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Linear regression model and interrelationship among water quality attributes of Tuikual river in Aizawl District, Mizoram

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Abstract: The current study was carried out over a one-year period (October 2019 to September 2020) where the samples were taken at monthly intervals to determine the impact of human activities on water quality. The research area was divided into four sampling locations along the river, from upstream to downstream. Municipal waste, biomedical effluents, untreated city garbage, domestic and sewage discharges from the catchment area are received at Sites 1 and 2; the downstream Sites 3 and 4 are typical tourist attractions that eventually join the Tlawng river. For the study of Tuikual river water quality, important parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Dissolved Solids (TDS), Total Hardness (TH), Nitrate-N and Phosphate-P were estimated. The results were then compared to water quality standards set by the United States of Public Health (USPH), Bureau of Indian Standards (BIS) and World Health Organization (WHO). The results indicate that systematic correlation coefficient calculation and regression analysis proved to be a practical method for quick monitoring the water quality of the Tuikual river. The results show that unplanned and direct waste discharge from various sources has significantly deteriorated water quality at all study sites. This investigation could lead to more in-depth studies of the Tuikual river's water resources, as well as the development of water management policies and activities.

Keywords: Pollutants, Anthropogenic activities, Physicochemical characteristics, Correlation coefficient, Linear Regression, Water Quality Standards

INTRODUCTION

Water is required for life to exist on Earth. The world is facing a major challenge in meeting the energy needs of a growing population. Water is becoming a limited resource attributed to human activities such as urban development, agricultural development, increased fertilizer use, poor land use planning and sewage disposal. Water pollution is primarily caused by anthropogenic activities such as industrialization, urbanisation and other forms of development. Due to the state's lack of a good drainage system, a significant proportion of domestic, agricultural and other wastes are discharged direct or indirect into nearby rivers (Lalparmawii and Mishra 2012). Rivers play an important role in absorbing or transporting municipal and industrial wastewater, as well as agricultural runoff.

The Tuikual river has been severely harmed and polluted as a result of mountainside development, municipal waste dumping and untreated sewage dumped directly into the river. A nearby plot of land is also used as a dumping ground, which significantly contributes to river pollution. Provided the aforementioned, the current research aimed to determine the water quality characteristics of the Tuikual river in Aizawl, Mizoram.

MATERIALS AND METHODS

The water samples were collected from the selected sites on monthly interval over a one-year period (October 2019 to September 2020). The Tuikual river is a river that flows through Aizawl, Mizoram, and has a lot of sentimental impact. It is a major tributary of the Tlawng river, which delivers water to Aizawl and a number of neighbouring communities. Figure 1 depicts the site location in the study area. Figure 1 shows the study area, which transports sewage drains, household wastes, city garbage, municipal solid waste and other contaminants from various parts of Aizawl.

Water samples were collected by utilising a 5 litre opaque plastic bottle. A portable pH and TDS meter was used to measure pH and TDS on the spot at sampling locations. The water samples were transported to the laboratory in an ice box within 24 hours of being collected and properly labelled for the analysis of DO, BOD, Total Hardness, Nitrate-N and Phosphate-P. The Modified Winkler's Azide Method was used to estimate DO and BOD, the Titrimetric Method was used to estimate Total Hardness, and the Spectrophotometric Method was used to estimate Nitrate-N and Phosphate-P (APHA 2005). The findings were compared to scientific standards established by organisations such as the BIS (2005), WHO (2004) and the USPH (1962). For the statistical analysis of the correlation coefficient and linear regression model, Microsoft Excel and SPSS-16.0 were used.

