WATER AND BOTTOM SEDIMENT QUALITY OF PAGATBAN RIVER IN NEGROS ORIENTAL, PHILIPPINES: 30 YEARS AFTER MINING CLOSURE

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Anthropogenic activities threaten the ecological functions and services of rivers. In particular, Pagatban River in Negros Island, Philippines experienced these threats as massive fish kills happened from 1979 to 1983 as a result of mine tailing pollution. This study explores the water quality of Pagatban River after three decades of post-mining operation. A one year longitudinal design was employed to monitor 17 water parameters in three study sites within a 15.81 kilometer stretch of Pagatban River. Water quality parameters of the river between seasons and across sites were analyzed using Kruskal-Wallis One-way Analysis of Variance. These parameters were also compared with national and international standards for water quality. Results revealed that total water volume, width of river, water volume per site, temperature, total suspended solids, phosphate (PO_4-P) and total *coliform* varied significantly between seasons. Meanwhile, width of river, water volume, velocity, depth of river, salinity and nitrate (NO_3-N) showed significant differences across sampling sites. Furthermore, the heavy metals in the waters of Pagatban River were below the detectable limit of 0.01 mg/L, however, the bottom sediments from the river mouth and river banks showed high levels of heavy metals that ranged from 0.1 mg/kg – 242.8 mg/kg. Although the general water quality of Pagatban River can be classified as Class C which is suited for aquaculture use, the amount of heavy metals in its bottom sediments is not compatible with any fishery activities in the area. In conclusion, this study confirms that the water quality of Pagatban River has improved significantly over the last three decades but its bottom sediment quality still has heavy metals that are 200 to 5,000 times higher than the acceptable levels.

KEYWORDS: heavy metals, mine tailing, Pagatban River, Negros Oriental, total coliform, water quality

INTRODUCTION

RIVER ECOSYSTEMS ARE among the endangered ecosystems because of unregulated human activities that imperil them. There are three anthropogenic threats that rivers in Asia face today, namely: [1] degradation of river basins due to deforestation, [2] Infrastructure developments that disrupt the functioning of biological ecosystems, and [3] river pollution (Dudgeon, 1992; Qiao et al., 2011). Deforestation has also been identified as the major cause of suspended sediment load and massive flooding in rivers. In cases of extreme siltation, species decline and disappearances are expected when habitats of aquatic organisms are altered. Meanwhile, infrastructure developments that regulate the flow of rivers such as levees, dikes, dams and canals have been known to disrupt fish breeding migration patterns. Estuaries in China are among the most turbid in the world with an annual terrestrial sediment load of 1,600 million tons that are largely caused by dredging, oil and gas explorations and many others (Wang, Wang, Guan, & Guo, 2011). Furthermore, river pollution in Asia is characteristically dominated by domestic wastes particularly fecal pollution (median coliform count of 10,000 l^{-1}) rather than industrial effluents except for Malaysia where river pollution was attributed to tin mining (Barril & Tumlos, 2002; Dudgeon, 1992; Malayang, Briones, & Catalan, 2002). Philippine rivers and streams, likewise, suffer from varying degrees of environmental disturbances from waste dumping as cities and municipalities expand (UNEP-IETC Report, 2009).

Studies conducted in Pagatban River on Negros Island between 1979 and 1981 indicated copper and zinc levels of 0.017-0.057 mg/L and 0.014-0.273 mg/L, respectively (Lowrie et al. as cited in Alcala, 1999). These were attributed to discharges from the mining company that operated in the area. Decimation of ecologically important species and persistent fish kills were observed in Pagatban River during that time (Alcala, 1984). No rehabilitation activities were recorded after the mining company closed down in 1984. Previous studies on the water quality of Pagatban River served as an important baseline data for comparison after three decades without mining activities. This river marks the boundary between Bayawan City and the Municipality of Basay; it receives the effluents from the open pit mining area.

The aim of the study was to compare the water quality of Pagatban River of Negros Island between seasons and across sites after three decades of post-mining activity. Seventeen water parameters were measured covering physico-chemical and biological aspects. From these water data, comparisons were made with international water quality standards set by US EPA (1986) and WHO (2011). Comparisons to the previous water data of Pagatban River (Alcala, 1999; Rosario, 1999) were also conducted to verify any improvement or further deterioration of its water quality. Results of this study will be useful for the identification of its water classification and appropriate usage based on the existing guidelines as provided by the Department of Environment and Natural Resources of the Philippines.

MATERIALS AND METHODS

Pagatban River is located in southern Negros separating the municipality of Basay and Bayawan City. The river has an average width ranging from 63 m to 78 m. The study area covered an approximate length of 15.81 kilometers and was divided into three sampling stations designated as upstream (Barangay Naghalin in Basay), midstream (Barangay San Miguel in Basay), and downstream (Barangay Pagatban in Bayawan). Upstream (Study Site 1) has a rugged terrain and is highly elevated. This was accessed by land transportation while midstream and downstream (Study Sites 2 and 3, respectively) were accessed using a motorized canoe.

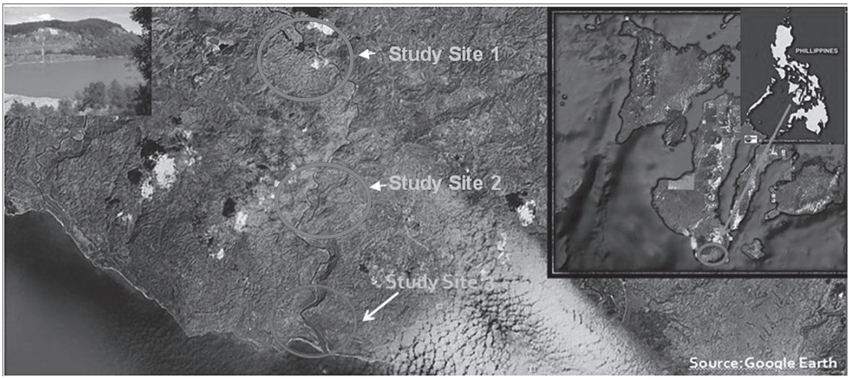


Figure 1. Map of Pagatban River, Negros Oriental showing the location of study sites. ***Site 1:* Upstream—Bgy. Naghalin, Basay:** Upper Upstream (Sitio Tigbayawan)—9.48573°N, 122.70893°E, Middle Upstream (Sitio Cabigtian)—9.48166°N, 122,71122°E, Lower Upstream (Sitio Cubi)—9.48063°N, 122.71181°E. ***Site 2:* Midstream—San Miguel, Basay:** Upper Midstream (Sitio Aya-aya)—9.41316°N, 122.71457°E, Middle Midstream—9.42133°N, 122.71214°E, Lower Midstream—9.41996°N, 122.71231°E. ***Site 3:* Downstream—Bgy. Pagatban,Bayawan:** Upper Downstream—9.38647°N, 122.71458°E,Middle Downstream—9.38844°N, 122.71251°E, Lower Downstream—9.38601°N, 122.71408°E. Upper left inset is the water-filled open pit copper mine that drains into the river.

