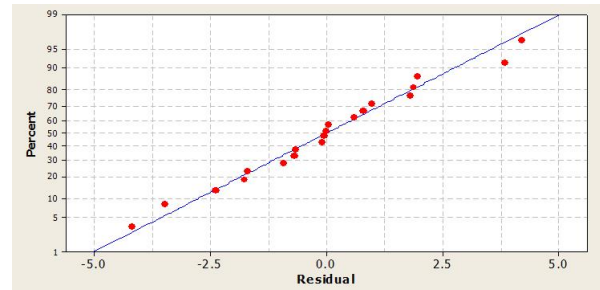**Figure 1**: Canonical representation of the stationary points.

Figure 2: Residual normal probability plot for second order regression model.

$$\hat{y} = \beta_0 + \frac{1}{2}x_s b' \qquad (8)$$

Once the stationary point is known, it is necessary to determine if it is a maximum, minimum or saddle point. This is done by transforming the model to a new coordinate system such that the origin lies at the stationary point and the axes are parallel to the principal axes of the fitted response surface. An example is given in Fig.1. The w-axes in Fig. 1 are the principal axes of the contour system and this can be expressed as

$$\hat{Y} = \hat{y}_s + \sum_{i=1}^{k} \lambda_i w_i^2 \qquad (9)$$

where $\hat{y}_s$ is the estimated response at the stationary point and $\lambda_1, \lambda_2, ..., \lambda_k$ are the eigen values of B. The variables $w_1, w_2, ..., w_k$ are the transformed independent variables which are called canonical variables. If the λ_i's are all negative, then x_s is a point of maximum response. If the λ_i's are all positive then x_s is a point of minimum response and if the λ_i's have different signs, then x_s is a saddle point

3. Results and Discussion

The codes, ranges and levels of independent variables which are Nitrogen, Phosphorus and Potassium were given in Table 1. The data were collected from the International Institute of Tropical Agriculture, Ibadan (IITA). The data comprised of the response variable (cassava yield (kg)) and three factors

Table 1. Codes, ranges and levels of independent variables of nitrogen, phosphorus and potassium.

Symbols	Predictor Variable	Code levels		
		-1	0	+1
x_1	Nitrogen (Urea)	40 kg/ha	80 kg/ha	120 kg/ha
x_2	Phosphorus (P_2O_5)	115 kg/ha	172.5 kg/ha	230 kg/ha
x_3	Potassium (K_2O)	30 kg/ha	45 kg/ha	60 kg/ha

Table 2. Central composite design for coded and uncoded forms.

Runs	Coded Variables			Uncoded Variables			Response (Y)
	x_1	x_2	x_3	Nitrogen	Phosphorus	Potassium	
1	-1	-1	-1	40	115	30	21.49
2	+1	-1	-1	120	115	30	17.55
3	-1	+1	-1	40	230	30	21.15
4	+1	+1	-1	120	230	30	11.97
5	-1	-1	+1	40	115	60	19.97
6	+1	-1	+1	120	115	60	12.88
7	-1	+1	+1	40	230	60	24.95
8	+1	+1	+1	120	230	60	9.73
9	-1.682	0	0	12.7	172.5	45	22.70
10	1.682	0	0	147.3	172.5	45	5.25
11	0	-1.682	0	80	75.8	45	30.44
12	0	1.682	0	80	269.2	45	23.21
13	0	0	-1.682	80	172.5	19.8	12.42
14	0	0	1.682	80	172.5	70.2	16.99
15	0	0	0	80	172.5	45	25.25
16	0	0	0	80	172.5	45	24.54
17	0	0	0	80	172.5	45	27.81
18	0	0	0	80	172.5	45	29.32
19	0	0	0	80	172.5	45	32.93
20	0	0	0	80	172.5	45	32.58
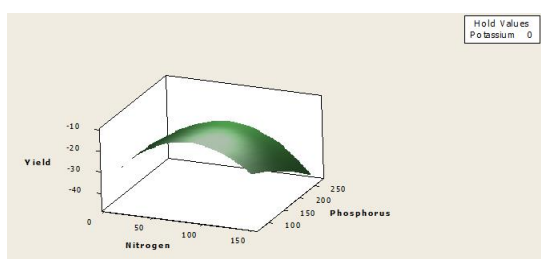
Figure 3: Surface plot for nitrogen and phosphorus on the yield of cassava.

