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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, Rajabhat University (Western Group), and Rajamangala University of Technology Rattanakosin. This Issue, Volume 17 Number 6 (November – December 2022). This issue contains of four interesting articles in multidisciplinary fields: (1) Assessing street greenery using imagery of Google Street View, (2) The process of teaching and learning to create students' identity, (3) Local government involvement in post-pandemic development initiatives for the Lao Khrang Ethnic Group of Nakhon Pathom Province, and (4) Bachelor of Technical Teacher Education versus Bachelor of Technical-Vocational Teacher Education: A comparative analysis of technical teacher education curricula.

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.

Yongyudh Vajaradul
Editor
Interdisciplinary Research Review

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Chitosan/Poly(vinyl alcohol)/Collagen Hydrogel Composites Containing Jackfruit Axis Extract for Wound Dressing Application

Arpanan Laipresert[1,*], Warisa Thungrit[1,*], and Patcharaporn Wutticharoenmongkol[1,*]
[1] Department of Chemical Engineering, Faculty of Engineering, Thammasat School of Engineering, Thammasat University, Pathumthani 12120, THAILAND

Abstract

Jackfruit (Artocarpus heterophyllus Lam.) axis (JFA), a non-edible waste from jackfruit, has been reported for its phytochemical compositions along with antioxidant and antibacterial properties. The aim of this study was to fabricate and investigate the properties of wound dressing composites containing JFA extract. JFA was extracted using sonication in ethanol. The yield of extraction was about 4.93%. The films of chitosan (CS)/poly(vinyl alcohol) (PVA)/collagen (Coll) hydrogel composites containing JFA extract were prepared from the mixed solutions of 1% w/v CS, 1% w/v PVA, and Coll at various ratios including 5/4/1, 5/3/2, 4/5/1, and 4/4/2 by weight of solution. The JFA extract was added to the mixed solution at 0.25% w/w. A solvent casting was performed followed by crosslinking via glutaraldehyde vapor treatment. The obtained films were named JFA-CS/PVA/Coll 5/4/1, 5/3/2, 4/5/1, and 4/4/2. The actual JFA extract content was 19 ± 3.6% based on the weight of dry film. The antioxidant activity of JFA extract was evaluated by 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay. The half-maximal inhibitory concentration (IC50) of JFA extract was 0.250 mg/mL. The JFA extract only exhibited antibacterial activity against Staphylococcus aureus (S. aureus), but not for Escherichia coli (E. coli), as determined by an agar disc diffusion method. The release of JFA extract from the hydrogel composite films was studied by total immersion method in distilled water at 37°C during 0-8 h. The JFA-CS/PVA/Coll 4/4/2 showed higher amount of JFA extract released than those from the ratios of 4/5/1, 5/3/2, and 5/4/1, respectively. The degree of water swelling and weight loss of the films appeared in a similar trend to those of the release study. The higher content of CS and lower content of Coll led to the lower amount of water swelling, weight loss, and JFA extract released. Lastly, all types of JFA-CS/PVA/Coll films exhibited antioxidant activity of about 46-51% and antibacterial activity against S. aureus. However, the JFA-CS/PVA/Coll 5/4/1 showed the least antioxidant and antibacterial activities. Based on the overall results, the JFA-CS/PVA/Coll films revealed the potential for use in wound dressing applications.

Keywords: Jackfruit axis, Herbal extract, Chitosan, Poly(vinyl alcohol), Collagen, Wound dressing

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1. Introduction

Wound healing is a process where destroyed or damaged tissue is cured or regenerated and replaced by newly produced tissue. Wound healing materials have been developed and have been utilized in which an ideal wound dressing should provide moist environment to support the growth of living cells, absorb exudate from the wound, prevent infections, and even accelerate tissue regeneration. The achievement of wound dressing development depends on the selection of matrix materials and the loaded drugs or bioactive compounds that possess antibacterial, antioxidant, and anti-inflammatory properties. Hydrogels have been widely used as wound dressings according to their ability to be swollen but not dissolve in water, which allow them to absorb exudate from wounds and to maintain the moist environment as well. Poly(vinyl alcohol) (PVA) is one of the interesting hydrogels employed as a carrier for controlled-drug release in wound dressings [1-3]. Crosslinking of PVA is performed by using radiation [4] and by chemicals e.g. potassium persulphate [5], glyoxal [6, 7], and glutaraldehyde [6, 8] to enhance its physical stability and to control the degree of swelling and weight loss during wound healing period.

In terms of biological activity and environmentally friendly, biodegradable, biocompatible, biomaterials, non-allergic, and non-toxic materials are promising materials for use in biomedical applications. Chitosan (CS) is one of the most interesting biomaterials for pharmaceuticals, tissue engineering, and wound healing. CS is a linear polysaccharide consisting of randomly distributed $\beta(1 \rightarrow 4)$-linked D-glucosamine and N-acetyl-D-glucosamine. CS is also considered hydrogel due to its three-dimensional network structure and water absorption ability. Moreover, it was reported that CS contains antioxidant activity in which pristine CS films, CS nanoparticles, and those loaded with thyme oil [9] and clove essential oil [10] were tested and exhibited antioxidant activities. Additionally, CS has antibacterial activities against *Staphylo-*

*Corresponding author; email: tpatchar@engr.tu.ac.th

coccus aureus (S. aureus) [10, 11], *Escherichia coli (E. coli)* [10, 12], *Bacillus subtilis (B. subtilis)* [12], *Listeria Monocytogenes (L. Monocytogenes)* [10], and *Salmonella Typhi (S. Typhi)* [10].

In addition, various proteins or partially hydrolyzed proteins, for example, elastin, silk fibroin, gelatin, and collagen, have been utilized in wound dressing materials to improve biocompatibility, cell proliferation, and cell differentiation. Nanofiber mats of CS/Coll enhanced cell migration, re-epithelization, vascularization, and expression of protein differentiation [13]. The composite wound dressings of CS/Coll/alginate exhibited hemocompatibility, non-cytotoxicity, and a higher rate of wound healing in rats than in gauze or CS [14].

On top of that, development of wound dressings can be carried out by incorporation of herbal extracts. CS/Coll membranes containing red propolis extract showed antibacterial properties [15]. Films of PVA containing various types of flower extracts from lavender, peppermint, hemp, verbena, and sage plants demonstrated antibacterial properties towards *S. aureus* and *E. coli.* and were non-toxic to the rabbit fibroblasts [16].

Jackfruit *(Artocarpus heterophyllus Lam.)* tree belongs to the family of Moracea. It is widely grown in tropical countries, especially in Southeast Asia, including India, Bangladesh, Myanmar, Sri Lanka, Philippines, Pakistan, Malaysia, and Thailand [17]. Ripe fruits are sweet and always eaten fresh. Jackfruit is usually consumed as a dessert or as an ingredient in Asian recipes. It is abundant in nutrients, including carbohydrates, carboxylic acids, fibers, minerals, and vitamins. There are six main parts of jackfruit including, flesh or pods, core or axis, pulp or rag, seeds, seed shells, and rind. Jackfruit contains a broad spectrum of antibacterial, antioxidant, anti-diabetic, anti-inflammatory, and anti-helmintics properties [17, 18]. Not only for its flesh, jackfruit rag and jackfruit axis (JFA) were also revealed for their antibacterial [19] and antioxidant [20] properties, respectively. Cytoprotective effect on human liver hepatoma cells was also evident from using JFA extract [20]. JFA extract is composed of 53 compounds with many types of functional components, for example, glycosides, lipids, organic acids, amino acid derivatives, nucleic acids, thiols, terpenoids, esters, alkaloids, phenolics, phytosterol, saponins, and flavonoid as disclosed by Li et. Al. [20].

In the present work, JFA was extracted and loaded into the hydrogel composite films of CS/PVA/Coll. The antioxidant and antibacterial activity of JFA extract were determined. The potential for use of the JFA-CS/PVA/Coll films as a topical transdermal patch or wound dressings was investigated. The release characteristics of JFA extract from the films were studied by the total immersion method in distilled water at 37°C for 0-8 h. The degree of water swelling and weight loss of the films were evaluated. Lastly, the antioxidant and antibacterial activity of the JFA-CS/PVA/Coll hydrogel composite films were determined.

2. Experimental

2.1 Materials

Fresh jackfruit axis (JFA) was brought from a local market in Pathum Thani, Thailand. Poly(vinyl alcohol) (PVA; degree of hydrolysis: 86.0–89.0%, MW: 85,000–124,000 g/mol) was purchased from SD Fine Chemicals (India). Collagen (Coll; liquid, from lamb placenta) was purchased from Chemipan Corporation (Thailand). Glutaraldehyde (25% aqueous solution) was purchased from Acros Organics (USA). Ethanol, methanol, and glacial acetic acid were purchased from Carlo Erba (Italy). Chitosan (CS; MW: 100,000-300,000 g/mol) and 1,1-diphenyl-2-picrylhydrazyl (DPPH) were purchased from Sigma Aldrich (USA).

2.2 Extraction of jackfruit axis

Fresh JFA was collected, cut into tiny pieces, and dried at 60°C for 8 h. Dried JFA was immersed in 99% ethanol at a solid:liquid ratio of 3 g : 45 mL. The mixture was sonicated for 30 min and further shaken at room temperature for 24 h. Solid residue was filtered out by vacuum filtration. JFA extract was collected as filtrate in which ethanol was subsequently evaporated by using a rotary evaporator. The obtained slurry was further dried in a vacuum oven at 75°C for 4 h. Lastly, dried JFA extract was obtained and kept in a desiccator. The percentage of yield of extraction was calculated according to an equation (1):

$$\text{Yield of extraction (\%)} = \frac{\text{mass of the dried JFA extract (g)}}{\text{mass of the initial dried JFA (g)}} \times 100 \qquad (1)$$

2.3 Preparation of the JFA-loaded CS/PVA/Coll films

The solution of 1% w/v CS was prepared in 0.1 M acetic acid by continuously stirring the solution at room temperature for 3 h. Aqueous solution of 1% w/v PVA was prepared by stirring the solution at 80°C for 5 h until a homogeneous solution was obtained. Coll solution was used as obtained. The composite solutions were prepared by mixing 1% w/v CS, 1% w/v PVA, and Coll at different weight ratios of 5/4/1, 5/3/2, 4/5/1, and 4/4/2. JFA extract was later added to the composite solution. For 100 g of the composite solution, 0.25 g of JFA extract was added and mixed thoroughly. The JFA extract-loaded composite solutions were casted onto a plastic plate. The solvent evaporation was allowed to proceed at room temperature for 24 h in a hood.

The obtained hydrogel composite films were designated as JFA-CS/PVA/Coll 5/4/1, JFA-CS/PVA/Coll 5/3/2, JFA-CS/PVA/Coll 4/5/1, and JFA-CS/PVA/Coll 4/4/2, respectively. Lastly, crosslinking of PVA was performed using a glutaraldehyde vapor treatment. The JFA-CS/PVA/Coll hydrogel composite films were placed in a closed plastic box containing a cup of glutaraldehyde (25% in water) at 40°C under a saturated atmosphere of glutaraldehyde for 5 h of each side of film. The hydrogel composite films were later placed in a hood for 1 h to allow evaporation of the remaining glutaraldehyde in the films. Glutaraldehyde acts as a crosslinking agent for both PVA and CS. The crosslinking reactions are demonstrated in Figure 1. The hydroxyl groups of PVA and the amine groups of CS react with aldehydic groups of glutaraldehyde to form acetal bonds and imine bonds, respectively.

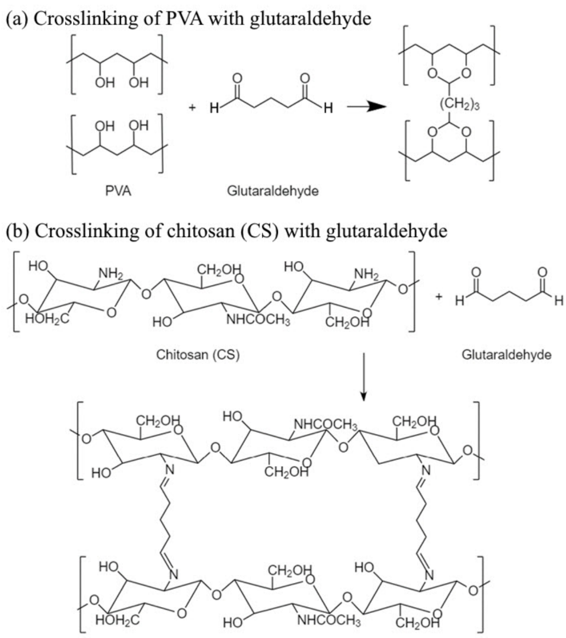

Figure 1: Crosslinking reactions of (a) PVA and (b) CS with glutaraldehyde.

2.4 *Water swelling and weight loss of the JFA-CS/PVA/Coll films*

The degree of water swelling and weight loss of the JFA-CS/PVA/Coll hydrogel composite films were determined after immersion in distilled water at 37°C for 4 h. Each sample was cut into a square shape of 2x2 cm2, dried in an oven at 40°C for 4 h, and immersed in 40 mL of distilled water. The initial dry weight of the sample was recorded as Mi. At 4 h of immersion, the weight of the wet sample was recorded as M. Afterwards, the wet sample was dried in an oven at 40°C for 4 h. The weight of the dried sample after immersion was recorded as Md. The percentages of water swelling and weight loss were calculated according to equations (2) and (3), respectively.

$$\text{Water swelling } (\%) = \frac{(M - M_i)}{M_i} \times 100 \tag{2}$$

$$Weightloss(\%) = \left(\frac{M_i - M_d}{M_i}\right) \times 100 \tag{3}$$

2.5 *Release of JFA extract from the JFA-CS/PVA/Coll films*

2.5.1 *Actual drug content*

Prior to investigating the characteristics of JFA extract release from the JFA-CS/PVA/Coll hydrogel composite films, the actual drug content (i.e., the actual amount of JFA extract in the films) was determined for use as base values in the release study. The film was cut into a square piece of 2x2 cm2 and was completely dissolved in distilled water by continuously stirring at 80°C for approximately 2 h. The obtained solution was diluted with distilled water and measured for its absorbance at a wavelength of 212 nm ($\lambda_{\max}$ of JFA extract) using a UV-vis spectrophotometer (Hanon I3). The amount of JFA extract was calculated against the predetermined standard curve plotted between the concentration of JFA extract and its absorbance at 212 nm.

2.5.2 *Release assay*

The release behaviors of JFA extract from the JFA-CS/PVA/Coll hydrogel composite films were studied by a total immersion method. The tested film was cut into a square shape of 2x2 cm2 and immersed in 40 mL of distilled water in a capped bottle at 37°C. The releasing medium was slowly stirred using a magnetic stirrer during the releasing time, ranging between 0 - 8 h. At each specified time point, 1.0 mL of the releasing medium was withdrawn and diluted with distilled water before measuring its absorbance at 212 nm. At each time of solution withdrawal, the same amount (1.0 mL) of distilled water was refilled into the bottle in order to keep a constant volume of releasing medium. The amount of JFA extract released were quantified from their absorbances against the predetermined standard curve of JFA extract in distilled water. The cumulative percentage of JFA extract released at each time point was calculated according to the equation (4):

$$\text{Cumulative JFA extract release}(\%) = \frac{C_t}{C_{total}} \times 100 \tag{4}$$

where C_t is the cumulative weight of JFA extract released at time t and C_total is the weight of the JFA extract in the CS/PVA/Coll films. The experiments were carried out in triplicate.