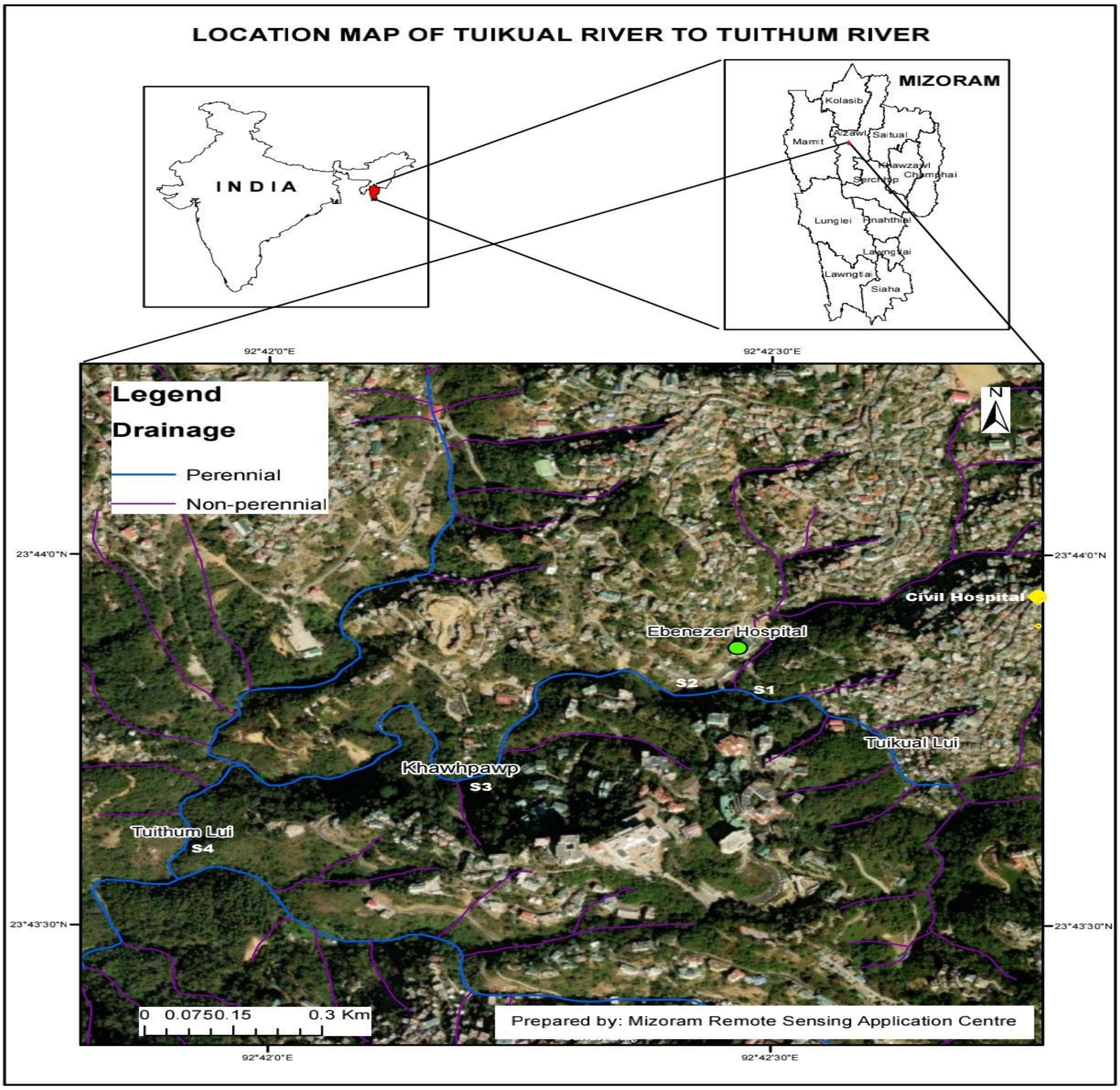

Figure 1. Study area

The following are descriptions of the four chosen sites.

Site 1- The site chosen was upstream of the river, near the source in the Khatla region (sample containing wastewaters from Aizawl Civil Hospital).

Site 2- It was chosen to assess the impact of tributary water containing domestic waste from settlements and hospital discharges at the New Secretariat Complex (after the convergence of Aizawl Civil Hospital and Ebenezer Hospital effluents, a sample was taken).

Site 3- Site 3 was chosen towards downstream of the river where the river obtains effluents from sandstone quarries (known as Khawhpawp river).

Site 4- It was chosen where the river joins the Tlawng river, downstream from the river (known as Tuithum river).

