doi: http://dx.doi.org/10.7719/jpair.v1i1.41

# A CROSS-SECTIONAL STUDY ON THE EXTENT OF FECAL CONTAMINATION OF CAGAYAN DE ORO RIVER ALONG FIVE URBAN BARANGAYS AND THE FACTORS AFFECTING CONTAMINATION, OCTOBER 2007 – JANUARY 2008

Mae Shayne Alvarez et al
Xavier University, Cagayan de Oro City

## ABSTRACT

*A cross-sectional study to determine the extent of fecal contamination of Cagayan de Oro river along five different urban barangays namely Barangay Macasandig, Barangay Puntod, Barangay Macabalan, Branagay Carmen and Marcos bridge (Barangay Consolacion) was conducted from October 2007 to January 2008. The Multiple Tube Fermentation Technique (MTFT) was used to identify the presence of fecal coliform in the five different sampling periods done every 2 weeks as well as confirm the presence of the indicator organism Escherichia coli in the water samples. A survey was also conducted to determine the possible factors that contribute to fecal contamination of the river. The Total fecal coliform values computed showed a high average MPN (Most Probable Number) score from all five sample areas which exceeded the standard acceptable value set by Australian and New Zealand Environment and Conservation Council National water quality guidelines (ANZECC, 2000) at 150 fecal coliform organsisms/100mL. Macasandig show the highest mean MPN value of ≥2400 fecal coliforms /100 ml, followed by the following Barangay arranged from highest to lowest; Puntod (2140 fecal coliforms /100 ml), Carmen (1880 fecal coliforms /100 ml), Macabalan (1624 fecal coliforms /100 ml), and Marcos Bridge (Consolacion) site (844 fecal coliforms /100 ml). The presence of E. coli was also confirmed indicating fecal contamination of the water samples. The factors that may have a contribution to the river's fecal contamination were: (1) the disposal of pet/livestock manure in the river, which was highest in Macasandig, (2) the number of comfort rooms draining to the river for those who have comfort rooms, and (3) the disposal of human wastes into the river for those who don't have comfort rooms.*

**Keywords:** Focus Contamination, Urban Barangay

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## INTRODUCTION

Access to a safe and adequate supply of water is a human right that is vital for man's dignity and health, thus, providing safe water for the poor is a key factor in improving health and economic productivity making it an essential component of any effort to alleviate poverty.[1] Pollution from human and animal waste is a major cause of deteriorating water quality and increased nutrient loads in coastal and inland waterways. In highly urbanized areas of major cities, overflow from sewers, illegal connections or leaks from broken sewer pipes are likely sources of human fecal pollution.[2] In the Philippines, diarrheal disease is the number one cause of morbidity and mortality for the past 20 years. Incidence rate is as high as 1,997 per 100,000 population, while mortality rate is 6.7 per 100,000 population. From 1993 to 2002, Water-borne diseases such as cholera, typhoid fever, hepatitis A and other food poisoning/food borne diseases were the most common outbreaks investigated by the Department of Health.[3] The health hazards arise mainly from the high numbers of pathogenic organisms that may be found in the water.[4] Viruses and bacteria transmitted through fecal contamination present a danger to bathers and recreational users, and from the accumulation of pathogens in fish and shellfish that may be used for human consumption. Pollution may directly influence one or more components of the dynamic equilibrium of physical, chemical and biological phenomena, which gives an ecological community its characteristics.[5] The annual economic losses caused by water pollution are estimated at 67 billion pesos. These include 3 billion pesos for health, 7 billion pesos for fisheries production and 47 billion pesos for tourism.[6]

Throughout the history of Cagayan de Oro City, the Cagayan de Oro River has been used for bathing, washing clothes, as food source and in recent years, its valuable contribution to ecotourism with its rapids ideal for white-water rafting, has been recognized by many foreigners and by fellow Filipinos as well.[7] With the increase in the population living along the river banks as a consequence of urbanization come the question of proper sewage disposal and possible fecal contamination of the river. However, despite this growing threat and rapid developments in the city, not much concern has been given to the Cagayan de Oro River as reflected by only a few studies done on assessing its water quality. Most of the studies done on Cagayan de Oro River are those concerning its physico-chemical properties.[7] One of the important approaches in assessing the water quality of Cagayan de Oro River is to determine the extent of fecal contamination in the river. This is essential in providing information regarding sanitation and health-improvement for the people, and also to bridge knowledge gaps that the concerned offices like the City Engineer's office and DENR need.