2.6 Antioxidant activity

The antioxidant activity of JFA extract and the JFA-CS/PVA/Coll films were evaluated by the radical scavenging DPPH assay. For the antioxidant activity of JFA extract, the aqueous solutions of JFA extract were prepared in a range of concentrations of 0.156 – 10.00 mg/mL. Each 1.0 mL of JFA extract solution was mixed with 3.0 mL of 0.5 mM DPPH solution in methanol. The mixture was kept in darkness for 30 min and was measured for absorbance at 517 nm by the UV-vis spectrophotometer. The control solution was a pristine 0.5 mM DPPH solution which was prepared and stored in the same condition as those of the tested samples. The antioxidant activity was calculated according to the equation (5):

$$\text{Antioxidant activity (\%)} = \frac{(A_C - A_S)}{A_C} \times 100 \quad (5)$$

Where A_C is the absorbance of the control and A_S is the absorbance of the sample.

Later, the concentration of JFA extract at which 50% of DPPH free radicals are scavenged (IC50) was calculated.

For the antioxidant activity of the CS/PVA/Coll films and the JFA-CS/PVA/Coll films, the tested film was cut into a square shape of 2x2 cm2 and immersed in 40 mL of distilled water at 37°C for 8 h. After that, 1.0 mL of the releasing media was withdrawn and mixed with 3.0 mL of 0.5 mM DPPH solution in methanol. The mixture was further kept in the darkness for 30 min. The absorbance at 517 nm was determined. The antioxidant activity of these films was calculated according to the equation (5). The experiments were carried out in triplicate.

2.7 Antibacterial activity

The antibacterial activity of JFA extract, the CS/PVA/Coll films, and the JFA-CS/PVA/Coll films against Gram-positive Staphylococcus aureus (S. aureus: ATCC 6538) and Gram-negative *Escherichia coli* (*E. coli*: ATCC 8739) bacteria were evaluated by the agar disc diffusion method. The circular filter paper disc saturated with 0.6 mg/mL JFA extract and the various types of JFA-CS/PVA/Coll films with a diameter of 6 mm were placed on a plate containing bacteria in agar. The agar plate was incubated at 37°C for 24 h. The observed diameter of clear zone which included the diameter of disc was measured. The clear zone of inhibition was calculated from the subtraction of the diameter of disc (i.e., 6 mm) from the diameter of clear zone and later divided by 2. Deionized water was used as a negative control, while ethanol was used as a positive control. Specifically, vancomycin and gentamicin were used as the positive controls for*S. aureus* and *E. coli.*, respectively.

3. Results and Discussions

3.1 Yield, antioxidant, and antibacterial activity of JFA extract

JFA was extracted by using 99% ethanol assisted with sonication and shaking for 24 h. The average percentage of yield was 4.93 ± 0.65%. The antioxidant activity of JFA extract based on DPPH free radical scavenging assay at the concentrations of 0.156, 0.312, 0.625, 1.250, 5.00, and 10.00 mg/mL were investigated. The antioxidant activities of JFA extract in a range of concentrations of 1.25 – 10 mg/mL were markedly high and were not much changed according to the change of concentration (see Figure 2), which was approximately 91 – 92%. For the lower range of concentrations, the antioxidant activity was decreased with decrease in JFA extract concentration. The half-maximal inhibitory concentration (IC50) of JFA extract (defined as the concentration at which 50% of DPPH free radicals are scavenged) was 0.250 mg/mL., which was determined from the data in a range of concentrations of 0.156 – 0.625 mg/mL.

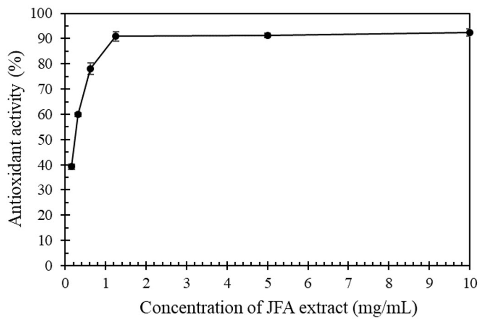

Figure 2: Antioxidant activity of JFA extract based on DPPH assay.

JFA extract was further investigated for antibacterial activity against Gram-positive S. aureus and Gram-negative E. coli bacteria by the agar disc diffusion method. The clear zone of inhibition are presented in Table 1. The JFA extract exhibited antibacterial activity against S. aureus only, but not for E. coli. Deionized water and ethanol were used as the negative and the positive control, respectively. Photographs of the bacteria cultured plates are shown in Figure 3.

From these results, the JFA extract possessed both the antioxidant and antibacterial activities and revealed the potential for use as an active ingredient in wound dressings. The hydrogel composite films of CS/PVA/Coll containing JFA extract were further fabricated. The study of the release behavior of JFA extract therefrom, water swelling, weight loss, antioxidant, and antibacterial properties of the films were performed.

3.2 Water swelling and weight loss of the JFA-CS/PVA/Coll films

The hydrogel composite films containing JFA extract were fabricated by solvent casting technique

Table 1. Antibacterial activities of JFA extract against S. aureus and E. coli as determined by the agar disc diffusion method.

samples	Clear zone of inhibition (mm)	
	S. aureus	***E. coli***
Negative control: deionized water	0.00 ± 0.00	0.00 ± 0.00
Positive control: ethanol	1.20 ± 0.15	0.50 ± 0.00
JFA extract	1.36 ± 0.42	0.00 ± 0.00

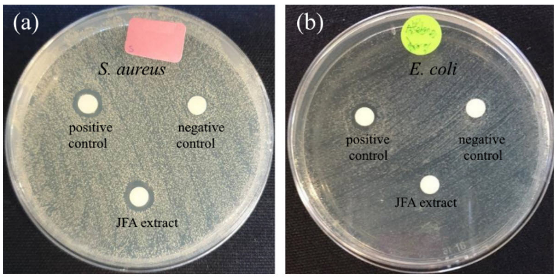

Figure 3: Photographs of the antibacterial activity testing by the agar disc diffusion method for the JFA extract against (a) *S. aureus* and (b) *E. coli.*

at various ratios of CS, PVA, and Coll. The obtained hydrogel composite films were designated as JFA-CS/PVA/Coll 5/4/1, JFA-CS/PVA/Coll 5/3/2, JFA-CS/PVA/Coll 4/5/1, and JFA-CS/PVA/Coll 4/4/2. These films were crosslinked by glutaraldehyde vapor treatment before use. The average thickness of the films was 135 ± 54 µm.

Degree of water swelling and weight loss are ones of the important parameters of the hydrogel, especially for use in wound dressing applications. The release behaviors can be explained in regards to the degree of water swelling in which the ability to hold water and to allow drugs to diffuse are related [21, 22]. Also, drug release according to the mass loss of the matrix is one of the release mechanisms [22].

Figure 4 shows the amount of water swelling and weight loss of the JFA-CS/PVA/Coll films at 4 h of immersion in distilled water. Similar trends of water swelling and weight loss were observed. These values ranked ascendingly as the JFA-CS/PVA/Coll films with the ratios of 5/4/1, 5/3/2, 4/5/1, and 4/4/2, respectively.

For the amount of water swelling, the values of the JFA-CS/PVA/Coll films with the ratios of 5/4/1, 5/3/2, 4/5/1, and 4/4/2, were 220.8 ± 8.2%, 296.5 ± 9.1%, 312.7 ± 12.8%, and 330.4 ± 13.3%, respectively. For the degree of weight loss, the values of the JFA-CS/PVA/Coll films with the ratios of 5/4/1, 5/3/2, 4/5/1, and 4/4/2, were 13.3 ± 1.2%, 15.2 ± 1.4%, 19.2 ± 2.6%, and 28.2 ± 3.1%, respectively.

Comparing the hydrogel composite films with different contents of CS, it seemed that the films with higher amount of CS (the ratios of 5/4/1 and 5/3/2) exhibited lower water swelling and weight loss than those of the films with lower amount of CS (the ratios of 4/5/1 and 4/4/2). The similar trends of observation were disclosed by other research that the crosslinked CS/PVA nanofibers had the lower water swelling and weight loss with the presence or increasing CS content [23, 24].

Comparing the hydrogel composite films with different contents of Coll, it seemed that the films with higher amount of Coll (the ratios of 5/3/2) exhibited higher water swelling and weight loss than those of the films with lower amount of Coll (the ratios of 5/4/1). The water swelling and weight loss of the hydrogel composite films with the ratio of 4/4/2 were also greater than those of the ratio of 4/5/1. Similar to the observations of Lan et al. [25] that the incorporation of Coll into porous PVA hydrogels for use in cartilage tissue engineering led to a higher degradation of hydrogels.

It is widely known that the amount of water swelling and weight loss notably correspond to the release behavior of molecules from the matrix [21]. The results of water swelling and weight loss are further discussed with the release characteristics in the next session.

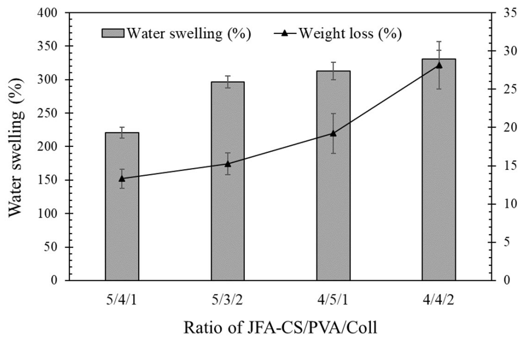

Figure 4: Water swelling and weight loss of the JFA-CS/PVA/Coll films at 4 h of immersion in distilled water.

3.3 *Release of JFA extract from the JFA-CS/PVA/Coll films*

Prior to studying the release characteristics of JFA extract from the JFA-CS/PVA/Coll hydrogel composite films, the standard curve of JFA extract was prepared. The plot between the concentration of JFA extract in distilled water and its absorbance at 212 nm (λ_{max} of JFA extract) was a straight line with the linear equation of $y = 0.002X + 0.0902$. The coefficient of determination (r^2) as to determine the best fit of the data was 0.929.

3.3.1 Actual JFA extract content in the JFA-CS/PVA/Coll films

The actual JFA extract contents in the JFA-CS/PVA/Coll films were determined for use as base values in the release study. The percentages of actual JFA extract contents were calculated from the actual weight of JFA extract presented in the film divided by the weight of the film. The average percentage of actual JFA extract content was 19 ± 3.6%.

3.3.2 Release characteristics of JFA from the JFA-CS/PVA/Coll films

The release of JFA extract from the hydrogel composite films was investigated by total immersion method in distilled water at 37°C during 0 – 8 h. Figure 5 shows the percentages of cumulative release amount of JFA extract from 4 types of films. The results were reported as the percentages of the cumulative weights of JFA extract released divided by the actual weight of JFA extract in the films. For all types of films, the burst release of JFA extract was observed at the initial time of release in a range of 0 – 20 min. Later, gradual release until reaching constant values appeared since approximately 180 min. The maximum amount of JFA released at 480 min (8 h) from the JFA-CS/PVA/Coll films with the ratios of 5/4/1, 5/3/2, 4/5/1, and 4/4/2 were about 24.1 ± 1.6%, 42.1 ± 3.1%, 44.4 ± 3.6%, and 47.1 ± 3.6%, respectively.

Interestingly, the results of the release study highly corresponded with the trend of the degree of water swelling and weight loss. Comparing the hydrogel composite films with different contents of CS, it was found that the films with higher amount of CS (the ratios of 5/4/1 and 5/3/2) exhibited lower amount of JFA extract released than those of the films with lower amount of CS (the ratios of 4/5/1 and 4/4/2). This was due to the lower water swelling ability of the JFA-CS/PVA/Coll film with the ratio of 5/4/1 and 5/3/2 films and therefore, the drug or substance molecules were more difficult to diffuse out from the matrix. Moreover, molecules can also be released from the mechanism of weight loss of matrix [22]. Since the JFA-CS/PVA/Coll 5/4/1 had the lowest weight loss among all types of films, it showed the lowest amount of JFA extract released.

Comparing the hydrogel composite films with different contents of Coll, it was noticed that the films with higher amount of Coll (the ratio of 5/3/2) exhibited much higher amount of JFA extract released than that of the films with lower amount of Coll (the ratio of 5/4/1). A similar trend was also observed for films with the ratios of 4/5/1 and 4/4/2, in which the film with higher amount of Coll (the ratio of 4/4/2) showed greater amount of JFA extract released than that of the film with lower amount of Coll (the ratio of 4/5/1). Repeatedly, this was due to the lower water swelling ability and lower weight loss of the film with the ratio of 5/4/1 compared to the ratio of 5/3/2 (also the ratio of 4/5/1 compared to the ratio of 4/4/2). Therefore, it was more inconvenient for the substance molecules to diffuse out from the matrix.

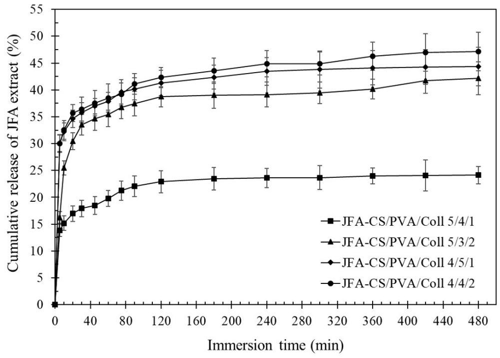

Figure 5: Cumulative release amounts of JFA extract from the JFA-CS/PVA/Coll films in distilled water at 37°C.

3.4 Antioxidant activity of the JFA-CS/PVA/Coll films

The antioxidant activity of the CS/PVA/Coll films (non-JFA extract loaded) and the JFA-CS/PVA/Coll films were examined by the DPPH assay. The scavenging of hydrogen radicals of DPPH can be evaluated by the decrease in absorbance at 517 nm (λ_{max} of DPPH) according to, the equation (5). The releasing media were collected at 4 h of immersion in distilled water and were quantified for the antioxidant activity.

