Internet Journal of Society for Social Management Systems Vol.12 Issue 2 sms19-6160
ISSN: 2432-552X
ORIGINAL ARTICLE

Perception-based Social Acceptability of Subsurface Flow Constructed Wetland Treated Dairy Farm Wastewater Reuse for Irrigation

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Abstract: Reclaimed water reuse for indirect consumption purposes such as irrigation helps resolve two key issues in integrated water management – high freshwater abstraction and water source contamination. The study aimed at identifying the social acceptability of dairy farm wastewater reuse for irrigation using a perception-based (senses of sight and smell) Likert scale questionnaire. Samples collected from the different laboratory-scale subsurface flow constructed wetland systems were sent to 200 respondents together with a questionnaire that was designed to gauge their knowledge on wastewater (effects, management, existing laws and possible reuse) and their willingness to use the different treatment effluents to irrigate their crops. Blind and learned perceptions of the respondents from their responses were gathered and analyzed. Based on the ANOVA and Duncan's Multi Range Test, acceptability level of the hybrid and the vertical system in series subsurface flow constructed wetlands are relatively high at 3.815 and 3.623 out of 5.000 on the average, respectively. Generally, after an array of socio-economic factors were considered, results of the study showed wastewater reclamation and reuse is acceptable and that the local community surrounding the dairy farm is more willing to use reclaimed wastewater to irrigate their crops – ornamentals, vegetables and fruit bearing trees – after going through the two-phase subsurface flow constructed wetland systems than the one-phase systems.

Keywords: constructed wetlands, perception-based acceptability, wastewater reuse

Received: 2019.07.31/ Accepted: 2020.01.28
Internet Journal of Society for Social Management Systems Published Date: 2020.07.10

1. Introduction

Freshwater – surface and ground water – are mainly used for agricultural, municipal/domestic, industrial and recreational purposes in the Philippines. Water after serving its specific purpose is converted to wastewater which is disposed to the environment and are naturally treated to recharge the freshwater source. Recently, freshwater sources for domestic and agricultural uses in the Philippines has decreased as brought about by poor water quality and water quantity depletion due to accelerated urbanization and development, fast-tracked population growth, excessive water abstraction, water pollution and continuously changing climate (Naz, 2013).

In search for alternative water sources, wastewater reclamation and reuse using different wastewater treatment technologies such as constructed wetlands have started to gain popularity. Constructed wetlands are compatible for animal farm and ranch wastewater treatment (Kadlec and Wallace, 2009). Being low-cost, sustainable, easy-operational and viable treatment option for wastewater treatment, constructed wetlands are on focus of different studies and are suitable for use in local communities (Liu et. al., 2018; Ramprasad et. al., 2017; Kadlec and Wallace, 2009).

1.1 Objectives

Ultimately, the study aims to identify the level of social acceptability of constructed wetland treated wastewater reuse for irrigation.

Specifically, the study aims to identify respondents' knowledge on wastewater, its effects to the environment, its management as idealized and implemented, and its possible reuse for indirect consumption. Also, the study aims to identify perception-based willingness pay of reclaimed dairy farm wastewater.

2. Methodology

To achieve the objectives of the study, laboratory-scale constructed wetland systems were used to treat dairy farm wastewater. Figure 1 summarizes the research flow used.