**A. Water Quality and Sanitation in Rivers**

Rivers are bodies of flowing water that are classified as surface waters. With the development of civilizations, the use of water has shifted from rural or agricultural to urban or industrial. This is generally according to the following sequence: drinking and personal hygiene, fisheries, navigation and transport, livestock watering and agricultural irrigation, hydroelectric power, industrial production (e.g. pulp and paper, food processing), industrial cooling water (e.g. fossil fuel and nuclear power plants), recreational activities and wildlife conservation.

"Water quality" is a term used to express the suitability of water to sustain various uses or processes.[2] At the beginning of the 21$^{st}$ century, 18% of the people of the world do not have access to safe drinking water and nearly 40% lacks adequate sanitation facilities. Only 35% of the urban waste water was treated in Asia in 2000.[9]

Geological, topographical, meteorological, hydrological and biological factors dictate the characteristics of surface waters which vary with seasonal differences in runoff volumes, weather conditions and water levels. Human intervention also has significant effects on water quality. Some of these effects are the result of the polluting activities such as the discharge of domestic, industrial, urban and other wastewaters into the watercourse (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin. Thus, although water may be available in adequate quantities, its unsuitable quality limits the uses that can be made of it.[8]

Water of good quality is crucial to sustainable socio-economic development. Aquatic ecosystems are threatened on a world-wide scale by a variety of pollutants as well as destructive land-use or water-management practices. Gross organic pollution leads to disturbance of the oxygen balance and is often accompanied by severe pathogenic contamination. [8]

**B. Fecal Pollution of Rivers**

Some areas of river receive a variety of organic wastes which are harmful to human health and aquatic organisms. Urban areas, farms, factories, and individual households all contribute to river contamination. These contaminants are important because some people rely on the river as a source of water or livelihood.[9] The most common important source of water contamination in developing countries is human feces.[10] Fecal pollution may occur because there are no community facilities for waste disposal, because collection and treatment facilities are inadequate or improperly operated, or because on-site sanitation facilities (such as latrines) drain directly into aquifers.[1,8.] As a result, human waste heavily pollutes many rivers and lakes in developing countries as evidenced by coliform counts in Asia's major rivers.[10]

Urban areas and agriculture on steep slopes located on large watershed also have very high probability to be impaired by pathogens.[11] The major source of fecal contamination is storm water runoff from urban land uses.[12] This is supported by a study which showed that a portion of areas with septic tanks and rainfall prior to collection of samples are good predictors of fecal pollution.[11] Furthermore, there is a large increase in the number of organisms in both water and sediments during heavy rain.[13]

**C. Microbial Indicators of Fecal Contamination**

Bacteria of the coliform groups are the major determinant of fecal contamination. They are often use to asses water quality and they have been established as indicator of other disease causing organisms that may pose a health risk to the public.[11] The presence of these indicator organisms in water is evidence of fecal contamination and, therefore, of a risk that pathogens are present. If indicator organisms are present in large numbers, the contamination is considered to be recent and/or severe.[8]

The main indicator of water quality and fecal contamination is *Escherichia coli* and it is the best predictor of gastrointestinal associated illness.[14] Such bacteria are not present individually, but as clumps or in association with particulate matter.

Pathogenic pollutants from untreated combined sewage, waterfowl feces, wildlife feces, and domestic pet waste are also found in the river especially during heavy rainstorm because storm water discharges these to the river and these pathogens are the major concern to human health.[11] Aside from rainfall and urban runoff as, stream stages, competition, and other biological factors are also indicators of increased coliform concentrations.[15] Factors such as temperature, salinity, and light intensity as well as initial loading and disappearance rate and the time and distance traveled by the water from the source to the river affects bacterial level. They also concluded that solar radiance and water temperature affect fecal coliform bacteria death rate. Rate of die-off of bacteria is a result of ultraviolet light, temperature stress, cell starvation, predation by other bacteria and protozoans, and removal by filter feeders.[11] Organic matter, sedimentation and biomass are also some factors that affect bacterial concentrations. The bigger the sedimentation grain, the higher the bacterial level which is related to the organic content and microbial biomass.[16]

