A Preliminary Assessment of Heavy Metal Pollution in Eastern Trinidad Water Systems and Soil Sediment

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Abstract

This assessment concentrated on heavy metal levels in Salybia Creek and Reef, as well as the Shark, Tompire, and Rio Grande Rivers in Eastern Trinidad, West Indies. Water was tested for basic drinkability, pH, alkalinity, and the approximate level of heavy metal pollution at each water site was measured in parts per billion (ppb). Accompanying soil samples had their pH, nitrogen, phosphorus, and potassium levels tested to measure any nutrient richness or depletions in the area. An observation of the type of aquaculture and life for each tested habitat was taken to guide in the estimated supportiveness of the environment. Heavy metal pollution was found to be strongly linked to the Tompire and Shark river systems.

Introduction

Environmental quality has a direct correlation with pollution and will vary depending on the degree of pollution in the area (Labianca 2018). While metals naturally accumulate throughout our environment, rapid urbanization and industrialization have contributed to an excessive increase in waste disposal (Hu 2013). This consequently damages the natural environment through various outlets, including soil and water, while exceeding certain heavy metal limitations may demonstrate detrimental effects to an organism or ecosystem (Yujun 2017). Although some metals are ubiquitous in the environment and considered essential ecological elements, even a number of trace metals can be toxic at low levels (Alonso 2002). The low solubility property of these metals causes their accumulation in sediments, which has a trophic cascade effect that transfers to aquatic organisms and eventually to primary consumers, including humans (Kim 2018). A sustainable clean water supply is needed for everyday anthropologic necessities such as drinking, cooking, and cleaning.

The Island of Trinidad has been undergoing an industrial boom as oil exploration in the area continues to increase and an urban sprawl continues in Port of Spain. The rapid expansion and urbanization have induced the investigation of metal and oil pollution in local water sources and tributaries (Balgobin 2018; Jacquin 2017; Mohammed 2017). Two endemic species of *Sargassum*, *Sargassum filipendula* and *Sargassum vulgare,* off of the Eastern coast of Trinidad has even begun to be used as biomarkers for pollution specifically relating to excess heavy metals (Seepersaud 2017). The objective of this study was to evaluate the heavy metal content residing in multiple water sources of Eastern Trinidad and Northeast coast to find any indication of water quality and pollution. Specifically tested were the Shark, Tompire, and Rio Grande Rivers, alongside Salybia Creek (currently nonflowing in separated pools) and Reef. This assessment will aid in a better understanding to the extent of water pollution on the island while serving as a valuable starting point for water quality comparison.

Materials and Methods

Water was collected from Salybia creek, one marine reef, and three river locations upon travel to the North-eastern quadrant of Trinidad.

Water samples were taken as sterile as possible and in the amount of 20 mL in glass vials. Sample containers were rinsed a minimum of three times with the water source before collection to minimize contamination. For freshwater running rivers, two samples were taken: one sample close to the shore of the most aggressive running of water, and the other in a calm pool south of the flowing sample site. Soil was taken if present and available in these locations, as well as at the deepest point of the river between the two samples. The saltwater location was tested using a sample closest to the shore accompanied with soil, a water sample at the first break of waves offshore (approximately two meters in), and a sample from the shoreline where the beach sand turned into soil that supports vegetation. Groundwater collection was taken from two locations that were separate and isolated, to observe any the differences.

Exact Sample Locations, in order of collection using GPS coordinates:

1. Shark River (10.8238, -61.0871): Five total samples sites were analyzed including; a swift flowing region between boulders upstream (water and soil); calm shaded shoreline near deepest point of calm pool between the sets of boulders where water was swiftly running (water and soil); Deepest point of calm water pool between the first two samples (soil only); shoreline downstream from previous samples before the beginning of new set of boulders and swift flowing water (soil and water); and, a rain pool that had collected approximately 60 meters from the last shore sample that was also plentiful of a juvenile tadpole population (water only). These were denoted sample numbers one through five respectively.
2. Tompire River (10.7864, -60.9594): Four total sample sites were analyzed including; closest location to a swift flowing region running over small boulders (water and soil); the edge of the bank downstream of the first sample where water was calm (water and soil); bottom of the river between the first two samples at the deepest and most calm point between samples (soil only); and, pooling area of river at fork that had no outlet and was the most calm (water and soil). These were denoted sample numbers six through nine respectively.
3. Salybia Creek (currently nonflowing) (10.8231, -60.9341): Four total sample sites were analyzed including; still northern pool relative to the street bridge (water and soil); still southern pool that runs the length under the bridge of an active bat colony (water and soil); patch of ground that was exposed between the first two samples, with an approximate length just short of one meter (soil only); and, a rain pool collecting on bridge road just above Salybia creek (water only). These were denoted sample numbers ten through thirteen respectively.

4. Salybia Reef at Keshorn Walcott Galera Point Lighthouse (10.8347, -60.9101): Three total samples sites were analyzed including; the shoreline directly in front of the path heading down to the beach from the lighthouse (water and soil); approximately 2 meters into the surf from the first sample where rocks and reef begin (water only); and, where the vegetation meets the beach and soil sediment begins (soil only). These were denoted sample numbers fourteen through sixteen respectively.
5. Rio Grande River (Three total samples sites were analyzed including; most rapidly flowing source in site (water only); still pool downstream from first sample (water only); and, the bottom of the river at deepest point between the two previously collected samples (soil only). These were denoted sample numbers seventeen through nineteen respectively.