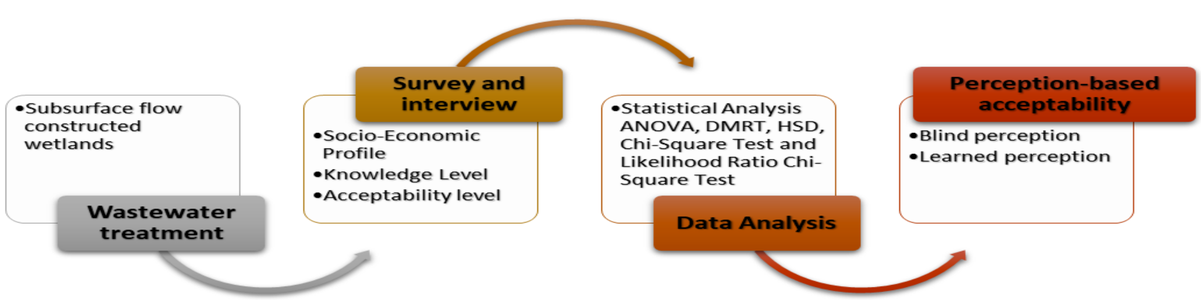

Figure 1. Research flow diagram

ISSN: 2432-552X

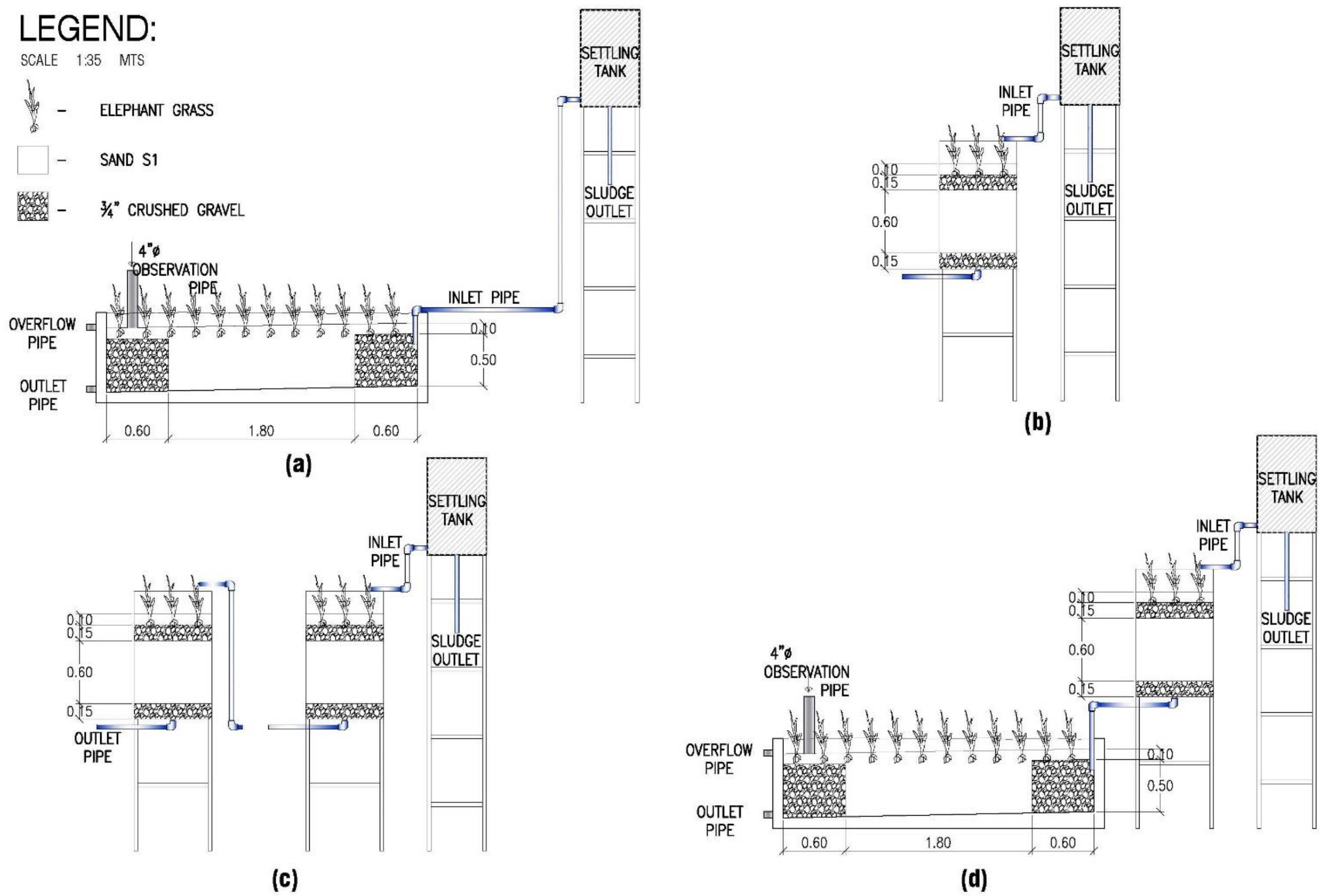

Figure 2. Subsurface flow constructed wetland set-ups (a) horizontal, (b) vertical, (c) vertical in series, and (d) hybrid.