Water sampling from the study sites was conducted during the dry season from February to May 2010 and the wet season from August to November 2010. Data validation through a community dialogue was conducted in November 2011 while intermittent water sampling continued until January 2012 on selected parameters. Water samples were obtained from every site in three replicates using 350-ml water bottles. The samples were stored in an ice box and were analyzed *in situ* through a make shift laboratory and later brought to the Chemistry and Biology Departments of Silliman University for further laboratory analyses. The analyses comprised of seventeen water parameters, namely: pH, temperature, dissolved oxygen, salinity, color, width, depth, total *coliform*, nitrate, phosphate, total suspended solids, velocity, volume per site, total volume, lead, copper, and zinc. Seventy two (72) measurements per parameter were conducted throughout the sampling period with the exception of the heavy metals: lead (Pb), copper (Cu), and zinc (Zn) measured twice every season for the water samples and once every season for the bottom sediments samples. The data on heavy metals were compared to the previous data of Alcala (1999) and Rosario (1999) to determine variations in concentrations across time.

The following methods were used to measure the water parameters: pH meter for water pH, thermometer for subsurface water temperature, ocular approximation using *sechi disk* for water color; Winkler titration, refractometer and vacuum filtration (GFC filter) methods for dissolved oxygen, salinity and total suspended solids, respectively. Furthermore, Cadmium Reduction method was employed to analyze nitrate (NO3-N); Ascorbic Acid colorimetric method for total phosphate (PO4-P) determination; aerobic plate count using EMB culture medium for the bacterial determination of total *coliform*; and flame atomic absorption spectrophotometry (AAS) for the analysis of heavy metals. River velocity was determined using a floater which was made to travel a known distance divided by the time spent to travel the said distance. Water volume per sub-site was calculated using the formula R = *width* (m) x *depth* (m) x *velocity* (m/sec). The formula used for the total water volume was $Q = R_1 + R_2 + R_3$ (Umali & Cuvin, 1988) where R is the flow volume at study sites 1, 2 and 3.

Descriptive statistics such as mean, minimum, maximum, standard deviation, and standard error were used for the analyses of physico-chemical and total *coliform* data. Normality in the data distribution was established using Shapiro-Wilk's test. The Kruskal-Wallis One-way Analysis of Variance was used to compare the means of the water parameters between sampling seasons and across sampling sites an alpha level of 0.05.

RESULTS

Physical Parameters of Pagatban River Between Seasons

The mean water temperature differed significantly between seasons (mean temperature during dry season = 31.03 ^{o}C; mean temperature during wet season = 28.53 ^{o}C; p value = 0.054) (Table 1). Although the water velocity did not differ significantly, the water volume per study site (R) and total water volume (Q) varied significantly between seasons (mean R during dry season = 19.43 m3/s; mean R during wet season = 33.76 m^3/s; p value = 0.025; mean Q during dry season = 58.26 m^3/s; mean Q during wet season = 110.84 m^3/s, p value = 0.021). The color of the river water during the dry season was dominantly clear green but murky brown during the wet season. The mean width of Pagatban River showed significant differences between seasons (mean width during dry and wet seasons = 63.06 m and 77.94 m, respectively; p value = 0.000). However, the mean depth of the river did not show significant variation between the seasons (mean depth during dry season = 1.24 m, mean depth during wet season = 1.28 m, p value = 0.169). Lastly, total suspended solids (TSS) differed significantly between seasons (TSS during dry season = 45.74 mg/L; TSS during wet season = 105.94 mg/L; p value = 0.001).

Chemical and Biological Parameters of Pagatban River Between Seasons

The pH level of Pagatban River did not differ significantly between dry and wet seasons (mean pH during dry months = 7.29; mean pH during wet months = 7.07; p value = 0.141). Dissolved oxygen (DO) levels did not vary significantly between seasons (mean DO during dry months = 9.26; mean DO during wet months = 9.76; p value = 0.096). Similarly, the salinity levels did not significantly vary between seasons (mean salinity during dry months = 0.105; mean salinity during wet months = 0.097; p value = 0.070). Meanwhile, total nitrate (NO_3-N) level of Pagatban River showed no significant variations (mean NO_3-N during dry months = 0.077 mg/L; mean NO_3-N during wet months = 0.12 mg/L; p value = 0.608). Total phosphate level (PO_4-P), on the other hand, differed significantly between seasons (mean PO_4-P during dry months = 2.57 mg/L; mean PO_4-P during wet months = 0.44 mg/L; p value = 0.001). The levels of heavy metals in the water of Pagatban River were below the limit of detection set by the analysis, thus, lead (Pb), copper (Cu) and zinc (Zn) were < 0.010 mg/L, < 0.032 mg/l and < 0.017 mg/L, respectively. However, the bottom sediments found at the river bank showed high heavy metal content. Composite sample analyses revealed that lead (Pb) level was 5.8 mg/kg, copper (Cu) was 242.8 mg/kg and zinc (Zn) was 41.8 mg/kg. Lastly, the level of total coliform varied significantly between seasons where mean total *coliform* during dry season was 1,867 cfu/mL and 18 cfu/mL during the wet season (p value = 0.04).

Water Parameters Across Study Sites

The mean pH values of Pagatban River indicated neutral values of above 7 (Figure 2). The midstream area showed the highest

Table 1. Physico-chemical and total *coliform* parameters of Pagatban River between dry and wet seasons (n=72/parameter; n=12/heavy metal in water; n=2/heavy metal in bottom sediments)