The term "**fecal coliform**" has been used in water microbiology to denote coliform organisms which grow at 44° or 44.5° C and ferment lactose to produce acid and gas although some organisms with these characteristics may not be of fecal origin and the term "thermotolerant coliform" is, therefore, more correct and is becoming more commonly used.[8] Fecal coliform consist of *Klebsiella* and *Escherichia coli* biotypes present in the intestines and feces of warm blooded animals.[17] Usually, more than 95 per cent of thermotolerant coliforms isolated from water are the gut organism *Escherichia coli*, the presence of which is definitive proof of fecal contamination. Nutrient-rich environments may encourage the growth or persistence of some species of thermotolerant coliform other than *E. coli*. This possibility should be considered when, for example, an unusually high result is obtained from water that was thought to be relatively clean. In such a case, the advice of a microbiology laboratory should be sought for the determination of the more specific indicator, *E. coli*.[8]

### D. The Consequence of Fecal Pollution in Rivers

The effects of fecal pollution vary. In developing countries intestinal disease is the main problem, while organic load and eutrophication may be of greater concern in developed countries (in the rivers into which the sewage or effluent is discharged and in the sea into which the rivers flow or sewage sludge is dumped). Pollution from diffuse sources, such as agricultural runoff, or from numerous small inputs over a wide area, such as fecal pollution from unsewered settlements, is particularly difficult to control. [8]

A safe and free source of water is essential to the community and health. In a developing country like the Philippines, water sanitation and supply faces a big challenge as poor water supply and sanitation can present a number of health hazards. Children in particular, face a dangerous health risk when they come in contact with fecally-contaminated waters through washing, bathing or drinking. This is true with the knowledge that diarrheal diseases claim the death of nearly 2 million children every year and have killed more children in the last 10 years than all people lost to armed conflict since World War II. In 1998, mote than 99% of these deaths (for children under the age of 14 years) occurred in developing countries.[18]

**E. The State of Cagayan De Oro River With Regards to Fecal Pollution**

The Cagayan de Oro River has an area of 1380 $km^2$. Its headwater emanates from the Kalatungan Mountain Range in the province of Bukidnon and empties into the Macajalar Bay of Cagayan de Oro City.[7]

Coliform analysis of rivers and other water systems in Misamis Oriental have been conducted.[7,19] Unfortunately, there has not been much studies geared towards the determination of fecal pollution in Cagayan de Oro River. However, in 2000, a coliform assessment of the river showed a high average MPN index far greater than the allowable 200 colony-forming units (CFU) per 100 mL water sample. This was observed in three sampling sited with the site in Carmen showing the highest count of 1002 CFU/100 mL.[7]

Generally, the study was done to determine the extent of fecal contamination Cagayan de Oro River along five urban barangays. Specifically, (1) to determine the MPN index of fecal coliforms in the water samples obtained from Cagayan de Oro River along the five selected urban barangays, (2) to determine whether the MPN index of fecal coliforms is acceptable according to specific standards, (3) to determine the barangay with the highest level of fecal contamination, and (4) to determine the possible factors that contribute to fecal contamination. It was was limited to the assessment of the presence of coliform specifically *Escherichia coli* in the Cagayan de Oro River. Chemical, BOD and bioassays of water analysis were not included in this research.

## MATERIALS AND METHOD

This research was designed as a cross sectional study on the extent of fecal contamination of the Cagayan de Oro River. It involved interview of the household occupants living along the banks of the sampling sites and water sample collection every 14 days from 5 different barangays over a three-month period (From October 2007-January 2008) using a standard procedure. Fecal coliform count was determined from the samples taken by using the Multiple Tube Fermentation Technique (MTFT).

A preliminary survey was conducted of the 5 sites in September 28, 2007. The interview of the household occupants was conducted last October 17, 2007 to assess the possible effects of household activities to fecal pollution in Cagayan de Oro River. ( Refer to the figures below)

**Figure 1.** Macasandig Sampling Site

**Figure 2.** Carmen Bridge Site

**Figure 3.** Marcos Bridge (Consolacion) Site

**Figure 4.** Barangay Puntod Site

**Figure 5.** Macabalan Site

Samples were collected from five (5) different stations along the river namely Barangay Macasandig, Barangay Puntod, Barangay Macabalan, and the other two samples were obtained from the city proper, particularly at the Carmen bridge and Barangay Consolacion (Marcos Bridge). The first and second sample collection was done last November 7 and 27, 2007 respectively. The third sampling was conducted last December 18, 2007. The fourth and the fifth sampling were done last January 8 and 29, 2008 respectively.