For this study, four subsurface flow constructed wetland systems (horizontal, vertical, vertical in series and hybrid) were simulated in a laboratory-scale model. Figure 2 illustrates constructed wetland set-ups used in the study. Each set up was loaded with two hundred liters (200L) of fresh dairy farm wastewater daily. The influent is retained in each set-up for eight (8) hours after which effluent samples were collected for laboratory analysis. Stakeholder interviews were conducted in accordance to the survey questionnaire to identify the perceptions and knowledge of the stakeholders to wastewater reuse – risks, technology and acceptability (USAID, 1996; Washington University, 2006). Two hundred (200) selected respondents were surveyed. For the preliminary questions, knowledge on the effects of wastewater to the environment (Q1 and Q7), current state of freshwater (Q3 and Q4), perception on Philippine water laws (Q5 and Q6), knowledge on wastewater treatment (Q2, Q8 and Q9), responsible stakeholders (Q10) and willingness to pay (Q11) were asked. Likert-Scale (Joshi, et. al., 2015) based questionnaire was designed so that the first part gauges their sensory perception on the water samples using their sense of sight and sense of smell without knowing where these water samples came from (blind-perception). The second part was designed to quantify the respondents' level of knowledge on wastewater, it's effect on the environment, laws pertaining to water and wastewater and their willingness to pay given a wastewater treatment facility is to be built. Last is that their sensory perceptions are again quantified whether they will use the samples after knowing that these samples came from the dairy farm wastewater (learned-perception). Figure 3 shows the effluent samples sent to the respondents.

Socio-economic data were collated together with the responses obtained in the survey conducted. Data gathered were analyzed using SAS® 9.4 software. For independency and significance relationships, tests such as Analysis of Variance Test (ANOVA), Duncan's Multiple Range Test (DMRT), Tukey's Honest Significant Difference (HSD), Chi-Square Test and Likelihood Ratio Chi-Square Test were done (Gomez and Gomez, 1984). Relationships between socio-economic factors with the respondents' knowledge on wastewater management were drawn. After which, perception-based acceptability of the dairy farm wastewater reuse for irrigation was obtained.

Figure 3. Raw wastewater (RAW), Vertical (VSFCW), Horizontal (HSFCW), Vertical in Series (VSF-VSFCW), and Hybrid (VSF-HSFCW) Effluent samples

3. Results and Discussion

3.1 Respondents' Socio-economic Profile

For this study, the confidence level used was 95% and confidence interval was 6.7 making the necessary sample size 195 samples. The conservative computed required number of respondents was rounded up to 200 respondents. The respondents were preselected considering the distance of their households to an existing dairy farm.

From the total respondents, 135 (67.5%) are female and 65 (32.5%) are male, 158 (79%) are married, 22 (11%) are single, 18(9%) are widows and 2 (1%) are separated. As summarized in Figure

4, all the respondents had formal schooling, 9 (4.5%) of them had Elementary Schooling, 166 (83) finished High School, 4 (2%) took up technical/vocational courses, 20 (10%) finished College and 1 (0.5%) have a master's degree. Majority of the respondents belong to two age brackets – 21-40 (87 or 43.5%) and 41-60 (85 or 42.5%). 25 respondents (12.5%) belong to the senior citizen bracket and the remaining 3 (1.5%) belong to the below 20 years old bracket.