For the CS/PVA/Coll films, the antioxidant activities of the films with the ratios of 5/4/1, 5/3/2, 4/5/1, and 4/4/2 were 38.68 ± 0.29%, 38.57 ± 0.35%, 38.12 ± 0.29%, and 38.84 ± 00.22%, respectively (see Figure 6). Even though there was no JFA extract presence, the CS/PVA/Coll films still exhibited antioxidant properties. The antioxidant ability could come from the presence of CS, which has been reported for its antioxidant activity [9, 10]. However, the difference of composition ratios had no effect on the antioxidant activity. For the JFA-CS/PVA/Coll films, the antioxidant activities of the films with the ratios of 5/4/1, 5/3/2, 4/5/1, and 4/4/2 were 46.40 ±0.31%, 50.79 ± 0.35%, 50.77 ± 0.32%, and 50.83 ± 0.35%, respectively (see Figure 6). Obviously, the films containing JFA extract (the JFA-CS/PVA/Coll films) exhibited greater antioxidant activities than those of the non-JFA extract-loaded films (the CS/PVA/Coll films). Notably, the presence of JFA extract helps improve the antioxidant activity of the films from about 38% to about 46 – 51%. However, the values of the films with the ratios of 5/3/2, 4/5/1, and 4/4/2 were not much different. Except for the films with the ratio of 5/4/1, it showed the lowest values among all types of films. This could be due to the lowest release amount of JFA extract from the film with the ratio of 5/4/1 and, therefore, there was the least antioxidant activity.

Table 2. Antibacterial activities of CS/PVA/Coll and JFA- CS/PVA/Coll films against S. aureus and E. coli as determined by the agar disc diffusion method.

samples	Clear zone of inhibition (mm)	
	S. aureus	***E. coli***
Vancomycin (positive control for S. aureus)	3.24 ± 0.24	N/A
Gentamicin (positive control for E. coli)	N/A	3.70 ± 0.05
CS/PVA/Coll 5/4/1	0.06 ± 0.01	0.00 ± 0.00
JFA- CS/PVA/Coll 5/4/1	3.30 ± 0.70	0.00 ± 0.00
JFA- CS/PVA/Coll 5/3/2	4.14 ± 0.18	0.00 ± 0.00
JFA- CS/PVA/Coll 4/5/1	4.02 ± 0.59	0.00 ± 0.00
JFA- CS/PVA/Coll 4/4/2	4.14 ± 0.84	0.00 ± 0.00

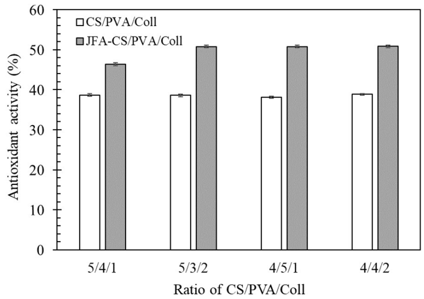

Figure 6: Antioxidant activities of the CS/PVA/Coll films and the JFA-CS/PVA/Coll films at 4 h of immersion.

3.5 Antibacterial activity of the JFA-CS/PVA/Coll films

Antibacterial activity of the CS/PVA/Coll films (only for the ratio 5/4/1) and the JFA-CS/PVA/Coll films against the Gram-positive *S. aureus* and Gram-negative *E. coli* bacteria was evaluated by the agar disc diffusion method. Table 2 shows the clear zones of inhibition that were measured from the photographs of the cultured plates (see Figure 7). The clear zones of inhibition of the positive control for*S. aureus* (vancomycin) and for *E. coli* (gentamicin) were also reported. For the CS/PVA/Coll 5/4/1 films, it had no antibacterial activity against *E. coli* as the inhibition zone was not observed, but it slightly inhibited the growth of *S. aureus*. The antibacterial activity against S. aureus could come from the presence of CS, which has been reported for its antibacterial properties [10, 11].

For all types of the JFA-CS/PVA/Coll films, they had no antibacterial activity against E. coli. However, they expressed excellent antibacterial activity against S. aureus., as observed from the large inhibition zones, which were even greater than that of the positive control (vancomycin). It should be noted that the antibacterial activity of the JFA-CS/PVA/Coll 5/4/1 film was the lowest among other JFA-CS/PVA/Coll films. This result corresponded well with the release study in which the JFA-CS/PVA/Coll 5/4/1 film had the lowest release amount of JFA extract and therefore led to the lowest antibacterial activity.

Based on the overall results, all types of the JFA-CS/PVA/Coll films exhibited excellent antioxidant and antibacterial activity against S. aureus. Even though the JFA-CS/PVA/Coll 5/4/1 expressed the least ability among these films. It was revealed that all types of the JFA-CS/PVA/Coll hydrogel composite films can be promising materials for use as topical transdermal patches or wound dressings.

4. Conclusions

In the present contribution, jackfruit axis (JFA) was extracted and loaded into the hydrogel composite films of CS/PVA/Coll. The films were prepared at various ratios of CS/PVA/Coll, including 5/4/1, 5/3/2, 4/5/1, and 4/4/2 by weight. The actual JFA extract content was 19 ± 3.6% based on the weight of dry film. Antioxidant activity of JFA extract as evaluated by DPPH assay showed that the half-maximal inhibitory concentration (IC_{50}) of JFA extract was 0.250 mg/mL. Antibacterial activity as determined by an agar disc diffusion method revealed that JFA extract inhibited growth of *S. aureus*, but not *E. coli*. The release of JFA extract from the hydrogel composite films (JFA-CS/PVA/Coll 5/4/1, 5/3/2, 4/5/1, and 4/4/2) was studied by the total immersion method in distilled water at 37°C during 0-8 h. The JFA-CS/PVA/Coll 4/4/2 showed higher amount of JFA extract released than those from the ratios of 4/5/1, 5/3/2, and 5/4/1, respectively. The amount of JFA extract release was in accordance with the trends of degree of water swelling and weight loss in which the higher content of CS and lower content of Coll led to the lower amount of water swelling, weight loss, and JFA extract release. Lastly, all types of JFA-CS/PVA/Coll films exhibited antioxidant activity in a range of 46-51% and antibacterial activity against S. aureus. To be noted, the JFA-CS/PVA/Coll 5/4/1 showed the least antioxidant and antibacterial activities among all types of films, which corresponded with the lowest amounts of JFA released. Based on the overall results, the JFA-CS/PVA/Coll films at all ratios which exhibited excellent antioxidant and antibacterial properties revealed the potential for use as topical transdermal patches or use in wound healing applications.

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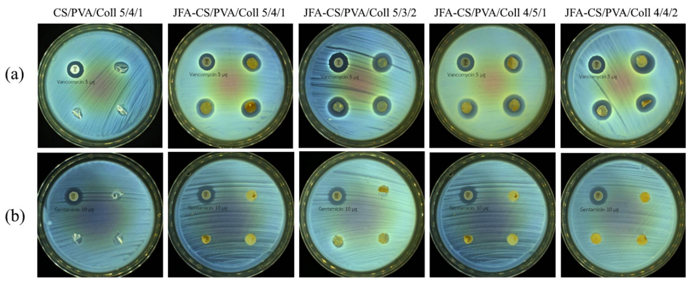

Figure 7: Photographs of the antibacterial activity testing by the agar disc diffusion method for the CS/PVA/Coll and the JFA- CS/PVA/Coll films against (a) *S. aureus* and (b) *E. coli.*

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Development of Indicators for Strategic Environmental Assessment (SEA) of Electric Power Development Program in Krabi Province, Southern Thailand

Jiranon Putta[1*] **and Chamlong Poboon**[1]

[1]**Doctor of Philosophy Program in Environmental Management, Graduate School of Environmental Development Administration, National Institute of Development Administration (NIDA), Bangkok, Thailand**

Abstract

The Strategic Environmental Assessment (SEA) is a systematic process to support decision-making in the formulation of a policy, plan, or program with a focus on participation. The development of indicators is an important process in the SEA. The objectives of this study were to develop and define appropriate and comprehensive indicators for the SEA of electric power development program in Krabi Province, Southern Thailand, and to determine weights for the dimensions and indicators. This study is a mixed-methods research project that collected data from the stakeholders in the area and experts through participatory processes as well as reviewing documents from various sources. The findings reveal that 16 indicators were developed in 4 dimensions, divided into 6 indicators in the economic dimension, 2 indicators in the social dimension, 5 indicators in the environmental dimension, and 3 indicators in the energy/technology security dimension. The Analytical Hierarchy Process (AHP) was employed for weighting the dimensions and the indicators. The developed indicators were well accepted by the stakeholders in the area and relevant agencies and were able to be adopted in the impact assessment of strategic alternatives for power development in the SEA.

Keywords: indicators; Strategic Environmental Assessment; power development; Krabi Province

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1. Introduction

Southern Thailand is a world-class tourist destination, then the electrical demand in the area has trendily increased due to a steady increase in tourist numbers. Krabi is one of southern provinces that tourists come to visit at most [1, 2]. The Ministry of Energy has set a construction plan for two new power plants in the south using coal fuel, one in Krabi and another in Songkhla [3]. Krabi Province has a small old power plant that currently serves as a supplementary plant. The rationale of the plan for constructing a plant in Krabi is that the Andaman side of Southern Thailand does not have a large power plant causing risk to energy security in the area.

On one hand, the construction of a large power plant in Krabi has been strongly opposed by tourism sector, fishery groups, and local people as well as NGOs and independent scholars from outside, as they are concerned with environmental pollution and health impacts, including the impacts on the integrity of natural resources and the environment in the area. On the other hand, a large number of community leaders and local people living around the site have strongly supported the construction as they believe the plant can create prosperity in the area and provide benefits to the local communities. This has resulted in a serious conflict between these two groups. This conflict had a serious impact on the development of electric power in Krabi as the relevant agencies could not construct a new coal-fired power plant in the area, and the direction of electric power development in the area was not clear.

As a result, in a near future Krabi Province may face a shortage of power supply that would strongly affect all economic sectors as well as the people's quality of life. Hence, the Strategic Environmental Assessment (SEA) can be applied to help cope with the problems. Unlike Environmental Impact Assessment (EIA), the Strategic Environmental Assessment (SEA) is a study at the policy, plans, and programs level, while EIA is a project-level study that focus on a detailed study of the

*Corresponding author; email: p.jiranon@gmail.com

impacts of a project [4-7]. One of the most important steps in SEA process is development of indicators for assessing strategic alternatives of the development [8].

The development of appropriate indicators for alternatives assessment requires a comprehensive review and analysis of the data, and significantly, opinions from the stakeholders. The overall framework is consistent with strategic issues and sustainable development objectives, embracing economic, social, and environmental aspects. It must have enough information and can be continuously monitored in the long term [4, 5, 8, 9]. This study is a part of SEA for electric power development of Krabi Province. The objectives are 1) to develop and define appropriate and comprehensive indicators for impact assessment of strategic alternatives for power development of Krabi Province in the SEA study, and 2) to determine weights for the dimensions and indicators which are consistent with technical and sustainable development principles, as well as acceptable to all relevant sectors.

1.1. Literature Review

Asian Development Bank (2015) [10] defined the indicators for conducting SEA study regarding energy development under 8 security issues in line with sustainable development which are pollution, land and biodiversity, water resources and aquatic biodiversity, climate change, food security, social security, health and safety security, and economic stability. In addition, the other studies suggested SEA-related indicators for electric power development include employment, cost of electricity generation, cost of technology investment, social return on investment analysis, and problems from migrant workers, etc. [11-14]. EPPO (2018) [15] defined the indicators for PDP 2018 as 3E, consisting of energy security, economics, and ecology. This was inconsistent with the sustainable development dimensions (economic, social, and environmental). However, some social indicators were not included in the indicators for the impact assessment of the SEA, such as public acceptance which was an important indicator in gaining acceptance from the locals [7].

2. Methodology

This study is a mixed-methods research. It was divided into 2 steps: the development and determination of indicators and the determination of weights of dimensions and indicators. The data were collected from key informants in the area and relevant experts.

2.1. Key informants

The key informants in this study were local leaders, representatives from tourism and fishing groups, NGOs that were active in the coal-fired power plant development project, and officers of relevant agencies, especially Krabi's electric generation office. They were derived from the stakeholder analysis and were purposively selected by the researchers. The stakeholders in the area were classified into two main groups: supporting and opposing groups of a coal-fired power plant. This is in accordance with Huailuek (2020) [16] and Sriruang (2019) [7] who studied the conflict in power plant development in Krabi Province and found that there were 2 main conflict groups in the area with very serious opposition to each other.

In addition, to help make the results of the study more accurate academically and acceptable to these 2 groups. The study additionally collected information from experts who were academics, senior government officers, and private sector who have high knowledge and experiences in the economic, social, environmental, energy, or technological field concerning power plant development.

2.2. Development and determination of indicators

The development and determination of indicators used a qualitative research method to collect primary data from the key informants, and secondary data from relevant documents. The key informants in this process of development and determination of indicators consisted of 103 local leaders and representatives of tourism and fishery groups in Krabi , NGOs, and officers of relevant agencies and 17 experts in economic, social, environmental, energy, and technological areas, totaling 120 people.

The data collection was a series of focus group discussions (3 rounds of group discussions) for the key informants and a semi-structured interview to collect data from the experts. The objectives of each round of focus group discussion are as follows:

The 1st round: To obtain the opinions of the key informants about the overall development direction of Krabi Province and their concerns towards different alternatives of power development.

The 2nd round: To let the key informants consider, criticize, and recommend the draft dimensions and indicators.

The 3rd round: To confirm the adjusted indicators by the key informants.

The data from each focus group discussion would be analyzed and synthesized based on the opinions of key informants to develop dimensions and indicators for the SEA of electric power development in Krabi Province.

2.3. Determination of weights of dimensions and indicators

The determination of weights of dimensions and indicators employed a quantitative research method by using a questionnaire to compile the opinions of key informants and applied the Analytical Hierarchy Process (AHP) in comparing weights of dimensions and indicators and summarize the weight values of the dimensions and indicators [17].

The respondents in this process were derived from representatives of stakeholders in the area who were selected by each group. For the group supporting the construction of coal-fired power plant, 9 local leaders and officers of relevant agencies were represented, while 10 local leaders, and representatives from tourism and fishery groups and NGOs were represented the opposing group. In addition, the 32 experts were also asked for weighting the dimensions and indicators.

This study used questionnaire as a tool to collect data from the key informants. The results were the weights of dimensions and indicators for the next step in the SEA of electric power development in Krabi Province.

3. Data Analysis

This study employed 2 methods of data analysis.

Part 1: the development and determination of indicators used content analysis, which are the qualitative analysis method for the data obtained from key informants and experts.

Part 2: the determination of the weights of dimensions and indicators employed the Analytical Hierarchy Process (AHP). AHP is a two-way comparison technique useful for analysts to focus on individual components or factors at a single time [18]. The pairwise comparison assigns weights between criteria in pairs by using numbers instead of values to calculating the importance scores between each criterion [17, 19]. In this study the scores are evaluated through pairwise comparison analysis of dimensions and indicators. The calculation are as presented in the Equation (1):

$$w_i = \frac{\sqrt[n]{\prod_{i=1}^{n} c_i}}{\sum^{n} \sqrt{\prod_{i=1}^{n} c_i}} \tag{1}$$

where w_i is the weight value of the dimension or indicator, n is the number of dimensions or indicators, C_i is the score value of the dimension or indicator, i is the order of the dimension or indicator, and is the respective product of points for each dimension or indicator.

The weights from the 3 groups were averaged to obtain the final weights for the proposed dimensions and indicators in order to draw acceptance from all groups of key informants especially the supporting and opposing groups of coal-fired power plant.