		2010 DRY SEASON				2010 WET SEASON				
Parameters	**Fresh water Std.**	**Max**	**Min**	**Average**	**S.E. (±)**	**Max**	**Min**	**Average**	**S.E. (±)**	***p* value**
pH	6.5-8.5	6.43	8.20	**7.29**	0.08	7.80	6	**7.07**	0.09	0.141
Temp. (°C) max. rise	3	34.20	26.20	**31.03**	0.34	30.10	26	**28.53**	0.11	**0.054**
D.O. (mg/L)	5	12	4	**9.26**	0.27	11.20	8	**9.76**	0.11	0.391
Salinity (g/L)	—	1	0	**0.11**	0.04	0.30	0	**0.10**	0.02	0.070
Width (m)	—	132	22	**63.06**	6.88	137	31	**77.94**	7.13	**0.000**
Depth (m)	—	4.17	0.35	**1.24**	0.16	4.47	0.47	**1.38**	0.13	0.169
Velocity/site (m/s)	—	0.77	0.07	**0.25**	0.02	1.24	0.07	**0.40**	0.05	0.060
R (m^3/s)	—	67.84	4.69	**19.43**	3.09	80.97	12.78	**33.76**	6.08	**0.025**
Q (m^3/s)	—	85.79	38.64	**58.26**	3.30	125.75	95.62	**110.84**	7.10	**0.021**
NO_3-N (mg/L)	10	0.20	0.008	**0.08**	.008	0.86	0.02	**0.12**	0.03	0.608
PO_4-P (mg/L)	0.20	4.87	1.764	**2.565**	0.294	1.81	0.07	**0.44**	0.06	**0.001**
TSS (mg/L)	30	220	0	**45.74**	10.24	167.20	11.2	**105.94**	5.32	**0.001**
Coliform (cfu/mL)		58,667	0	**1,867**	1,569	90	0	**18**	4.69	**0.040**
Pb in water (mg/L)	0.05	—	—	**<0.018**	—	—	—	**<0.010**	—	—
Cu in water (mg/L)	1.0	—	—	**<0.018**	—	—	—	**<0.032**	—	—
Zn in water (mg/L)	5.0	—	—	**<0.036**	—	—	—	**<0.017**	—	—
Color				**b-c**				**b-c**		
Pb in soil (mg/kg)	0.025	—	—	**5.8**	—	—	—	**<1.00**	—	—
Cu in soil (mg/kg)	0.045	—	—	**242.80**	—	—	—	**222.40**	—	—
Zn in soil (mg/kg)	0.090	—	—	**41.80**	—	—	—	**51.40**	—	—

Freshwater standard is based on DENR DAO 34-90, US EPA and WHO; temp= temperature; DO= dissolved oxygen; R= water volume/study site; Q=total water volume; NO_3-N=nitrate; PO_4-P=phosphate; TSS=total suspended solids; Pb=lead; Cu=copper; Zn=zinc; b-c=brown to clear green; **p* value in **bold** font indicates statistical significance; *p* value in regular font indicates non-significance

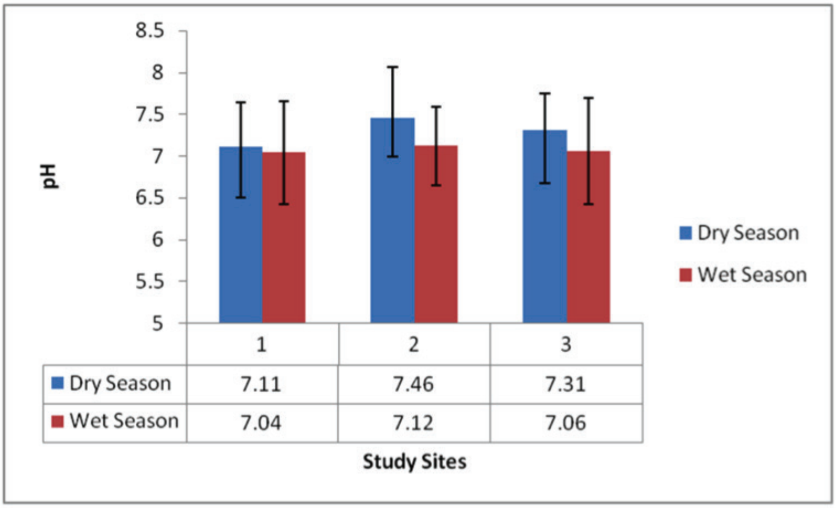


Figure 2. Mean water pH of Pagatban River across study sites and between seasons.

mean pH values of 7.46 and 7.12 during dry and wet seasons, respectively. The mean pH did not vary significantly across the three study sites (p value = 0.488).

The highest mean water temperature was recorded at the upstream area during the dry season with an average of

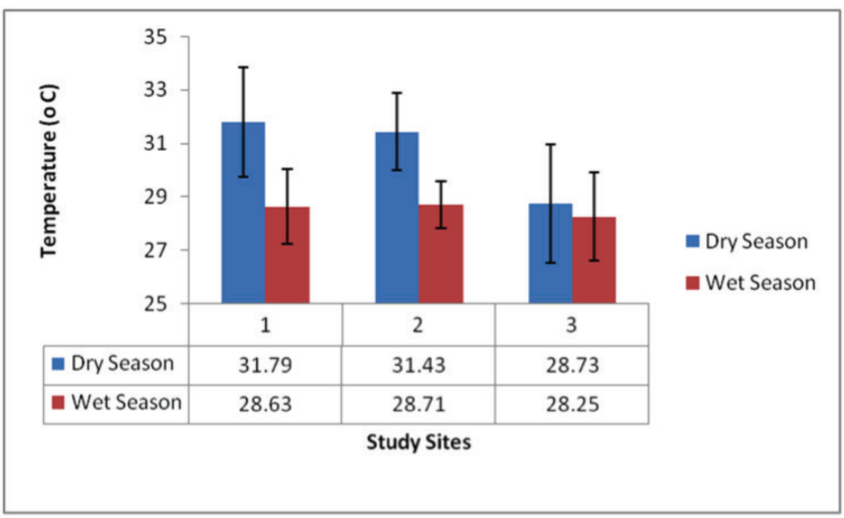


Figure 3. Mean water temperature of Pagatban River across study sites and between seasons

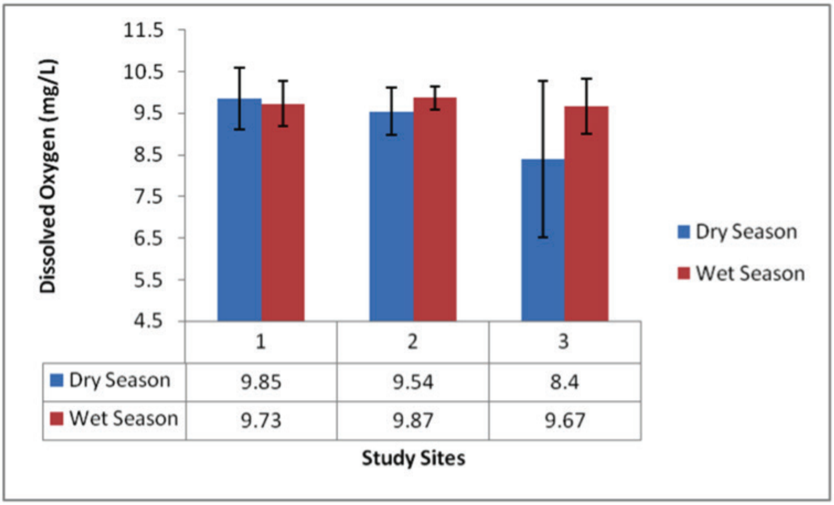


Figure 4. Dissolved oxygen levels of Pagatban River across study sites and between seasons

31.43°C while lowest mean water temperature was recorded at the downstream area during the wet season with an average of 28.25°C (Figure 3). There was no significant difference of the mean water temperature across the three sites (p value = 0.414).