RESULTS AND DISCUSSION

pH

According to the results of the current investigation, the pH was found to be lowest at Site 1 (6.7) in the month of June and highest at Site 4 (8.2) in the month of December. The pH of the river water was observed to be lower during the rainy season at Site 1 (Figure 2), which could be due to ambient disintegration resulting in increased of carbon dioxide concentrations (Fella et al. 2013).

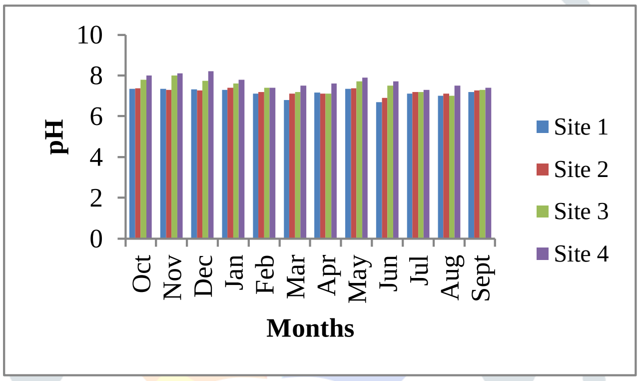

Figure 2. Monthly variation in pH of river water

DISSOLVED OXYGEN

The DO content was lowest at Site 2 (4.2 mg/L) in June and highest at Site 4 (8.1 mg/L) in December. The findings indicate that the DO value was higher than what has been permitted by the BIS (Table 1). DO content was discovered to be relatively high during the winter months (Figure 3), possibly due to its increased solubility, low microbial decomposition of decaying organic matter and low bacterium respiratory demand at relatively low temperature (Sunar and Mishra 2016).

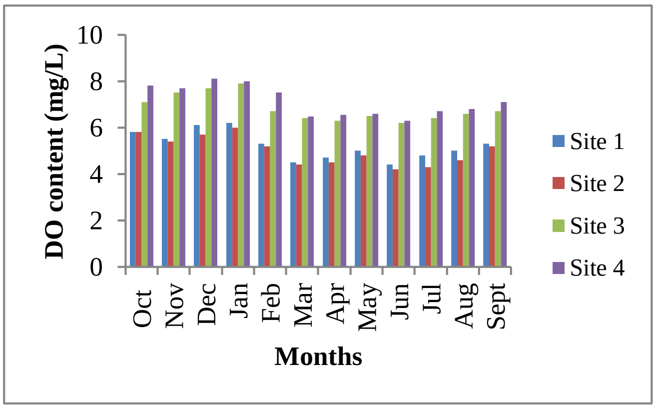

Figure 3. Monthly variation in DO of river water

BIOLOGICAL OXYGEN DEMAND

The BOD level was lowest at Site 4 (0.3 mg/L) in January and highest at Site 2 (3.6 mg/L) in June. According to the results, the BOD value exceeded the BIS allowable limits (Table 1). During the rainy season, it was discovered that the BOD level of the river water was higher (Figure 4), which may be related to an increase in dissolved oxygen consumption by microbial activities brought by an increase in organic waste due to rainwater runoff from the catchment area.

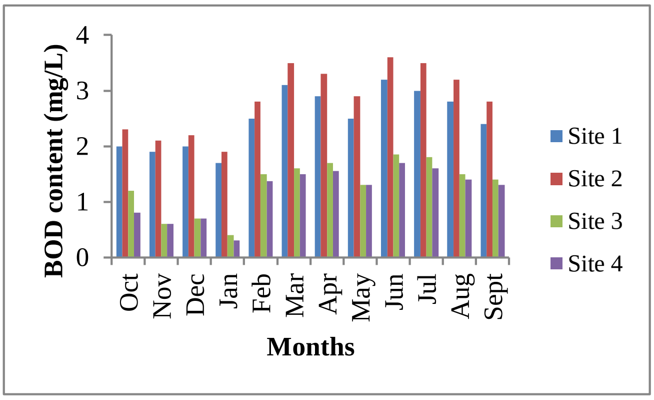

Figure 4. Monthly variation in BOD of river water

TOTAL DISSOLVED SOLIDS

Site 4 had the lowest total dissolved solids content level (60 mg/L) in the month of September, and Site 1 had the highest level (291 mg/L) in the month of March. The higher total dissolved solids content during the summer months (Figure 5) could be due to a lack of availability of water in the source materials, resulting in a high accumulation of inorganic salts and organic matter; on the other hand, the low amount during the rainy season could be due to dilution of high rainfall (Thasangzuala and Mishra 2014).

