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Water Quality Index as Exposure Indicator for Addressing Climate Change Vulnerability of Selected Communities in Negros Occidental

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ABSTRACT

Access to and quality of water have been major concerns for communities that are at risk because of climate change impacts. The importance of having sufficient supply of good water quality is vital for the community. The study focused on assessing water quality and presenting the parameters via a Water Quality Index (WQI), which would look at the source and discharge among selected communities of the province of Negros Occidental and provide the community with an indication of what needs to be addressed for their community needs. The WQI for the communities noted a general outcome for "Acceptable" quality for both the source and discharge water, which shows that the condition of the water source indicates low exposure. Analyzing the WQI and its component parameters provided insight on areas of satisfactory quality and those that require attending to, which can be done through policy-making, engineering intervention, and education.

Keywords
climate change, vulnerability assessment, exposure, water quality, water quality index

INTRODUCTION

Climate change is accountable for negative physical changes in the global environment. It continues to harm societies because the environment continues to be harmed and our lack of awareness and vulnerabilities exposed our people to greater risks (Gosling & Arnell, 2016). Climate change is therefore not only an issue that should be dealt with by environmentalists and scientists.

Water quality is a major aspect in the environment that has been affected by climate change (Duran-Encalada, Paucar-Caceres, Balanda, & Wright, 2017). Water quality involves understanding characteristics of water that would express the impact of climate change (Hounslow, 2018; Michalak, 2016). Water quality is also important in assessing water availability, because the quality of water, whether potable or not, is an important determining factor (Pesce & Wunderlin, 2000; Department of Environment and Natural Resources, 2016). In assessing water quality, specific parameters would be chosen to respond to urging needs (Gholizadeh, Melesse, & Reddi, 2016).

The impaired water quality is an indication of a deeper problem, especially with reference to the limitation of the resources (Michalak, 2016), compromises in domestic use (van Vliet, Flörke, & Wada, 2017), and the unavailability of the water as a whole. Water-quality impacts have continued to be affected by weather conditions, wherein long-term impacts would result in climate-related concerns (Powell, Kløcker Larsen, De Bruin, Powell, & Elrick-

Barr, 2017)). Increasing global temperature results in accelerated bacterial growth. Furthermore, the insights drawn from Delpla, Jung, Baures, Clement, and Thomas (2009) noted that the water quality parameters have bene affected due to the changing quality of water, which may include the following: decrease in dissolved oxygen, increase in pH, and the increase in general nutrients of the water. These parameters would affect the inherent water quality, resulting in complications that may be exacerbated due to climate change. Whitehead, Wilby, Battarbee, Kernan, and Wade (2009) also noted that there are significant impacts that climate change would cause to water, which would include nutrient loading being increased and various deposits of contaminants (Scholes, 2016).

Kundzewicz and Krysanova (2010) contended that the inherent availability of water can mean much for the community, wherein sufficient availability given a certain level of quality can be an indication of the community's response to climate change, particularly in how exposed the community is. Moreover, the nature of contamination of the water source can result because of the climate change effects, which can affect domestic use and influence policymaking (Eisenhauer, Hoover, Remais, Monaghan, Celada, & Carlton, 2016; Bharti & Katyal, 2011).

The analysis of the parameters would give due insight on the nature of the quality of water, especially with reference to how the value of the parameter can affect the overall condition of water (Wu, Wang, Chen, Cai, & Deng, 2018). The parameters of concern were biological or biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, fecal coliform, and ammonia-nitrogen (NH3-N).

According to Clesceri et al. (1999), biological oygen demand is the amount of dissolved oxygen that is consumed by aerobic biological organisms in the process of decomposing organic material. It is a measure of the pollution level of the water, wherein high BOD would indicate highly polluted waters (Wen, Schoups, & Van De Giesen, 2017). BOD values of higher than 50 mg/L would indicate potential contamination that must be further assessed (Dasgupta & Yildiz, 2016). The metric would then be used in congruence with dissolved oxygen, which, according to Clesceri et al. (1999) would be the amount of the free oxygen that is sufficient for supporting life. One consideration is that the higher the DO, the better the condition of the water body (Haiger & Hayder, 2016).

pH, according to Clesceri (1999) is the measure of the acidity/alkalinity of a given water sample. Hounslow (2018) noted that the solubility of acidic/alkaline components can affect the inherent balance of the water, which can result in compromise in terms of biological life. The assessment of pH must be within the netural value of 7 which would provide the best outcome for water quality (Aziz, Sarosa, & Rohadi, 2020).

Fecal coliform is described as the presence of pathogenic microorganism in water, which can be detected using the indicator organism, Escherichia coli (Mayo & Kalibbala, 2018; Dakhlalla & Parajuli, 2019). Albrecht (2017) noted that the changing weather patterns and the presence of precipitation events resulted in fecal coliform increase. Fecal coliform loads increased by 71.2% due to climate change effects, which would then create problematic outcomes in the water supply (Jeon et al., 2019). Hence, fecal coliform must be assessed because of its potential problem in terms of water supply. Turgeon (2012) noted that the measures of monitoring fecal coliform count would contribute toward assessing the welfare of water in terms of maintaining such quality.

