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Environment, Water

Analysis of Water Quality from the Rivers Colne, Holme and Calder Flowing through Huddersfield/Mirfield

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Introduction

It is a truism that water is a valuable resource. Rivers are among the major suppliers of freshwater resources for humans and other terrestrial organisms. Thus, without rivers humans could not have survived. The importance of river systems has been elucidated even during the rise of the Egyptian Civilization. The Nile River for instance has provided humans with food, drink, fertile soil and even a site for settlement (Hassan and Al Rasheedy, 2007). The ecosystem services that the river provide to people since time immemorial include water supply for cleaning, dilution and removal of waste and decomposition, commerce, transportation and recreational activities such as rafting (Karr and Chu, 2000).

As time goes by, people have paved the way for economic development. As a result, the demand for agriculture, industry and domestic consumption of water and related resources also increased over time. To date, surface water pollution due to toxic chemicals released from mining industries, factories and even human settlements is a major issue all over the world.

The fact that freshwater resource supply on earth is very limited has always remained a challenge to humans on how to maintain water supply. This challenge has always been a concern to both engineering and politics. On the aspect of engineering, the main concern is to harness more water, keep water supply clean, and protect properties from inundation (Karr and Chu, 2000). Politics, on the other hand, tries to address geopolitical boundaries and control of resources. Again, it is a harsh reality that the earth's water supply cannot keep up at the pace of economic development. Water supplies are becoming more and more insufficient that ever before while engineering feats cannot impede water floods from causing damage to properties. Long-term shifts in climate and flow patterns of the river system have put human engineering efforts in vain (Karr and Chu, 2000).

As humans focus on engineering and politics, other living organisms that also depend on the riverine system and are also important indicators of water quality are being neglected. Some reports indicate the loss of local fisheries (Taylor, 1998) while fishes in some river systems are not safe to eat because of water contamination. Indeed, decline in water biota determines the integrity of water quality (Karr and Chu, 2000). It is in this regard that water quality monitoring is very essential.

The most direct measure of the integrity of a water body is through the assessment of biological indicators that are present within the river system. Besides biological indicators, physicochemical factors such dissolved oxygen, temperature, pH, turbidity, total dissolved solids, conductivity, ammonia and phosphate content are some of the factors that are essential to water quality monitoring. These parameters were linked to the biota that thrived within the river system (Karr and Chu, 2000; Reynoldson et al., 1995). The results of these relational studies also served as a basis for the standardization of an ideal water chemistry that could support life.

In this study, the main objective is to assess the water quality of Colne, Holme and Calder River that drains through the catch basin

Huddersfield/Mirfield. This study will focus on the physicochemical aspects of the three river systems.

Study site. Sampling was carried out in the three river systems of West Yorkshire, England--Colne, Holme and Calder Rivers. Colne River is a confluence of Redbrook Clough and Haigh Clough at the Close Gate Bridge (53°36'19" N, 1°57'28" W). Together with Holmes River (i. e. confluence point at Huddersfield, 53°38'20" N, 1°47'04" W), Colne River (i. e. river mouth 53°40'49" N, 1°43'52" W) drains to Calder River at Mirfield. Colne River extends at about 20 kilometers. The river passes through the villages of Marsden, Slaithwaith, Milnsbridge and Huddersfield before it meets the Calder River in Cooper Bridge. Colne River supplies water to the Colne Valley for wool and cotton production. Along Huddersfield, there are numerous factories and other industrial activities along the Colne riverside. Holme River is a tributary of Colne River, and its length is 13. 86 kilometers. Brownhill Reservoir and Dobbs Dike supply water to Holmes River. Before Holmes River joins Colne River its path flows from north to northeast passing through Holmesbridge, Holmesfirth, Thongsbridge, Brockholes, Honley, Berry Brow and Lockwood. Most of the riverbanks in the upper part of Holmes River are also highly urbanized.