The outputs of these 2 parts were the developed indicators and weights of dimension and indicators for the impact assessment of strategic alternatives of electric power development program in Krabi Province.

4. Results

From the analysis of primary and secondary data described above, the key findings of this study can be divided into 4 parts as follows:

Part 1: Key issues from focus group discussions

The group opposing the construction of the coal-fired power plant suggested key issues related to the development direction of Krabi Province which are: 1) the environmentally-friendly development should be a main concept for Krabi Province development since the area has a high potential for development based on its natural resources and can link to sustainable development. The development of industry is possible but there should not be a large factory in the area as it can pose the adverse impact on the environment and local people. Moreover, the province development should be linked to the context of the area, especially tourism and fishery which are consistent with the local resources. 2) The electric power development in Krabi should focus on alternative energy since various sources of raw materials can be obtained from the area especially biomass. In addition, the alternative energy can help minimize environmental and health impacts from production of power. Meanwhile, the coal-fired supporting group expressed their concern that renewable energy, such as solar energy, is not stable that can significantly affect the energy security. Moreover, if there is a high proportion of electricity production from renewable energy, it will affect the price of electricity. They also believed that modern technology of coal-fired power plant can control the impact on the environment and can retain the price of electricity. However, both groups agreed that base-load plant was still necessary for energy security, although the opposing group accepted only a gas power plant not a coal-fired power plant.

Part 2: Key issues from the experts

From the interviews, several experts suggested that since the development direction of Krabi Province is focused on tourism and services, the area needs a stable electric power supply. In addition, the development of power plant in Krabi has to consider 3 principles: 1) sufficiency and continuity of the power supply, 2) suitability of electricity price, and 3) low pollution and low impact on the environment and local people. The development of renewable energy has limitations such as the availability and price of raw materials and the stability of power especially solar power, etc. Hence, Krabi electric power development is still necessary to have a base-load power plant using fossil fuel with modern technology to control pollution. However, some of the experts mentioned about the significance of international agreement on climate change in which the power production sector is one of the main focuses of the carbon reduction policy. Hence, the development of power supply in the area should be in line with this agreement by moving towards the alternative energy not fossil fuel. In conclusion, according to the experts' opinions, the development of electric power in Krabi should be in accordance with the 4E principles: Economic, Environmental, Energy security, and Engineering.

Part 3: Dimension and indicators for alternatives assessment

Based on the content analysis of the data from key informants and reviews of related documents, this study developed and defined dimensions and indicators for the SEA's alternatives assessment of power development in Krabi as follows:

Four dimensions were established. The first 3 dimensions are in accordance with the sustainable development principles, consisting of 1) economic, 2) social, and 3) environmental dimension. In addition, the 4th dimension, which is another important issue in power development, is energy/technology security dimension.

Sixteen indicators were developed and determined under the 4 dimensions. Six indicators are of economic dimension: employment, tourism, fishery, agriculture, revenue from selling raw materials/fuel, and electricity price per unit. Two indicators are of social dimension: acceptance of people towards generation of electricity and change in health status of local people. Five indicators are of the environmental dimension: water quality, air quality, solid waste, aquatic biodiversity, and greenhouse gas emissions. Lastly, three indicators are in dimension of energy/technology security: fuel/energy sufficiency, power distribution ability, and efficiency of pollution treatment technology. Details of the dimensions and indicators as well as their references are shown in Table 1.

The draft of dimensions and indicators for the assessment process developed from reviewing related document and the opinions of key informants and experts were brought into a final focus group discussion of key informants in Krabi Province. Though there were some questions from the participants, after discussions and explanations from the researchers, the majority of key informants accepted that these dimensions and indicators were suitable with the context of power development in Krabi and could be used for the impact assessment process in the SEA process. Thus, the study can proceed to the next step of determining the weight score of these dimensions and indicators.

Part 4: Weights of dimension and indicators

Determination of the weights of dimensions and indicators was carried out by using the Analytical Hierarchy Process (AHP). The data were collected from key informants as respondents. The total number of respondents were 51 people from 3 groups—the supporting group, the opposing group, and the experts. To draw the acceptance from the 2 groups in the area, the study gave importance to all groups equally. The primary weights of dimensions and indicators from each group were then averaged to conclude the final weights which would be used in the assessment. The final weights were revealed to all respondents. The details are shown in Table 2.

Consequently, when determining the weights of dimension and indicators for the assessment process in the SEA, it was found that the environmental dimension was the highest weighted dimension at 0.331. Indicator 2.1 Acceptance of residents towards the electricity generation was with a weight of 0.117, followed by Indicator 2.2 Change in health status of local residents, and Indicator 4.3 Efficiency of pollution treatment technology with a weight of 0.104 and 0.888, respectively. The indicator with the least weight was Indicator 1.1. Employment with a weight of 0.028.

5. Discussions

The results of this study determined sixteen indicators for alternatives assessment in the SEA study of power development in Krabi Province. They are divided into 4 dimensions: economic, social, environmental, and energy/technology security which are in accordance with the sustainable development principle and the studies of the Office of Natural Resources and Environmental Policy and Planning (ONEP) (2007) [24] and Poboon (2013) [14]. These indicators can be applied in the SEA of the electric power development program in Krabi which have been accepted by all sectors.

In sum, it can be seen from the weighting scores of dimensions that the environment (0.331) is the most important dimension in alternatives assessment of the power plant development, followed by economy (0.276), society (0.221), and energy/technology security (0.172), respectively. This is consistent with the results of the study of Poboon (2013) [14] and Takamol et al. (2021) [25]. However, this is not consistent with Abdul, Wenqi, and Tanveer (2021) [26] who prioritized renewable energy sources for electricity generation through the AHP-VIKOR integrated approach in Pakistan, which found that the highest rated dimension was the economic dimension, followed by environment, energy quality, with the political and social dimensions having the least weight.

Moreover, the weighting score of the indicators with the highest value is acceptance of people towards electricity generation (0.117), followed by change in health status of local people (0.102), both of which are the social dimension indicators. The third highest score indicator is efficiency of pollution treatment technology (0.088). These results indicate that power development in Krabi must have minimal impact on the environment and local people and must be accepted by all sectors in the area [14]. The fourth highest score indicator is electricity price per unit (0.077), indicating that the price of electricity is important as the higher price can put a burden to business and all groups of the local people [15, 20]. On the other hand, the lowest score indicator is employment (0.028). This

Table 1. Dimensions, indicators and their references

Dimensions/ Indicators	**Definitions**	**References**
	Economic	
Employment	Increase in employment as a result of power development, including employment to carry out various activities in the power plant.	[10, 12, 20], experts' opinions and focus group discussions
Tourism	Potential changes in tourism business in the area, both positive and negative, caused by power development, especially number of entrepreneurs and income from tourism.	[14, 20], experts' opinions and focus group discussions
Tourism	Potential changes in tourism business in the area, both positive and negative, caused by power development, especially number of entrepreneurs and income from tourism.	[14, 20], experts' opinions and focus group discussions
Fishery	Potential changes in fishery, especially local fishery if different types of electric power generation are developed.	[20], experts' opinions and focus group discussions
Agriculture	Potential changes in agriculture caused by power development, which can be both positive and negative, such as changes in agricultural productivity, change in farmland.	Experts' opinions and focus group discussions
Revenue from selling raw materials/fuel	Increase in people's income as a result of power development especially income from sales of raw materials/fuels such as rubber wood, other biomass, and energy crops, etc.	[10, 13, 20, 21], experts' opinions and focus group discussions
Electricity price per unit	Price per unit of electricity generated by different technologies/fuels, including transmission and distribution costs, and other costs.	[15, 20], experts' opinions and focus group discussions
	Social	
Acceptance of people towards generation of electricity	People accept or oppose the power generation project in the area. This is mainly due to the level of confidence in the pollution control process and the expected benefit or negative impact on the area and their communities.	[14], experts' opinions and focus group discussions
Change in health status of local people	Changes in both positive and negative determinants of health from power generation, including availability and quality of medical services, environmental quality, risk of accident, etc.	[10-12, 22], experts' opinions and focus group discussions
	Environmental	
Water quality	Changes in surface water and coastal seawater quality due to power generation processes, with important parameters such as water temperature, dissolved oxygen content and heavy metal content, etc.	[10-12, 14, 22-24], experts' opinions and focus group discussions
Air quality	Amount of primary air pollution emissions, including sulfur dioxide (SO2), nitrogen oxides (NOx) and particulate matter smaller than 2.5 microns (PM2.5), which are generated and released into the atmosphere from power generation.	[10-12, 14, 22-24], experts' opinions and focus group discussions
Solid Waste	Solid wastes from the power generation process such as bottom ash, fly ash and the other wastes which can have negative impact on the environment and local people. In addition, the ability to manage or recycle such wastes are considered.	[10-12, 14, 22], experts' opinions and focus group discussions
Aquatic biodiversity	Changes in the abundance of larvae of important aquatic fauna caused by power generation activities and related activities such as fuel transportation, etc.	[10, 12, 14, 15, 24] and experts' opinions
Greenhouse gas emissions	Amount of greenhouse gas emissions from power generations calculated in the form of carbon dioxide equivalence.	[10, 12, 14, 15] and experts' opinions
	Energy/technology security	
Fuel/energy sufficiency	Availability of the amount of fuel/energy that can be used to generate electricity to meet the electricity demand with the continuous stability of power generation.	[10, 15], experts' opinions and focus group discussions
Power distribution ability	Ability of power generation technologies to provide electrical power to meet the demand of various sectors in terms of quantity and quality without problems of power supply interruption, power outages, etc.,	[10, 15], experts' opinions and focus group discussions
Efficiency of pollution treatment technology	Efficiency of technology for treatment of pollution from power generation, such as air pollution, water pollution and waste, etc.	[10, 15], experts' opinions and focus group discussions

Table 2. Weights of dimensions and indicators

Indicators	supporting	opposing	experts	Total*	Adjusted**	Ranking
Economic (0.276)						
Employment	0.042	0.010	0.050	0.102	0.028	15
Tourism	0.025	0.044	0.061	0.130	0.036	14
Fishery	0.025	0.049	0.057	0.131	0.036	14
Agriculture	0.029	0.082	0.054	0.165	0.045	11
Revenue from selling raw materials/fuel	0.041	0.111	0.043	0.195	0.054	10
Electricity price per unit	0.171	0.038	0.069	0.278	0.077	4
Social (0.221)						
Acceptance of people towards generation of electricity	0.180	0.155	0.192	0.528	0.117	1
Change in health status of local people	0.153	0.178	0.142	0.472	0.104	2
Environmental (0.331)						
Water quality	0.081	0.069	0.060	0.210	0.070	7
Air quality	0.085	0.063	0.081	0.228	0.076	5
Solid Waste	0.070	0.058	0.050	0.17	0.059	8
Aquatic biodiversity	0.063	0.080	0.074	0.218	0.071	6
Greenhouse gas emissions	0.034	0.062	0.070	0.167	0.055	9
Energy/technology security (0.172)						
Fuel/energy sufficiency	0.093	0.046	0.098	0.236	0.041	13
Power distribution ability	0.104	0.050	0.095	0.249	0.043	12
Efficiency of pollution treatment technology	0.137	0.237	0.142	0.515	0.088	3

* The sum of the weight for each indicator was divided by 3 as it gave equal importance to the 3 groups.
**Adjusted is the weight of each indicator multiplied by the dimension weight.

is likely because the stakeholders see that changes in employment are not solely the result of the development of electric power, but are the consequences of various economic activities such as tourism and other occupations in the area [16].

6. Conclusion and Recommendations

Key findings of this study are the indicators that were accepted by all stakeholders and can be used for the SEA study of electric power development program of Krabi Province. In addition, they could be applied in relevant energy development studies or the other SEA studies. However, as the other studies certainly have different context, the indicators should be modified to be consistent with their study objectives and arising issues. Moreover, the most important step in development of the indicators is public participation. Hence, any SEA studies that expect to obtain appropriate and acceptable indicators must pay the highest attention in stakeholder analysis and involvement of the stakeholders throughout the process to ensure acceptable results.

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Autonomous Oxygenation System on Buoyancy for Aquaculture Ponds with Low Energy Consumption and Non-Mechanical Drives Unit

Boonthong Wasuri[1]* Adisorn Kaewpukdee[2]

[1]Department of Industrial Arts, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Thailand
[2]Department of Electrical Engineering, Faculty of Science and Technology, Nakhon Pathom Rajabhat University, Thailand

Abstract

Aerating the pond by converting electrical energy into mechanical energy to mix air with water to produce dissolved oxygen (DO) is high electricity consumption, which is considered low efficiency compared to adding pure oxygen to the water of similar energy consumption. The idea proposed is to produce pure oxygen with solar energy to aerate the pond water efficiently. This can solve problems for farmers by reducing the mortality rate of aquatic animals and increasing productivity. An automatic oxygen-filling system on a buoy, therefore, is built in this research. Moreover, the performance of an automated oxygenation system on a buoyancy system for a low-energy aquaculture pond without mechanical propulsion for aerating was determined. This article discusses the construction of a floating buoy driven by solar energy and pure oxygen gas generating equipment. The system of automation control, processing and sensors, and data transmission with the server of the system is designed based on available technology. The result of research and local knowledge showed that the developed system can create a technique for producing oxygen gas sufficiently to supply water sources. It is a way to directly add 100% pure oxygen to water, which is more than the traditional method that adds only 21% pure oxygen. This system also focuses on low-cost development, at least lower than the market price, including in engineering, so that it is affordable by aqua farmers.

Keywords: oxygen generator; buoyance; aquaculture ponds; dissolved oxygen
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1. Introduction

Aquaculture has expanded widely due to market demand, and Thailand has high aquaculture potential. In 2015, freshwater animals produced in fisheries are up to 435,765 tons of aquatic animals with 25,469.5 million Baht [1]. It can be seen that the amount of aquatic animal production produced in 2015 was less than in 2009 at 553,700 tons, which is caused by problems such as the environment, water quality problems from natural disasters, and epidemic problems. The major problem is water quality problems [2]-[5]. There are many factors affecting water quality problems. Nevertheless, the primary causal factor is that the oxygen content in the water is less than the standard set for each aquaculture species due to the current increase in aquaculture densities per pond size [2], which causes the dissolved oxygen content to decrease rapidly. Another issue is the energy consumption of dissolved oxygen, which is particularly problematic in locations where power is not yet available. Aquaculture growers have been obliged to use generators to generate power to aerate oxygen to the water. They employ a propeller-type aeration device, which is popular in aquaculture ponds but consumes much electricity to raise the dissolved oxygen in the pond because of the need to increase the number of impeller sets to enhance the oxygen content. Consequently, Figure 1 shows that farmers must pay more to produce aquatic animals.

Based on a study of the literature on aeration systems in aquaculture conducted by researchers. Solar energy has been discovered to be a viable energy source for aeration into the water in various ways [3]. Furthermore, the generation of hydrogen gas and oxygen from water is being investigated [4], [5], as the development of water quality management systems in ponds offers information or alerts farmers, and decreases losses or regulates water quality to maintain continuous quality [6]-[8].