Another important parameter is the ammonia-nitrogen content of water. As noted by Zia, Shuhao, Baomei, Lan, and Xiaobin (2019), ammonia-nitrogen is the nutrient responsible for plant growth and bacterial proliferation. Ammonia-nitrogen is an indication of human activity in waters, which would give insight on the level of contamination that exists (Zhang, Lai, Gao, & Xu, 2015; Duan et al., 2016). Another study showed the changing nitrogen loads that may affect the ecosystem, which would then affect human activity (El-Khoury et al., 2015).

Doell et al. (2015) and Delpla, Jung, Baures, Clement, and Thomas (2009) present the value of understanding how climate change must be integrated into water management. Analysis of water would then point toward the facilitation of change that would likewise promote better protocols of change, which would mean better policy building and practice by the people (Pandey, Kala, & Pandey, 2015) and a clear assessment of what is realy affecting water quality (Malsy, Flörke, & Borchardy, 2017).

The study aimed to determine the Water Quality Index of the source and discharge of Brgy. Cadiz Viejo, Cadiz City; Purok Seaside of Brgy. Tangub, Bacolod City; Purok Sambag of Brgy. Lopez Jaena, Murcia; and Barangay 40, Bacolod City.

Brgy. Cadiz Viejo is a coastal community that is known for its tourism and its fishing livelihood. The water body found nearby is the Guimaras Strait, wherein the community's discharge flows into as the water passes from source. Cadiz Viejo is rural in characteristic, with few urbanized structures found in the community. Brgy. Tangub is also a coastal community, but it is highly urbanized, since it is found in the lone distinct of Bacolod. The communities of emphasis had been the coastal communities, which the residents have noted to be at the end of the discharge pipeline of wastewater; hence, the heightened pollution concentration may be present.

Purok Sambag of Brgy. Lopez Jaena, Murcia, is a rural community in the inland portion of the island, wherein agricultural practice dominates. It is also a highly elevated community, situated at the inland of the Negros Island. One problem noted by the community members is the scarcity of water, which has resulted in the change of agricultural practice. Brgy. 40 is also designated as an inland community, but of the urbanized nature. Brgy. 40 is among the many barangays found in the city of Bacolod, wherein a lot of population movement exists, which can also attribute to the increased pollution movement.

Understanding the water quality index shall give the community members a qualitative idea about how they affect the water quality and how the water quality affects them. The interaction between the community members and the environment would likewise pave the way for understanding what policies can be made in order to cultivate proactive change in the community.

METHODOLOGY

The goal of the Water Quality Index is to provide a qualitative perspective on the condition of water based on normalization of each parameters that represent different characteristics that constitute a body of water (Kannel, Lee, Lee, Kanel, & Khan, 2007; Koçer & Sevgili, 2014). Parameters (Biological Oxygen Demand, Dissolved Oxygen, pH, Fecal Coliform, and Ammonia-Nitrogen values) are converted into sub-indices, in which they have been treated with statistical normalization to transform their readings along a 0 to 100 scale, with 0 as the lowest possible quality determinant and 100 as the highest possible quality determinant (Kannel et al., 2007). Normalized data would then be calculated based on equation (1) which has been adopted by multiple literature and proposed by Rodriguez de Bascarón (Abrahão et al., 2007; Bharti & Katyal, 2011; Pesce & Wunderlin, 2000). The following equation is shown below:

$$WQI = \frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \qquad (1)$$

Table 1
Normalization of Parameters

Parameter	P_i^a	C_i^b										
		100	90	80	70	60	50	40	30	20	10	0
		Analytical Value										
BOD	3	< 0.5	< 2	< 3	< 4	< 5	< 6	< 8	< 10	< 12	< 15	> 15
DO	4	≥ 7.5	> 7.0	> 6.5	> 6.0	> 5.0	> 4.0	> 3.5	> 3.0	> 2.0	≥ 1.0	< 1.0
pH	1	7	7/8	7/8.5	7/9	6.5/7	6-9/5	5/10	4/11	3/12	2/13	1/14
Fecal Coliform	3	< 50	500	1,000	1,500	2,000	3,000	4,000	5,000	7,000	10,000	> 14,000
NH_3-N	3	0	0.03	0.05	0.10	0.20	0.30	0.40	0.50	0.75	1.00	> 1.25

[a] Relative weight
[b] Normalization factors

The variables utilized in the equation were the following: C_i, which indicates the concentration or value of a given contaminant, which was normalized, and P_i, which represents the relative weight assigned based on the importance in the given water quality parameter (between 1 and 4), and n represents the total number of the parameters. Normalization of the data was done with respect to the following matrix as seen in Table 1.

The subjecting of the water quality parameters to a normalized equation would then provide a qualitative result wherein values between 0 and 15 would indicate Very Bad water quality, values between 16 and 30 would indicate Bad water quality, values between 31 and 60 would indicate Regular water quality, values between 61 and 90 would indicate Acceptable water quality, and values between 91 and 100 would indicate Good water quality (Abrahão et al., 2007).