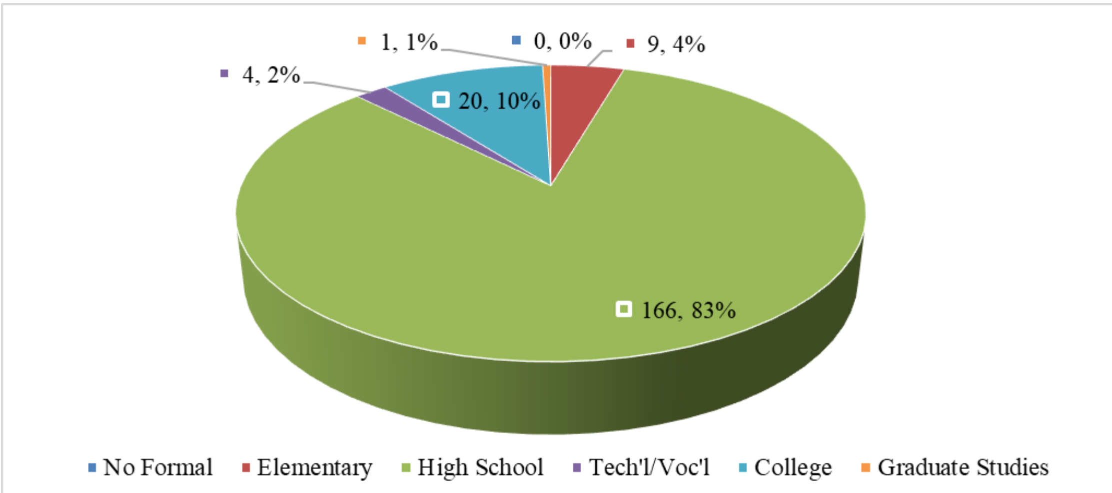

Figure 4. Respondents' educational attainment profile

Farming and ornamental gardening are among the main sources of income of the people in Tuntungin-Putho. The respondents were composed of two income brackets because no one admitted earning greater than Php 500,000.00 annually. 177 (88.5%) of the respondents said they belong to the below Php 100,000.00 annual income bracket and the remaining 23 (11.5%) belong to the Php 100,001.00 to 500,000.00 bracket. 88 (44%) of the respondents said they are unemployed since majority of them are mothers who stay at home but have farms or gardens to tend to every day. 61 (30.5%) have small businesses and are self-employed and the remaining 51 (25.5%) say they are employed to different industries – processing and services related jobs to name a few.

The respondents claim to have small household sizes. There are only two household classifications recorded in the study. First is the small household size with 1 to 3 members only and the other being medium household size with 4 to 6 family members. No one belonged to the large household size of more than 6 members. 67 (33.5%) of the respondents are from small households and the remaining 133 (66.5%) are from medium households.

The respondents were grouped in two ways – first, based on the length of farming or gardening experiences and second, based on the type of crop they have. Figure 4 illustrates the first basis that created 5 groups namely (1) less than 1-year farming experience, (2) 1 to 5 years farming experience, (3) 5 to 10 years farming experience, (4) 10 to 15 years farming experience and (5) more than 15 years farming experience. Originally, the second grouping basis was intended to create at least six groups but since no one is farming forage crops the forage group was deduced. As illustrated in Figure 5, the remaining groups based on the type of crop filter are (1) ornamentals and cut-flower group, (2) grains group, (3) fruits and vegetables eaten raw group, (4) fruits and vegetables eaten processed group, and (5) fruit-bearing trees group. These two grouping modes were designed to investigate whether farming experience and type of crop being produced will affect their decision regarding the reuse of dairy farm wastewater to irrigate their crop production farms aside from the blind perception and the learned perception differentiation.