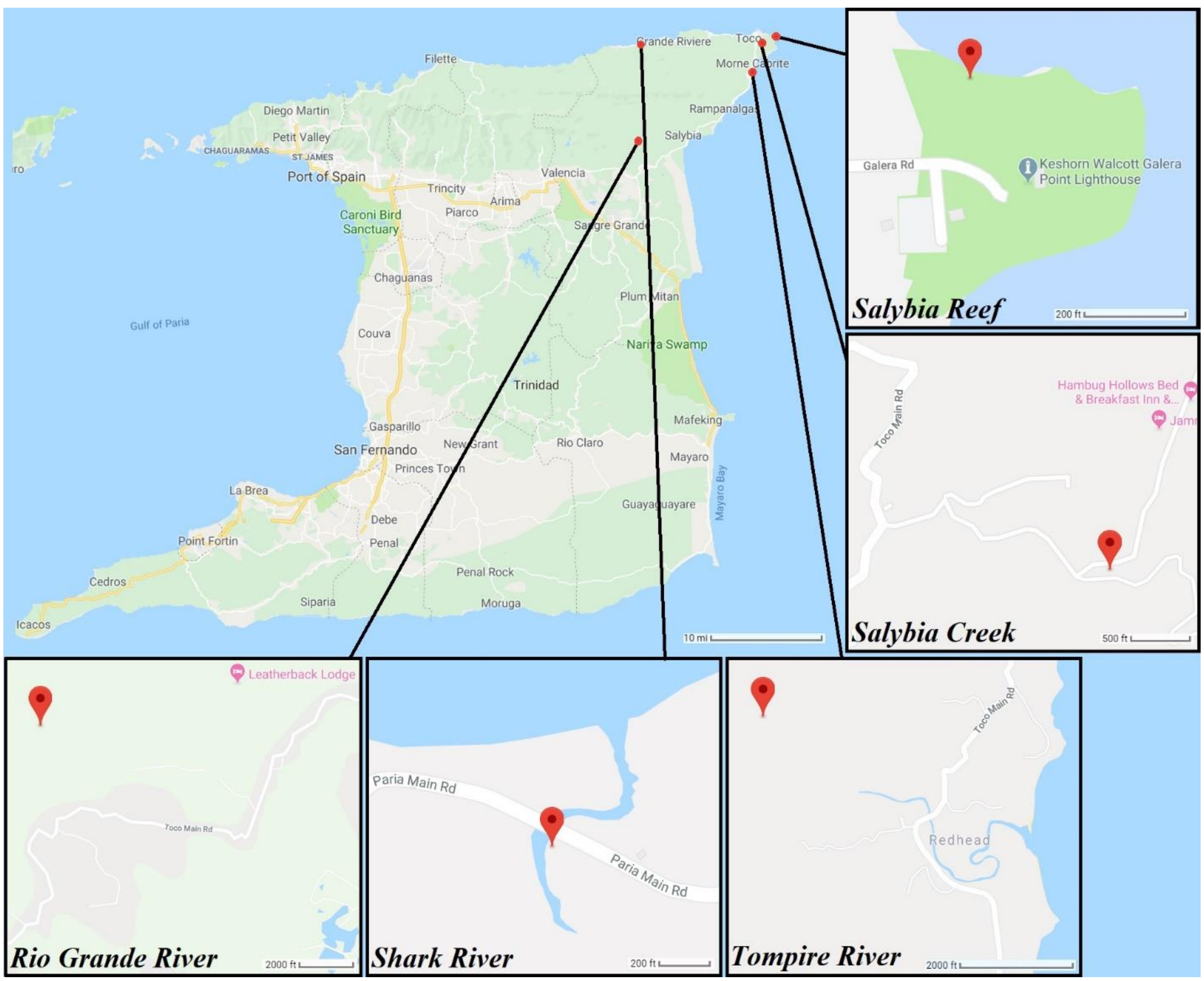

Figure 1. *Sample site collection map*

The water samples were first analyzed using Technically Pure drinking water home test kit with a sensitive level for lead and fluoride. The strips tested for pH (6.5-8), total hardness (30-600 mg/L), lead (zero ppb), fluoride (one mg/L), residual chlorine (zero mg/L), total chlorine (zero mg/L), nitrate (zero mg/L), nitrite (zero mg/L), iron (zero mg/L), copper (zero mg/L), bromine (zero mg/L), total alkalinity (100-200 mg/L), Cyanuric acid (30-50 mg/L) and carbonate root (0-20 mg/L) with their acceptable levels listed in correspondence. Industrial Test Systems 480309 SenSafe metals check water strips were also used to test for any heavy metals present including: Cadmium, Cobalt, Copper, Iron (ferrous), Lead, Mercury, Nickel, Zinc and other +2 valence metals. This test uses a nonspecific but very sensitive indicator that detects a variety of common heavy metals that are concerning. A safe and unpolluted reading should measure <10 ppb.

Soil and sediment samples were collected using clean and uncontaminated sealable ziploc bags and labeled with the appropriate sample ID site and any necessary onsite information. A soil probe was used to obtain core soil material at least one inch under the surface for a more accurate analysis. A 3-in-1 soil meter was also used to record the pH, light intensity, and moisture level onsite. Wetness of soil does not affect the analysis or results. Soil samples were analyzed in the state of their original collection using a Luster Leaf 1601 Rapitest Soil Test Kit to observe the levels of pH, Nitrogen, Phosphorus, and Potassium. The samples were then dried to test the change pH using an Environmental Concepts 1663 Professional Soil Test Kit.

Results

Table 1. *Water sample summary table.*

	Sample Number	pH	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Heavy Metals Check (ppb)
	Control	6.5	20	0	<10
Shark River	1	6.5	30	50	20
	2	6.5	30	50	<10
	4	6.5	30	50	<10
	5	6.5	30	100	200
Tompire River	6	6.5	30	50	<10
	7	6.5	30	50	<10
	9	6.5	30	50	<10
S. Creek	10	6.5	30	10	20
	11	6.5	30	10	20
	13	6.5	30	10	50
S. Reef	14	6.0	600	50	<10
	15	6.0	600	50	<10
Rio Grande	17	6.5	30	100	<10
	18	6.5	30	100	<10

Lead, fluoride, residual chlorine, total chlorine, nitrate, nitrite, iron, copper, bromine, and carbonate root are excluded from this table. This is due to their consistent values of zero mg/L, or ppb, and acceptable levels for drinking. Cyanuric acid results were excluded completely due to consistent unreadable results on every sample.

