EVALUATION AND SELECTION OF AN APPROPRIATE TAPIOCA PROCESSING WASTEWATER TREATMENT TECHNOLOGY FOR APPLICATION IN TAN CHAU DISTRICT, TAY NINH PROVINCE

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ABSTRACT

Although tapioca processing has contributed substantially to economic development, it has also been a significant pollution source in Vietnam. Existing tapioca wastewater treatment technologies are diverse and, in many cases, unsustainable. Screening for a sustainable and appropriate treatment technology requires careful analysis of technical, economic, environmental and social factors. In this research a set of 4 primary and 21 secondary criteria has been developed for evaluation of tapioca wastewater treatment technologies. The order of importance is identified as technical criteria (weight value of 55%), economic criteria (25%), environmental criteria (13%) and social criteria (7%). Among the 21 secondary criteria, legal compliance and treatment efficiency are the most significant technical factors; investment cost, land requirement and institutional and political are the three most important economic, environmental and social factors, respectively. Applying the criteria to 3 typical wastewater treatment technologies in Tan Chau district of Tay Ninh province, the research has selected a highly appropriate technology for the local, which employs both biological and physico-chemical treatment. In the future, researches of this kind may need to include climate change mitigation and adaptation capacity of the technology in the criteria.

Keywords: Analytic Hierarchy Process (AHP), evaluation criteria, tapioca processing wastewater, Tay Ninh province.

1. INTRODUCTION

Tapioca processing wastewater often has very high organic and TSS concentrations, up to 7,000- 41,000 mg COD/L, 6,000-23,000 mg BOD5/L, and 500-4,100 mg TSS/L in large scale facilities [1], which are, respectively, 70-410 times, 200-760 times and 10-82 times higher than regulated by the QCVN 63:2017/BTNMT, A level. Nitrogen and phosphorus contents in tapioca wastewater can be in the range of 106-368 mg/L and 48-86 mg/L, respectively [2]. With only 10% of wastewater treated to discharge standard, tapioca processing has seriously polluted the environment where this kind of production exists [4].

The problem with the existing tapioca wastewater treatment technologies in Vietnam is the lack of sustainability. The existing treatment systems often start with waste separation, sedimentation and neutralization. Then they are followed by one of the typical processes including (1) treatment through a series of biological lagoons; (2) upflow anaerobic sludge blanket (UASB) followed by activated sludge and polishing pond; (3) combination of physical and chemical treatment, including flocculation and flotation followed by anaerobic biological treatment and aerobic (biological lagoon) treatment; and (4) activated sludge treatment. The advantages and disadvantages of these processes are summarized hereinafter.

Process (1): Treatment is made via a series of biological lagoons at hydraulic retention time of 20-50 days. This process allows energy savings with low investment and operating costs, requires no operational skill but needs long adaptation times, large areas, does not provide a complete treatment of pollutants and responses poorly to input loading fluctuations. Failing barriers allow wastewater from anaerobic lagoons seep into aerobic lagoons, ruining treatment efficiency, or into the soil below to contaminate groundwater. In fact, these systems proved to be ineffective with COD, BOD and nitrogen in the effluent exceeding discharge standards. In addition, bad odor from anaerobic lagoons is a common problem of this technology.

Process (2): Treatment is made with UASB followed by activated sludge and a polishing pond. UASB reactors can operate at high loading rates and provide elevated efficiency. However, shock loads in UASB reactors could vigorously upset the operation of downstream aerobic biological modules; and UASB are not suitable for the intermittent operation mode because of its slow adaptation and recovery.

Process (3): The combination of physical and chemical treatment, including flocculation, flotation followed by anaerobic biological treatment (UASB) and aerobic (biological lagoon), is adopted. The combination of physical and chemical processes at an early stage allows the reduction of organic pollutant concentrations in the wastewater before biological treatment. However, the large consumption of flocculation chemicals for the high COD in wastewater increases the O&M cost.

Process (4): This technology utilizes activated sludge only. The downside of this kind of technology is that it does not provide the required levels of treatment to a wastewater with very high organic matter and N, P concentrations.

The existing tapioca wastewater treatment systems have in many cases been designed using inappropriate technologies and/or loading rates. As a result, the post-treatment wastewater did not meet regulatory requirements. In recent years, several largescale facilities tend to choose anaerobic biological technology (biogas) for power production. However, the treatment after the anaerobic modules have not been properly designed to ensure discharge standard compliance.