However, in terms of water aeration efficiency or quality, the method of oxygenation using pure oxygen from liquid oxygen tanks was tested [9-10]. In

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

Figure 1: The propeller aerators are commonly used in aquaculture ponds.

addition, automated oxygen monitoring and management systems for high-density marine fish farms are being developed. The device can accurately monitor the dissolved oxygen concentration of ponds and water treatment ponds, and it may show reports and graphics, as well as record data and alarms. The technology may also automatically boost the quantity of dissolved oxygen by instructing the oxygen machine and solenoid valve to provide pure oxygen at the specified time [9]. In only 5 minutes, the artificial oxygen mixer had the greatest oxygen diffusion rate of 4.93 kgO2/hr. Under seawater standard circumstances, dissolved oxygen can be raised from 0.00 mg/l to saturation with a minimal wastage rate of 9.81 percent when utilized with pure oxygen gas. Consequently, in an emergency, oxygen mixers may be utilized in combination with pure oxygen. In terms of adding oxygen to improve water quality, it was discovered that the oxygen aeration pump had a maximum efficiency of 0.06 kgO2/kw.hr owing to the lowest energy usage.

In the next section, the concept of the autonomous oxygenation system on buoyancy for aquaculture ponds with low energy consumption and non-mechanical drives unit is explained as the methodology and theory for building the prototype. Section 3 shows innovation buoyancy for aquaculture ponds prototype in the lab, and section 4 describes the experimental results when using the prototype on the farm. Finally, the conclusion is discussed in section 5.

2. Methodology and Theory

The amount of oxygen in aquaculture must always be controlled to maintain good quality which is a factor in the growth of aquatic animals. The low amount of oxygen in the water causes less oxygen to breathe in the water, and it also impairs the growth of the aquatic animal or weakens it, and eventually dies. This section will describe the modeling of buoyancy for aquaculture ponds. The concept consisted of the solar cell panel as an energy source, power control unit, and battery charge. The oxygenation equipment and oxygen measuring device were created. Also, the processing and control unit and the device for data communication system were built.

2.1. Buoyancy and stability

Buoyant Force (FB) is the lose weight of object on the liquid equalization to the liquid weight the same as the object floated volume. For the forces at work in buoyancy, the object floats at rest because the upward force of buoyancy is equal to the downward force of gravity [10]-[14]. The buoyant force is given in the equation (1).

$$\overrightarrow{F_B} = pVg \tag{1}$$

where $\overrightarrow{F_B}$ is buoyant force measured in Newton (N), p is density of the liquid measured in g/cm^3 or kg/m^3, V is the volume of the displaced body of liquid measured in m^3, and g is the gravitational acceleration. Therefore, the buoyant force is equal to the weight of the liquid when the volume of the liquid is equal to the volume of the object floated under the liquid. Object density is the proportion between the mass and volume of the object. It can give as the equation (2) [15]-[18].

$$p = \frac{m}{V} \tag{2}$$

m is the mass of object measured in gram *(g)* or kilogram *(kg)*. Then, we can design the buoyance for aquaculture ponds.

2.2. Energy and charger controller units

The electric producer is applied from the solar cell, which transduced the ultraviolet light to electrical energy. The electrical energy obtained is the direct current, measured in Watts (W). In the control units, there is the charge controller, an electric charge from the solar cell into the battery. However, the amount of electric charging is propitiated for saving the battery lifetime and supplying the electric current to the load. Therefore, when the battery is full, the charge controller stops or charges less. In other words, solar energy is controlled by the electric charge controller in case the battery is full. The energy is supplied to the system when there is no sunlight or at nighttime. The electrical supply from the solar system consists of the solar cell panel, battery, and solar charge controller.

1) The specification of solar cell panel can be calculated as the following. The processor and collector unit requires 5 Volts and 2 Amperes (10 Watts), the oxygen generator unit requires 12 Volts and 5 Amperes (60 Watts), and the control and oxygen supply units require 12 Volts and 1 Ampere (12 Watts). Consequently, the total power consumption is 82 Watts for 5 hours a day. Therefore, the solar cell panel is 82 Watts.

2) For the battery for collecting electric charge from the solar cell panel, Sealed Lead Acid (SLA) battery is used, which is cheaper than Deep Cycle (DC) battery. The battery requires 12 Volts and 70-ampere hours (Ah) or greater than, etc., 12 Volts 80 Ah and 12 Volts 100 Ah.

3) The electric charge controller controls the charge of electricity into the battery, thereby prolonging the battery's lifespan. The battery must be equal to or greater than the current (Amperes) flowing from the solar cell panel to the battery, so the specific charge controller should be larger than the current of the solar panel.

The technology of electrolysis oxygen generator is distinguished between water and gas by using the electrolysis method. It is the process of passing an external direct current (DC) current into the electrolyte solution through various metal plates. It conducts electricity through a solution and then causes a chemical reaction as shown in Fig. 2. The apparatus used to separate a solution with electricity is called an electrolyte cell or electrolytic cell. The main components of the system are the electrode, electrolyte solution container, and direct current generators such as batteries or solar cells, as shown in Fig. 2.

For oxygen concentrator design, 1) Electrode (anode and cathode) is stainless steel 316L, size 120x70 x 0.5 mm., total 8 pairs. 2) DC power supply uses electricity from the battery through the control system, size 12 Volts 80 Ah. 3) Electrolyte solution uses baking soda solution ($NaHCO_3$). The researchers applied electricity to the water to separate hydrogen and oxygen gas, which can be used to produce simple oxygen. The researchers developed a series of wet electrolysis, which is immersed in water and compounds to produce oxygen. Efficiency is improved by controlling the frequency voltage and continuing to supply electricity as shown in Fig.2.

2.3. Developed a sensor to measure the dissolved oxygen content in water

The dissolved oxygen sensor is divided into two groups. 1) Optical sensor is used to detect red light emitting from blue light emitting coated with an oxygen-enriched substance. 2) Electrochemical sensor uses the principle of detecting ions in a solution from electrochemical electrolysis. The researchers applied micro-current sensor technology to a polarographic DO sensor through a coupling and amplification circuit to measure the measurement process and the specified probe properties. This is in the process of further development, calibration, and performance of use for the future.

3. Innovation Buoyancy for Aquaculture Ponds

All developed systems were installed on buoys for preliminary testing. As shown in Fig. 3, the systems include the solar generation system, the oxygen generation system, and the sensor and control system.

The energy from the solar cells was tested through the charge controller from 8:00 a.m. to 5:00 p.m. Then the light intensity, charge voltage, charge current and electric power from the solar panel were collected. The test was repeated five times, and the results were analyzed by statistical data, as shown in Table 1. From Table 1, the system can charge energy from sunlight for about 8 hours, focusing on the use of open space (floating on the surface of the pond), which is sufficient to charge the battery for use after sunset or not enough light.

The use of an automated oxygenation system on the developed buoys was tested. Production of pure oxygen (O_2) was added to the aquaculture tank. Four-three-month-old Red Tilapia were taken to test and reared. Then, the concentration of pure oxygen (O_2)produced by the developed system was approximately 94.4 percent, measured with the Oxygen Analyzer model JAY-120. Table 2 shows that the designed oxygen generation system can produce oxygen for aquatic animals when used in the pond as well. The value of DO is within the standard that aquatic animals can survive when compared to a small pond that uses water circulation and a small jet system. It was found that in the experiment, the system can produce oxygen continuously for about 8-9 hours continuously. It is electrically charged during the day and at night using the power of a battery charged by a solar panel.

4. Experimental and Results

The eight low-power, non-mechanical-powered, buoyancy-based automated oxygenation systems for aquaculture ponds were built. The actual test was carried out in the animal pond at Nong Din Daeng Subdistrict, Mueang District, Nakhon Pathom Province, Thailand. The details of the construction of an automatic oxygen filling system on the developed buoys are presented below.

4.1. Implementation of the autonomous oxygenation system on buoyancy for aquaculture ponds

The 8 buoy systems are set up at the point that needs to add oxygen within the culture pond. Next, the water quality standards such as pH, salinity, and dissolved oxygen in water were measured before the introduction of the developed oxygen filling system. When the

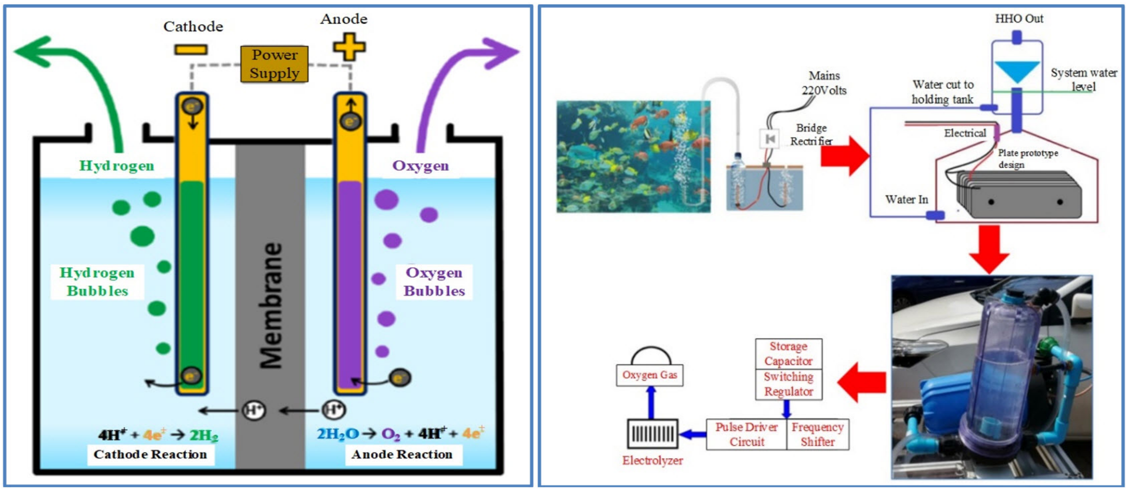

Figure 2: Principle of separation of gas from water by electrolysis method [11].

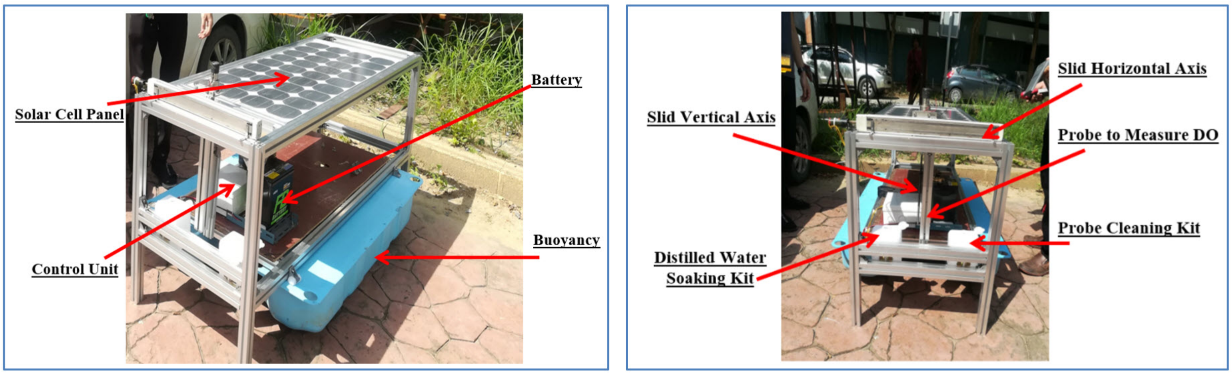

Figure 3: Solar power generation and oxygen generation system on a prototype buoy.

Table 1. Solar cell battery charge test results.

Time Period	Number of Test	Mean of Test Charging the Power from Solar Cell			
		Light intensity	Voltage charging	Current charging	The Power from Solar
	(Time)	(lux)	(Volt)	(Ampere)	Cell Panel (Watt)
8.00 am.	5	16220	12.5	0.6	7.50
9.00am.	5	23870	12.7	0.7	8.89
10.00am.	5	43650	12.8	0.9	11.52
11.00am.	5	76490	13.0	1.02	13.26
12.00am.	5	98035	13.7	1.05	14.39
13.00pm.	5	93750	13.5	1.07	14.15
14.00pm.	5	86180	13.1	0.95	12.45
15.00pm.	5	5690	13.1	0.75	9.83
16.00pm.	5	3990	12.7	0.72	9.14
17.00pm.	5	1130	12.4	0.61	7.56

system was activated, the dissolved oxygen measurement test was performed every 1 hour, starting from 8:00 AM to 7:00 PM. The tests were repeated five times and the measured values were averaged.

From Table 3, the study found that the system can supply oxygen to the 168 cubic meter pond. By estimating that one set of buoys can produce approximately of 394.45 oxygen (mg-O2/kg/h). It can produce oxygen for 400 fish at 500g size. The value of oxygen in water (DO) was approximately not less than 5 mg/l throughout the experiment. The system can measure water quality and transmit data to the server system at any time. The oxygen supply can be controlled manually (Manual) or automatically via wireless communication/via Web application, including charging and supplying power. It can supply oxygen to the water at about 390 mgO2/kg/h. Additionally, the system is able to alert the maintenance via an audit file through the visual display device and test the functionality via the Internet or web application.

Table 2. Comparison of two aerations dissolved oxygen before-after.

Time Measurement (minute)	Number of Test (time)	Mean of Air Temperature (Celsius)	Mean of Water Temperature (Celsius)	Amount of Dissolved Oxygen (DO) (mg/l)			
				Electrolysis oxygen generator method		PSA Concentration oxygen generator method	
				Before	After	Before	After
10	5	34.3	32.2	5.40	6.40	5.56	6.28
20	5	34.3	32.2	5.40	6.45	5.56	6.35
30	5	34.2	32.3	5.40	6.59	5.56	6.39
40	5	34.1	31.2	5.40	6.83	5.56	6.54
50	5	34.1	31.3	5.40	6.94	5.56	6.68
60	5	34.0	31.2	5.40	7.06	5.56	6.87
70	5	33.2	30.5	5.40	7.18	5.56	7.03
80	5	33.2	30.3	5.40	7.30	5.56	7.09
90	5	33.3	30.1	5.40	7.43	5.56	7.11
100	5	33.2	30.0	5.40	7.46	5.56	7.20
110	5	32.3	30.3	5.40	7.55	5.56	7.26
120	5	32.2	30.2	5.40	7.59	5.56	7.30

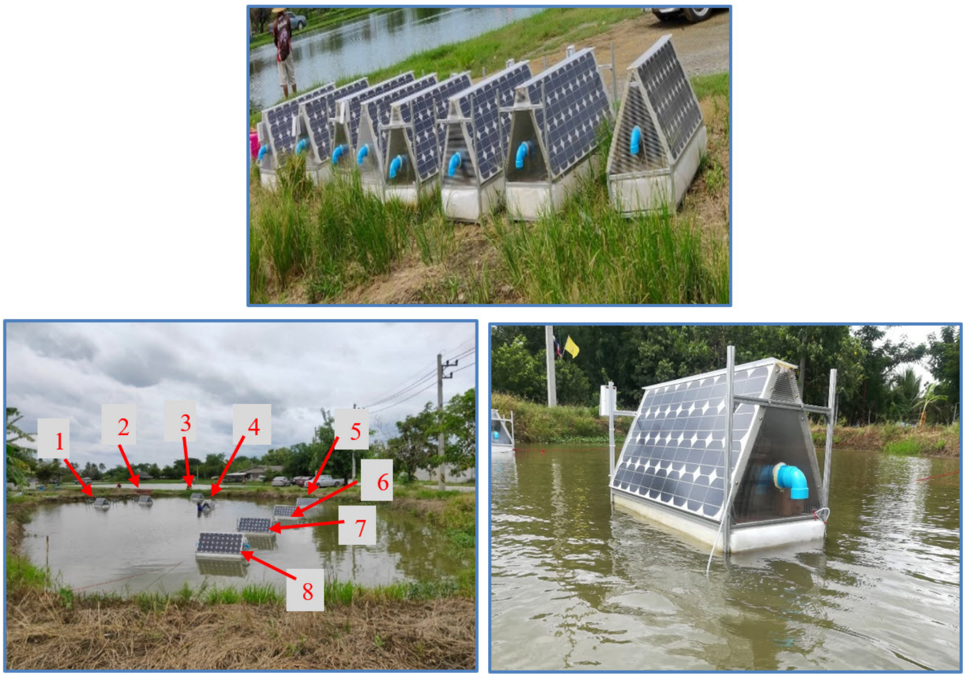

Figure 4: The implementation of autonomous oxygen generation on buoyancy for aquaculture ponds

Table 3. The results of testing the implementation of the automated oxygen filling system on the developed buoys.