Table 2. *Soil sample pH and nutrient summary table.*

	Sample Number	pH	Dry pH	Nitrogen	Phosphorus	Potassium
	Control	7.5	7.5	adequate	defficient	depleted
Shark River	1	6.5	7.5	depleted	sufficient	sufficient
	2	7.0	7.5	depleted	adequate	sufficient
	3	6.5	7.5	depleted	sufficient	sufficient
	4	7.0	7.0	depleted	sufficient	sufficient
Tompire River	6	7.0	7.5	depleted	adequate	adequate
	7	6.0	6.5	depleted	adequate	sufficient
	8	7.5	7.0	depleted	adequate	adequate
	9	7.0	7.0	depleted	sufficient	sufficient
S. Creek	10	6.5	7.0	depleted	adequate	sufficient
	11	6.0	6.5	depleted	adequate	sufficient
	12	6.0	6.5	depleted	adequate	sufficient
S. Reef	14	7.5	>8	depleted	deficient	adequate
	16	7.0	7.0	depleted	sufficient	surplus
Rio Grande	19	6.5	7.5	depleted	sufficient	sufficient

Discussion

The results in *Table 1* demonstrate very probable heavy metal pollution at both the Shark River and Salybia Creek. The SenSafe water metals check is only a screening tool and does not specify levels of each metal present, only a total +2 valence metal content. Each river will be discussed separately and in the order of collection analysis. Lead, Iron, and Copper are all be excluded as pollutant culprits due to their individual test strips reporting zero values.

Sample location 1: Shark River shows consistent low levels of alkalinity and only one section of the river coming up positive for accumulation of heavy metals. Alkalinity levels are consistent and low for this specific river. For alkalinity levels to be considered normal in a freshwater river the range must be between 100-250 mg/L (Fondriest 2013; Hill 1997). Alkalinity mainly works as a buffer to protect the water against any sudden changes in pH which also protects aquatic organisms from these changes (Fondriest 2013). Low alkalinity can cause the pH of a water to become acidic which negatively affects the hatching and development of most aquatic animals (Fondriest 2013; Reeder 2017). There was active and adequate aquatic life at this location, but no previous survey to compare diversity to except for the appearance of the Trinidadian guppy, *Poecilia reticulata*, which is known to reside in these water systems (Hornaday 1995). The alkalinity levels both explain the slightly less than neutral pH and fall into the preferred pH range (6.5-9) of the majority of aquatic creatures (Fondriest 2013).

Unexpected at this site was the indication of pollution in sample one at the swift flowing region between boulders upstream. Flowing regions usually indicate the best quality of water within the system, but pH has also been shown to affect the solubility and toxicity of heavy metals that reside in the water (Tchounwou 2012). The highest polluted sample in the entire project was found in sample five at the rain pool that had collected approximately sixty meters from the shoreline. This sample demonstrated an astounding 200 ppb in a pool that was no more than one square meter and was plentiful of developed juvenile tadpoles. It is not surprising to find amphibians making use of this, even with heavy pollution, as heavy metals and phosphorous compounds do not affect the survival of most amphibians (Egea-Serrano 2012). Because this pool was isolated and a distance from shore, the soil itself may be rich in natural heavy metals and heavily concentrated when forced to support small pools of water for extended time. Both polluted samples from this location were saved for further testing in the Texas A&M water analysis laboratory.

Sample location 2: The Tompire River mirrors the consistent low levels of alkalinity and pH in Shark River. This river also supported an adequate number of aquatic species with no previous survey to compare diversity, except for the presence of *P. reticulata* (Lindholm 2015). There was no indication of any heavy metal pollution at this particular site of the river. Heavy metal tests showed results that indicated more than 10 ppb, but significantly less than 20 ppb and were therefore dismissed from possible pollution levels. The portion of the river sampled sits directly under on an active agriculture site which is a probable reason for the indication of a slightly higher than normal heavy metal level (Mahabir 2004).