The mean dissolved oxygen (DO) values of Pagatban River

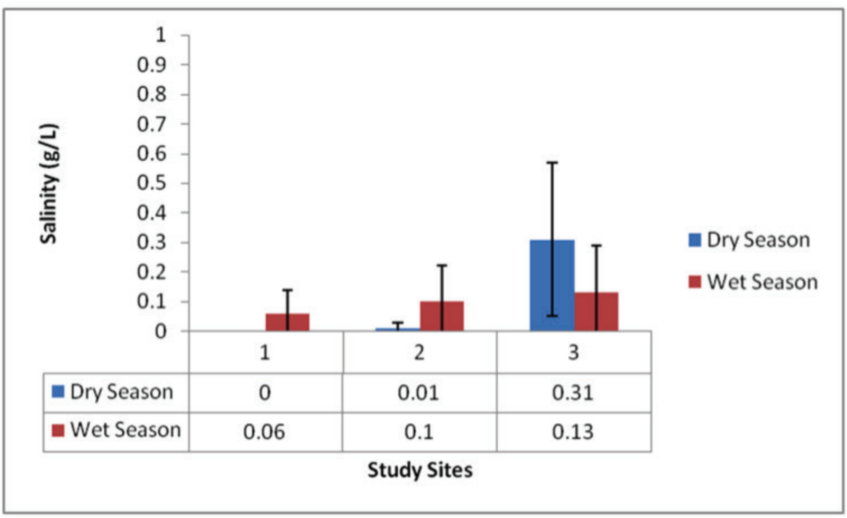
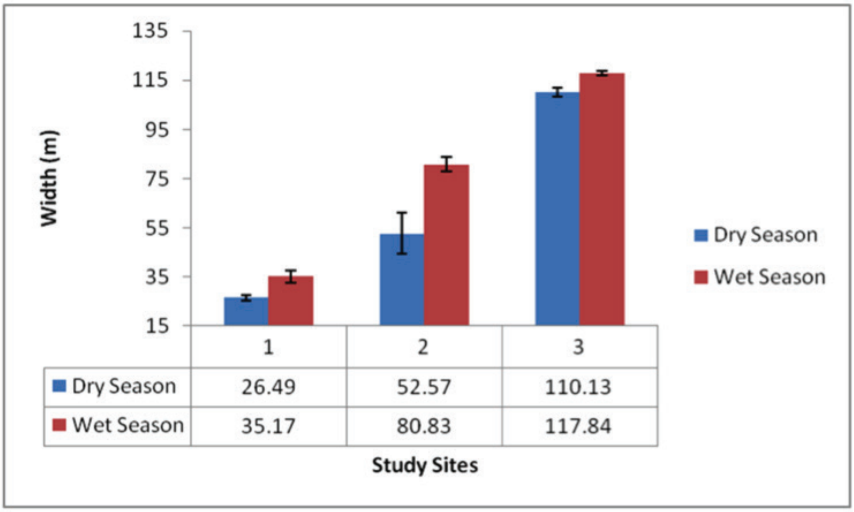


Figure 5. Mean salinity levels of Pagatban River across study sites and between seasons

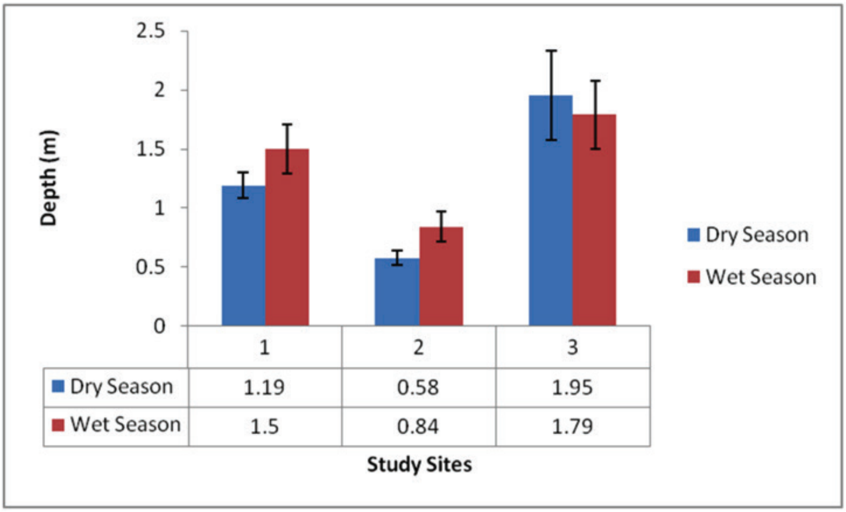


	1	2	3
Dry Season	26.49	52.57	110.13
Wet Season	35.17	80.83	117.84

Figure 6. Mean width of Pagatban River across study sites and between seasons

remained above 8 mg/L between seasons and across study sites (Figure 4). There was no significant difference of the DO levels across the three study sites.

The mean salinity values throughout the study sites ranged from 0 g/L to 0.31 g/L. The highest salinity values were consistently observed at the downstream area which averaged to 0.31 g/L and



	1	2	3
Dry Season	1.19	0.58	1.95
Wet Season	1.5	0.84	1.79

Figure 7. Mean depth of Pagatban River across study sites and between seasons

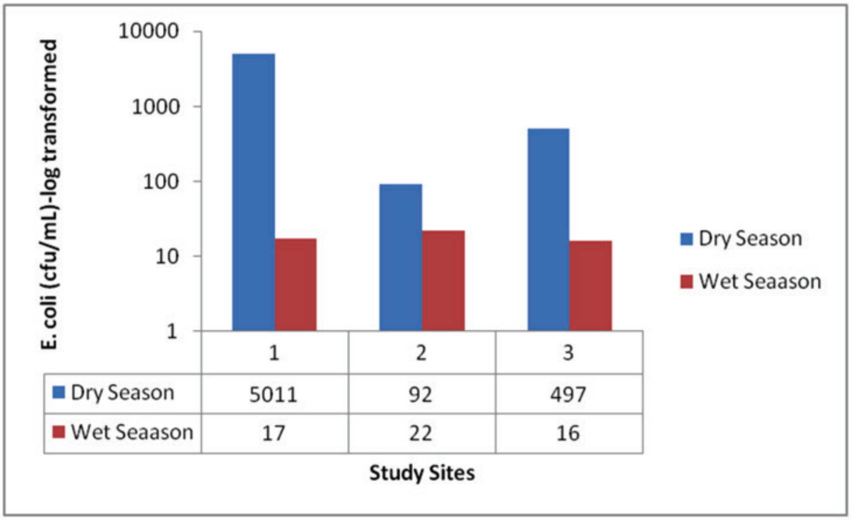


Figure 8. Levels of total coliform in Pagatban River across study sites and between seasons

0.13 g/L during the dry and wet seasons, respectively (Fig. 5). The lowest average salinity of 0 g/L was recorded in the upstream area during the dry season. The mean salinity varied significantly across the three study sites (p value = 0.002).