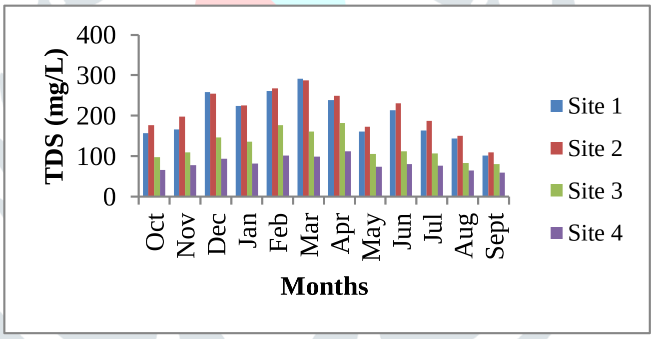

Figure 5. Monthly variation in TDS of river water

TOTAL HARDNESS

Total hardness content was lowest at Site 4 (62 mg/L) in September and highest at Site 2 (198 mg/L) in March. Total Hardness was discovered to be higher in the summer season (Figure 6), which could be attributed to water evaporation, salt addition from sewage inflow, along with detergents and soaps used during bathing and washing (Chhetry and Pal 2012).

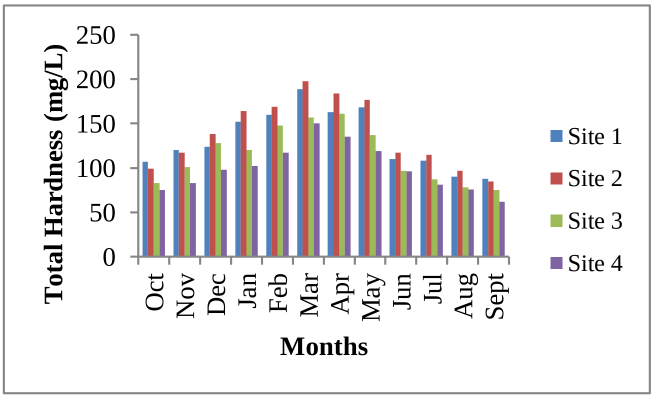

Figure 6. Monthly variation in TH of river water

NITRATE-N

The Nitrate-N content value was lowest in December at Site 4 (0.16 mg/L) and highest in July at Site 2 (0.47 mg/L). Higher nitrate-N content values were observed during the rainy season (Figure 7), which may be related to the waste discharges through rainwater organic material, which enhances the breakdown of organic matter and emits ammonia, which aerobic bacteria then oxidise into nitrite and nitrate (Asha and Diwakar 2007).

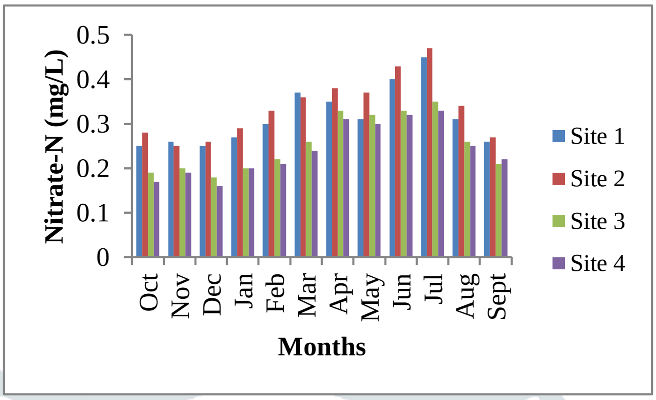

Figure 7. Monthly variation in Nitrate-N of river water

PHOSPHATE-P

The Phosphate-P content was lowest at Site 4 (0.059 mg/L) in January and highest at Site 2 (0.44 mg/L) in June. The findings indicate that the Phosphate-P value was higher than the USPH permissible limit (Table 1). Phosphate-P content increased during the rainy seasons (Figure 8) may be related to agricultural run-off containing phosphate fertilizers brought on by heavy rain and sewage waste inflow (Koshy and Nayar 2000).