Buoyancy Item	Mean of Air Temperature (Celsius)	Mean of Water Temperature (Celsius)	Amount of Dissolved Oxygen (DO) (mg/l)	
			Before	After
1	33.89	32.56	4.21	5.09
2	33.76	32.44	4.21	5.13
3	33.89	32.56	4.35	5.13
4	33.89	32.56	4.21	5.13
5	33.89	32.56	4.54	5.15
6	33.89	32.56	4.34	5.07
7	33.89	32.56	4.41	5.12
8	33.76	32.44	4.49	5.14

4.2. *Cost and saving for farmers*

Analysis and evaluation of engineering economics from the buoyancy oxygen filling system consisted of 1) electric power generation and distribution system 120 watts (12 V,50 Ah), costing 10,000 baht, 2) oxygen production system not less than 1.25 LPM, electric power, costing 10,000 baht, 3) Water Oxygen Monitoring (DO) system, costing about 10,000 baht, 4) control system and data transmission, costing about 5,000 baht, and 5) floating frame and other accessories, costing about 5,000 baht. Finally, the price of the developed system is about 40,000 baht per set. It can continuously produce at least 90% pure oxygen gas at least 180 liters per hour or at least 900 liters per day, from 5 working hours.The designed and developed buoyancy oxygenation system can produce approximately 180,000 liters of oxygen per year (based on 200 working days per year). Oxygen transfer efficiency (SOTR) is not lower than 0.020 kg oxygen per hour, which can estimate the cost of operating the break-even point payback period and net present value (NPV) as follows: 1) estimated operating expenses is equal to 106,800.00 baht per year, 2) break-even point is to produce 1,702.00 kg per year, and 3) payback period is 0.925 years or approximately 11 months. Finally, the net present value (NPV) is 43,200.00 baht.

5. Conclusion

This research and development is a design of buoyancy with its power source. It is an oxygen production device, the control system, processing, and sensors with solar energy. Pure oxygen gas is generated and information is sent and received by working with the server of the designed system. This research focuses on techniques for producing sufficient oxygen for supplying to water sources according to the scope of technology and energy available. It is controlled by a microcontroller or computer system automatically. The design is low-cost research and development which all components used are domestic materials with the price lower than the market price or based on appropriate technology, which uses various knowledge to design an engineering system for agriculture to be practical in the field.

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Monitoring and Evaluation of Hydraulic Off-Takes Sensitivity in Left Main Canal Scheme in Chiang Rai Province

Pattana Kayachai[1*], Sayam Aroonsrimorakot[1], and Chanchai Sangchyoswat[1]

[1]**Center for Agricultural Resource System Research, Chiang Mai University, Chiang Mai 50200, Thailand**
[2]**Department of Sociology, Imphal College, Manipur State, India**

Abstract

The study aims at monitoring and evaluation the sensitivity of hydraulic off-takes and improving implementation program of selected hydraulic off-take in the Left Main Canal scheme (LMC scheme) to help manage the Mae Lao irrigation scheme (MLIS), Chiang Rai province in the dry season. Water scarcity is always a serious problem in the dry season due to over cultivated area, investigating irrigation water supply along the main canal level in terms of equity of water distribution is necessary to the monitoring and evaluation. 13 selected hydraulic off-takes structures along the LMC are measured by the off-take sensitivity indicator for identifying low, medium and high values of off-takes sensitivity. All results found that the upstream-end section has low sensitivity values (less than 1), while the middle and downstream-end sections have high sensitivity values (greater than 2). According to these study results, the recommendation for implementation program of selected off-takes along to the LMC are such that 1. For the low off-take sensitivity values covers the upstream-end section only require intermittent gate adjustments 2. For the medium off-take sensitivity values includes some parts of the upstream-end only require moderate adjustment and frequency maintenance program 3. While the high sensitivity, including almost all structures located from the middle to the downstream-end section, would require frequent adjustments, calibrations, and maintenance program before the beginning of wet and dry seasons.

Keywords: Off-takes sensitivity; Monitoring and Evaluation; Irrigation scheduling

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1. Introduction

The Left Main Canal scheme (LMC scheme) is one sub irrigation district area, under the Mae Lao Irrigation Scheme (MLIS). The LMC scheme supply irrigation water for the 1,920 ha of paddy (rice growing) area in the dry season. Over-cultivation and poor performance of hydraulic structures [15] lead to extreme water scarcity during dry season. Over cultivation necessitates more irrigation supply; while poor performance of hydraulic structures adversely affects water distribution equity, particularly, from main canal level to secondary canal level. Therefore, monitoring and evaluation of hydraulic off-take sensitivity during the dry season (March to the end of April) is fundamental to improve cost-effectiveness of ensuring water distribution equity along the main canal level.

Hydraulic off-take sensitivity is the approach to assess flow variation of hydraulic control structures for irrigation. This approach was developed by [4], [6] studied the sensitivity of hydraulic structures. By applying this approach at the canal level, and then [10] developed the concept of sensitivity for conveyance system levels in order to investigate the overall levels of the system and the effects of water perturbation for irrigation water distribution.

Sensitivity study of irrigation water conveyance covers all levels of conveyance system. MASSCOTE approach [7] was developed by FAO in year 2007 to investigate hydraulic off-takes sensitivity from subsystem of irrigation conveyance to overall conveyance system. Moreover, there have been many studies relevant to hydraulic sensitivity. For example, [5] studied hydraulic sensitivity indicators to assess canal operations at irrigation canal networks in Iran. [14] studied the influence of cross-regulator settings on off-takes through hydraulic structure sensitivities in the Doroodzan irrigation network in Iran. In Thailand, [8] studied the sensitivity of main hydraulic structures to monitor water distribution plans and operate hydraulic structures within irrigation canal networks managed by the Royal Irrigation Department (RID).The study

*Corresponding author; email: Pudd.Woody@gmail.com

has two main objectives : 1. to investigate the sensitivity of off-takes on the main canal level during dry season in the LMC scheme 2. to improve implementation program of hydraulic off-take structures on the main canal level.

1.1. Study Area

In the Figure 1., the LMC is one of four major sub-irrigation schemes under the MLIS, which is the large irrigation scheme in the northern of Thailand. The LMC scheme is located in Amphur Mae Lao, Chiang Rai province. It is one of two irrigation districts (the Right Main Canal scheme and the Left Main Canal scheme) belonging to the larger MILS scheme. Generally, the LMC scheme supplies irrigation water for rice paddies in the irrigation service area. The LMC scheme is divided into five irrigation zones. During the dry season, irrigation service area can supply irrigation water in Zone 2 (43 ha), Zone 3 (450 ha), Zone 4 (890 ha), and Zone 5 (537 ha) respectively.

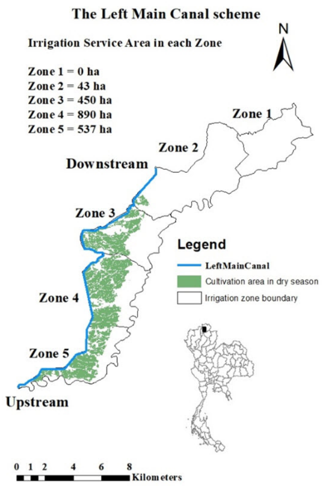

Figure 1: The Left Main Canal (LMC) scheme

1.2. Off-takes in the main canal system

In the LMC scheme, the main canal length is 24.7 km. 13 hydraulic from the total of 17 off-take structures were selected for this study. Selected hydraulic off-takes and all position along the leftside of main canal in each structure were shown in the Table 1.(*).

1.3. Irrigation scheduling

Generally, irrigation scheduling during dry season starts on January and finishes by May every year. The scheduling controls irrigation supply along with the main canal level by rotational flow pattern from zones 5 to zone 2. In Table 2., the scheduling starts from zone 5 (2 days), zone 4 (2 days), zone 3 (3 days) tozone 2 (3 days). In this study, selected days for measuring hydraulic off-take sensitivity started from 17^th March to 21^st April for 36 days.

1.4. Theory

1.4.1. Flow description of hydraulic off-takes

Concept of off-takes sensitivity was originally published by the FAO report no. 63 in year 2007 [3]. In the Figure 2., flowing description through hydraulic off-takes with different downstream conditions (free-flow or submerged conditions).

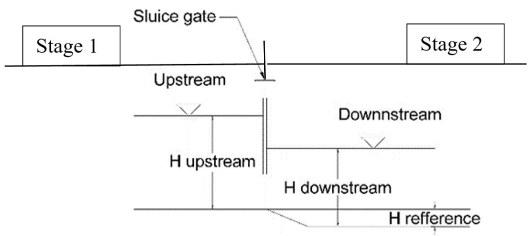

Figure 2: Flowing description through hydraulicoff-takes with different downstream

According to Figure 2., general governing equations of flow through hydraulic off-takes are:

$$q = aA\,(H_{us} - H_{ds})^{\alpha} \quad \text{(Stage 1)} \qquad (1)$$

$$q = a'b\left(H_{ds} - H_{ref}\right)^{\beta} \quad \text{(Stage 2)} \qquad (2)$$

Where, A is flow section parameter through the structure (A is area through the orifice for an undershot flow, and A is the crest length for an overshot flow);a is discharge coefficient equal to $c(2g)^{0.5}$;c is flow coefficient function of the shape of the flow (c 0.5 for an orifice);a' and b are hydraulic parameters of the stage 2;a, b are exponent equal to 1/2 for undershot flow, to 3/2 for overshot, and about to 1.6 for normal flow;H_{us} is water level upstream of the structure;H_{ds} is water level downstream of the structure;H_{ref} is areference level depending on the downstream flow conditions;q is discharge through the structure.

H_{ref} is a constant reference level taken at: (1) the crest level of the weir where there is ameasurement weir; or (2) a reference level (bottom bed or a crest level) further downconditioning the flow at the structure. It is assumed that dH_{ref} equals 0.

1.4.2. Conditions of flow through hydraulic off-takes

Free-flow conditionsat the offtake, equation in stage 2 is irrelevant and itreduces to one equation as equation in stage 1. Then, Hds is taken either as the crest level of the weirin the case of overshot, or as the orifice axis in the case of undershot. Moreover, flow parameters characteristics (α and β) are affected by flow conditions in the Table 3.

Table 1. Weights of dimensions and indicators

Zone	Position(km + m)	Hydraulic structure
5	3+756	Off-take 1*
	5+023	Off-take 2*
	5+600	Off-take 3*
4	7+455	Off-take 3.1*
	8+123	Off-take 4*
	8+848	Off-take 5*
	9+862	Off-take 6*
	10+621	Off-take 7*
	11+672	Off-take 8*
	12+976	Off-take 9*
3	16+006	Off-take 10*
	17+468	Off-take 11*
	18+429	Off-take 11.1*

* Selected hydraulic structure off-takes for study

Table 2. Irrigation scheduling for the LMC scheme during the dry season (2020)

Month	Zone 5	Zone 4	Zone 3	Zone 2	Zone 1
March	**17,18**	**19,20**	**21,22,23**	**24,25,26**	**27,28,29**
	30,31				
April		**1,2**	**3,4,5**	**6,7,8**	**9,10,11**
	12,13	**14,15**	**16,17,18**	**19,20,21**	22,23,24

Bold numbers are selected days for study

2. Methodology

The methodology of study has been adapted from [1], which was developed as a tool to improve irrigation project by monitoring and evaluation. The procedure was summarized by steps as below.

1. *Identification target of hydraulic off-takes in the main canal level*, selected to study for 13 hydraulic off-take structures, was measured the water level at upstream and downstream in each structure (see in Table 1.).

2. *Setting objectives that two objectives of this study* (to investigate the sensitivity of off-takes on the main canal level during the dry season and to improve implementation program of hydraulic off-take structures in the study area) were set in the study through measurement of hydraulic off-takes sensitivity as the indicator.

3. *Defining hydraulic off-takes measurement* that the measurement of water depth (upstream and downstream) was measured by two operation gate staffs during selected time periods for 36 days (see in Table 2.).

4. *Analysis outputs* that two outputs (sensitivity of hydraulic off-takes and implemented program operation of hydraulic off-takes), was analyzed by the hydraulic off-takes sensitivity indicator and then all indicators were analyzed for searching low, medium and high sensitivity values in each structures along to the main canal for improving implementation program of hydraulic off-takes in the main canal level.

2.1. Data collection

To investigate the variation of irrigation supply of the main canal level in the dry season, data was collected during March to April (see in Table 2.) in year 2021and 13 hydraulic structures will be selected to measure the water at upstream and downstream in each structure at the LMC scheme. For investigation of characteristics of main canal level, semi-structure interview will be held on the office before the irrigation supply season began by irrigation staffs using a Participatory Rural Appraisal (PRA) technique [2].

2.2. Analysis

The analysis of this study consisted of two steps according to two study objectives. Off-takes sensitivity analysis and implementation program of hydraulic off-take structures analysis were analyzed through relevant information in data collection procedure.