Calder River extends at about 72 kilometers in Northern England. It passes through several villages to include Cornholme, Mirfield, Dewsbury and Wakefield. The river has 39 reservoirs that provide water supply in some parts of the country. A portion of Calder was developed into a canal to make way for the Calder and Hebbel Navigation. Calder also houses various species of fishes such as salmon, perch, trout and the like in the upstream.

Aside from supplying water to industries, the river is also used as a recreational site for various watersports.

Sampling Method. There is a total of 21 sampling points for all three river systems. There are eleven sampling points (i. e. Hay Green, Marsden, Booth Bank, Slaithwaite, Linthwaite, Milnsbridge, Paddock, Longroyd, Newsome, Bradley Mills and Colne Bridge) for water quality analysis of the river Colne. Seven sampling points (Digbey Residence, Holmbridge, Holmfirth, Thongsbridge, Brockholes: located above outlet, outflow, below outlet, Lockwood: the main area and in Queens Mill Lane) were included in Holme River with three subsampling points taken in Brockholes and two in Lockwood. In Calder, only three main sampling points were considered, namely Cooper Bridge, Bracken Hill and Mirfield. Surface water temperature for each sampling point was directly measured on the site along with other parameters such as dissolved oxygen, pH, conductivity, ammonia, phosphate and total dissolve solids using a multi-parameter water quality meter. A 250 ml of water sample taken from each sampling point to determine the biochemical oxygen demand from the initial dissolved oxygen that was previously measured using the electron probe instead of titration.

Statistical Analysis. Descriptive statistics such as mean and standard deviation were used to describe the general trends that were observed for all river systems and their corresponding tributaries. A one-way ANOVA was used to determine whether the mean values of each parameter were significantly different within the tributaries of the main rivers or significantly different among the river systems. Statistically significant results were further subjected to post-hoc analysis using Tukey’s test.

Results

The highest average surface temperature was recorded in the Calder River at 8. 93 °C followed by Colne and Holme rivers at 8. 70 °C and 8. 33 °C respectively. Similarly Calder River has the highest mean reported value in terms pH (7. 40 ± 0. 11), conductivity (443. 23 ± 127. 71 μS), ammonia (1. 40 ± 0. 34 mg/L), phosphate (0. 47 ± 0. 28 mg/L) and total dissolved solids (316. 06 ± 89. 18 mg/L). Despite the highest ammonia and phosphate recorded in Calder River as compared to Colne and Holme, Calder River yielded the lowest mean biochemical oxygen demand (5. 33 ± 0. 71 mg/L). The average pH level in Colne is 7. 40 ± 0. 53 while the pH in Holme is 7. 18 ± 0. 53. Colne has the highest recorded average in terms of biochemical oxygen demand (6. 12± 4. 92 mg/L), ammonia (0. 23 ± 0. 07 mg/L) and phosphate (0. 09 ± 0. 04 mg/L). Besides pH level, Holme has the lowest recorded value for conductivity (223. 29 ± 106. 72 mg/L) and total dissolved solids (161. 06 ± 77. 74 mg/L) (Table 1).

Analysis of variance suggested that there is no significant difference in the mean values of temperature (mean 8. 61 ± 0. 65, p = 0. 336) for all three river systems along with their respective tributaries. Similarly, variations within and among groups for parameters like biochemical oxygen demand (6. 12 ± 4. 18, p = 0. 71) and pH level (7. 32 ± 0. 36, p = 0. 436) were not significant. However, conductivity (262. 11 ± 128. 14, p <0. 05), ammonia (0. 41 ± 0. 45, p <0. 001), phosphate (0. 15 ± 0. 17, p <0. 001) and total dissolved solids (187. 84 ± 91. 56, p <0. 05) yielded significant results in the analysis of variance among the three rivers Holme, Colne and Calder (Table 2).