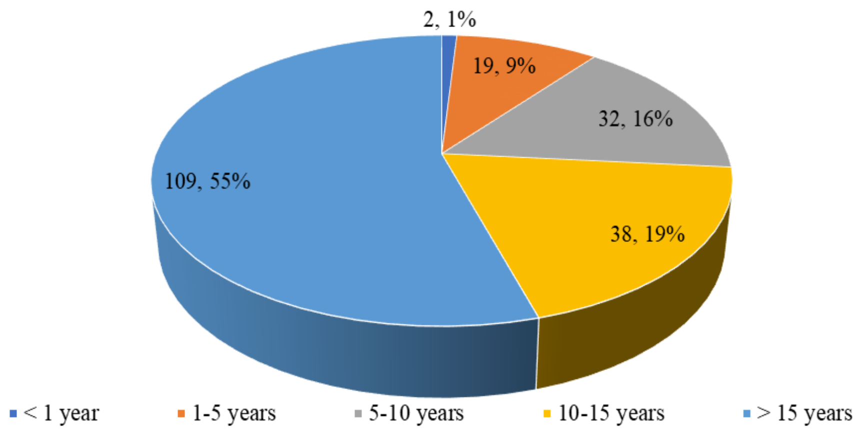

Figure 4. Respondents' farming experience profile

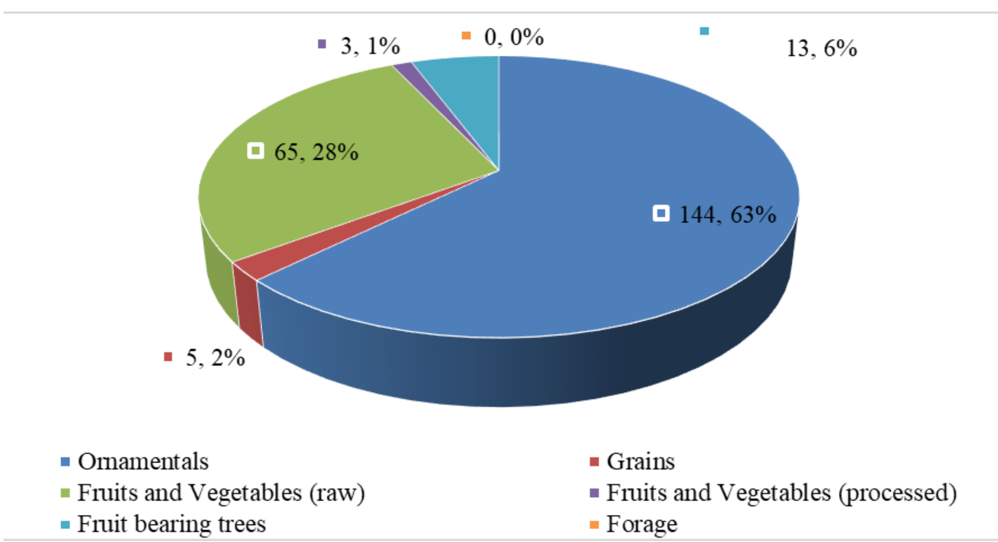

Figure 5. Repondents' cultivated crops profile

3.2 Wastewater Management Knowledge

Chi-square and likelihood ratio analyses were done to determine the dependency of the respondents' knowledge on wastewater management to the socio-economic factors considered. Table 4-14 summarizes the Chi-square analysis results while Table 4-15 summarizes the results of the Likelihood

Ratio Chi Square Test with Educational Attainment (ED), Sex (S), Civil Status (CS), Household Size (HHS), Employment (EMP), Annual Income (INC), Farming Experience (FX) and Type of Crops (CROP) as the parameters.

Table 1. Chi-Square Test Results for Wastewater Knowledge

	ED	S	CS	HHS	EMP	INC	FX	CROP
Q1	**$1.4 x 10^{-2}$**	0.91	0.14	0.53	0.30	0.24	**0.03**	0.37
Q2	**$1.00 x 10^{-4}$**	0.88	0.88	0.53	0.53	0.07	**$3.00 x 10^{-3}$**	**$1.00 x 10^{-3}$**
Q3	**$1.00 x 10^{-4}$**	0.71	0.71	0.33	0.33	0.20	**$1.00 x 10^{-4}$**	0.72
Q4	0.90	0.45	0.98	0.49	0.90	0.75	**0.05**	0.97
Q5	0.19	0.24	0.95	0.81	0.20	**0.03**	0.46	0.10
Q6	**0.04**	0.26	1.00	0.87	0.23	**0.03**	0.41	0.35
Q7	**$5.2 x 10^{-3}$**	0.64	0.97	0.55	**$1.18 x 10^{-2}$**	**0.01**	0.23	0.07
Q8	0.96	0.09	0.33	0.66	0.63	0.08	0.09	0.98
Q9	**$1.00 x 10^{-4}$**	**$2.40 x 10^{-3}$**	0.93	0.26	0.48	0.65	**$2.00 x 10^{-4}$**	0.99
Q10	0.97	**0.02**	0.39	0.69	0.09	0.13	**$1.00 x 10^{-4}$**	**$1.20 x 10^{-3}$**
Q11	0.53	0.45	**$4.00 x 10^{-4}$**	0.78	0.36	0.49	0.94	0.58