Very Bad water would indicate water that has high levels of contamination and should not be used for consumption of any kind as it poses acute and long-term risk. Based on Table 1, the value for the Very Bad water quality would indicate BOD levels higher than 12 mg/L, DO levels of lower than 1.0 mg/L, pH range of very acidic (2) and very alkaline (13), fecal coliform concentrations above 7,000 MPN/100 mL, and ammonia-nitrogen concentrations above 0.75 mg/L.

Bad water quality has intermediate levels of contamination that may not pose immediate risk for the person. Regular water quality has no beneficial or problematic effect, but it may contain some contaminants that do not comply with regulations. Based on Table 1, the value for the Bad water quality would indicate BOD levels higher than 12 mg/L, DO levels of lower than 1.0 mg/L, pH range of very acidic (2) and very alkaline (13), fecal coliform concentrations above 7,000 MPN/100 mL, and ammonia-nitrogen concentrations above 0.75 mg/L.

Regular water quality means that the contaminant levels are within permissible limits that would neither have harmful effects on the people who utilize the water nor beneficial effects. According to Table 1, the range for Regular water quality would be BOD levels between 5 and 10 mg/L, DO levels between 3 and 5 mg/L, pH range between 4 and 7, fecal coliform concentrations between 2,000 and 5,000 MPN/100 mL, and ammonia-nitrogen concentrations between 0.20 and 0.50 mg/L. Although these values may be beyond specified DENR standards, they do not necessarily indicate a harmful effect or beneficial effect on the consumer.

Acceptable water quality means that a majority of the contaminants are within permissible values. Referring to Table 1 as a basis, BOD values would be between 2 and 5 mg/L, DO values would be between 5 and 7 mg/L, pH range between 6.5 and 7, fecal coliform of concentrations between 500 and 1,500 MPN/100 mL, and ammonia-nitrogen concentration values between 0.03 and 0.10 mg/L.

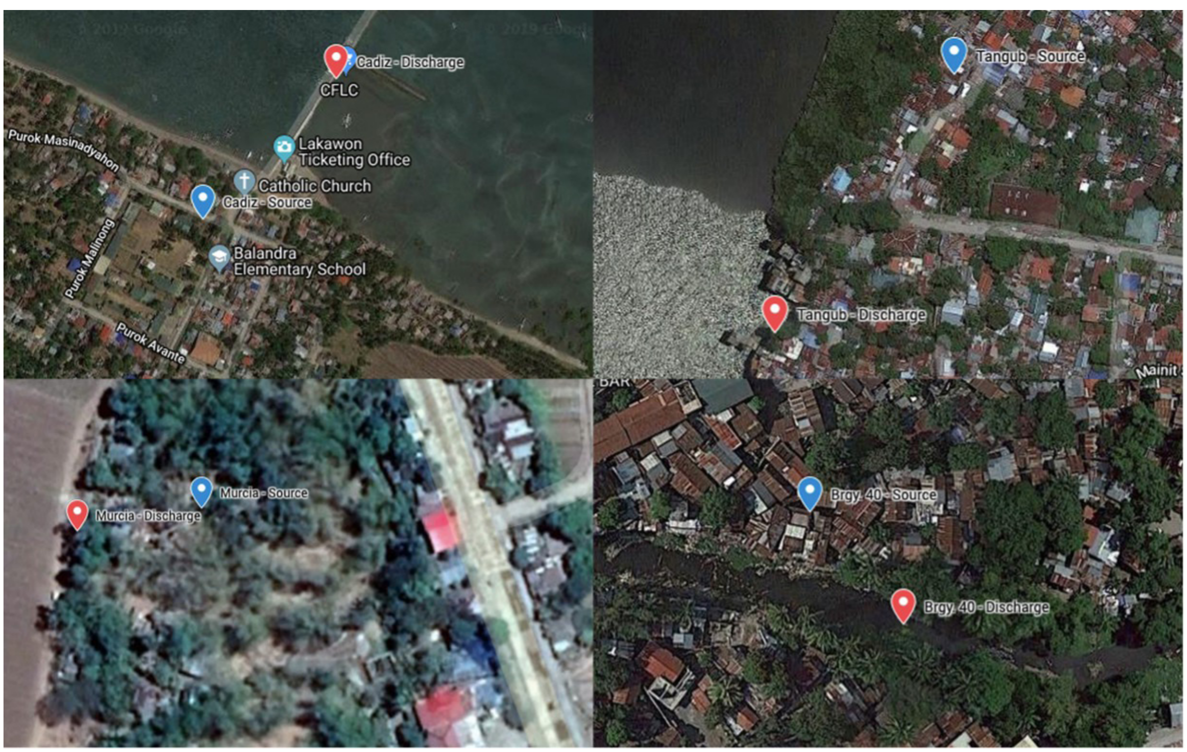
Good water quality indicates that a significant amount of the contaminants is within or below permissible values. From Table 1 as a basis, the BOD values sould be lower than 0.5 mg/L, DO should be higher than 7.5 mg/L, pH should be kept at 7, fecal coliform concentrations should be lower than 50 MPN/100 mL, and ammonia-nitrogen concentrations should be lower than 0.03 mg/L.