Figure 1 shows the seven plates of graphs of mean values of all physic-chemical parameters considered in this study. Plates A, B and C are parameters of water quality whose mean values are not significant within and among the three river systems—Holme, Colne and Calder rivers. Those parameters whose mean values were significantly different as shown in plates D, E, F and G were further subjected to post-hoc analysis (i. e. Tukey’s Test). The result of the post-hoc analysis that are indicated in small letters a, b and c. The letter denotes the differences in mean values of each river system. For instance, the mean value of conductivity in Holme is significantly different from Calder, but not in Colne.

Post hoc analysis shows that the river Calder contribute much to the variation of mean values of conductivity, ammonia and phosphate concentration and total dissolved solids. Based on the results of the Tukey's test, the mean conductivity of Holmes is not significantly different from the mean conductivity and total dissolved solids of Colne however, the mean significantly varies at $p < 0.05$ with the obtained value in Calder. Conductivity and total dissolved solids in Colne does not significantly vary with Holme but is also significantly different from Calder at $p < 0.05$. The mean values of ammonia and phosphate concentration in Colne is not significantly different from Holme but is also significantly different from Calder at $p < 0.001$ (Figure 1, Table 2).

Discussion

Based on the EU directive, the proposed water quality standards are classified as Class I, II, III, IV and V. Class I, refers to the drinking water quality standard which in this case, the comparison of the results does not apply because surface water temperature was considered. Thus, the standards for Class II, III, IV and V were used instead to compare and characterized the three rivers because these river classes cover the ecosystem function of the river—the capacity of the river to support life. Water temperature is very essential because it influences the amount of dissolved oxygen in the water and even the sensitivity of an organism to toxic waste. It also affects the rate of biological and chemical processes. For instance, fishes that thrive on rivers depend on a particular temperature for their optimal growth and survival. Salmon requires a temperature range of 5-11°C during their embryo spawning stage, while the average temperature required for the survival of juvenile salmon is 20°C. Since water temperature fluctuates as climate season changes, the standard surface water temperature varies also as season changes and how the river system is classified according to its function (Wenner et al., 2004; Brungs and Jones, 1977 in US EPA, 2012). Salmonid waters are different from cyprinid waters following the Moldovan standards. The propose water quality standard for water temperature for salmonid water should be less than 8°C during winter (i. e. Class II and III). In cyprinid water (i. e. Class IV/V) the proposed value of surface water temperature during winter should be greater than 8°C (OECD, Date Unknown). The recorded mean temperature values of Holme, Colne and Calder rivers falls within the cyprinid water standard. However, according to some reports the upstream portion of Calder River is also a breeding ground for Salmon and other species of fishes.

Another important water quality parameter is pH. This parameter marks the acidity or the alkalinity of the water. Similarly, pH also affects the biological processes in the water. In fact, a diverse array of aquatic organisms prefers a pH value ranging from 6. 5-8. 0. Beyond this range of pH value suggests a stressful environment for the streams and rivers that limits organisms to proliferate. Effluent discharge and eutrophication are some of the main factors that alter the water chemistry of surface water (Singh et al., 2013; OECD; US EPA, 2012). The average pH value estimates of Holme, Colne and Calder Rivers also falls within the standard range of both EU and US EPA standards. However, it is too early to tell whether these rivers could support a diverse aquatic organism because there are other factors that affect water chemistry.

Surface water temperature and pH influence the biochemical oxygen demand in a river. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen that is required by microorganisms to breakdown organic matter. The process of organic and inorganic decomposition in rapids and streams is faster than that of deep waters because these two bodies of water are highly aerated. A high value of BOD does not necessarily indicate that there is a low oxygen concentration in a body of water. However, a high rate of BOD may indicate that there is a risk of reduction of dissolved oxygen that may greatly affect the survival of higher forms of aquatic organisms such as fishes. A low value of dissolved oxygen level in the river may cause stress to these organisms leading to their suffocation and death (Al-Badaii et al., 2013). The standard BOD level set by the European Union is 5 mg/L for both salmonid and cyprinid waters. However, the mean BOD of three river system fell short from the EU standard (Table 1). The result of BOD test is opposite to the convention that deep water has a higher BOD as opposed to rapids and streams because there is a greater extent of industrial activity in the sampling points in Calder River as opposed to that of Holme and Colne rivers.