The highest mean width and depth values were recorded in the downstream area between seasons and across the study sites. The average width and depth of the downstream area during the dry season were 110.13 meters and 1.95 meters, respectively, whereas the average width and depth during the wet season were 117.84 meters and 1.79 meters, respectively. Both parameters varied significantly across the three study sites (p value = 0.000 for width and depth, respectively).

The total *coliform* bacteria which serve as an indicator of biological pollution in the river was highest during the dry season specifically at the upstream area which averaged to 5,011 cfu/mL. Over-all, coliform levels were low during the wet season which ranged from 16 cfu/mL to 22 cfu/mL. Although the levels varied significantly between seasons (p value = 0.04; Table 1), no significant difference was observed across the study sites (p value = 0.43).

Nutrient level of the river such as nitrate (NO_3-N) was highest at the downstream with an average of 0.10 mg/L and 0.19 mg/L during dry and wet seasons, respectively. All nitrate values

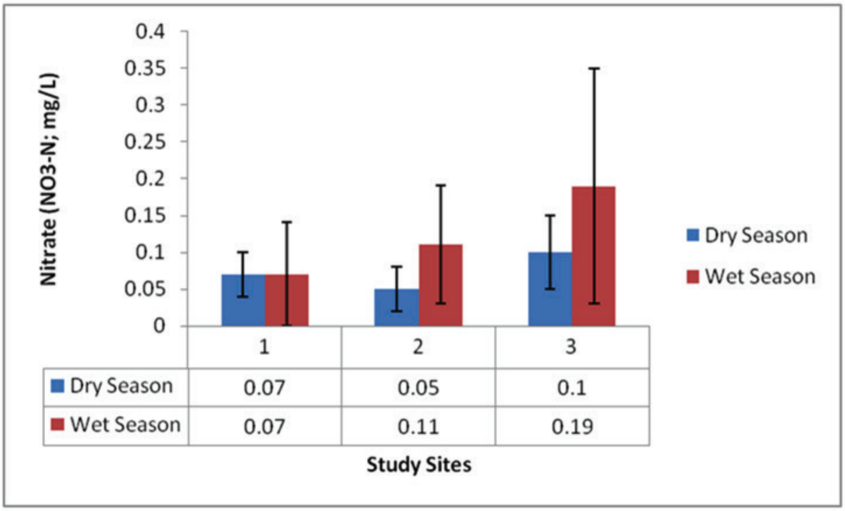


Figure 9. Nitrate concentrations of Pagatban River across study sites and between seasons

were below the maximum permissible limit but was observed to be lowest in the upstream. There was a significant difference in the nitrate levels across the three study sites (p value = 0.047). In contrast, the phosphate (PO_4-P) level was highest at the upstream which averaged to 2.99 mg/L during the dry season

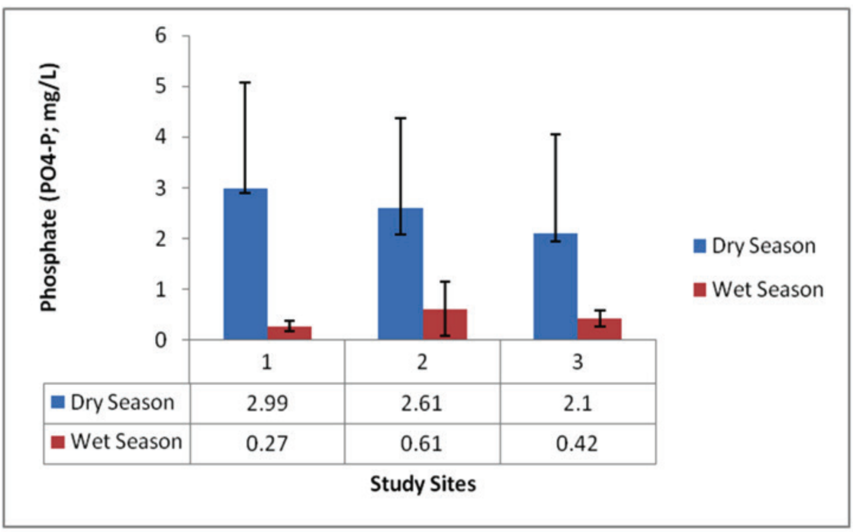


Figure 10. Phosphate concentrations of Pagatban River across study sites and between seasons

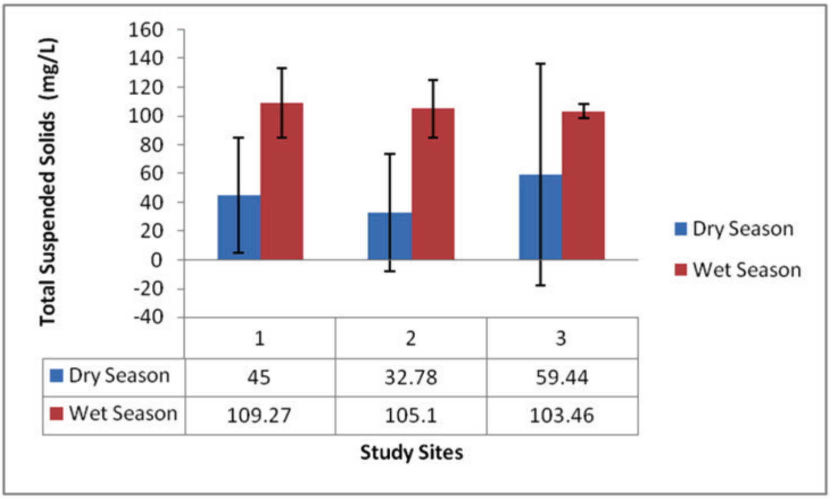


Figure 11. Total suspended solids of Pagatban River across study sites and between seasons

and was lowest at the downstream which averaged to 2.1 mg/L. During the wet season, the phosphate levels decreased across the three study sites and ranged from 0.27mg/L to 0.61 mg/L. All phosphate values were above the maximum permissible limits set by national and international water quality standards. Phosphate levels did not have significant differences across the study sites (*p* value = 0.749), however, there was a significant difference between seasons (Table 1). Over-all mean phosphate levels were more than 10 times higher than permissible limit of 0.2 mg/L for recreational water.

The total suspended solids (TSS) levels in Pagatban River were very high during wet season throughout all study sites which ranged from 103.45 mg/L to 109.27 mg/L. The water quality was most turbid between the months of August and November which coincided with the wet season. During the dry season, the TSS was highest at the downstream with an average of 59.44 mg/L. There was no significant difference of the TSS levels across the three study sites (*p* value = 0.390) but a significant difference between seasons was recorded (Table 1).