In addition to the mentioned technical aspect, economic, environmental and social factors such as investment costs, operating and maintenance costs, land requirements, operating personnel qualifications, environmental legal requirements that could be more stringent in the future etc. are of great concerns, but have not been systematically taken into account when choosing tapioca wastewater treatment technologies. This research developed a set of criteria for evaluation of tapioca wastewater treatment technologies and applied it in Tan Chau district of Tay Ninh province, since this province possesses the largest cassava planting area, accounting for 10%, of the whole country's cassava planting area [3], and has 74 tapioca processing facilities [4].

2. MATERIALS AND METHODS

2.1. Materials

This research studied wastewater treatment systems in 19 out of the total of 20 tapioca processing facilities of Tan Chau district of Tay Ninh province. The facilities are located in Suoi Ngo, Tan Dong, Tan Ha, Tan Hoi and Thanh Dong communes. 3 facilities operate at medium scales (15-40 tons of tapioca/day), while the other 16 facilities run at industrial scales (50-250 tons of tapioca/day). The wastewater treatment systems have design capacities of 600 m^3/day in 1 facility, 1,000-1,250 m^3/day in 5 facilities, and 2,000-3,080 m^3/day in the remaining 13 facilities. The wastewater treatment technologies classified into 3 typical categories denoted A, B and C, are detailed in Section 3.2.

From our analysis, these facilities provided removal efficiencies of 97.1%-99.6% for COD, 98.6%-99.6% for BOD5, 95.1%-99.5% for TSS, 66.7-88.6% for total nitrogen and 54.3-91.9% for total phosphorus. Most of them had COD, BOD_5 and total nitrogen concentrations in the effluent within allowable limits of regulatory standard. Cyanide (CN^-) was not detected in all treated wastewater samples. However, total phosphorus and total coliforms were found higher than regulatory requirements in 15 and 11 facilities, respectively.

Other relevant data i.e. types and amount of chemicals used, investment cost, operation cost etc. were also collected for the research.

2.2. Methods

2.2.1. Development of evaluation criteria

Studies around the world have given different views on the sustainability or appropriateness of waste treatment technologies. According to Alaerts *et al.* (1990), a waste treatment system is feasible if it is economically and technically efficient, reliable and easily manageable. Feasibility criteria were identified as (a) environmental feasibility; (b) reliable; organizationally and technically manageable; (c) financial feasibility; and (d) reusable [6]. Lettinga (2001) highlighted pollution prevention and resource conservation of a technology. The must-have characters of a sustainable technology were listed as (a) requiring less resources /energy or enabling the production of resources/energy; (b) good performance and stability; (c) flexible in term of other scale application; (d) simple to construct, operate and maintain [7]. Dummade (2002) suggested 4 primary and 15 secondary indicators for foreign technology sustainability in developing countries, which were (a) technical sustainability; (b) environmental sustainability; (c) economic sustainability; and (d) socio-political sustainability. Acceptability and availability of supportive government policies and their continuity were two amongst four socio-political sustainability criteria [8]. Kshitij Upadhyay (2017) evaluated the sewage treatment plants in India by 3 criteria and 9 sub-criteria with the following ranking: (a) environmental criteria (BOD, COD and TSS removal, and pH); (b) economic criteria (capital cost, land requirement, operation and maintenance (O&M) cost); and (c) technical/administrative criteria (performance and reliability) [9]. Hanh (2018) took into account the adaptability of the technologies to climate change. A set of 6 criteria for sustainability evaluation of urban wastewater treatment plants in Vietnam was established: (a) capacity and performance; (b) O&M cost; (c) the appropriateness of technology in local conditions; (d) operational requirements of equipment and treatment works; (e) adaptability to climate change impacts and the fluctuation of input values; and (f) being safe and environmentally friendly. The first and second criteria held the highest priorities [10]. Alejandro P.R. et al. (2019) [11] considered 9 indicators, 7 of them environmental (Abiotic Depletion, Acidification, Eutrophication, Global Warming, Ozone Layer Depletion, Human Toxicity and Photochemical Oxidation) and the other 2 were economic indicators (capital costs and Operation & Management costs).