2.2.1. Off-takes sensitivity analysis

The off-takes sensitivity is defined as a ratio of the relative variation of outputs (downstream water level) to the variation of the inputs (upstream water level) of controlled gate of water distribution. This is shown in equation (3).

$$Sensitivity = \frac{Variationofoutputs}{Variationofinputs} \tag{3}$$

The sensitivity of off-takes and the cross regulators are shown in equations (2) and (3).

$$Soff-take = \frac{Dq/q}{DH}\ (m^{-1}) \tag{4}$$

Where S off-take is the sensitivity of off-takes, Dq/q is the ratio of relative discharge of the hydraulic struc-

Table 3. Conditions of flow and reference to be considered in calculations

Specific conditions	HREF	Stage 2. equation	α	β
Undershot free flow	Orifice axis	Not needed	0.5	no
Overshot free flow	Crest level of the weir	Not need	1.5	no
Undershot submerged by a downstream measurement weir	H crest of the measurement weir	Need	0.5	1.5
Undershot submerged normal uniform flow	H bed bottom of the downstream canal section	Need	0.5	1.66

ture and DH is the water differential depth upstream and downstream (m).

In equation (5), head equivalent (HE) is developed to reduce the equation term(q. DH) in equation (4). It represents to the characteristics of flow condition (undershot or overshot flow) as shown in the Figure 2.It can be shown in the equation (5).

$$HE = (Hup - Hds)/[(\alpha/\beta)(Hds - Href)](m) \quad (5)$$

In this study, assumption of flow conditions is defined as the undershot free flow, so, the head equivalent (HE)is equal to different depth between H up and H ds due to irrelevant equation of stage 2 (is not consideration) in the Table3.

According to the equation (4), the term of differential equation (Dq/q) is represented by the exponential value as constant term ()of hydraulic off-takes and DH is represented by HE. So, the hydraulic off-takes sensitivity equation is newly developed in the equation (6).

$$Soff - take = \frac{\alpha}{HE}\,(m^{-1}) \quad (6)$$

The meaning of hydraulic off-takes sensitivity can be defined as follows: low sensitivity (less than 1), medium sensitivity (between 1 and 2), and high sensitivity values (over 2).

2.2.2. *Implementation program of hydraulic off-take structures analysis*

All sensitivity of hydraulic off-takes was mapped in the table for searching low, medium and high values of sensitivity index of each structure along the main canal of the study area.If any structures were high sensitivity values, it will be required to increase frequency of operation maintenance and calibration in the implementation programs, referred by the Thai Royal Irrigation Management manual[11], [12] and [13].

3. Results

3.1. *Hydraulic off-takes sensitivity in the main canal level*

Measurement of water level sites began fromzone 5 to zone 2 respectively. However, in real situation, the measurement could not be measured in zones 2 due to no irrigationwater supply in this zone. General characteristics of hydraulic control structures on the main canal level during measurement the water depth can be described that:

o Cross-regulators in the main canal are not fully opened or some structures are closed. Both overshot flows and submerged flow conditions can be occurred along in the canal. o The cross regulator and hydraulic off-takes on the secondary canal level were fully open.

An average hydraulic off-takes sensitivity on the main canal level was shown intheFigure 2.,It concluded that in the upstream-end section, the off-take sensitivity values of zone 5, from 3+756 km to 5+600 km, demonstrated low sensitivity values (less than 1), except for off-take 1, had a medium sensitivity value (1.14). Next, in the middle-end section, the off-takes sensitivity in zone 4 (7+455 km to 8+976 km) showed higher sensitivity values (over 2), except for off-take 4, had a medium sensitivity value (1 - 2). And the downstream-end section in Zone 3, 16+006 km to 18+429 km was a high sensitivity value.

For the weekly averages of off-takes sensitivities along the main canal level in the Table 4, zones 5 increased from weeks 1 to 3 and decreased from weeks 3 to 4., zone 4 slowly increased from week 1 to week 2, sharply increased in week 3, and then decreased form weeks 3 to week 4. And the sensitivity values for zone 3 increased from week 1 to week 2; however,both weeks 3 and 4 could not be measured due to no irrigation water supply in this area.

3.2. *Improving implementation program of hydraulic off-takes on the main canal level*

Final results of this during selected time period provided helpful information to improveimplementation program through operation and maintenance program in the main canal level of the study area. It can be described as below.

In the Table5., almost hydraulic off-take structures were generally high off-takes sensitivity (over 2). These structures had highly variation of irrigation supply, so adjustment, calibration, and maintenance programs of hydraulic control should be strictly monitored(more than 2 times per year).In this study, there are three groups of off-take structures of sensitivity values (low, medium, or high). Groups with low

Table 4. Average hydraulic off-takes sensitivity per week in the main canal system

Zone	Position	Hydraulic structure	Average sensitivity of off-take in each week(m^{-1})			
			Week 1 (March)	**Week 2 (April)**	**Week 3 (April)**	**Week 4 (April)**
5	3+756	Off-take 1	0.98±.02	1.06±.02	1.34±.05	1.17±.30
5	5+023	Off-take 2	0.71±.01	0.94±.06	0.83±.03	0.76±.05
5	5+600	Off-take 3	0.67±.07	0.65±.02	0.70±.06	0.49±.04
			Week 1 (March)	**Week 2 (April)**	**Week 3 (April)**	**Week 4 (April-May)**
4	7+455	Off-take 3.1	1.41±.06	1.67±.00	4.01±.16	1.55±.30
4	8+123	Off-take 4	1.30±.21	1.88±.21	1.93±.07	0.66±.12
4	8+848	Off-take 5	3.94±.61	3.33±.00	6.70±.45	2.56±1.61
4	9+862	Off-take 6	4.01±.16	3.75±.42	5.63±.63	3.84±0.71
4	10+621	Off-take 7	2.19±.19	6.25±2.08	1.97±.81	2.86±0.47
4	11+672	Off-take 8	3.35±.22	1.19±.19	1.66±.34	4.82±3.51
4	12+976	Off-take 9	3.06±.79	2.50±.00	1.34±.58	1.20±.47
			Week 1 (March)	**Week 2 (April)**	**Week 3 (April)**	
3	16+006	Off-take 10	3.30±1.14	2.15±.29	NA	
3	17+468	Off-take 11	3.69±.51	3.20±.96	NA	
3	18+429	Off-take 11.1	2.83±.04	4.79±1.73	NA	

Remark: the value less than 1 = low sensitivity, the value between 1 to 2 = medium sensitivity
Remark: and the value more than 2 = high sensitivity, NA = Not available

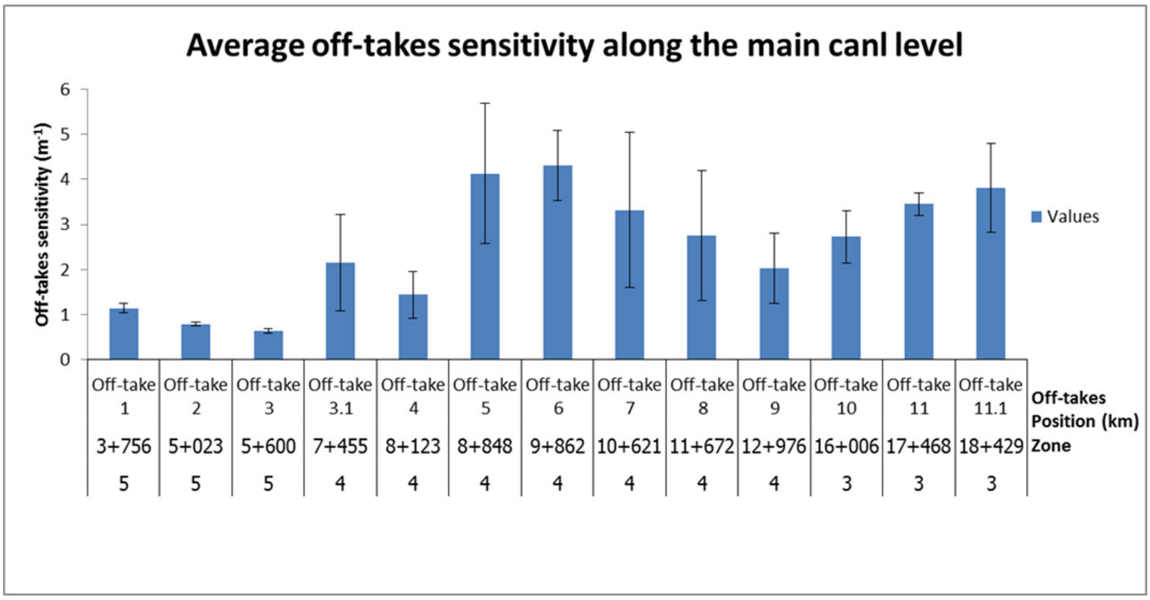

Figure 3: Average off-takes sensitivity along with main canal level.

off-take sensitivity (off-takes 2 and 3) should be required only low-frequency gate adjustments program (1 time per year), groups with medium off-take sensitivity should be requiredmoderate frequency adjustments and maintenance program(both wet and dry season starting). And the last group (high sensitivity) should be requiredmost frequent operation, adjustments, calibration, and maintenance program(more than 2 times per year).

The implementation procedure; operation, adjustment, calibrate and maintenance program are referenced by the RID manual.

4. Discussion and conclusion

4.1. Discussion

According to thesestudy objectives, to make improvements or modifications of irrigation supply management on the main canal level, relevant factors affect to achieve the goal of monitoring and evaluation in this study can be described as below.

o Experienced staff capable for measuring water levels and high-quality measurement tools is necessary to measure water level data accuracy because more accuracy data of H us and H ds needed to require a skillful for using staff gauge and read all water depth values.

o For the assumption of the study, the undershot free flow condition was chosen to considerate because two

Table 5. Improvements of implementation process on the main canal level

Off-take structures	Off-take sensitivity	Adjustment/ improvement of the implementation process
Off-takes 2 and 3	Low	Low frequency of adjustment(1 time per year)
Off-takes 1 and 4	Medium	Average frequency of adjustment and maintenance(both wet and dry season starting) maintenance(both wet and dry season starting)
Off-takes 3,3.1,5,6,7, 8, 9, 10, 11 and 11.1	High	Most frequent adjustments, operation, calibration, and maintenance(more than 2 times per year)

major reasons that (1) reduction a complexed equation in flow condition (stage 2.) in order to simplified to get water depth information and (2) smoothly flow of water in the main canal during the most water scarcity period in the dry season. So, the flow assumption will be a concept according to [10].

o Although, the irrigation scheduling was set by the rotational flow, started from zone 5 (2 days), zone 4 (2 days), zone 3 (3 days) tozone 2 (3 days), in the real situation of irrigation supply, it was a continuous flow (not a rotational flow). The irrigation scheduling cannot control to supply irrigation water from zone 5 to zone 2 because the water user group of upstream-end section open hydraulic off-takes. So, the water user groups among middle and downstream- end section were not enough received the irrigation supply. This why the reason that almost hydraulic off-takes (middle and downstream- end sections) were high off-take sensitivity because these areas had low water depth level in each hydraulic off-takes. So, almost flow condition in these sections were not undershot flow condition, this cause affected to variation of sensitivity of off-takes.

o Operation and maintenance program including, monitoring the water level and calibrating of hydraulic infrastructures, i.e., off-takes, cross-regulator on the main canal level should be implemented appropriately according to RID manuals. All of actions should be strongly support relevant equipment, people and budget by the irrigation management budget (by the RID and by the local irrigation budget) according to the participatory irrigation management concept, have been promoted by the RID.

o The water user group necessary to join the monitoring waterlevel in the main canal level. Two main reasons of importance of water user groups were (1) strength of water user groups through the strict rule of water usage for control to open and close all off-takes along to the LMC needed to handle a tailed-end problem in irrigation supply topic and (2) participatory irrigation management from hydraulic off-takes network distribution to field irrigation distribution needed to operate and maintenance by them according to the participatory irrigation management concept because only government sector could not possibly to operate and maintain all irrigation network distribution in the LMC scheme.

4.2. Conclusion

Study results point to conclusion that almost all hydraulic sensitivity in upstream-end section show slow sensitivity values (less than 1), the middle and downstream end sections show high sensitivity values (over than 2). And for the implementation program of hydraulic off-takes on the main canal level, the recommendation focuses on frequency of calibration, operation and maintenance program of these structures that the low off-take sensitivity (off-takes 2 and 3), is on the upstream- end section, only required low-frequency adjustments, the groups of medium off-take sensitivity, including some parts of the upstream- end section, require moderate frequency adjustments and maintenance. While most of the high sensitivity structures located from the middle to the downstream- end of the canal, require frequent adjustments, operation, calibration, and maintenance program.

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Correlation of Biosocial Factors and Health Literacy with Competency of Older Adults on Management and Health Promotion for Older Adults in Urban Communities, Bangkok Metropolis

Benyapa Muksiritipanun[1], Theerapon Phungdee[2*], Duangrat Kaveenuntachai[1], and Khemika Rojtangkom [3]

[1]**Kuakarun Faculty of Nursing, Navamindradhiraj University, Dusit, Bangkok, Thailand 10300**
[2]**Faculty Education, Kasetsart University Bang, Khen, Bangkok, Thailand 10903**
[3]**Faculty Nursing and Health, Suan Sunandha Rajabhat University, Dusit, Bangkok, 10300 Thailand**

Abstract

This cross-sectional descriptive-correlational design aimed to examine correlation of biosocial factors and health literacy with competency of older adults on management and health promotion for older adults in urban communities, Bangkok Metropolis. The sample group consisted of older adults in urban communities in Bangkok Metropolis and recruited with stratified random sampling by the population ratio of older adults in each community with a total of 196 participants. Research instruments were employed for data collection, including a demographic questionnaire, a self-administered questionnaire of health literacy questionnaire, and self-administered questionnaire of the competency of older adults. Data were analyzed by descriptive statistics and Pearson's correlation coefficient.

The findings revealed that an education level factor and a chronic disease factor were correlated with the low level of competency for the overall management and health promotion (r =.273,p < 0.001; r =.226,p <0.001, respectively) with a statistical significance level of .01. Moreover, the health literacy factor, including the access to the health information and service, the knowledge and understanding of the health of older adults, the health information communication of older adults, the ability to choose the appropriate guidelines, and the appropriate health management correlated with the competency on overall management and health promotion (r = .456,p <0.001; r = .632,p <0.001; r = .587,p <0.001; r = .576,p <0.001; r = .620,p <0.001; r = .425,p <0.001, respectively) with a statistical significance level of .01.

In conclusion, the biosocial factors, namely the education level factor, the chronic disease factor, and the health literacy factor, correlated with the competency of older adults for management and health promotion.

Biosocial factors and health literacy in correlation with the competency of older adults on management and health promotion for older adults will be brought into effective programs for the health promotion in older adults in urban communities.