In terms of water velocity per site, the highest values were recorded at the upstream during dry and wet seasons which averaged to 0.34 m/s to 0.68 m/s, respectively. There was a significant difference of the water velocity across the three study

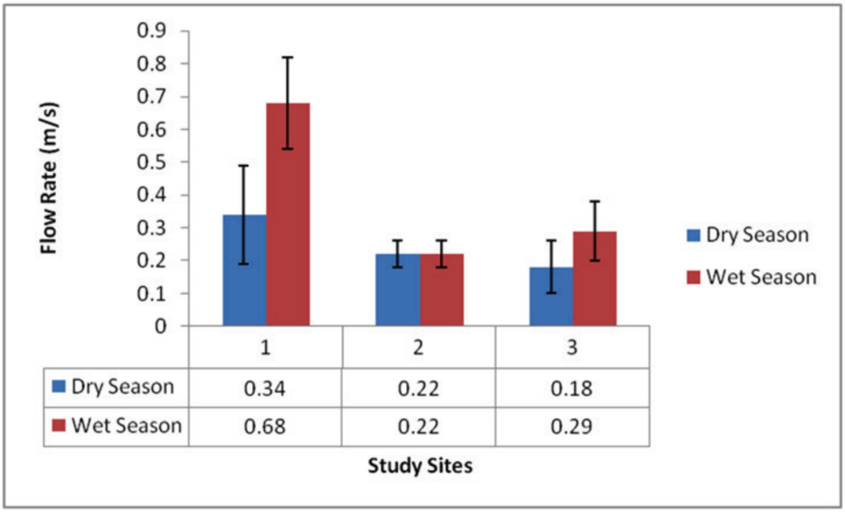


Figure 12. Water velocity of Pagatban River across sites and between seasons

sites (p value = 0.000) but none between seasons (Table 1).

Finally, water volume (R) was highest at the downstream between seasons and across sites which averaged to 39.45 m^3/s and 52.22 m^3/s during dry and wet seasons, respectively. The lowest water volume was recorded at the midstream which averaged to

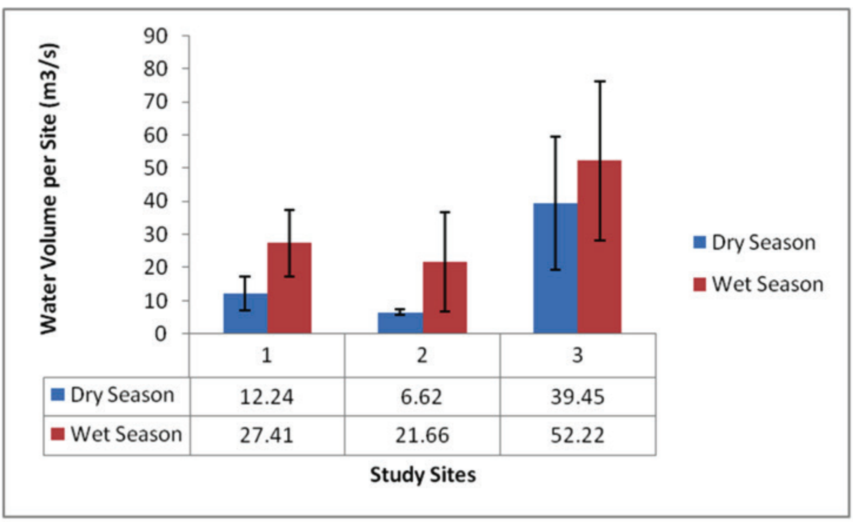


Figure 13. Water volume (R) of Pagatban River across study sites and between seasons

6.22 m^3/s during the dry season. There was a significant difference of the water volume across the study sites (p value = 0.000) but none between seasons (Table 1).

Significant differences of the water parameters of Pagatban River between seasons and across sites were established by Kruskal-Wallis Analysis of Variance. Of the thirteen parameters analyzed between dry and wet seasons, seven differed significantly, namely: temperature, width, flow volume/site (R), total flow volume (Q), phosphate (PO_4-P), total suspended solids (TSS) and total coliform levels (Table 1). Six differed significantly across sites (Table 2), namely: salinity, width, depth, nitrate (NO_3-N), water velocity, and flow volume per site (R). The total volume (Q) was not included in the Kruskal-Wallis Analysis of Variance because Q was the sum of the water volume (R) in the three study sites and comparison was not plausible; Q could, however, be compared between dry and wet seasons. Water pH and dissolved oxygen (DO) were the only parameters of Pagatban River that did not vary significantly between seasons and across study sites using the same test. The rest of the parameters may vary either as an effect of season or sites or a combination of both.

Heavy metals such as lead (Pb), copper (Cu) and zinc (Zn) in the waters of Pagatban River were below the detectable limit of 0.01 mg/L (Table 3). These levels were also below the maximum permissible limit set by the Department of Environment and Natural Resources. However, the heavy metals in the sediments of Pagatban River particularly those located at the river banks in all study sites showed high levels of heavy metals that ranged from <1 mg/kg to 242 mg/kg. These portions of the river where the samples were taken showed a characteristic grey color on the surface and a deep yellow-orange color below the surface.

DISCUSSION

Tropical rivers are characterized by temporal and spatial variations due to the interplay of season, river basin lithology, vegetation, slope, and land use. In the studies of Dudgeon (1992; 2000), tropical Asian rivers were characterized as having high temperature, low water volume and low suspended solids during dry season with inverse levels during the wet months. Similarly, Philippine rivers were characterized with seasonal variations as noted in

Table 2. **Mean Values and Standard Deviations of Selected Water Parameters Across Sites**

Parameters	Dry Season			Wet Season			P value
	Upstream	Midstream	Downstream	Upstream	Midstream	Downstream	
pH	7.11(+.53)	7.46 (+.60)	7.31(+.44)	7.04 (+.61)	7.12 (+.47)	7.06(+.64)	0.488
Temp.(oC)	31.79(+2.04)	31.43(+1.44)	28.73(+2.22)	28.63(+1.41)	28.71(+.87)	28.25(+1.66)	0.414
D.O.(mg/L)	9.85(+.74)	9.54(+.57)	8.40(+1.88)	9.73(+.54)	9.87(+.27)	9.67(+.66)	0.080
Sal. (g/mL)	0.00(+.00)	0.01(+.02)	0.31(+.26)	0.06(+.08)	0.10(+.12)	0.13(+.16)	**0.002**
Width (m)	26.49(+1.3)	52.57(+8.4)	110.13(+1.8)	35.17(+2.5)	80.83(+2.9)	117.84(+.96)	**0.000**
Depth (m)	1.19(+.11)	0.58(+.06)	1.95(+.38)	1.50(+.21)	0.84(+.13)	1.79(+.29)	**0.000**
Coliform (cfu/mL)	5011(+9948)	92(+121)	497(+657)	17(+30)	22(+40)	16(+21)	0.430
NO_3 (mg/L)	0.07(+.03)	0.05(+.03)	0.10(+.05)	0.07(+.07)	0.11(+.08)	0.19(+.16)	**0.047**
PO_4 (mg/L)	2.99 (+2.08)	2.61(+1.75)	2.10(+1.95)	0.27(+.10)	0.61(+.53)	0.42(+.16)	0.749
TSS (mg/L)	45.00(+40)	32.78(+41)	59.44(+77)	109.27(+24)	105.10(+20)	103.46(+5)	0.390
velocity (m/s)	0.34 (+.15)	0.22(+.04)	0.18(+.08)	0.68(+.14)	0.22(+.04)	0.29(+.09)	**0.000**
R (m^3/s)	12.24(+5)	6.62(+1)	39.45(+20)	27.41(+10)	21.66(+15)	52.22(+24)	**0.020**