From the above review, key findings are in sustainability and appropriateness assessment of wastewater treatment systems/technologies, environmental and social factors have gained growing interest.

In the context of Vietnam, an appropriate technology for tapioca wastewater treatment should ensure (1) environmental legislation compliance; (2) cost effectiveness, i.e. low investment costs, low operation costs, minimal energy costs, and reusable post-treatment wastewater. Therefore, the set of criteria should include criteria that enable the assessment of these two requirements.

2.2.1.1. Technical criteria

This criterion refers to the performance of the wastewater treatment technology itself. The treatment systems need to ensure the compliance with environmental regulations, which is the most important goal to achieve. Aspects that need attention are:

Legal compliance: notifies if a technology can meet the legislative requirements. The environmental regulations are not limited to the national technical regulation on effluent of tapioca processing facilities (QCVN 63:2017/BTNMT), but also cover noise, ambient air, bad odor, general waste and hazardous waste which may be generated by wastewater treatment systems.

Treatment efficiency: considers specific removal efficiency for each pollutant. In practice, several treatment systems may provide legal compliance at the same cost while one of them may offer higher removal efficiency for a given pollutant. That pollutant may be unregulated at present but could be regulated in the future. From this view, higher treatment efficiencies may ensure compliance with future regulatory standards.

Reliability of the system: reflects the responsiveness of the system in case of changes, e.g. the flowrate or the concentration of pollutants in the influent, system error e.g. power cut, equipment malfunction, etc., or human error.

Manageability of the system: includes ways to ensure system operation and maintenance. Supervisors' and operators' competence are also considered.

2.2.1.2. Economic criteria

This criterion measures the total costs and benefits of technologies, taking into account its entire life cycle and hidden costs that are not included in the traditional assessments. Economic criteria enable the screening for technologies that have the lowest investment capital, the lowest operating cost, and require less land for construction under the same economic condition.

Investment cost: enables the comparative analysis of construction costs of different alternatives in the same location and economic condition.

Operation cost: enables the comparative analysis of possible alternatives. O&M costs represent an important item in the overall feasibility of a system.

2.2.1.3. Environmental criteria

This criterion is intended to assess environmental impacts of the different treatment technologies, including the reuse of treated wastewater and solid waste.

Sustainability: considers if the technologies support the ecosystems and biodiversity conservation.

Material and energy need: takes into account the need for building materials, equipment, chemicals, considering the level of self-sufficiency in construction, operation and maintenance.

Land requirement: considers the availability of land and/or cost of land use. The possibility to impair natural landscape is also considered.

Air and noise pollution: implies aerosol carrying pathogens from activated sludge modules, irritating noise from running pumps and sedimentation of pollutants into surface water.

Waste recovery and reuse: assesses the possibility of collection and use of biogas from anaerobic treatment modules, and reuse of post-treatment wastewater or waste sludge from biological wastewater treatment modules.

2.2.1.4. Social criteria

This criterion takes into account social, political and cultural dimensions relevant to the potential acceptability of treatment technologies in the local context.

Social acceptability: reflects society's judgment of the technology's importance and its expected socio-cultural influence. It often leads to local development of more suitable versions and greater proliferation of the technology.

Institutions and politics: require a minimum management capacity in both governmental and private areas to successfully develop wastewater treatment technologies.

Operational resources: considers the supervisors' and operators' competence.

4 primary and 21 secondary criteria are suggested for the appropriateness evaluation of tapioca wastewater treatment technologies (Figure 1).