Researchers were assigned to the 5 barangays comprising the sampling sites for this study to collect water samples. The researchers simultaneously practiced on the sampling technique used in the experiment prior to the actual sampling. The sampling in each station was done through an area-integrated approach made by combining a series of samples taken at various sampling points spatially distributed in the water body (but usually all at one depth or at predetermined depth intervals). This was accomplished by using a multi-purpose sampler made from transparent Gatorade glass bottles.[3] Upon arrival at the sampling site, the researchers used row-boats to get water samples. The sampling bottles were immersed and allowed to fill up in the middle portion of the river at a depth of 20 cm in each sampling site. A total of 5 sampling bottles were obtained from all the sites for every sampling day. The collected samples were then placed in a box containing ice to maintain the temperature below 10°C determined by using a thermometer for transport to the laboratory.[3]

All materials such as sampling bottles, test tubes, Petri dishes, and other necessary materials were washed a day before sampling with a non-ionic detergent and rinsed at least three times with distilled water before autoclaving at a temperature of 120°C at 15 psi for thirty minutes.[8]

To determine the presence and number of coliform bacteria, MTFT was used. This was done by planting of a series of measured sample portions into tubes containing favorable culture media. The test had three different stages: the Presumptive test, the Completed test and the Confirmatory.[3] The presumptive test consisted of inoculating a specific dilution concentration (3 concentrations were used) into a Durham tube with lactose broth medium. Three (3) replicates were done for every dilution concentration. The test tubes were observed over a 48 hour incubation period. A positive test was confirmed by the presence of turbidity with gas formation in the culture tubes.

The confirmed and completed tests made certain that the positive results obtained in the presumptive test are in fact due to coliform bacteria and not of other kinds of bacteria. This part of the method was done by inoculating a loopful of culture from the positive tubes in the presumptive part in Durham tubes containing Brilliant Green Lactose Broth (BGLB). Turbidity with gas formation in the BGLB tubes confirmed the presence of coliforms in the sample. Petri-plates with Eosin Methylene Blue (EMB) Agar were also inoculated with inoculums from the positive lactose broth tubes from the presumptive part of the test. Growth of colonies with green metallic sheen in the EMB agar confirmed the presence of *Escherichia coli,* a fecal coliform.

The MPN (Most Probable Number) index was then obtained using the table which gives the corresponding index based on the number of positive BGLB tube combinations for every dilution done with the water samples from the five different sites.

Survey questionnaires were given to the randomly selected houses living along the banks of the river to determine the different factors like household and livestock activities that may contribute to the level of fecal contamination of the river.

## RESULTS

The total coliform counts for all the sampling sites were obtained using the Multiple Tube Fermentation Technique. This technique determines the presence and number of coliform bacteria through the planting of a series of measured sample portions into tubes containing favorable culture media.[3] The MPN(Most Probable Number) indices obtained for all five sampling dates throughout the duration of the study markedly exceeded the highest acceptable fecal coliform count for fresh waters as set by the Australian and New Zealand Environment and Conservation Council National water quality guidelines (ANZECC, 2000) at 150 fecal coliform organisms/100mL.[20]

**Table 1. MPN Indices for All 5 Sampling Dates Per Sampling Site With Average MPN Indices Arranged from Highest to Lowest**

| Sampling Sites | MPN INDEX for Sampling Date 1 (November 7, 2007) | MPN INDEX for Sampling Date 2 (November 27, 2007) | MPN INDEX For Sampling Date 3 (December 18, 2007) | MPN INDEX for Sampling Date 4 (January 8, 2008) | MPN INDEX for Sampling Date 5 (January 28, 2008) | Average MPN Index Per 100 ml |
|---|---|---|---|---|---|---|
| Macasandig | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 |
| Puntod | ≥2400 | ≥2400 | ≥2400 | ≥2400 | 1100 | 2140 |
| Carmen | 1100 | 1100 | ≥2400 | ≥2400 | ≥2400 | 1880 |
| Macabalan | ≥2400 | 460 | ≥2400 | ≥2400 | 460 | 1624 |
| Marcos Bridge | 210 | 460 | 1100 | 1100 | 1100 | 844 |

As seen in Table 1 For the sampling site in Macasandig, fecal coliform counts for all the five sampling dates showed consistent MPN indices of ≥2400 fecal coliforms per 100 ml of the sample. Thus, the average MPN index was computed at ≥2400 fecal coliforms per 100 ml.(see table 6) The completed tests also confirmed the presence of *Escherichia coli* in the water samples obtained from the site. This was demonstrated by the growth of bacterial colonies with green metallic sheen on Eosin Methylene Blue (EMB) agar (see Figure 1 above).