Temp.= temperature; DO = dissolved oxygen; Sal. = salinity; NO_3=nitrate; PO_4=phosphate; TSS=total suspended solids; R = water volume/site; *p value in **bold** font indicates statistical significance; p value in regular font indicates non-significance

Table 3. **Comparative Analysis of Heavy Metals in the Water and Bottom Sediments of Pagatban River**

	Lowrie, *et al.* as cited by Alcala, 1999	**Rosario, 1999**	**Guino-o, *et al.* [this study]**	**Maximum Permissible Limit WHO**	**DENR**
Pb in water (mg/L)	—	—	<0.010 - <0.018	0.05	0.05
Cu in water(mg/L)	0.017-0.057	<0.01	<0.018 - <0.032	1.0	0.05
Zn in water(mg/L)	0.014-0.273	—	<0.017- <0.036	5.0	—
				Maximum Permissible Limit EPA	
Pb in sediment (mg/kg)	—	—	<1- 5.8	0.025	
Cu in sediment (mg/kg)	—	—	222.4 - 242.8	0.045	
Zn in sediment (mg/kg)	—	—	41.8-51.4	0.090	

several studies (Carumbana, 2002; Linaugo, Turbanos, Pacalioga, Patiluna, & Menes, 2010; Olaguer, Mendoza, Pakingking, & Yamamoto, 2010). In this particular study, seven of the 13 water parameters showed significant variations between dry and wet seasons. Specifically, the mean values of temperature, width, water volume per site (*R*), total water volume (*Q*), phosphate (PO_4-P), total suspended solids (*TSS*) and total *coliform* varied significantly between seasons. Furthermore, significant variations across study sites were observed for salinity, width, depth, nitrate (NO_3-N), velocity and water volume per site. The results also show an apparent decline of the water quality of this river in relation to national and international water standards. Moreover, excessive water volume resulted to severe flooding of the entire river during the wet season causing drowning incidents of farm animals and people; destruction of houses along the river banks, and damage to agricultural crops as reported by the residents to the local government units. Poor forest cover oftentimes causes severe flooding during the wet season; in Negros Island the remaining primary forest cover is four percent of its land area (ESSC, 1999). Flooding is a common event in many areas of this island.

Among the water parameters of Pagatban River that draw critical attention are the high mean values of the following parameters: [1] Phosphate (PO_4-P), [2] Total *coliform*, [3] Heavy metals in the sediments, and [4] Total suspended solids. Study results revealed that phosphate levels increased 15 times higher than the maximum permissible limit of 0.2 mg/L during the dry season and two times higher than the permissible limit during the wet season. Anthropogenic activities that lead to high phosphate levels include the use of commercial fertilizers in the nearby sugarcane farms of Pagatban whose peak use fall during the dry months of February to May. Agricultural farming in the areas of Basay and Bayawan, where the river cuts across, contributes to chemical runoffs (e.g., phosphate, nitrate) during rainy weather. Processes that cause these include sub-surface nutrient leaching, soil erosion, effluents released from sugar mill washings of sugar cane or farm equipment. However, phosphate readings seemingly decrease during the wet season due to the diluting effects of heavy rains and river flooding. This pattern in nutrient influx which was also observed in the studies of Dudgeon (1992) and Carumbana (2002) confirms that river ecology is significantly affected by the seasonality of land discharges. Furthermore, the same studies indicated that monsoonal rains tend to dilute the levels of nutrients in the rivers while the dry season, particularly during El Niño phenomenon tend to concentrate them. Interestingly, the Yang Tze River in China does not follow this pattern; it experiences peak nitrogen, phosphorus and bicarbonate loadings during the flood season (Wang, Wang, Guan, & Guo, 2011). In this particular case, spatial variations and other environmental factors may play significant influence than just seasonal variation insofar as phosphate and nitrate are concerned.

Secondary contributors to the high phosphate levels of Pagatban River are laundry washing and bathing activities by the nearby residents. Soaps and detergents contain phosphates and sulfates that can increase the phosphate load of a water body (Molles, 1999, p. 509). Previous studies in Jalaur River in Panay, Naungan River in Leyte, and Bago River in Negros Occidental, and (Guino-o, 2005; Borlongan, Golez, & Lorque, 2010; Linaugo, Turbanos, Pacalioga, Patiluna, & Menes, 2010) have documented that rivers tend to be used as receptacles for wastewater from industries, domestic households and agriculture. In the study of Fang (2000), phosphate is generally a limiting factor in the environment, however, discharges of raw sewage, disposal of detergents from domestic households can lead to phosphate overloading in an aquatic system.

The indicator species for biological pollution in freshwater bodies is the *coliform* bacteria. The total *coliform* level was generally higher in the dry season than in the wet season. It was also highest in the upstream as compared to midstream and downstream. The variations in the levels of *coliform* bacteria across the three study sites can be attributed to the response of the residents to the presence of the research team. During the first month of the sampling period, water buffalos were commonly found in the upstream area of the river near the sampling sites but were no longer present during the succeeding months. Lower levels of coliform bacteria may have been observed during the wet season due to the diluting effects of heavy rain and flooding. Most households in the upstream and midstream areas did not have access to sanitary toilets as well, thus, open defecation is practiced in these areas. Although the total *coliform* levels did not show significant differences across the study sites, this study confirmed that Pagatban River was contaminated with *coliform* bacteria at a level above the maximum permissible limit during the dry season.