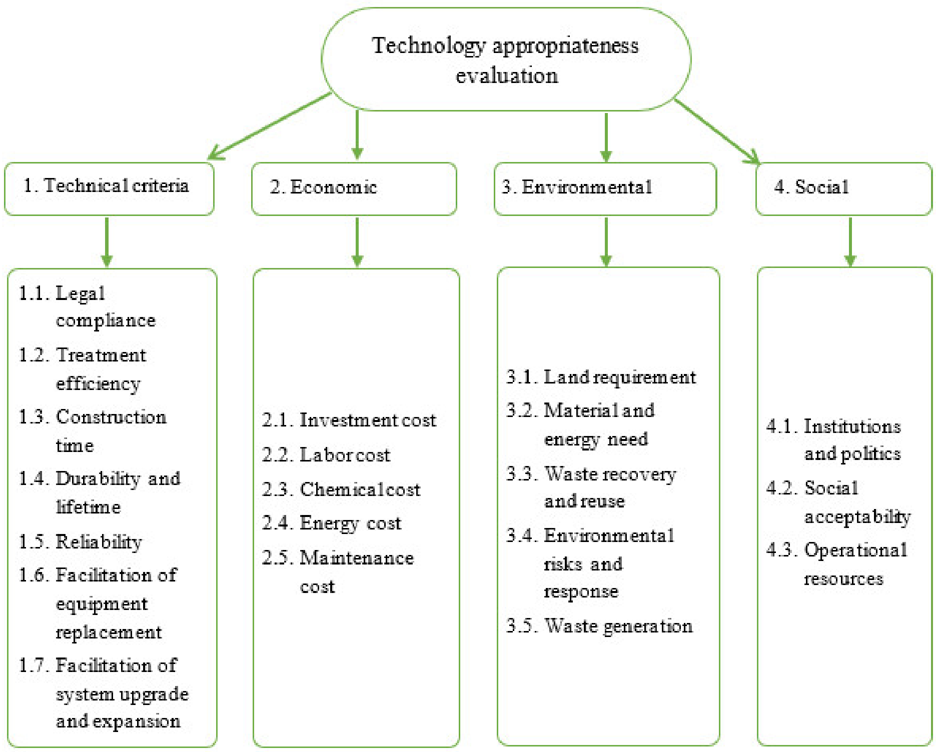

Figure 1. Primary and secondary criteria for appropriateness evaluation of tapioca wastewater treatment technology

The set of criteria enables the evaluation of environmental risks but not climate change. In the future, researches of this kind may need to include the technology's potential climate change mitigation and adaptation in the criteria.

2.2.2. The analytic hierarchy process (AHP)

This research uses the AHP developed by Thomas L. Saaty [5]. Six (06) environmental experts were consulted with questionnaires on the levels of importance of the developed primary criteria. A pair-wise comparison matrix was set up based on the survey results and the evaluation scale (Table 1).

Table 1. Comparison scale in AHP

Level of importance	Definition	Explanation
1	Equal importance	Two criteria have the same level of importance
3	Moderate importance	Experience and judgment are slightly more inclined to this criterion factor than the other
5	Strong importance	Experience and judgment strongly more inclined to this criterion than the other
7	Very strong importance	One criterion is prioritized more than the other and expressed in practice
9	Extreme importance	One criterion is extremely more important than the other
2, 4, 6, 8	Intermediate values	Compromise between two levels of judgment

The weights of the primary criteria were determined and standardized. The Consistent Ratio (CR) of the weights calculated by equation (1) should be less than or equal to 0.1, or else the procedure would be repeated from the expert consultation step.

$$CR = CI / RI \tag{1}$$

Where:

CI (consistency index) $= (\lambda_{max} - n) / (n - 1)$

λ_{max} (specific value of comparison matrix) = average value of consistent vector
n: the number of elements in the comparison matrix
consistent vector = weighted sum vector / weight vector
the weighted sum vector = matrix comparing × weight vectors

RI (random index): available for use in [5]

A similar procedure was performed for the secondary criteria. Aggregate weight, which present the priority levels in the whole set of criteria of each the secondary criterion, was calculated by the following formula.

Aggregate weight = specific weight × weight vector of primary criteria

2.2.3. Assessment of the appropriateness of tapioca wastewater treatment technologies in Tan Chau district, Tay Ninh province

We collected data and wastewater samples from 19 tapioca facilities in Tan Chau district, Tay Ninh province. Three (03) typical tapioca processing wastewater treatment technologies were assessed with the developed criteria set.

For each technology, performance scores were assigned to each secondary criterion in 5 levels: 0; 25; 50; 75 and 100. The higher a performance was, the more a particular criterion contributes to the technology's optimization, and therefore, the higher score should be assigned. For example, if a technology provides post-treatment wastewater with very low pollutant concentrations, its performance score should be 100. These performance scores were then converted into evaluation scores taking into account the importance (priority level) of each secondary criterion in the whole set of criteria. The total scores of the criteria set were used to assess the appropriateness of technologies in a specific locality guided in Table 2.