MPN indices for the Carmen site were: 1100 for the first and second sampling dates, and ≥2400 for the third, fourth and fifth sampling dates. All values are beyond the set limit for fecal coliforms. The average MPN index was computed to be 1880 coliforms per 100 ml sample. The presence of *E.coli* was also confirmed in the completed test.

MPN indices for the Marcos Bridge site was 460 for the first and second sampling dates, and 1100 for third, fourth, and fifth sampling dates. An average MPN index of 844 coliforms per 100 ml was computed for the site as seen in the table above. The presence of *E. coli* was also confirmed in the completed test of the technique used.

Puntod showed high coliform counts for all the sampling dates yielding an MPN index of ≥2400 coliforms per 100 ml sample during the first to the fourth sampling dates, and an MPN index of 1100 coliforms/100 ml sample for the fifth sampling date. Growth of bacterial colonies with green metallic sheen on EMB also confirmed the presence of *E. coli* in the samples obtained. The average MPN index computed for the site is 2140 coliforms per 100 ml sample (see Table 1)

MPN indices obtained for all the sampling dates in Macabalan also exceeded the acceptable count. The second and fifth sampling dates gave an MPN index of 460 coliforms per 100 ml sample, the rest of the sampling dates were consistent at ≥2400 coliforms per 100 ml sample. An average MPN index of 1624 coliforms per 100 ml was computed for the site (See Table 1 above). *E. coli* was also present in the water samples as demonstrated in the completed part of the analysis.

Table 1 above shows high average MPN indices that were obtained for all five sites. These average MPN indices also exceeded the allowable 150 coliforms per 100 ml set by the Australian and New Zealand Environment and Conservation Council National water quality guidelines (ANZECC, 2000). Among all the sites, Macasandig showed the highest average MPN index of ≥2400 coliforms per 100 ml, followed by Puntod with an average MPN index of 2140 coliforms per 100 ml sample , then Carmen with an average of 1880 coliforms per 100 ml sample. Macabalan folds the fourth rank with an average of 1624 coliforms per 100 ml sample, and lastly the Marcos Bridge site with an average MPN index of 844 coliforms per 100 ml sample. The results suggest considerable fecal contamination of the Cagayan de Oro River.

A survey conducted before actual sampling involved households living along the banks of the sites where sampling was done. A total of 107 respondents were interviewed. This figure comprised of 20 respondents from the Macasandig site, 10 from the Carmen site, 14 from the Marcos Bridge site, 37 from Puntod and 26 respondents from the Macabalan site. Table 2 below shows the important results of the survey related to factors that may have a bearing in fecal contamination.

**Table 2. Human Activities that Contribute to Fecal Contamination in the Macasandig, Carmen, Marcos, Puntod, and Macabalan**

| Barangay | Number of household respondents | Total Population per Barangay* | Percent household respondents with toilets draining into the river | Percent household respondents without toilets and disposing their wastes into the river | Percent household respondents disposing livestock manure into the river | Average MPN index (coliforms / 100 ml sample) |
|---|---|---|---|---|---|---|
| **Macasandig** | **20** | **47188** | **0%** | **5%** | **82%** | **≥2400** |
| **Carmen** | **10** | **18875** | **10%** | **10%** | **40%** | **1880** |
| **Marcos Bridge (Consolacion)** | **14** | **8786** | **14%** | **29%** | **40%** | **844** |
| **Puntod** | **37** | **15797** | **11%** | **19%** | **11%** | **2140** |
| **Macabalan** | **26** | **15615** | **19%** | **15%** | **50%** | **1624** |

In Macasandig, none of the respondents with their own toilets admitted of having toilets that drained directly into the river. 10% of the respondents did not have any comfort room and disposed their wastes into the river. Among the respondents with livestock, 82% disposed their animals' wastes into the river.

Of the total number of respondents in Carmen, 10% claimed to have their own comfort rooms but draining directly to the river. 10% of the respondents did not have their own comfort rooms and admitted of disposing their wastes into the river. Among the respondents who raised livestock, 40% admitted of direct drainage of the animals' fecal wastes directly into the river.