The levels of heavy metals in the waters of Pagatban River were low with values ranging from < 0.010 mg/L to <0.036 mg/L compared with the data of Rosario (1999) and Lowrie and colleagues (as cited by Alcala, 1999) which ranged from <0.010 mg/L to 0.273 mg/L. This reflected a –87% variance from previous level indicating that heavy metals in the waters of Pagatban River have been diluted after three decades without mining activity. According to US EPA water quality guideline (1986, p. 477), however, copper levels at 0.006 mg/L is already lethal to the blue mussel and is known to cause hepatic toxicity and gastrointestinal disorder. Lead (Pb) at the level of 0.1425 mg/L is lethal to amphipods and can cause adverse neurological development, impaired renal function, hypertension and infertility among animals. In this study, the over-all findings revealed that heavy metals in the waters of Pagatban River were below the maximum permissible limit set by DENR and WHO (2011). However, the bottom sediments or soil samples taken from the river banks across the three study sites showed high levels of heavy metals which ranged from < 1mg/kg to 242.8 mg/kg. Heavy metals in the water of this river appear to be very low but they are concentrated in the river substrate through time. This observation can be attributed to the mine tailings from the mining activities in Basay dating back to the 1980s which led to the mass killing of the aquatic organisms in this river. The present heavy metals in the bottom sediments of Pagatban River—lead (Pb), copper (Cu), zinc (Zn)—were found to exceed the maximum limit set by EPA which were 0.025 mg/kg, 0.045 mg/kg and 0.090 mg/kg, respectively. Thus, lead (Pb) in Pagatban River was 200 times higher than the permissible limit; while copper (Cu) and zinc (Zn) were 5,000 times and 600 times higher than the permissible limits, respectively. Based on the water quality of Pagatban River, it can be classified as Class C water which is suited for aquaculture, however, the amount of heavy metals in its bottom sediments is still not compatible with any fishery activities in the area.

After 30 years of no-mining activities in the nearby areas of Pagatban River, chemical analyses confirmed that heavy metal contamination still persists in its bottom sediments, thus posing an environmental threat. This finding has implications to the food web, and food chain in the aquatic ecosystem. Heavy metal contamination affects all food trophic levels from smallest microbenthos to the top predator in the food web in the process of biological magnification. The work of Power (1990) demonstrated that certain fishes act as keystone species in food webs in rivers where their presence exerts a strong effect on the structure of the communities they inhabit. When the threshold level for heavy metal is reached, it causes mortalities not only to the keystone species but also to other biological species in the food web of the river. In Pagatban River, there is a reason to believe that invertebrates may be contaminated with heavy metals and therefore must be protected along with the other species so as not to repeat a mass decimation of aquatic organisms as what happened in the past. As a safety precaution, fishery resources of Pagatban River must be analyzed for heavy metal contamination since the residents of Pagatban and the neighboring areas are dependent on these resources as food.

Total suspended solids or TSS, an indicator of the amount of sediment in a river system, in Pagatban was found to be two times higher than the maximum permissible limit of 50 mg/L during wet season. However, the mean TSS level during the dry season was lower than the permissible limit. Significant difference of the TSS levels between dry and wet seasons was recorded but no significant difference across study sites. The high values of TSS during the wet season can be linked to several factors such as increased water volume, velocity, and subsequent soil erosion from heavy rains and turbulent water mixing during typhoons. Sediments from the upstream and upper midstream areas were also collected by the mid-catch basin of the lower midstream site which eventually reached their way to the downstream.

CONCLUSION AND RECOMMENDATIONS

The general water quality of Pagatban River is classified as Class C water except for its phosphate, total coliform, heavy metals in the sediments, and total suspended solids where the latter exceeded the maximum permissible limits set by national and international environmental agencies. Significant seasonal variations were observed in the following water parameters: width, water volume per site, total water volume, total suspended solids, total *coliform*, temperature, and phosphate (PO_4-P). Significant site variations were noted in the following water parameters: velocity, width, water volume per site, salinity, nitrate (NO_3-N), and depth. Although the heavy metals in the waters of Pagatban River were below the detectable limit set by the analyses, the very high levels of heavy metals in its sediments do not compliment with any fishery activity such as the propagation and growth of fishery resources.

In order to sustain and improve the water quality of Pagatban River in Negros Oriental, Philippines, the following recommendations are proposed:

1. Full implementation of the Clean Water Act of 2004 (RA 9275) at the barangay level of the local government units which prohibits the dumping of wastewater into creeks, rivers and marine waters without undergoing treatment processes. The same law mandates all local government units (LGUs) to share in the management and improvement of the water quality within their territorial jurisdictions. Pagatban River is a shared river between the City of Bayawan and the Municipality of Basay, thus, a co-management scheme between the two local government units is a wise step in the over-all management of this river. The establishment of a river monitoring system by the local government unit is also suggested to operationalize the Clean Water Act. Furthermore, it is suggested that the monitoring results will be reported during the monthly meeting of the barangay for proper management.

2. Due to the large volume of water that runs through Pagatban River during the wet season, a flood warning system is suggested for the local government units to consider in their future plan of action. The effects of flooding have been reported by the residents of Pagatban to be more destructive in the past three years. A flood warning system will promote safety to people's lives and properties in the nearby areas of the river.

3. Clandestine operation of small-scale mining in the side of Basay area has to be stopped by the concerned local government units at the level of the barangay in order to protect its water quality and accompanying biodiversity. The improved river quality of Pagatban River after three decades of no mining in its nearby area will be lost if mining activity

is allowed at any scale. Pagatban River should be protected from any type of pollution because it is an identified fishing ground of economically-important fishes particularly in the downstream area. Fishery resources of Pagatban River must be analyzed for heavy metal contamination since the residents of Pagatban and the neighboring areas are dependent on these resources as food.

4. River bank stabilization technologies have to be adopted along Pagatban River. Appropriate technologies that can be considered by the local government units include rip-rapped dikes and gabions (e.g., rock-filled wire baskets) in the downstream of the river, mangrove planting in the estuaries, restoration of riparian vegetation in the midstream and upstream with indigenous Philippine flora (vetiver grass *Vetiveria zizanioides* coupled with geotextile from coconut) and the continuing reforestation of the Bayawan-Basay watershed by the Provincial DENR of Negros Oriental. The downstream was the widest among the three sites of the river and this will continue to widen if river bank stabilization strategies are not implemented. River bank erosion and siltation will also be addressed when these technologies are implemented thereby improving the over-all health of Pagatban River and the ecosystems near it.

5. The implementation of ecological sanitation programs by all barangays near Pagatban River is recommended in this study. Strategies such as "zero open defecation" program can be realized when a barangay provides adequate numbers of communal toilets in the area. Dumping of industrial, domestic, and agricultural wastes into the river will not happen when barangays have accessed to a sanitary landfill, compost area and regulated communal dumpsite as provided by RA 9003 (Ecological Solid Waste Management Act of 2000).

6. The continuing linkage of the local government unit with non-governmental organizations to address environmental issues such as river biodiversity, conservation and management is a practical step in sustaining initiatives for a healthy freshwater ecosystem. For instance, local government units can tap the services of the academe with capabilities for water analysis in

monitoring a river system. This can be implemented through a service learning program where the expertise of the academe is put into practical use and at the same time address the need for the exposure of students to good environmental practices.

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