Table 2. Likelihood Ratio Chi-Square Test Results for Wastewater Knowledge

	ED	S	CS	HHS	EMP	INC	FX	CROP
Q1	0.12	0.91	0.06	0.52	0.32	0.31	0.06	0.16
Q2	0.20	0.82	0.58	0.48	0.55	0.27	**0.02**	0.07
Q3	0.57	0.57	0.66	0.25	0.62	0.23	**$1.40 x 10^{-2}$**	0.45
Q4	0.87	0.42	0.94	0.41	0.86	0.73	0.07	0.87
Q5	0.35	0.23	0.93	0.81	0.19	**0.03**	0.42	0.22
Q6	0.15	0.25	1.00	0.87	0.22	**0.03**	0.36	0.17
Q7	0.35	0.57	0.88	0.51	**0.01**	**0.05**	0.42	**$1.08 x 10^{-2}$**
Q8	0.98	0.06	0.68	0.55	0.54	0.26	0.30	0.97
Q9	**0.04**	**$2.0 x 10^{-3}$**	0.83	0.22	0.51	0.70	0.11	0.96
Q10	0.93	**0.1**	0.23	0.55	0.10	0.19	0.06	**0.02**
Q11	0.64	0.32	0.52	0.61	0.29	0.20	0.90	0.43

3.3 Perception-based Acceptability

Figures 4 and 5 summarizes perception-based social acceptability analysis derived from the survey responses.

For the perception according to sense of sight using α=0.05, the test showed that VSF-VSFCW and VSF-HSFCW effluents acceptability ratings are not significantly different, with the latter having the highest mean acceptability scores of 3.820 and 3.7250, respectively. On the other hand, HSFCW, VSFCW and Raw effluents were declared significantly different with decreasing acceptability scores. With regards to pay, DMRT showed that there were no significant differences to the mean amount the respondents are willing to pay with VSF-HSFCW effluent having the highest mean amount of Php 12.70, followed by VSF-VSFCW effluent with the mean amount of Php 12.650.

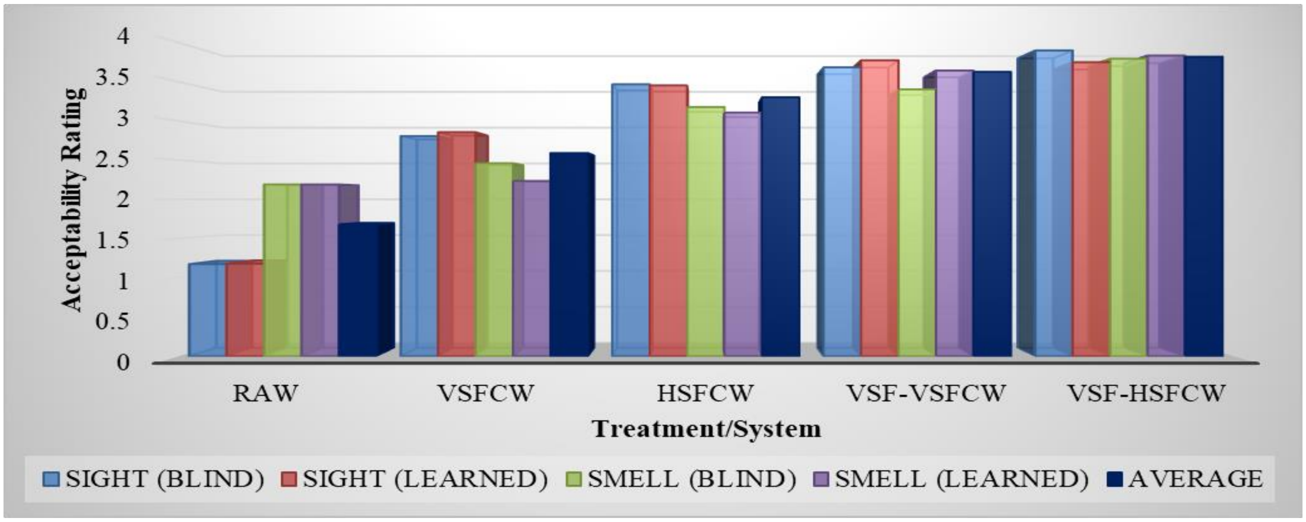

Figure 4. Mean comparison of acceptability rating both blind and learned perception.