each at two levels as follow: Nitrogen (40 kg/ha & 120 kg/ha), Phosphorus (115 kg/ha & 230 kg/ha) and Potassium (30 kg/ha & 60 kg/ha). The predictors variable (Nitrogen, Phosphorus and Potassium) were optimized by using 2^3 central composite design (CCD) with six axial points ($\alpha = 1.682$) and six center points leading to a total of twenty experiments. From Table 2, the result of the central composite design values of α was given and for the three independent variables, the optimum value of α was 1.682 for both coded and uncoded forms of the design. Based on the CCD re-

sults, the fitted response surface first order regression model results in Table 3 showed that 28.21% ($R^2 = 0.2821$) of variation in the response variable could be accounted for by the independent variables (x_1, x_2 and x_3).

Moreover, using the results in Table 3, only Nitrogen fertilizer was statistically significant on the yield of cassava, the P-value was less than 0.05 (0.027 < 0.05). This implied that Nitrogen fertilizer was very critical in the production of cassava by farmers $Y = 21.1565 - 4.7432x_1 - 1.1898x_2 + 0.2238x_3$ with R^2 (Coefficient of Determination) = 28.21% or 0.2821. In order to determine the lack of fit for the first order regression, the hypothesis was set as

H_0: There is no lack of fit (insignificant)

H_1: There is lack of fit (significant)

$\alpha = 0.05$.

Then, the lack of fit test was determined using the result of the Analysis of variance in Table 4 where the lack of fit P-value (0.036) < 0.05, therefore H_0 was rejected and this indicated the presence of curvature. In essence, the first-order model was not an appropriate approximation therefore, there was a need to construct a second-order regression model.

Table 3. Response surface first order regression analysis.

Term	Coefficient	SE Coefficient	T-Value	P-Value
Constant	21.1565	1.613	13.114	0.000
Nitrogen	-4.7432	1.952	-2.430	0.027
Phosphorus	-1.1898	1.952	-0.609	0.551
Potassium	0.2238	1.952	0.115	0.910

Table 4. Analysis of variance for response surface first order regression analysis.

Source	DF	SEQ SS	ADJ SS	ADJ MS	F	P-Value
Regression	3	327.27	327.270	109.090	2.10	0.141
Linear	3	327.27	327.270	109.090	2.10	0.141
Nitrogen	1	307.25	307.252	307.252	5.90	0.027
Phosphorus	1	19.33	19.334	19.334	0.37	0.551
Potassium	1	0.68	0.684	0.684	0.01	0.910
Residual Error	16	832.82	832.818	52.051		
Lack-of-Fit	11	769.49	769.495	69.954	5.52	0.036
Pure Error	5	63.32	63.323	12.665		
Total	19	1160.09				

The second order regression model (Polynomial regression modeling) was performed based on the responses of the corresponding coded values of the three different process variables. Table 5 was used to present the results obtained. The regression estimates, standard error of estimate, t-value and probability value associated with the estimate of linear, quadratic and interaction effects were presented. The result as well indicated that not all main effect had a significant effect on cassava yields. For instance, for an increase in x_1 by one unit, the yield of cassava would decrease by 4.7432 units. Indeed, for an increase in x_2 by one unit, the yield of cassava would decrease by 1.1898 units. Similarly, an increase in x_3 by one unit, the yield of cassava would increase by 0.2238 units. The results in Table 5 revealed as well that x_1, x_1x_1 and x_3x_3 were statistically significant on the yield of cassava with P-value that was less than 0.05 ($0.000 < 0.05, 0.000 < 0.05$ and $0.000 < 0.05$ respectively). This implied that x_1 and x_3 were very critical in the production of cassava by cassava farmers. In addition, the value coefficient of determination was 92.40% ($R^2 = 0.9240$) and this implied that 92.40% of the variation in the response variable could be accounted for by the variables (x_1, x_2 and x_3).

$$Y = 28.7519 - 4.7432x_1 - 1.1898x_2 + 0.2238x_3$$
$$- 5.3081x_1^2 - 0.7650x_2^2 - 5.0500x_3^2 - 1.6712x_1x_2$$
$$- 1.1488x_1x_3 + 0.9688x_2x_3$$

with R^2 (Coefficient of Determination) = 92.40%

In order to determine the lack of fit for the second order regression, the hypothesis was set as

H_0: There is no lack of fit (insignificant)
H_1: There is lack of fit (significant)
$\alpha = 0.05$.