Sample location 3: Salybia Creek shows the lowest of alkalinity levels but are still accompanied by acceptable pH levels. The alkalinity level of this sample location was expected to be between 20-200 mg/L due to its stagnant condition. The 10 mg/L difference from the expectation proves not to be significant enough to cause any detrimental changes to the pH (*Table 1*). There are signs of aquatic life still thriving in these stagnant pools, including shrimp and caiman. All water samples collected from this location showed a consistent reading of 20 ppb heavy metal pollution. Although, sample thirteen was collected in a rain pool and may indicate that a source of pollution may also reside in the soil. The portion of the creek that was sampled sits directly on an active agriculture site which could be the direct contributor to this low-level pollution (Mahabir 2004). All samples from this location were saved for further testing in the Texas A&M water analysis laboratory in order to conclude this theory.

Sample location 4: Salybia Reef also shows less than normal alkalinity levels, even for seawater. Seawater typically contains alkalinity levels between 100-125 mg/L (Fondriest 2013; Hill 1997). The significantly low alkalinity explains the lower than normal pH of a water that is supposed to be highly basic. This reef may also be subject to ocean acidification, a product of climate change (Fabry 2008). There is no indication of heavy metal pollution from prescreening, although there was a slight presence of *Sargassum* spp. coming in with the surf. This is a bioindicator that demonstrates there is heavy metal and oil pollution collecting off of this coast, which has been noted in studies in the area (Seepersaud 2017).

Figure 2. *Sargassum spp.*

Sample location 5: Rio Grande River presented the most stable drinkability levels with no apparent indication of heavy metal pollution. Aquatic diversity is present and thriving, but no previous surveys to compare to.

Soil samples show consistent acceptable levels for phosphorus and potassium, but with an overall nitrogen depletion in sediments from all locations. Nitrogen and phosphorous residing on sediment particles and dissolved in water are a significant source of nutrients for autotrophic organisms, such as algae, and can correlate directly with harmful algae blooms (Malcom 1976). All fresh water systems demonstrated moderate to sufficient algae with not enough nitrogen to be fearful of any harmful blooms. This is surprising considering all sample sites were within a close proximity to land used for agriculture (Mahabir 2004). The exact reason for the lack of nitrogen is unknown, but the presence of a metabolizable carbon energy source can significantly enhance the rate of nitrogen depletion during the nitrogen cycle and is not in this circumstance due to natural nitrate levels (Kelso 1997). Nitrates may also be present in groundwater conserving the correct proportions for the nitrogen cycle in water systems. Soil nutrient levels are within acceptable range and are considered not to have an impact on the water quality or ecosystems (Horneck 2011).

Conclusion

The world water crisis is real (Newton 2016). A sustainable clean water supply is needed for everyday anthropologic necessities such as drinking, cooking, and cleaning. Islands, like Trinidad, have outdated water treatment system if they even have them at all, with little to no enforcement and compliance on water pollution control rules (Mahabir 2004). This means that it is more likely to accumulate pollution in the water systems and surrounding oceans (Mahabir 2004). It is normal for natives to use these water systems daily, either pumped to their living quarters or using straight inside the source itself. Consequences from this pollution include damage to the natural environment and ecosystems, and most importantly, damage to human health, both short and long-term (Yujun 2017). Heavy metals have already been found at unacceptable levels in the western river systems of Trinidad (Mohammed 2017). These heavy metals have already been linked to high levels in fish, mussels, and oysters being farmed in the area (Balgobin 2018; Rojas de Astudillo 2002;). It has been concluded that the Shark and Tompire Rivers, as well as Salybia Creek, are all potential polluted water systems via heavy metals. Once the system is polluted, so is the food being harvested from these waters, and then directly onto a someone’s plate (Yujun 2017). Continuation on pollution studies on the Island of Trinidad will aid in future water pollution mitigation and compliance with the current water pollution policies implemented by the Trinidad government. This work is meant to be a reference point for further studies.