Table 2. Appropriateness level of technologies versus evaluation scores

Evaluation scores	Level of appropriateness
Scores ≤ 25	Very low
25 < scores ≤ 50	Low
50 < scores ≤ 75	Medium
Scores >75	High

3. RESULTS AND DISCUSSION

3.1. Determination of the weight vectors

Consultation results of six (06) experts and calculation of the importance of primary criteria in pairs are presented in Table 3. Two (02) of the experts have doctor degrees in environmental engineering. The other two (02) hold master degrees and have been working in the field of wastewater treatment design/construction for more than 15 years. The last two (02), one doctor degree and one master degree, have more than 12 years of experience in environmental management. The pair-wise comparison matrix, weight vectors and consistency ratio (CR) of primary criteria are shown in Table 4 and Table 5 below.

Table 3. Importance levels of primary criteria in pairs

Criteria in comparison	Consultation results						Mean value
	1	2	3	4	5	6	
Technical criteria and economic criteria	3	5	3	3	5	1	3
Technical criteria and environmental criteria	5	3	7	3	3	3	4
Technical criteria and social criteria	5	7	9	7	9	5	7
Economic criteria and environmental criteria	3	1	3	5	1	1	2
Economic criteria and social criteria	5	3	5	5	7	5	5
Environmental criteria and social criteria	1	3	1	1	1	3	2

Table 4. Pair-wise comparison matrix

	Technical criteria	Economic criteria	Environmental criteria	Social criteria
Technical criteria	1	3	4	7
Economic criteria	0.33	1	2	5
Environmental criteria	0.25	0.5	1	2
Social criteria	0.14	0.2	0.5	1

Table 5. Weight vectors of the primary criteria

No.	Primary criteria	Weight value
1	Technical criteria	0.5544
2	Economic criteria	0.2515
3	Environmental criteria	0.1295
4	Social criteria	0.0647

CR for the primary criteria is 0.019, demonstrating the consistency of the weight vectors. The weight vectors in Table 5 and Figure 2 indicate that technical criteria are considered the most important criteria. Increasing environmental pollution and declining water quality are the primary reasons behind the importance of complying with discharge regulations. Economic criteria are at the second rank as investment cost and O&M cost for a technology determine if the technology is appropriate for the finance management of the facility. Environmental criteria come in the third position, revealing that environmental protection is getting more attention as the decision makers recognize the dual benefits of saving resources and energy and limiting waste to the environment. Social criteria hold the least importance in the local context for the time being.

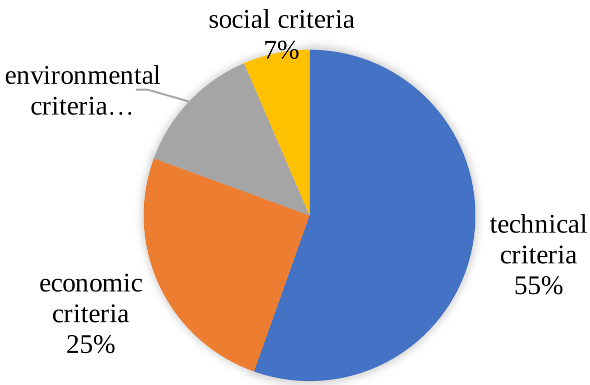

Figure 2. Relative importance of the primary criteria

Calculations for secondary criteria are presented in Table 6 and Table 7. The consistency of the weight vectors was confirmed by the CRs of less than 0.1 (Table 7).

Legal compliance and treatment efficiency are found to be the top priorities among technical criteria, accounting for 18% and 12% respectively of the whole set of criteria. This finding is in line with studies of Kshitij Upadhyay (2017) [9], and Hanh (2018) [10]. A popular explanation is that legal compliance is the ultimate purpose of a wastewater treatment technology and high treatment efficiency directly guarantee the legal compliance success.