The water samples were collected over a period of three months: December 2018, January 2019, and February 2019. Figure 1 shows the specific points of collection. This collection resembled preliminary testing in preparation for the intervention, which would take place during the intervention phase of the project. The limitation of the collection involved only wet-season collection, so only comparison between the source and the discharge was done.

RESULTS, DISCUSSION, AND IMPLICATIONS

The first site where water sampling was done had been Cadiz, wherein a visual assessment of the source specified was slightly turbid. No wastewater treatment plant was present, except a mangrove that facilitated the secondary water treatment of the community. Source water samples were gathered in triplicate. Discharge water samples were gathered in triplicate. The source of the water was identified

Figure 1
Source (Blue) and discharge (Red) points for water quality analysis. Top Left: Cadiz, Top Right: Tangub, Bottom Left: Murcia, Bottom Right: Brgy. 40



to be an Artesian well at the specified coordinates (11° 0′ 3.17386″ N, 123° 11′ 57.7638″ E) whereas the discharge was identified to be a position away from the shore, where, according to the locals, all of their water flows into, which is located at the specified coordinates (11° 0′7.84521″N, 123° 12′2.27808″E). The BOD of the source was high with an average of 12.67 mg/L compared to the discharge with an average of 1 mg/L. This may be due to the source being near an elementary school, wherein the potential for contaminant percolation is high. Moreover, the discharge water may be diluted because of the nonpoint-source nature of the discharge. For DO, the lower DO (2.47 mg/L) of the source compared to that of the discharge (5.5 mg/L) confirms the inverse relationship with BOD. The pH of the water source was also slightly less alkaline (7.79) compared to the discharge (8.21). For Ammonia-Nitrogen, the high value of 0.84 mg/L at the source is alarming, given the threshold is very low. The discharge, due to the dilution, had an ammonia-nitrogen concentration of 0.09 mg/L. Finally, for the fecal coliform, which denotes the presence of E.coli, the count was high at 86 MPN/100 mL compared to the discharge, which was rated at 18.67 MPN/100mL. It is possible that the high value of fecal coliform may be due to the concentration of contaminant at the source compared to that in the discharge, which is evident because of the water source being continuously open, which would allow microbial contamination to occur. The water quality of the source is noted to be of a value of 39, which shows an interpretation of Regular. The value has been attributed to the high value of fecal coliform and the ammonia-nitrogen levels because of the adjacency of the water source. The designated water source is involved near the elementary school of the barangay; hence, it is accessed by all. One important finding is that the source of the water is continuously open, which would promote contamination by the fecal coliform. High nitrogen levels may be attributed to the presence of residential quarters around the water source. For the discharge, the water quality index score is 80, which is regarded as Acceptable. Possible reasons for the high value involve the dispersion of the contaminants in the adjacent water body and the inherent presence of a mangrove that would reduce contamination of the water body. Overall water quality index considering the average of the two scores is 60, which is interpreted as Regular.

The second month results show a change in the parameters. BOD was higher for the source as compared to the discharge. DO was higher at the discharge. pH was more alkaline at the discharge. Ammonia-nitrogen was higher at the source. Finally, fecal coliform was higher at the source. This indicated the source is more contaminated than the discharge. The source only had a water quality index rating of Regular, whereas the discharge had a higher rating of being Acceptable. This resulted in an overall rating of Acceptable water quality. During the second month of data gathering, the water quality has remained the same with a score of 39, which is interpreted as Regular. The water quality parameters are comparable to that of the Month 1 results, which goes to show that similar water consumptive behaviors have been noted. For the discharge, the water quality index has increased to 85, which was noted through the increase of the DO from an average of 5.5 mg/L in Month 1 to 6.5 mg/L in Month 2. The overall water quality index has increased by 2 units in accounting of the improvement of the water quality parameters.

The third month showed a change in the parameters. BOD was higher at the source. DO was higher at the discharge. pH was more acidic at the source. Ammonia-nitrogen was higher at the source. Fecal coliform was higher at the source. Water quality at the source was Regular. Water quality at the discharge was better with an interpretation of Acceptable. The findings from the third month of data gathering noted that there was an increase of water quality index score from 39 to 57, wherein the score of 57 is interpreted as Regular. The possible reasons for the improvement of quality may be due to the lack of contaminants percolating into the source. The notable improvement had been due to the reduction of BOD from 12 mg/L to 6 mg/L. For the discharge, the water quality index deteriorated from 85 to 82, but still within the Acceptable limit. The possible reason included slight increase in BOD from <2 to 2 mg/L and also the increase in fecal coliform concentration from 20.33 MPN/100 mL to 28 MPN/100 mL.