Literature Cited

Alonso, M. L., Benedito, J. L., Miranda, M., Castillo, C., Hernández, J., & Shore, R. F. (2002). Interactions between toxic and essential trace metals in cattle from a region with low levels of pollution. *Archives Of Environmental Contamination And Toxicology*, *42*(2), 165–172. Retrieved from http://search.ebscohost.com.srv-proxy1.library.tamu.edu/login.aspx?direct=true&db=mdc&AN=11815807&site=eds-live

Balgobin, A., & Singh, N. R. (2018). Impact of anthropogenic activities on mussel (Mytella guyanensis) in the Gulf of Paria, Trinidad. *Marine Pollution Bulletin*, *135*, 496–504. https://doi-org.srv-proxy1.library.tamu.edu/10.1016/j.marpolbul.2018.07.056

Egea-Serrano, A., Relyea, R. A., Tejedo, M., & Torralva, M. (2012). Understanding of the impact of chemicals on amphibians: a meta-analytic review. *ECOLOGY AND EVOLUTION*, *2*(7), 1382–1397. https://doi-org.srv-proxy2.library.tamu.edu/10.1002/ece3.249

Fabry, V. J., Seibel, B. A., Feely, B. A., & Orr, J. C. (2008). Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science: Journal Du Conseil*, (3), 414. Retrieved from http://search.ebscohost.com.srv-proxy2.library.tamu.edu/login.aspx?direct=true&db=edsovi&AN=edsovi.00009456.200804000.00015&site=eds-live

Fondriest Environmental, Inc. (2012) pH of Water. *Fundamentals of Environmental Measurements*. https://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/

Horneck DA, Sullivan DM, Owen JS, Hart JM (2011) Soil test interpretation guide. http://www.sanjuanislandscd.org/Soil_Survey/files/page18_3.pdf. Accessed 15 Jun 2019

Jacquin, L., Dybwad, C., Rolshausen, G., Hendry, A. P., & Reader, S. M. (2017). Evolutionary and immediate effects of crude-oil pollution: depression of exploratory behaviour across populations of Trinidadian guppies. *Animal Cognition*, *20*(1), 97–108. https://doi-org.srv-proxy1.library.tamu.edu/10.1007/s10071-016-1027-9

Kelso, B. H. L., Smith, R. V., Laughlin, R. J., & Lennox, S. D. (1997). Dissimilatory nitrate reduction in anaerobic sediments leading to river nitrite accumulation. *Applied and Environmental Microbiology*, *63*(12), 4679-4685. Retrieved from https://www-scopus-com.srv-proxy2.library.tamu.edu/record/display.uri?eid=2-s2.0-0030732678&origin=inward&txGid=0b185812e575fb8a2bb8ff614a74e031

Hill, T., & Neal, C. (1997). Spatial and temporal variation in pH, alkalinity and conductivity in surface runoff and groundwater for the Upper River Severn catchment. *Hydrology and Earth System Sciences*, (3), 697. Retrieved from http://search.ebscohost.com.srv-proxy2.library.tamu.edu/login.aspx?direct=true&db=edsdoj&AN=edsdoj.63236c35ba0a4c9e8c6d586e25f7300d&site=eds-live

Hornaday, K., Alexander, S., & Breden, F. (1995). Distribution of a Repeated DNA Sequence in Natural Populations of Trinidad Guppy (Poecilia reticulata). *Copeia*, *1995*(4), 809. https://doi-org.srv-proxy2.library.tamu.edu/10.2307/1447029

Hu, Y., Zeng, E. Y., Cheng, H., Shih, K., Liu, X., & Bai, J. (2013). Assessing heavy metal pollution in the surface soils of a region that had undergone three decades of intense industrialization and urbanization [electronic resource]. *Environmental Science and Pollution Research*, *20*(9), 6150–6159. https://doi-org.srv-proxy1.library.tamu.edu/http://dx.doi.org/10.1007/s11356-013-1668-z

Kim, H.-T., & Kim, J. G. (2018). Seasonal variations of metal (Cd, Pb, Mn, Cu, Zn) accumulation in a voluntary species, Salix subfragilis, in unpolluted wetlands. *Science of the Total Environment*, *610–611*, 1210–1221. https://doi-org.srv-proxy1.library.tamu.edu/10.1016/j.scitotenv.2017.08.137