Investment cost proves to be the most important secondary economic criteria for assessment of a tapioca wastewater treatment technology, holding 12% of the whole set of criteria. In Vietnam, it is generally recognized that investment in a wastewater treatment plant is a significant expense for an enterprise and should be kept as low as practicable without major change in its expected performance. The O&M cost of this research is divided into 4 components which are labor cost, chemical cost, energy cost and maintenance cost. In fact, the O&M cost in this research holds 13% of importance, 1% higher than investment cost. Similar results were found by Kshitij Upadhyay [9] namely that operation cost was of greater importance than investment cost (18%=0.283×0.643 as compared to 8%=0.283×0.283). In Hanh's research (2018) [10], O&M cost was the second ranked primary criteria, contributing

21.1% and 20.9% of the whole set of criteria taking into account max and min values, respectively. Investment cost was not studied under her research. This confirmed the important role of O&M cost.

The land requirement has a priority level of 4.8%, overweighing other environmental criteria relating to resources/energy consumption and waste recycling. In fact, in many cases tapioca facilities are located in the vicinity of cities, where land prices normally are high, and therefore, land requirement for wastewater treatment systems is certainly of great concern.

Among social criteria, institutions and politics are the most important factors with a priority level of 4.5%, nearly the same to that of land requirement. Social acceptability makes up only 0.9% in the total importance.

Table 6. Aggregate weights of secondary criteria

No.	Criteria	Specific weight	Aggregate weight
1.1	Legal compliance	0.3232	0.1792
1.2	Treatment efficiency	0.2207	0.1223
1.3	Construction time	0.1203	0.0667
1.4	Durability and lifetime	0.0966	0.0536
1.5	Reliability	0.0819	0.0454
1.6	Facilitation of equipment replacement	0.0611	0.0339
1.7	Facilitation of system upgrade and expansion	0.0560	0.0311
1.8	Operator training time	0.0403	0.0223
2.1	Investment cost	0.4802	0.1207
2.2	Labor cost	0.2251	0.0566
2.3	Chemical cost	0.1111	0.0279
2.4	Energy cost	0.1175	0.0295
2.5	Maintenance cost	0.0661	0.0166
3.1	Land requirement	0.3687	0.0477
3.2	Materials and energy need	0.2653	0.0343
3.3	Waste recovery and reuse	0.1870	0.0242
3.4	Environmental risks and response	0.0956	0.0124
3.5	Waste generation	0.0835	0.0108
4.1	Institutions and politics	0.6902	0.0446
4.2	Social acceptability	0.1492	0.0096
4.3	Operational resources	0.1606	0.0104

Table 7. CRs of secondary criteria

No.	Criteria	CR
1	Secondary criteria of Technical criteria	0.052
2	Secondary criteria of Economic criteria	0.017
3	Secondary criteria of Environmental criteria	0.019
4	Secondary criteria of Social criteria	0.004