The second site of water sampling was done at the coastal portion of Brgy. Tangub, specifically Purok Seaside. While the water was slightly turbid upon initial visual assessment, a mangrove was present that facilitated the treatment of water from the houses to the discharge point, which is the water body. Both source and discharge samples were done in triplicate. The source of the water was identified to be a common well in which most of the community attained their water with the specified coordinates (10° 37′ 52″ N, 122° 55′ 32″ E). The discharge of the water was identified to be approximately 1.5 meters off the shore, wherein it is noted as a non-point source at the specified coordinates (10° 37′ 48″ N, 122° 55′ 29″ E). The BOD of the source (13 mg/L) was higher than that of the discharge (3.67 mg/L). This may be due to the source being at the center of many houses, which may result in the percolation of contaminants to the well. Moreover, the discharge water sample was diluted since it was collected at the non-point source. The DO value of the source was lower at 3.07 mg/L compared to that in the discharge at 5.83 mg/L, which is reflective of the inverse relationship with BOD. For pH, the source was slightly more acidic (6.91) compared to the discharge (7.18). It may be due to the increased presence of wash water and other alkaline-related that may have flown into the discharge area. Ammonia-Nitrogen of the source was lower at 0.33 mg/L compared to in the discharge at 0.98 mg/L, which is a good indication of improved water quality. However, both values are still beyond the threshold, allowable limit. Fecal coliform at the source was high at 89.33 MPN/100 mL compared to in the discharge at 20.33 MPN/100 mL. More contaminants are expected given the location and the continuous utilization of the water at the source, without the proper sanitation practices being done. Analysis of the Water Quality Index of the water sample of the first month of data gathering in Tangub noted that the source water had a value of 48, indicating regular water. Compared to the discharge, which was rated at 65, noting an Acceptable interpretation, the water quality of the discharge was better than that at the source. The attribution to such finding may be done with respect to the fact that the mangrove may have contributed to the reduction of contaminants. Overall, the water quality index of the water in Tangub was 57, which is considered Regular water quality. Brgy. Tangub is a coastal barangay in Bacolod City, Negros Occidental, wherein the water quality of the source is 48, with an interpretation of Regular. The high value of the BOD has been due to the source being adjacent to the household. Upon interviewing with one of the residents, the source of water was actually the deep wells found in their homes, and the resident mentioned that almost all of the adjacent households retrieved their water from the said source. One important result is the high ammonia-nitrogen content which may be attributed to the percolation of the contaminant since the source is within the residential community. The discharge identified had a water quality index score of 65, which was acceptable. The higher water quality had been attributed to lower BOD because of the presence of the mangrove that may have contributed to the reduction of the contaminant. Although the water quality is reflected as higher than that of the source, the level of ammonia-nitrogen is higher, being 0.98 mg/L in the discharge compared to 0.33 mg/L, which shows an increase of nitrogenous waste in the discharge portion.

The results of the second month were as follows. The BOD of the source is higher at the source, while the DO is higher at the discharge. The pH is more acidic at the source compared to the discharge. Ammonia-Nitrogen is higher at the discharge, and fecal coliform is higher at the source. This indicates a varied outcome in comparable contamination among the source and discharge exists. Both the source and discharge had acceptable rating for water quality. During the second month of data gathering, the water quality of the source increased, which can be noted through lowered BOD, with 5.67 mg/L in the second month compared to 13 mg/L in the first month. Also, the ammonia-nitrogen concentration decreased from 0.33 mg/L to 0.04 mg/L which may be attributed to the lack of activities involving solid waste production since January was an off-season month. The percolation into the soil accompanied by the lack of rainfall did not promote increased contamination in the water source. In the discharge, the water quality decreased because of the prevalence of poor waste practices. In fact, comparing to the fecal coliform count of 20.33 MPN/100 mL in Month 1, the value shot up to 76.33 MPN/100 mL in Month 2. Poor waste practices have contributed to the increased contamination of the discharge, which can harm ecological life.

The third month water quality changed as follows. BOD was higher at the source; DO was higher at the discharge. pH was more acidic at the source. Ammonia-nitrogen was higher at the discharge. Fecal coliform was higher at the source. Overall water quality analysis yielded Acceptable for both source and discharge. The third month of data gathering noted an improvement of the water quality in the source, from 70 to 79, with the rating of Acceptable. This was noted through the reduction of fecal coliform count from 81 MPN/100 mL to 44.67 MPN/100 mL. For the discharge, the water quality improved from 61 to 70, with a rating of Acceptable. The reduction of fecal coliform count from 76.33 MPN/100 mL to 20 MPN/100 mL provided the increase in water quality.

The third site of water sampling was done at Purok Sambag, Brgy. Lopez Jaena, Murcia. Initial visual assessment noted that the water was turbid. The source was identified to be a well situated at the center of the houses, which were at the circumference of a 2-m radius. The discharge point was a creek in which it is identified as the water coming from non-point sources. The source was identified as a well situated at the center of houses at a rough radial distance of 2 meters from each house at the specified coordinates (10° 34′ 30.2″ N, 123° 4′ 27.12″ E). The discharge point was noted to be the creek wherein the water of the community had flown upon release by each household at the specified coordinates (10° 34′ 29.99″ N, 123° 4′ 25.96″ E). The BOD at the source is higher (13.33 mg/L) compared to that in the discharge (12.67 mg/L). Possible increase of BOD involves the presence of contaminants that are found since the source is situated near homes. At the discharge point, slightly lower BOD is due to the possible dispersion of the contaminants in a wide area. For DO, the source value is 7.33 mg/L, but for the discharge is it very low at 0.7 mg/L. The low DO is a signifier about the lack of sustainable oxygen for life. The pH of the source is slightly more alkaline (7.9) compared to the discharge (7.5). For ammonia-nitrogen, the source contained lower concentrations (0.17 mg/L) compared to the discharge (6.02 mg/L). What is alarming at the discharge is that the high ammonia-nitrogen is well beyond the threshold for the ammonia-nitrogen limit. Finally, fecal coliform concentration decreased from the source (89 MPN/100mL) compared to the discharge (55.67 MPN/100mL). Water sample analysis subjected to the Water Quality Index revealed that, at the source, the water quality was Acceptable. At the discharge, it was Regular, although it is at the threshold because of the high ammonia-nitrogen concentration. Generally, the water quality in Murcia is Regular.