Labianca, C., De Gisi, S., & Notarnicola, M. (2018). Assessing the Correlation between Contamination Sources and Environmental Quality of Marine Sediments Using Multivariate Analysis. *Environmental Engineering & Management Journal (EEMJ)*, *17*(10), 2391–2399. Retrieved from http://search.ebscohost.com.srv-proxy1.library.tamu.edu/login.aspx?direct=true&db=8gh&AN=133682881&site=eds-live

Lindholm, A. K., Sandkam, B., Pohl, K., & Breden, F. (2015). Poecilia picta, a Close Relative to the Guppy, Exhibits Red Male Coloration Polymorphism: A System for Phylogenetic Comparisons. *PLoS ONE*, (11), e0142089. https://doi-org.srv-proxy2.library.tamu.edu/10.1371/journal.pone.0142089

Mahabir, S. (2004) Integrated water resource management in Trinidad and Tobago. Interim report IR-04-008, IIASA, Laxenburg, Austria

Malcolm, R. L., & Durum, W. H. (1976). Organic carbon and nitrogen concentrations and annual organic carbon load of six selected rivers of the United States. Retrieved from http://search.ebscohost.com.srv-proxy2.library.tamu.edu/login.aspx?direct=true&db=cat03318a&AN=tamug.813096&site=eds-live

Mohammed, F., Sieuraj, J., & Seepersaud, M. (2017). A preliminary assessment of heavy metals in sediments from the Cipero and South Oropouche Rivers in Trinidad, West Indies. *Environmental Monitoring & Assessment*, *189*(8), 1–21. https://doi-org.srv-proxy1.library.tamu.edu/10.1007/s10661-017-6077-1

Newton, D. E. (2016). *The Global Water Crisis: A Reference Handbook : A Reference Handbook*. Santa Barbara, California: ABC-CLIO. Retrieved from http://search.ebscohost.com.srv-proxy1.library.tamu.edu/login.aspx?direct=true&db=nlebk&AN=1215751&site=eds-live

Reeder, B. C. (2017). Primary productivity limitations in relatively low alkalinity, high phosphorus, oligotrophic Kentucky reservoirs. *Ecological Engineering*, *108*(Part B), 477–481. https://doi-org.srv-proxy2.library.tamu.edu/10.1016/j.ecoleng.2017.06.009

Rojas de Astudillo, L., Chang Yen, I., Agard, J., Bekele, I., & Hubbard, R. (2002). Heavy metals in green mussel (Perna viridis) and oysters (Crassostrea sp.) from Trinidad and Venezuela. *Archives Of Environmental Contamination And Toxicology*, *42*(4), 410–415. Retrieved from http://search.ebscohost.com.srv-proxy1.library.tamu.edu/login.aspx?direct=true&db=mdc&AN=11994781&site=eds-live

Seepersaud, M. A., Ramkissoon, A., Seecharan, S., Powder-George, Y. L., & Mohammed, F. K. (2017). Environmental monitoring of heavy metals and polycyclic aromatic hydrocarbons (PAHs) in Sargassum filipendula and Sargassum vulgare along the eastern coastal waters of Trinidad and Tobago, West Indies. *Journal of Applied Phycology*, *30*(3), 2143–2154. https://doi-org.srv-proxy1.library.tamu.edu/10.1007/s10811-017-1372-3

Tchounwou P.B., Yedjou C.G., Patlolla A.K., Sutton D.J. (2012) Heavy Metal Toxicity and the Environment. In: Luch A. (eds) *Molecular, Clinical and Environmental Toxicology*. Experientia Supplementum, vol 101. Springer, Basel

Yujun Yi, Caihong Tang, Tieci Yi, Zhifeng Yang, & Shanghong Zhang. (2017). Health risk assessment of heavy metals in fish and accumulation patterns in food web in the upper Yangtze River, China. *Ecotoxicology and Environmental Safety*, *145*, 295–302. https://doi-org.srv-proxy1.library.tamu.edu/10.1016/j.ecoenv.2017.07.022