14% of the responding households in the Marcos Bridge Site had their own comfort rooms but admitted of having no septic tanks with the wastes draining directly into the river. 29% of the total respondents admitted of disposing their fecal wastes into the river. The rest claimed of using their nearby public toilet where they had to pay P2.00 to use the facility. 40% of the respondents who raised livestock disposed their animals' wastes into the river.

In Puntod, 11% of the respondents had toilets that drained directly into the river. On the other hand, 19% of the total respondents did not have toilets and disposed their fecal wastes directly into the river. Also, 11% of those who raised livestock disposed their livestock's wastes into the river.

In Macabalan, 19% of the total respondents had toilets that drained directly into the river. 15% did not have toilets and disposed their wastes into the river. 50% of the respondents who raised livestock disposed their animals' wastes into the river.

In general out of the 107 respondents living along the banks of all the sampling sites, 11% of the households had their own toilets, however, these toilets drained directly into the river. 16% of the respondents did not have toilets and disposed their fecal wastes directly into the river. Lastly, 47% of the respondents who grew livestock disposed the animals' wastes into the river.

## DISCUSSION

The Cagayan de Oro River falls under the Class B Category of surface waters intended for primary contact recreation (e.g. bathing, swimming, etc...) based on the classification scheme of inland surface waters set by the Environmental Management Bureau of the Department of Environment and Natural Resources.[6] The Australian and New Zealand Environment and Conservation Council National water quality guidelines (ANZECC, 2000) for primary contact, state that the median bacterial count in fresh waters should not exceed 150 fecal coliform organisms/100 ml. For secondary contact, which involves activities that generally have less frequent body contact with water (e.g. boating, fishing), the median value in fresh waters should not exceed 1000 fecal coliform organisms/100 ml.[20]

In the series of five samplings done in this study, all the mean MPN indices obtained for each sampling site markedly exceeded the standards for fecal coliform for primary contact surface water set by the ANZECC, 2000 guidelines. Macasandig showed the highest MPN index of $\geq$2400 coliforms/100 ml. Puntod ranked second among all the sampling sites with a mean MPN index of 2140 coliforms/100 ml. Carmen came up with the third highest mean MPN index of 1880 coliforms/100 ml. The mean MPN index for Macabalan ranked fourth with a value of 1624 coliforms/100 ml. Lastly, the Marcos

Bridge site (Barangay Consolacion) obtained the lowest mean MPN index among all the sites however, this value still far exceeded the fecal coliform standard of 150 fecal coliform organisms/100 ml for primary contact surface waters. (see Table 1 above)

The mean MPN indices obtained for all the sampling sites alarmingly exceeded the allowable fecal coliform organisms in surface waters. For instance, in the Marcos Bridge site, although it obtained the lowest mean MPN index, this value is still more than 5 times the standard coliform count set by the ANZECC, 2000 guidelines. Macasandig with the highest mean MPN index exceeds the ANZECC standards by about 16 times. Except for the mean MPN index obtained for the Marcos Bridge site, all other indices also exceeded the standards for secondary contact surface waters. The presence of *Escherichia coli* was also confirmed in the samples. The high fecal coliform concentrations obtained, particularly the confirmation of the presence of *E. coli* in the samples taken from the different sites along the Cagayan de Oro River indicates the presence warm-blooded animal wastes, especially that of human origin.

It is generally accepted that gastrointestinal pathogens in fecal matter will die at the same rate as the indicator bacteria; therefore, high concentrations of fecal indicator bacteria like *E. coli* indicate an increased likelihood of pathogens being present.[21] A person swimming highly contaminated water has a greater chance of getting sick from swallowing disease-causing organisms, or from pathogens entering the body through cuts in skin, the nose, mouth, or the ears. Diseases and illnesses such as typhoid fever, hepatitis, gastroenteritis, dysentery, and ear infections can be contracted in waters with high fecal coliform counts.[20] This is significant in the case of the Cagayan de Oro River since the households living along its banks rely on the river for most of their daily activities like bathing. The high mean MPN indices indicative of fecal contamination are also significant in that the presence of possible pathogens poses a risk to people who utilize the river for recreational activites especially with the growing popularity of the city as a tourist destination for white water rafting. Fecal contamination of the river will cost the city a considerable amount of revenue loss from ecotourism as well as an increased expenditure on health care with the possible increase in the incidence of water-borne diseases.