Brgy. Lopez Jaena is situated in Murcia, Negros Occidental. More specifically, the site of interest was Purok Sambag, which has faced considerable impact due to climate change. The water quality index of the source is rated at 69, which is considered as Acceptable. The communal water source was noted because of its situation which was at the center of the community. The source was away from residential homes, which indicated low levels of contaminants. The BOD, however, is high, which may be due to the percolation due to lack of piping structures that would curb the movement of contaminants. The discharge, however, was sufficiently worse in comparison, with a quality index of 32, which may be noted as Regular in quality. What is notable is the ammonia-nitrogen concentration, which was, on average, 6.02 mg/L. The high level shows contamination in which, upon interviewing with the residents, the discharge area was identified as the location wherein all wastewater would runoff toward.

The second month results are as follows. BOD was significantly higher at the discharge. DO was higher at the source. pH was more acidic at the discharge. Ammonia-nitrogen was higher at the discharge. Fecal coliform was also higher at the discharge. This indicates that the discharge is more polluted than the source. Water quality analysis shows that the source has a Good water quality whereas the discharge has a regular water quality. Compared to Month 1 findings, the water quality of the source has significantly improved, with a score of 93, which is interpreted as Good. The BOD significantly reduced from 13.33 mg/L to <2 mg/L, which may be attributed to the lack of contaminants flowing into the water source. The fecal coliform concentration also decreased from 89 MPN/100 mL to 16 MPN/100 mL, noting the improvement of water quality. For the discharge, the score improved from 32 to 43, albeit being still under the interpretation of Regular. The significant improvement was noted with the reduction of ammonia-nitrogen concentration from 6.02 mg/L to 1.35 mg/L.

The third month showed that BOD was higher at the discharge, DO was higher at the source, pH was more acidic at the discharge, ammonia-nitrogen was higher at the discharge, and fecal coliform was higher at the discharge. This indicated that the discharge was more polluted than the source. Compared to the findings in Month 2, the water quality of the source significantly reduced from 93 to 85, which has a rating of Acceptable. The possible reasons for such reduction are BOD concentration reduction from <2 mg/L to 1 mg/L and the pH change 7.2 to 6.03. For the discharge, the score was increased from 43 to 71, which had an interpretation of Acceptable. One thing to note during the data collection of the discharge was that the original site had dried up during the time of data gathering, so the alternative solution is to locate another site where the discharge of the community would be delivered. The same environmental parameters were considered to maintain the integrity of the results.

The final site of water sampling was Brgy. 40, where the initial visual assessment of the water was turbid. The source was a water pump at the middle of the cluster of houses. The discharge was identified to be the river in which plastic waste and other waste were present at the shore. The source was identified at the pump near a cluster of houses as the specified coordinates (10° 39′ 29.87″ N, 122° 57′ 7.32″ E). The discharge was identified to be the river at the specified coordinates (10° 39′ 28.96″ N, 122° 57′ 8.09″ E). The BOD of the source (13 mg/L) was higher than that of the discharge (9 mg/L), which may be attributed to the contamination of the pump. The DO of the source (1.67 mg/L) is lower than that of the discharge (4.3 mg/L), which verifies the inverse relationship with BOD. The pH of the source is slightly more acidic (6.54) than the discharge (7.01), which may be attributed to the fact that part of the discharge involves wash water. For the ammonia-nitrogen, the source (0.14 mg/L) had lower concentration compared to the discharge (1.83 mg/L). This is expected given that the discharge would contain heavy amounts of nitrogenous contaminant. The fecal coliform has reduced from the source (69 MPN/100 mL) to the discharge (43.67 MPN/100mL). The analysis of the water samples in Brgy. 40 all yielded a water quality index rating of Regular. This means that the water is at the border-line, and the water may eventually attain a lower quality status.

Brgy. 40 is a densely populated community in Bacolod City. The houses are closely connected with one another and the people live in closely-knit communities. The water quality index is 48 at the source and 50 at the discharge, which is Regular. The water quality index is noted as follows because of the high ammonia-nitrogen in both the source and discharge. The water quality index shows that more can be done with the conditions at hand. The problem can be noted that the source and discharge have similar indices, which means that the source is contaminated, so this creates a concern for the community. The conditions in Brgy. 40 must be addressed due to the situation of the barangay containing a public market, which may contribute to the continuous use of water and the concerns in the wastewater management.

The second month results are shown as follows. BOD was higher for the source. DO was higher for the

Figure 2
Trend of water quality indices for a three-month period of the source of selected communities.