Then, the lack of fit test was determined using the result of the analysis of variance in Table 6 where the lack of fit P-value (0.836) > 0.05, therefore H_0 was accepted and this implied that the second order regression model was adequate for the response surface. The model was as well appropriate based on the values of R^2 (Coefficient of Determination) at 92.40% and $\bar{R}^2$ (Adjusted R^2) at 85.56% respectively. This implied that 92.40% of variations in the response variable was explained and the model had a good fit. The Normal Probability plot in Fig. 2 from the residual in the second order regression model showed neither response transformation was required nor there was an apparent problem with normality, therefore, the residual was normally distributed. This was also used to verify that the model was stable and suitable.

Since the response surface has been approximated by the second-order model, then it was important to determine the required level of the three factors that can guarantee the maximum yield of cassava without incurring an extra cost of input. A three-dimensional (3D) surface plot was constructed to investigate the interactive effect of the two factors on the yield within the experimental ranges. The 3D surface plots in Fig. 3 to Fig. 5 revealed the interaction between the response variables and the independent variables. Fig. 3 denoted the surface plot of the cassava yield as a function of Nitrogen and Phosphorus at Potassium of 0 kg/Ha and Nitrogen and Phosphorus were revealed to have a direct effect on the yield of cassava up to a certain level, then yield of cassava decreased with an increase of Nitrogen and Phosphorus. An increase of Nitrogen and Phosphorus, up to a maximum of 63.95 kg/Ha and 154.35 kg/Ha respectively could give a maximum cassava yield of 29.90 kg/ha.

The surface plot of the cassava yield as a function

Table 5. Response surface second order regression analysis.

Term	Coefficient	SE Coefficient	T-Value	P-Value
Constant	28.7519	1.2110	23.741	0.000
Nitrogen	-4.7432	0.8035	-5.903	0.000
Phosphorus	-1.1898	0.8035	-1.481	0.169
Potassium	0.2238	0.8035	0.278	0.786
Nitrogen*Nitrogen	-5.3081	0.7822	-6.786	0.000
Phosphorus*Phosphorus	-0.7650	0.7822	-0.978	0.351
Potassium*Potassium	-5.0500	0.7822	-6.456	0.000
Nitrogen*Phosphorus	-1.6712	1.0498	-1.592	0.142
Nitrogen*Potassium	-1.1488	1.0498	-1.094	0.300
Phosphorus*Potassium	0.9688	1.0498	0.923	0.378

Table 6. Analysis of variance for response surface first order regression analysis.

Source	DF	SEQ SS	ADJ SS	ADJ MS	F	P-Value
Regression	9	1071.92	1071.92	119.102	13.51	0.000
Linear	3	327.27	327.27	109.090	12.37	0.001
Nitrogen	1	307.25	307.25	307.252	34.85	0.000
Phosphorus	1	19.33	19.33	19.334	2.19	0.169
Potassium	1	0.68	0.68	0.684	0.08	0.786
Square	3	704.24	704.24	234.746	26.62	0.000
Nitrogen*Nitrogen	1	335.70	406.06	406.058	46.05	0.000
Phosphorus*Phosphorus	1	1.01	8.43	8.433	0.96	0.351
Potassium*Potassium	1	367.53	367.53	367.531	41.68	0.000
Interaction	3	40.41	40.41	13.470	1.53	0.267
Nitrogen*Phosphorus	1	22.34	22.34	22.345	2.53	0.142
Nitrogen*Potassium	1	10.56	10.56	10.557	1.20	0.300
Phosphorus*Potassium	1	7.51	7.51	7.508	0.85	0.378
Residual Error	10	88.17	88.17	8.817		
Lack-of-Fit	5	24.85	24.85	4.969	0.39	0.836
Pure Error	5	63.32	63.32	12.665		
Total	19	1160.09				

Table 6. Analysis of variance for response surface first order regression analysis.

Variables	Descriptions	Optimal Values
x_1	Nitrogen	63.95
x_2	Phosphorus	154.35
x_3	Potassium	45.56
Y	Yield	29.90

of Nitrogen and Potassium at Phosphorus of 0 kg/ha was displayed in Fig. 4. Nitrogen and Potassium were revealed to have a direct effect on the yield of cassava up to a certain level, then the yield of cassava decreased with an increase of Nitrogen and Potassium. An increase of Nitrogen and Potassium up to a maximum level of 63.95 kg/ha and 45.56 kg/ha respectively could give a maximum cassava yield of 29.90 kg/ha. Fig. 5 is the surface plot of the cassava yield as a function of Phosphorus and Potassium at Nitrogen of 0 kg/ha. This showed that Phosphorus and Potassium had a direct effect on the yield of cassava up to a cer-

tain level, then the yield of cassava decreased with an increase of Phosphorus and Potassium. An increase of Phosphorus and Potassium, up to a maximum of 154.35 kg/ha and 45.56 kg/ha respectively could give a maximum cassava yield of 29.90 kg/ha.