A coliform assessment of 3 sites along the Cagayan de Oro River was conducted in 2000.[7] The sites included Kabula located upstream, Carmen, and Macabalan (during high-tide and low tide). The study showed mean MPN indices of 405 coliforms/100 ml for Kabula, 1003 coliforms/100ml for Carmen, 746 coliforms/100ml (low tide) and 326 coliforms/100 ml (high tide) for Macabalan. The average MPN indices obtained from this study also showed high fecal contamination exceeding the ANZECC standards with Carmen showing the highest index. In comparison, the MPN values obtained from this more recent assessment of fecal contamination showed the same trend as the previous study wherein Carmen has a higher mean MPN index than Macabalan (low tide). However, it is important to note that the mean MPN indices obtained in this study has increased to almost if not twice the values obtained in 2000. This indicates an increase in fecal contamination of the river in these sites (Carmen and Macabalan) over the span of 8 years.

There are a number of factors that may have an influence on the fecal coliform concentrations obtained from the study. For instance, fecal indicator organisms cannot grow in natural environments outside their host, because they are adapted to living in the gastrointestinal tract. Temperatures exceeding growth tolerance, sunlight, competition from other bacteria, predation by protozoa and other microorganisms, lack of food sources and inhibitory environmental chemicals are reported to limit the survival time of intestinal bacteria from a few hours to days in thus the concentration of bacteria is highly dependent on the timing of the sampling, amount of fecal matter dose and dilution, and environmental conditions. In general, the closer a sample is taken to the time and/or entry point of contamination, then the higher the concentrations of the bacteria. Inversely, the longer and/or further away from the point of entry, the detectable concentrations of bacteria will be lower.[21] Thus, it is possible to consider that the high fecal coliform concentrations obtained from the sampling sites may be attributed a closer distance of the sampling site from the point of entry. This is supported by the fact that all the samples were taken from areas in each site where houses cannot be found along the banks. The survey conducted confirmed the occurrence of human activities among these households that contribute to fecal contamination like drainage and disposal of human feces as well as livestock manure directly into the river. Transport, dilution, dispersion, and concentrations of fecal coliform are also strongly influenced by the timing, spatial distribution, and amount of rainfall, runoff, and stream flow, as well as light penetration, which is reduced by turbidity.[22] However, all samples were taken from the different sites at a time when no rain occurred the night before. All the water sampling was also done during low tide, thus, variations due to tidal changes for the MPN indices obtained are not determined.

In the survey conducted in October 2007, human activities along the sampling sites that have impact on the degree of fecal contamination included the presence toilets without septic tanks which drained directly into the river, households without toilets who disposed their solid wastes into the river and livestock owners who drained or disposed animal manure into the river (See Table 2 above). All these activities were present in all the sampling areas except for the occurrence of toilets without septic tanks but draining into the river in Macasandig where there was a 0% turn out. Among those with toilets that drained directly into the river, Macabalan showed the highest percentage of respondents (19%). On the other hand, the highest percentage of fecal waste disposal into the river for those who did not have their own toilets was highest in the Marcos Bridge site at 29%. Disposal of animal manure into the river by livestock owners was highest in Macasandig at 82%. Thus, there is a probability that the occurrence of such a practice influences the high fecal coliform concentration obtained for this site. Population densities in each of the specified areas also showed a direct relationship with the degree of fecal contamination. Macasandig for instance has the greatest population density among the five barangays and average MPN index is also highest for this area. The same relationship is true for the Marcos Bridge (Consolacion) area where in the lowest population density as well as the lowest mean MPN index was found. However, it is difficult to rely on the these survey results to establish a statistical correlation between such factors and the occurrence of high mean MPN indices in the sampling sites involved. Answers to the survey questions were highly subjective and it is possible that some of the respondents were not entirely truthful in answering the questions. It is also important to note that the respondents included only those houses located along the banks of the specific part of the river where the sampling was done. Thus, different results may be gathered further upstream or down stream of the sampling areas recommending a wider area of coverage for future studies to look further into this aspect of population and human activity relationship to the degree of fecal contamination along the river and arrive at a more definite conclusion.