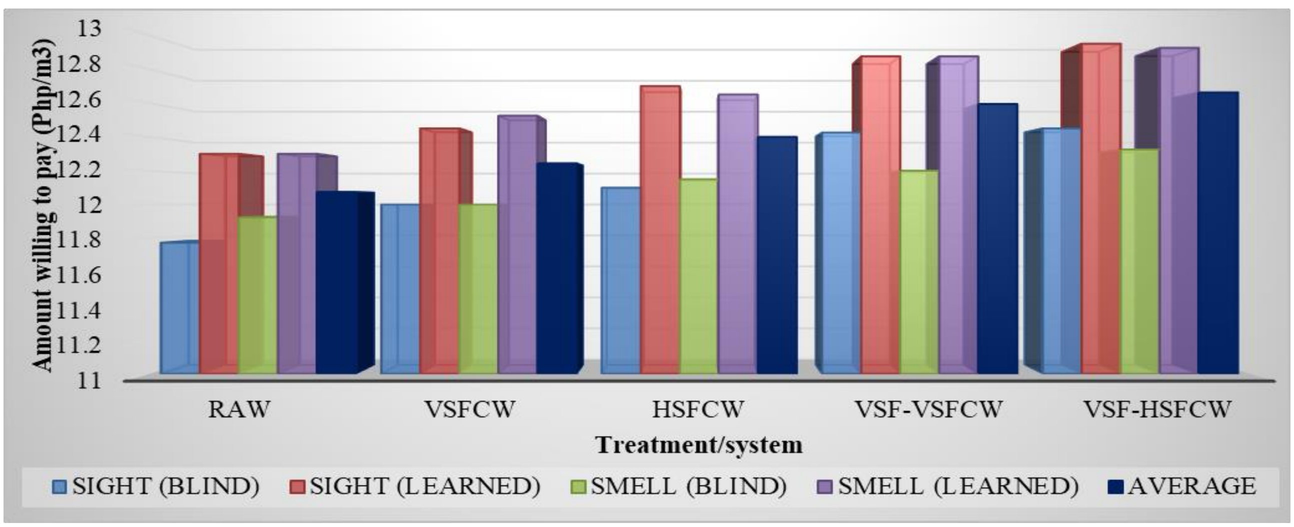

Figure 5. Mean comparison of amount respondents are willing to pay for both blind and learned perception.

For the perception according to sense of smell using α=0.05, the test showed that HSFCW, VSF-VSFCW and VSF-HSFCW effluents acceptability ratings are significantly different as they belong to different Duncan grouping, with the latter having the highest mean acceptability scores of 3.810, 3.520 and 3.140, respectively. On the other hand, VSFCW and Raw effluents were declared not significantly different from each other but significantly different from the former group of effluents with decreasing acceptability scores of 2.3475 and 2.190, respectively. With regards to pay, DMRT showed that there were no significant differences to the mean amount the respondents are willing to pay with VSF-HSFCW effluent having the highest mean amount of Php 12.6250, followed by VSF-VSFCW effluent with the mean amount of Php 12.5375.

The respondents' willingness of paying does not significantly differ as they all need to irrigate their crops regardless of the source. Results show that among the five treatment effluents majority of the respondents would choose, in decreasing order, VSF-HSFCW, VSF-VSFCW, HSFCW, VSFCW and Raw effluents as irrigation water.

4. Conclusion and Recommendation

In terms of knowledge on wastewater management, it can be concluded that the respondents know the adverse effects of wastewater to the environment more so on human health and wellbeing. The respondents acknowledge the existence of laws and government control measures but lacks bit in the implementation as indicated in the low ratings of the knowledge on the existence and implementation of such control measures. But nonetheless, majority of the respondents agrees that wastewater should be treated before disposal and that natural treatments can be done to wastewater for reuse. Also, high level of willingness to be taxed or charged was observed given that a wastewater treatment facility is in place. In terms of responsibility majority of the respondents agrees that it should be the government who should take main responsibility roles in the establishment and management of a wastewater facility, but the second majority acknowledges that it should be more of a collaborative effort of all the stakeholders.