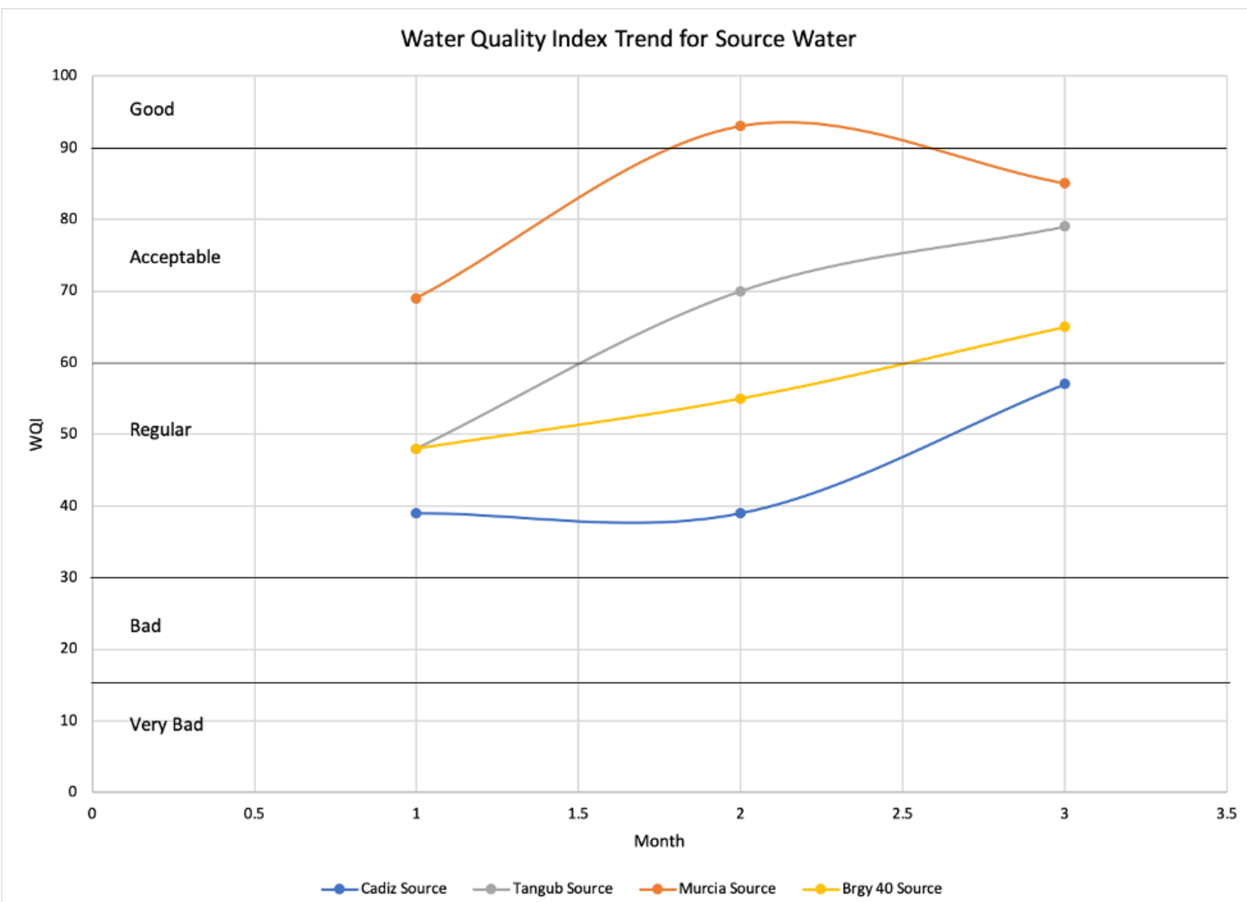
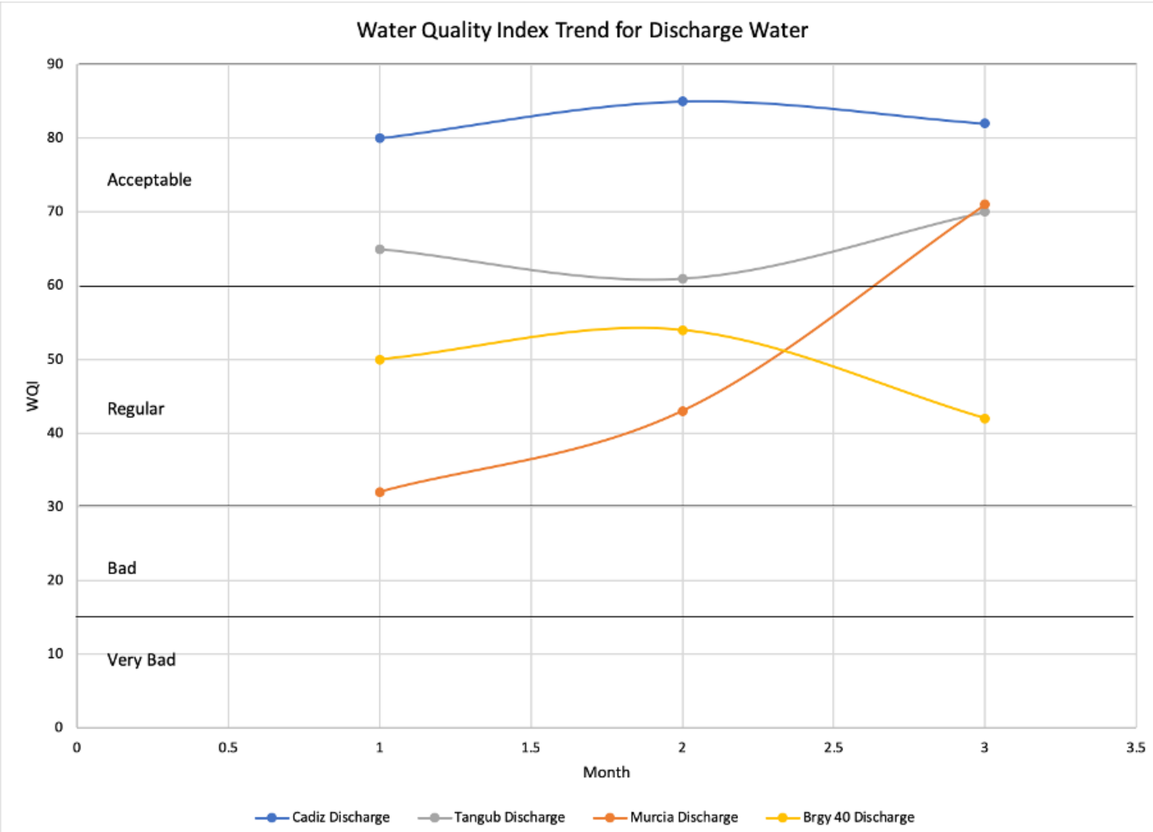