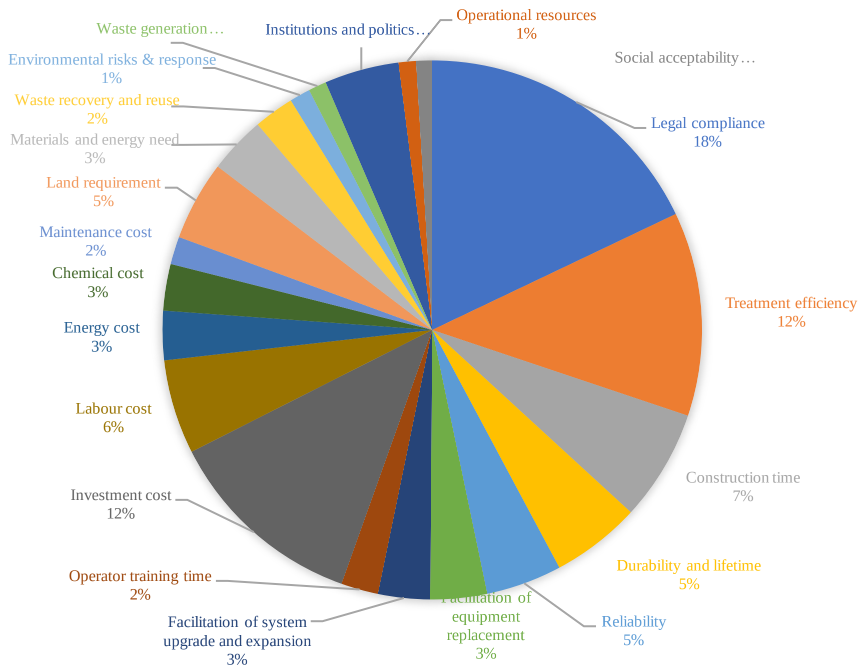

Figure 3. Relative importance of the 21 secondary criteria

3.2. Appropriateness assessment of tapioca processing wastewater treatment technologies in Tay Ninh province

Three (03) typical (core) wastewater treatment technologies, denoted as A, B and C hereinafter, were employed by the 19 tapioca facilities in Tan Chau district of Tay Ninh province. Technology A makes use of a series of lagoons for the treatment: (a) anaerobic lagoons, (b) facultative lagoons and (c) aerobic lagoons. Technology B adopts a biogas system and aerobic treatment, with following main modules: (a) biogas tank(s) (secondary treatment); (b) equalization tank; (c) a series of 3 aeration tanks; and (d) a sedimentation tank. Technology C employs both biological and physicochemical processes for pollutant removal, with (a) biogas tank; (b) biological (anoxic and aeration) tanks; and (c) physicochemical reaction tank.

Technology A has the lowest investment cost of the 3 technologies, low operational skills and maintenance requirements, no chemical need, insignificant energy demand. However, lagoon establishment requires a large area and land use pressure would be an obstacle for system expansion in the future. Biological lagoons are generally sensitive to the changes in influent properties. The great limitation of this technology is the limited capacity to remove pollutants and high likelihood of environmental risks i.e. odors and wastewater leakage.

Technology B performance is generally better than technology A's, but worse than technology C's. Investment cost is also in the middle range. Technology B requires no chemicals and less land, gives off less uncontrolled emissions into the ambient air and soil than technology A, and enables biogas recovery and waste reuse. This technology is more resistant to changes in the influent's flowrate and pollutant concentrations although these changes would unavoidably impair the performance. However, this technology has high power consumption and the system upgradability is constrained by the high cost.

Technology C offers the highest treatment efficiency, requires very little space and enables the reuse of wastewater and energy (biogas). Like Technology B, it is expected to be responsive to changes in input characteristics. This technology can be implemented at any size at reasonable costs. Although electromechanical equipment is expensive, its local availability supports the replacement of broken pieces. The drawbacks of technology C are the high demand for chemicals and the higher O&M cost as compared to technology B and C.

In general, technology B and C have many advantages over technology A.

We use the developed set of criteria in the previous part of this research to assess the appropriateness of the three (03) technologies above. Evaluation scores (Table 8) reveal that Technology C (flowchart in Figure 4), is the most appropriate tapioca wastewater treatment technology for Tan Chau district.

Table 8. Appropriateness assessment of 03 typical tapioca processing wastewater treatment technologies in Tan Chau district of Tay Ninh province

No.	Evaluation criteria	Evaluation score		
		Technology A	Technology B	Technology C
1	Technical criteria	27	29	34
1.1	Legal compliance	10.7	10.7	10.7
1.2	Treatment efficiency	3.6	5.4	7.2
1.3	Construction time	2.6	1.8	2.6
1.4	Durability and lifetime	2	3	3
1.5	Reliability	1.7	2.5	3.3
1.6	Facilitation of equipment replacement	1.8	1.8	2.7
1.7	Facilitation of system upgrade and expansion	1.6	1.6	2.4
1.8	Operator training time	2.6	2.6	1.8
2	Economic criteria	15	13	18
2.1	Investment cost	5.7	5.7	7.5
2.2	Labor cost	2.9	1	2.9
2.3	Chemical cost	3.7	2.7	3.7
2.4	Energy cost	1.7	2.5	2.5
2.5	Maintenance cost	0.6	1.3	1.9
3	Environmental criteria	10	20	19
3.1	Land requirement	4.3	8.7	6.5
3.2	Materials and energy need	2.8	4.3	2.8
3.3	Waste recovery and reuse	1.5	3	6
3.4	Environmental risks and response	1.1	1.6	1.6
3.5	Waste generation	0.6	1.9	1.9
4	Social criteria	6	11	8
4.1	Institutions and politics	1.4	4.2	2.8
4.2	Social acceptability	1.3	1.9	1.9
4.3	Operational resources	3.5	5.2	3.5
	Total score	58	73	79
	Level of appropriateness	Medium	Medium	High