Social acceptability analysis of dairy farm wastewater reuse for irrigation done showed that farmers are willing to use reclaimed water from the subsurface flow constructed wetlands. Specifically, the study utilized two sensory perceptions – sight and smell. Then willingness to pay for the use of the samples provided was also asked. According to the results of the study, the two-phase subsurface flow constructed wetland systems are the most socially accepted options both in terms of sensory perception as well as willingness to pay.

For the acceptability for use in irrigation using the sense of sight, the hybrid subsurface flow constructed wetland system was top rank followed by the vertical in series subsurface flow constructed wetland system. The analysis of variance and the Duncan's Multi Range Tests results shows that two systems were not significantly different with acceptability ratings of 3.820 and 3.7250 out of 5.00, respectively. With regards to the one-phase subsurface flow constructed wetland systems, results show low-ratings were given to the horizontal and vertical subsurface flow constructed wetlands with 3.4575 and 2.830 out of 5.00 ratings respectively. These ratings were significantly different from each other and significantly different from the ratings of the two-phase systems. But it was worth noting that ratings of the effluents from the four systems were significantly different from that of the raw wastewater based on what the respondents see.

Likewise, for the acceptability for use in irrigation using the sense of smell, the hybrid subsurface flow constructed wetland system was top rank followed by the vertical in series subsurface flow constructed wetland system with 3.81 and 3.52 out of 5.00 ratings respectively. These ratings defined the systems to be significantly different based on DMRT grouping which only concludes that the respondents choose to use effluent from the hybrid system more than the vertical in series for irrigation based on what they smell. With regards to the one-phase subsurface flow constructed wetland systems, results show low-ratings were given to the horizontal subsurface flow constructed wetlands with 3.10 out of 5.00 ratings which was significantly different from the two-phase systems. Lastly, the vertical subsurface flow constructed was given the lowest rating with a mean of 2.44 out of 5.00 which was significantly different to the ratings of the other three systems and was insignificantly different from that of the raw wastewater.

Frequency analysis was also done to identify the mode of all the responses gathered to which both of the two-phase systems got a mode score of 5 indicating that majority of the respondents gave a rating of 5 on either of the two systems based on what they see, regardless of either not knowing or knowing where the samples came from. As to the sense of smell, the hybrid system got the highest mode score of 5.00 followed by the vertical in series with 4.00.

In the willingness to pay aspect, the mean value for all the samples are not significantly different based on the ANOVA and DMRT results. This simply imposes that in view of the high demand for irrigation water, the farmer respondents are willing to pay for their consumption. Though the means are not significantly different, the mean highest amount the respondents are willing to pay is Php 12.70/m^3 based on sense of sight and Php 12.625 based on sense of smell. Frequency analysis was also done for the willingness to pay and got a unanimous amount of Php 10.00/m^3 for the blind perception responses for all samples. Learned responses differed from P10.00/m^3 for raw and HSFCW samples and Php15.00/m^3 for the VSFCW, VSF-VSFCW and VSF-HSFCW samples considering the sense of sight. While looking into the Learned response using the sense of smell, the raw sample got the lowest mode of P10.00/m^3 and the treated effluents got a modal rating of P15.00/m^3. These values prove that the farmers are willing to pay for irrigation water that is to be provided to them because come what may they have to irrigate their crops but given the choices between the five samples they would choose the effluent from the VSF-HSFCW first and the effluent from the VSF-VSFCW second.

Social acceptability of wastewater reuse by the local community is demand driven. Education and Farming Experience among other socio-conomic factors affect respondents' knowledge and perception. Social acceptability is independent on the respondent's sensory (sight and smell) perception because perception-based scores are not significantly different.

Based on the results, the two-phase subsurface flow constructed wetlands namely hybrid and vertical in series systems were more acceptable than the one-phase – vertical and horizontal – subsurface flow constructed wetland systems as secondary dairy farm wastewater treatment. The acceptability ratings derived from the study could be used as a take off point to focus future studies on the development of the two-phase subsurface flow constructed wetland systems increasing the removal efficiency physico-chemical contaminants like ammonia, nitrate, nitrite, phosphates, total coliform and fecal coliform among others. In depth study on the design and configuration can be done to serve this purpose.

Acknowledgement

The authors would like to express deepest gratitude to all the support received specifically to Laguna Water District Aquatech Resources Corporation (LARC) and SESAM WaterLab for your unwavering support.

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