Figure 3
Trend of water quality indices for a three-month period of the discharge of selected communities.



discharge. pH is more acidic for the source. Ammonia-nitrogen was higher for the discharge. Fecal coliform was higher at the source. Water quality analysis showed that it was Regular. Compared to Month 1, the water quality of the source improved from 48 to 55, with an interpretation of Regular. BOD concentration improved from 13 mg/L to 11.33 mg/L. The change was not significantly prevalent because of the worsening of the fecal coliform count from 69 MPN/100mL to 91.33 MPN/100 mL. For the discharge, the water quality index score also improved from 50 to 54, with an interpretation of Regular. BOD concentration reduced from 9 mg/L to 7 mg/L.

The third month findings indicated that BOD was higher at the discharge. DO was higher at the source. pH was more acidic at the source. Ammonia-nitrogen was higher at the discharge. Fecal coliform was higher at the discharge. Compared to Month 2, the water quality of the source improved from 55 to 65, with a rating of Acceptable. The possible reasons include a reduction of BOD from 11.33 mg/L to 5 mg/L and fecal coliform from 91.33 MPN/100 mL to 59.67 MPN/100 mL. For the discharge, the water quality score was reduced from 54 to 42, securing a rating of Regular. The increase in ammonia-nitrogen from 0.98 mg/L to 1.99 mg/L influenced the lowering of the water quality.

Collating the information obtained through the assessment of water quality, an overall Water Quality Index can be derived by comparing the change in Water Quality over time, to assess and project what may happen to the water quality of the communities. Figure 2 shows the trend of the water quality indices of the communities' source. The Cadiz source water has shown a gradual increase in water quality, which may indicate that the temporal element may contribute to lower contaminant content of the water. The Tangub source water has also shown a gradual improvement in quality over three months. The possibility is that continuous retrieval of the water prevents additional contamination. For the Murcia source, a slight improvement in water quality was noted between months 1 and 2, but a decline became evident toward month 3. Possible contamination of the source may exist. For the Brgy. 40 source, the water quality has improved over the past few months. Generally speaking, the overall trend of the water quality indices is positive with an improvement of quality. However, what can also be inferred from the figure is that the Cadiz source is only at the Regular quality while that of the Murcia, Tangub, and Brgy. 40 are at the Acceptable level.

Figure 3 shows the water quality index trend for the discharge water of the selected communities. What can be noted is that the discharge quality at Cadiz has slightly increased over the three-month period. For Tangub, there is a sudden dip between months 1 and 2 regarding the water quality, but the month 3 performance involved an increase of water quality. For Murcia, a rapid increase of water quality was noted at the discharge. However, for Brgy. 40, there was an overall decrese of water quality at its discharge. While the water quality of Cadiz, Tangub, and Murcia were Acceptable, that of the Brgy. 40 was of Regular quality.

As stipulated by Bharti and Katyal (2011), understanding water quality indices can provide a qualitative measure of the water quality of surface water that can promote policymaking initiatives that would combat climate change.

CONCLUSION AND RECOMMENDATIONS

While the WQI provides an overall picture to the situation of the community, an inspection of each parameter should be done to pinpoint the exact problem that the community's water source and discharge have. These insights shall not only provide the community members with further measures to improve overall water quality.

The Water Quality Index served as in indicator of Exposure because of the lowered resilience of the community if the community has poor access to sufficient water, one of a quality that they can use for their everyday utilization, and, hopefully, drink. Being able to have water of good quality is also reflective of a community's practice, wherein the members are careful about what they contribute to the environment around them.

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