Wastewater → Trash rack → Collection pit → First biogas tank → Second biogas tank →
→ Equalization tank → Anoxic tank → Aeration tank → Sedimentation tank → Flocculation tank →
→ Coagulation tank → Sedimentation tank → Polishing pond → Receiving waterbody
↳ Drying bed

Figure 4. Technology C for tapioca wastewater treatment

This result is quite consistent with general observations mentioned above. In general, B and C technologies were considered to be compliant with current effluent standards, ensuring that post-treatment wastewater meets discharge standards. The main weakness of technology C is the lack of local expertise at the time being, which lowers social criteria score. However, its high technical score increases its overall score. Technology B was highly evaluated for technical, environmental and social friendly characters, but gained worse economic scores. The various levels of importance of evaluation criteria have facilitated the comparison of the three technologies to select technology C as the most appropriate.

4. CONCLUSIONS

While contributing substantially to the economic development, tapioca processing has also been identified as a significant source of pollution due to the highly contaminated wastewater. Although the existing technologies for tapioca wastewater treatment are so diverse, in many cases they are unsustainable. Screening for a sustainable and appropriate treatment technology requires careful consideration of various relevant factors. This research has, while studying wastewater treatment systems of 19 out of 20 tapioca processing facilities in Tan Chau district of Tay Ninh province, developed a set of criteria with 4 primary and 21 secondary criteria for appropriateness evaluation of tapioca wastewater treatment technologies. The order of importance has been identified as: technical criteria (weight value of 55%), economic criteria (25%), environmental (13%) and social criteria (7%). Among the 21 secondary criteria, legal compliance and treatment efficiency are the most significant technical factors; investment cost, land requirement and institutional and political are the three most important economics, environmental and social factors, respectively. Using the criteria set on 3 typical wastewater treatment technologies in Tan Chau district of Tay Ninh province, the research has been able to select a highly appropriate technology for the locality, which employs both biological and physicochemical treatment. In the future, however, it is recommended that researches in this field include climate change mitigation and adaptation of the technology in the evaluation criteria.

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TÓM TẮT

ĐÁNH GIÁ VÀ LỰA CHỌN CÔNG NGHỆ XỬ LÝ NƯỚC THẢI TINH BỘT MÌ ÁP DỤNG THỰC TIỄN TRÊN ĐỊA BÀN HUYỆN TÂN CHÂU, TỈNH TÂY NINH

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Chế biến tinh bột sắn đã đóng góp một phần không nhỏ vào phát triển kinh tế, tuy nhiên, nó cũng là nguồn gây ô nhiễm nghiêm trọng ở Việt Nam. Công nghệ xử lý nước thải tinh bột sắn rất đa dạng và trong nhiều trường hợp là không bền vững. Chọn lọc công nghệ bền vững và phù hợp đòi hỏi phân tích cẩn thận các yếu tố kỹ thuật, kinh tế, môi trường và xã hội. Nghiên cứu này đã xây dựng bộ tiêu chí với 4 tiêu chí cấp 1 và 21 tiêu chí cấp 2 để đánh giá công nghệ xử lý nước thải sản xuất tinh bột sắn. Thứ tự mức độ quan trọng được xác định là: tiêu chí kỹ thuật (trọng số 55%), tiêu chí kinh tế (25%), tiêu chí môi trường (13%) và tiêu chí xã hội (7%). Trong số 21 tiêu chí cấp 2, tuân thủ pháp luật và hiệu quả xử lý là các yếu tố kỹ thuật quan trọng nhất; chi phí đầu tư, yêu cầu đất đai, thể chế và chính trị là các yếu tố kinh tế, môi trường và xã hội quan trọng nhất. Áp dụng bộ tiêu chí trên 3 công nghệ xử lý nước thải điển hình trên địa bàn huyện Tân Châu, tỉnh Tây Ninh, nghiên cứu đã lựa chọn một công nghệ phù hợp cao với địa phương, trong đó sử dụng kết hợp xử lý sinh học và hóa lý. Trong tương lai, các nghiên cứu kiểu này cần có thêm các chỉ tiêu đánh giá về khả năng giảm nhẹ và thích ứng với biến đổi khí hậu của công nghệ.

Từ khóa: Phương pháp phân tích phân bậc (AHP), tiêu chí đánh giá, nước thải tinh bột mì, tỉnh Tây Ninh.