As significant as the results of this study are, one cannot rule out the possible sources of error aside from those previously mentioned throughout the discussion. Important among these is the experimental errors that may have occurred. One is the accuracy of the measuring devices like balances, graduated cylinders, flask, etc... It is also important to consider imperfections in the method used to determine the MPN indices for this study, specifically the Multiple Tube Fermentation Technique. False positive results may occur when certain non-coliform bacteria suppress coliforms or act synergistically to ferment Lauryl tryptose broth. A significant number of false positive results can also occur in the brilliant green bile broth when chlorinated primary effluents are tested, especially when stormwater is mixed with the sewage. False negatives may occur with waters containing nitrates.[21] These factors can also significantly influence the results obtained in the study.

The National Water Regulatory Board has identified Cagayan de Oro as one of the nine water-critical urbanized areas where water is consumed intensively.[23] It is therefore very important that the quality of our water resources be maintained according to the set standards to ensure better health for the people, sustain proper sanitation and protect the income-generating resources in our city. Particular attention must be given to improved sanitation and sewerage as these are among the social factors that contribute to the degree of fecal contamination in surface waters. Strict implementation of the existing laws that serve to protect our rivers like the Clean Water Act of 2004 must also be given priority. As we gear ourselves toward a more socially and economically developed society, efforts must also be focused on a developmental process that does not compromise and disrupt the existing balance in our ecosystem. The result of this study knocks upon the doors of the specific government agencies responsible for the proper care, monitoring and maintenance of the valuable resource that is the Cagayan de Oro River.

## CONCLUSIONS

The results of this study revealed that Cagayan de Oro River is fecaly contaminated as was shown by the high average MPN indices obtained from the five sampling sites which exceeded the standard allowable fecal coliform value set by ANZECC at 150 fecal coliform organisms per 100 ml. Macasandig show the highest mean MPN value of $\geq$2400 fecal coliforms /100 ml, followed by the following Barangay arranged from highest to lowest; Puntod (2140 fecal coliforms /100 ml), Carmen (1880 fecal coliforms /100 ml), Macabalan (1624 fecal coliforms /100 ml), and Marcos Bridge

(Consolacion) site (844 fecal coliforms /100 ml).

Factors that were determined to be present that may have a contribution to the river's fecal contamination were: (1) the disposal of pets/livestock manure in the river, which showed highest in Macasandig, (2) the number of comfort rooms draining to the river for those who have comfort room, and (3) the disposal of human wastes on the river for those who don't have comfort rooms.

## RECOMMENDATIONS

1. Weekly sampling should be done for more conclusive and satisfactory results. Samplings done during different weather conditions (e.g. after rainfall) as well determination of possible differences in the MPN indices in one site during high tide and low tide can be done to establish a more specific influence of these factors in the fecal contamination of the Cagayan de Oro River.

2. The physico-chemical aspect of the river such as BOD, pH, turbidity, temperature as well as total dissolved solids (TDS) should also be determined to have a more thorough analysis and profile of the river.

3. A wider study on the other barangays where river water passes through should be conducted, especially those places used for white water rafting located upstream to further establish the implications of fecal contamination of the river on the socio-economic aspects of the city especially in the area of tourism.

4. A further investigation on the health implications of fecal contamination especially along the river side barangays. This can be done by conducting a study regarding morbidity and incidence of gastrointestinal disease in relation to the extent of fecal contamination in every barangay. Other water-borne diseases can also be investigated for this matter

5. At least three (3) sites from upstream, middle and downstream where water sample be taken per sampling area to further confirm and to provide a more precise fecal coliform index per site.

6. More facility and equipment in the med.ical laboratory for more extensive researches. There is a need for improved glassware and equipment availability and efficiency to meet the laboratory demands of this study. This is also important to support more extensive and accurate water analysis studies in the laboratory.

7. The use of other techniques to determine coliform counts other than the multiple tube fermentation technique should be done to confirm the obtained results and rule out flaws of this method like the membrane filter method and others.

8. Lastly, focus on improved education of the public especially those living along the river regarding its importance and the implications of fecal contamination of the river especially on health must be done. This goes along with the stricter and more extensive implementation of laws by concerned government agencies that serve to protect the water quality of the river and the welfare of the people. The need for proper sanitation and sewage disposal must also be addressed one way of which is to provide more public toilets with well-engineered septic tanks that the people can use for free. Residents that raise livestock must be educated of the proper disposal of animal wastes as well as warned of possible sanctions upon violation of the existing regulations.

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