Water conductivity is also influenced by inorganic dissolved solids and water temperature. The geological features of streams and rivers can also affect conductivity. For instance, streams having a substrate dominated by clay have a higher rate of conductivity because clay holds ionized materials (Burcham, 1988; Graham, Rossie and Hubert, 2010). Based on various researches, a stream having a conductivity ranging from 150 to 500 µS/cm could support a variety of fishes and elsewhere this range suggests that the water condition could be detrimental for fishes and other macroinvertebrates to survive. Based on the US EPA standards for conductivity, this indicates that three rivers can still support life forms.

Water temperature and pH level not only affects the BOD level, but can also have a significant effect in the toxicity of ammonia. A high pH level allows the formation of high concentrations of ammonia. Ammonia is a by-product of decomposition of natural and anthropogenic decomposition of organic matter. This substance can cause fish kill and long term exposure to this substance can result to abnormalities such as enlarged organs and gill deformities during the fish growth (Abdelmeguid et al., 2013). The toxicity of this substance also affects benthic and surface water organisms. The standard concentration of ammonia for salmonid water is 0. 8 mg/L to 1. 2 mg/L while the level of ammonia for cyprinid water should be 3. 2 mg/L or higher. In terms of ammonia concentration, the rivers Holme and Colne could be classified as Class II/III while Calder River is classified as Class IV/V.

Besides nitrogen, phosphorus concentration is also one of the parameters that are commonly monitored for the nutrient condition of freshwater ecosystems. Phosphorus like other nutrients can also have an indirect negative effect within the aquatic community through primary production such as an increase in algae biomass. When algal biomass increase this in turn, may also cause some changes in the water chemistry that would make it less suitable for other aquatic organisms to survive (Hanranan et al., 2003). For salmonid waters the ideal phosphorus concentration should fall between 0. 4 to 0. 75 mg/L while in cyprinid waters the phosphorus content should be 1. 2 mg/L or slightly higher. The both the ammonia and phosphorus condition of the three river system also falls within the range of salmonid waters.

Total dissolved solids are important because of its effect in the water balance or osmosis in the cells of aquatic organisms. Osmosis maintains an organism at a particular depth to which it is adapted (i. e. swelling and shrinkage of cells could make organisms float or sink) (Yancey et al., 2014). Dissolved solids comprise ions such as phosphorus or nitrates. The main source of TDS includes agricultural run-off and discharge from industries. The maximum total dissolved solids (TDS) that a freshwater can hold is 2000 mg/L. A freshwater body having a TDS beyond the maximum limit beyond 2000 mg/L according to the US EPA standard could highly affect the spawning capacity of fishes such as salmon (Weber-Scannell and Duffy, 2007). The mean TDS of the three rivers is still within that range where aquatic organisms such as salmon and perch could be supported.

Temperature profile in surface waters along with pH and BOD can be easily affected by externalities unlike other parameters such as conductivity, ammonia, phosphorus and TDS that also yielded significant results. But this is not to say that those parameters that obtained significant results are better predictors of water quality in Holme, Colne and Calder River than the other parameters because there are various factors that could affect the result of the study. Sigificant differences in conductivity, ammonia, phosphorus and TDS levels within and among the rivers Holme, Colne and Calder may be attributed to the extent of industrial activity within the sampling points and the geological aspects of the river system as well. Similarly, that Calder River is the source of variation may be linked to the geological and topographical characteristic of the river and also the extent of industrial developments as compared to the two rivers. Further, it is also likely that Calder River yields the highest mean values of all the significant parameters that were considered because the two rivers, Holme and Colne also drain their discharge to Calder River.

Conclusion

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