In order to determine the optimal settings, a canonical analysis was performed by obtaining the stationary point

$$b = \begin{bmatrix} -4.7432 \\ -1.1898 \\ 0.2238 \end{bmatrix}$$

$$B = \begin{bmatrix} -5.3081 & -0.8356 & -0.5744 \\ -0.8356 & -0.7650 & 0.4844 \\ -0.5744 & 0.4844 & -5.0500 \end{bmatrix}$$

and

$$B_0 = 28.7519$$

The computed stationary point is;

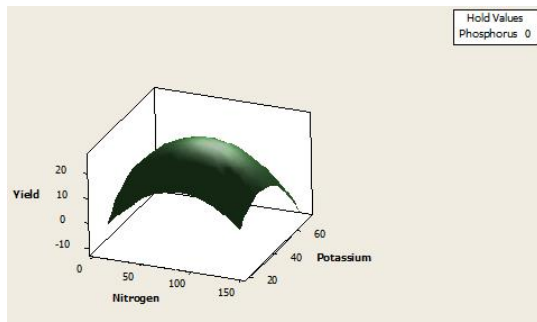$$x_s = \begin{bmatrix} -0.4011 \\ -0.3157 \\ 0.0375 \end{bmatrix}$$

Figure 4: Surface plot for nitrogen and potassium on the yield of cassava.
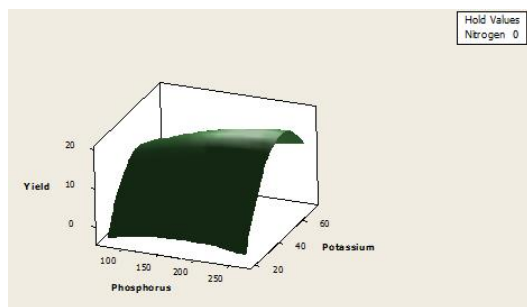

Figure 5: Surface plot for phosphorus and potassium on the yield of cassava.

and the predicted response at the stationary point is $\hat{y} = 29.90$. The eigen values of the matrix B obtained are

$$\lambda_1 = -0.5414, \lambda_2 = -4.7859, \lambda_3 = -5.7958$$

Then, the Canonical form is

$$\hat{y} = 29.90 - 0.5414w_1^2 - 4.7859w_2^2 - 5.7958w_3^2$$

Since all the eigen values were negative, the stationary point was a point of the estimated maximum yield of cassava and in order to optimize independent variables (nitrogen, phosphorus and potassium), the first partial derivatives of the regression model were equated to zero according to x_1, x_2 and x_3 respectively. Thereafter, the stationary points were substituted in equation (1) to obtain the optimal values given in Table 7. This result implied that the highest yield of cassava was 29.90 kg/plot when 63.95 kg/ha of Nitrogen, 154.35 kg/Ha phosphorus and 45.56 kg/ha of potassium (K_2O) were applied to a Cassava farm.

4. Conclusions

The research work was used to determine the optimal operating conditions for cassava production on an over-used farmland that required fertilizer application. The methods used were Central Composite Design and Response Surface Methodology. A three factors central composite design (CCD) was applied and

the dependent variable was cassava yield while the independent variables were Nitrogen (x_1), Phosphorus (x_2) and Potassium (x_3) fertilizers. The first order regression model showed a significant lack of fit and this made its inappropriate. A second-order regression model considered exhibited no lack of fit after the ANOVA test while the values of R^2 and $\bar{R}^2$ showed that higher level of variations in the response variable was explained and the model had a good fit. The normal probability plot was used to validate the model since the residual was normally distributed. The two-factor interactions were revealed with 3D response surface plots while the canonical form was obtained. The stationary point was the maximum point since the eigenvalues are all negative. The optimal value indicated that the highest yield of cassava was 29.90 kg/plot when 63.95 kg/ha of Nitrogen, 154.35 kg/ha phosphorus and 45.56 kg/ha of potassium (K_2O) were applied to an over-used land where cassava was planted. In essence, this research work has been used to show that central composite design and response surface methodology can efficiently be applied for modeling crops optimal yield.

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