Keywords: biosocial factors; health literacy; competency for management and health promotion; older adults

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1. Introduction

Nowadays, the society of the aging population shows the trend to be extending and appears to be two times more population than the children population. At the same time, the proportion of the working-age population begins to decrease. In 2021, while the aging population in Thailand was counted to be 16.73% of the country's population, it was found to be 18.78% of the population in Bangkok and the largest aging population in the country. (1) Furthermore, the health problems of older adults in Bangkok urban communities are very complex and more than 80% of older adults reported having chronic diseases. The most-found diseases included hyperlipidemia, hypertension, and diabetes which were reported by 83%, 76%, and 53% of older adults, respectively. (2) This group of diseases has led to more death than the other group and is caused by consuming sweet, greasy, and salty food, packaged food, fast food, processed food, and the behavior of adding fish sauce, sugar, and salt into food. These inappropriate consumption behaviors provoke various diseases in older adults. Moreover, 10% of older adults in Bangkok urban communities are bedridden patients (2) and most of them have physi-

*Corresponding author; email: theerapon.phu@ku.ac.th

cal health problems, including the need for multiple medicines in each meal, urinary incontinence, and insomnia. These older adults need more assistance from families, communities, and healthcare teams for daily needs, physical rehabilitation, and long-term support from the people in the communities with the will to assist. (3)

The development of the competency of older adults in management and health promotion is significant as a proactive healthcare service approach of the Ministry of Public Health. (4) This approach enhances the academic knowledge, attitude, and skills of the village health volunteers to fully assist the healthcare service for the older adults in the communities with the associated network of community health. (5) Previous studies illustrated that health promotion knowledge was essential for the competency of health care in older adults. There were the skills and ability to access the knowledge, the knowledge and understanding for performance analysis, the older adult health management, the ability to guide in healthcare, the promotion of older adult health management, and the ability to promote healthcare for older adult patients. (6)

The majority of studies on the health literacy of older adults in Bangkok were survey studies and qualitative research about the keys to building health literacy for individuals. The results of those studies showed that most older adults possessed the health literacy level of a fair and poor, while the keys to building health literacy are to help them access, understand, assess, and apply the health knowledge for better health of self and others. (7) However, little is known about the factors that influence older adults' competency in management and health promotion, which are necessary for health knowledge promotion to support older adult patients in the communities. Thus, this statement of problems exposes the need to explore the biosocial factors and health literacy correlated with the competency of older adults for management and health promotion for older adults. These factors demonstrated correlation on health promotion for older adults.

Objective This study aimed to examine the correlation between biosocial factors (sex, age, education level, and chronic disease), health literacy, and the competency of older adults on management and health promotion for older adults in urban communities, Bangkok Metropolitan.

Hypotheses 1. Biosocial factors (sex, age, education level, and chronic disease) are correlated with older adults' competency for management and health promotion for older adults in urban communities, Bangkok Metropolitan.

2. Health literacy is correlated with the competency of older adults on management and health promotion for older adults in urban communities, Bangkok Metropolitan.

2. Conceptual Framework

3. Methodology

The conceptual framework is derived from the concept of health literacy. This concept believes that the ability to access health information, services, knowledge and understanding for self-analysis, self-assessment, and self-management would affect health management and promotion.

A cross-sectional descriptive correlational design was utilized.

Population and Sample Group

The target population for the current study was 1,014 older adults from 10 Bangkok urban communities. These sampling communities were around Navamindradhiraj University and featured similar lifestyle and urban community characteristics.

Sample size was calculated using Cochran's formula with a reliability level of 95% and an acceptable error of 0.5%. comes from the percentage of older adults with poor health literacy. (8)

The estimated sample size was 196 with stratified random sampling using the ratio of older adults in each community. Then, simple random sampling would be with the list of older adults in each community with the acceptable characteristics according to the criteria.

Instruments

The research instruments consisted of 4 items about personal information, 30 items for health literacy questionnaire, and 50 items for older adult competency questionnaire. There are three levels of scores for each item: poor, fair, and good.

Instrument Validation Test

The research instruments were tested for the content validity by five experts. The health literacy assessment and the older adult competency assessment were evaluated for the content validity index (CVI) with score 0.86 and 0.88, respectively. The reliability using Cronbach's alpha coefficient analysis with reliability level of .87 and .88, respectively.

Human Subjects Protection

The ethical approval to implement the study was gained from the Central Research Ethics Committee (CREC) in Thailand, no. COA-CREC083/2021. The researchers had declared the study's objective, the right to refuse to answer, the right to withdraw from the study, that their personal information would be kept private, and the raw data would be immediately terminated after the study finished. After that, the consent forms were signed. The pilot study was conducted using 30 participants who met the inclusion criteria, and this number was not included in the final sample size.

Data Collection 1. Requesting the official letter from the Dean of Kuakarun Faculty of Nursing, Navamindradhiraj University, to be sent to the Minister of the Ministry of Public Health, Bangkok, to explain the

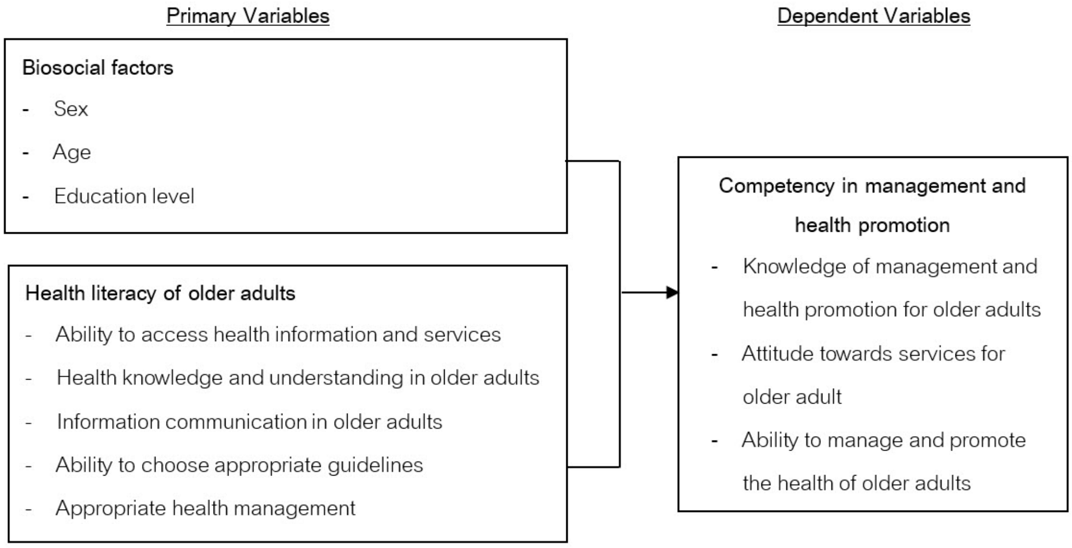

Figure 1: Conceptual Framework

objective of the study and ask for permission to gather the data.

2. Meeting with the sampling group and asking for their cooperation.

3. Gathering and validating the data and asking the participants to complete the self-administered questionnaire when needed.

The data collection was undertaken between December and January 2022.

Data Analysis

1. Conducting a descriptive analysis using a software package to gain frequency, mean, percentage, and standard deviation.

2. Analyzing the biosocial factors and the health literacy correlating the competency of older adults for management and health promotion in older adults using Pearson correlation.

4. Results

The sample consisted of 196 older adults with 29.6% male and 70.4% female. The majority of the participants were between 60 – 69 years old (66.84%) with an average age of 67.98 years (S.D. = 6.37). Most participants informed that their highest level of education was an elementary school certificate (49%) and a high school/vocational certificate (57.1%). Most reported chronic diseases covered hypertension (57.1%), hyperlipidemia (37.2%), and diabetes (26%).

The health literacy level analysis showed that most participants acquired overall fair health literacy level (66.84%). When investigating each factor, most health literacy scores were found to be at a fair level, including the ability to access health information and services (48.98%), health knowledge and understanding in older adults (51.02%), the ability to choose appropriate guidelines (51.53%), the appropriate health management (47.45%), and the health media literacy (53.57%). However, information communication in older adults was revealed to be at a fair and good level (40.30%). Moreover, the analysis of the competency of older adults in management and health promotion showed that the majority of the participants earned a good level of older adult health knowledge and promotion (65.82%). While an attitude towards older adult services reported a fair level of literacy (76.53%), the ability to manage and promote the health of older adults also signified a fair level (62.75%), as showed in Table 1.

In Table 2, the correlation analysis emphasized on the fact that the biosocial factors and the chronic disease factor correlated with the competency of older adults on management and health promotion for older adults (r = .280,p <0.001; r = .209, p = .003, respectively) and the overall management and health promotion (r = .273,p <0.001; r = .226,p <0.001, respectively) with a statistical significance level of .01. In terms of the health literacy and the competency of older adults, it found that the ability to access health information and services and health knowledge and understanding in older adults correlated with the competency in the attitude towards older adult services (r = .144,p <0.001; r = .207,p <0.001), the ability to manage and promote the health of older adults (r = .480,p <0.001; r = .615,p <0.001), and the competency on overall management and health promotion (r = .456,p <0.001; r = .632,p <0.001) with a statistical significance level of .01. For the informative communication among older adults, the ability to choose appropriate guidelines, and the health media literacy correlated with the ability to manage and promote health (r = .603,p <0.001; r = .615,p <0.001; r = .186,p <0.001) and the competency on overall management and health promotion (r = .587,p <0.001;

r = .576, p <0.001; r = .425, p <0.001) with a statistical significance level of .01. Regarding the overall health literacy, the appropriate health management factor correlated with the older adult health knowledge and promotion (r = .172, p <0.001), the ability to manage and promote health (r = .465, p <0.001), and the competency on overall management and health promotion (r = .620, p <0.001) with a statistical significance level of 0.01.

5. Summary and Discussion

The biosocial factors in terms of education level and chronic diseases were correlated with the ability to manage and promote the health of older adults. The competency for overall management and health promotion indicated that education level implies the level of knowledge and skills, which are the factors affecting one's ability to manage and promote their health. This finding is in line with previous studies (9) that pointed out the correlation between education level and the ability of older adults to support themselves. Moreover, the correlation between the chronic disease factor and the competency of older adults was indicated. As seen by the fact that older adults with chronic diseases got a high score in terms of health literacy, especially what is related to those diseases, which in turns they are able to take care of themselves. (10)

The health literacy regarding access to health information and services hinted at correlation with the attitude towards services of older adults and the competency for the overall management and health promotion. A possible explanation is that utilizing own skills to choose sources of information, knowing to search for information on how to perform, and fact-checking yield a positive attitude and skills about management and health promotion. This result is also relevant to previous studies that access to health information by participating in social activities to gain access to health information with ease can assist older adults in helping themselves and others. (7, 11)

Moreover, the health literacy concerning health knowledge and understanding of older adults were correlated to the attitude towards services for older adults, an ability to manage and promote health, and the competency for the overall management and health promotion. Because of the knowledge and the correct understanding of the guidelines bring a good attitude and the ability to manage and promote the health of oneself and others. This finding confirms previous studies (12), which revealed that health knowledge and understanding correlated with improved health behavior in older adults.

The health literacy involving information communication of older adults showed a correlation with the ability to manage and promote health and the competency for management and health promotion since the ability to communicate, whether speaking, reading, writing, and persuading others to understand and accept the information about how to behave affect the ability to manage and promote health. (6, 11) Besides, it is in compliance with the previous studies which stated that the lack of healthy communication skills might lead to more mistakes in decision making about health. On the other hand, good health communication skills in older adults will facilitate managing and promoting health for oneself and others. (7, 13)

Health literacy is related to the ability to choose appropriate guidelines. It also correlated with the ability to manage and promote health and the competency for the overall management and health promotion. Older adults who read and understand health information may explore more knowledge and decide on the uses of appropriate resources of information to promote the health of oneself and others in the community. This result is aligned with the previous studies (11, 12), which indicated that the ability to choose the appropriate guidelines is correlated to the self-care behavior of older adults.

In addition, health literacy in connection with the appropriate health management was shown to be correlated with the knowledge of health management and promotion, the ability to manage and promote health, and the competency on overall management and health promotion. As a result of having the ability to set a goal, plan, perform accordingly, act on the ways to perform in the right track, older adults also need the knowledge to act accordingly for effective management and appropriate health promotion. (7, 11)

For the health literacy regarding the health media literacy, the correlation between the ability to manage and promote health and the competency for the overall management and health promotion were seen by the ability to fact-check the sources of information and the ability to compare the ways of communication to avoid the risks on health of oneself and others. Furthermore, a media assessment facilitates the direction to older adults' competency management and health promotion. (6) This is in line with the previous studies pinpointing that health information assessment conducted by actively searching for information, understanding it thoroughly, and exchanging it improves the ability to help oneself and others. (7)

In conclusion, the results showed that educational level, chronic disease, and health literacy significantly correlated with the competency for management and health promotion among older adults in urban communities.

Suggestions The suggestions from the results of the study were as follows:

1. This study showed that most older adults reported a fair overall health literacy level. Therefore, it is suggested to support the improvement of older adults' overall health literacy level by developing programs for health literacy promotion for older adults.

Table 1. Number and percentage of samples divided by health literacy level and the competency for management and health promotion of older adults (n=196)

Viable	Level					
	Good		Fair		Poor	
	No.	%	No.	%	No.	%
Health literacy						
Ability to access health information and services	43	21.94	96	48.98	57	29.08
Health knowledge and understanding in older adults	66	33.67	100	51.02	30	15.31
Information communication in older adults	79	40.30	79	40.30	38	19.40
Ability to choose appropriate guidelines	49	25	101	51.53	46	23.47
Appropriate health management	44	22.45	93	47.45	59	30.10
Health media literacy	64	32.65	105	53.57	27	13.78
Overall health literacy	18	9.18	131	66.84	47	23.98
Competency for management and health promotion						
Knowledge of management and health promotion for older adults	129	65.82	56	28.57	11	5.61
Attitude towards service for older adult	46	23.47	150	76.53	0	0
Ability to manage and promote the health of older adults	28	14.29	123	62.75	45	22.96
Overall competency for management and health promotion	49	25.0	144	73.5	3	1.50

Table 2. Biosocial factors and health literacy affecting the competency of older adults on management and health promotion for older adults in urban communities, Bangkok Metropolitan (n=196)

Biosocial factors and health literacy	The competency of older adults on management and health promotion for older adults			
	Knowledge of management and health promotion for older adults	Attitude toward services for older adult	Ability to manage and promote the health	Overall competency for management and health promotion
Biosocial factors				
1. Sex	0.006	0.015	0.002	.007
2. Age	0.074	0.038	-0.022	.003
3. Education level	-0.062	0.099	0.280*	.273*
4. Chronic disease	0.069	0.086	0.209*	.226*
Health literacy				
1. Ability to access health information and service	-0.138	0.144*	0.480*	0.456*
2. Health knowledge and understanding in older adults	0.073	0.207*	0.615*	0.632*
3. Information communication in older adults	0.050	0.103	0.603*	0.587*
4. Ability to choose appropriate guidelines	0.079	0.050	0.615*	0.576*
5. Appropriate health management	0.172*	0.110	0.465*	0.620*
6. Health media literacy	-0.046	0.032	0.186*	0.425*

* Statistical significance level of .01

2. This study showed the significant correlation between the competency for management and the health promotion of older adults. Thus, it is suggested to organize projects to advance health literacy in older adults so that they can help themselves and others.

The suggestions for future studies were as follows:

1. It is suggested to examine the predisposing factors, the enabling factors, and the reinforcing factors which affect the competency of older adults on management and health promotion of older adults in the communities.

2. It is suggested to develop a program about the competency of older adults for management and health promotion of older adults in the communities.

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