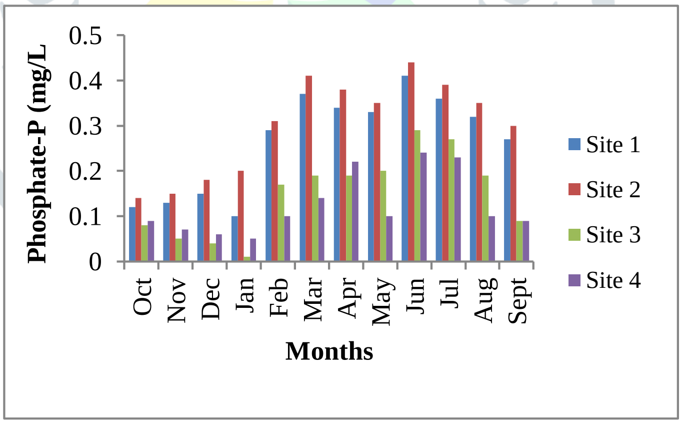

Figure 8. Monthly variation in Phosphate-P of river water

Table-1: Standards for water quality from different scientific organisations and a variety of water quality traits covered in this study.

Parameters	Standards	Recommending agencies	Range of water quality at the time of this study period
pH	6.5-8.5	BIS	6.7-8.2
DO (mgL^{-1})	5	BIS	4.2-8.1 mg/L
BOD (mgL^{-1})	3	BIS	0.3-3.6 mg/L
TDS (mgL^{-1})	500	BIS/WHO	60-291 mg/L
Total hardness (mgL^{-1})	300	WHO	62-198 mg/L
Nitrate-N (mgL^{-1})	10	USPH	0.16-0.47 mg/L
Phosphate-P (mgL^{-1})	0.1	USPH	0.059-0.44 mg/L

Table-2: Correlation coefficient between the studied water quality parameters

	pH	DO	BOD	TDS	TH	Nitrate	Phosphate
pH	1						
DO	0.77*	1					
BOD	-0.85*	-0.96*	1				
TDS	-0.12	-0.02	0.07	1			
TH	-0.07	-0.17	0.11	0.81*	1		
Nitrate	-0.65	-0.86*	0.83*	0.08	0.18	1	
Phosphate	-0.81*	-0.96*	0.97*	0.12	0.19	0.92*	1

*Correlation is significant at the 0.01 level.

According to the statistical analysis (Table 2), there is a highly positive and significant correlation ($p<0.01$) between pH and DO (r=0.77), BOD and Nitrate-N (r=0.83), BOD and Phosphate-P (r=0.97), TDS and Total Hardness (r=0.81), Nitrate-N and Phosphate-P (r=0.92). A highly negative and significant correlation ($p<0.01$) was found between pH and BOD (r= -0.85), pH and Phosphate-P (r= -0.81), DO and BOD (r= -0.96), DO and Nitrate-N (r= -0.86), DO and Phosphate-P (r= -0.96).

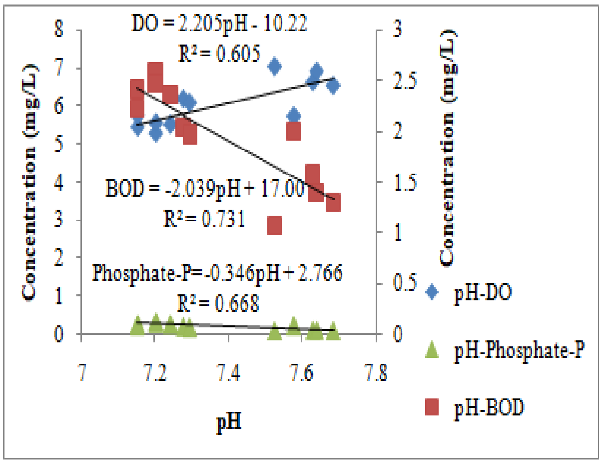

Figure 9 (a)

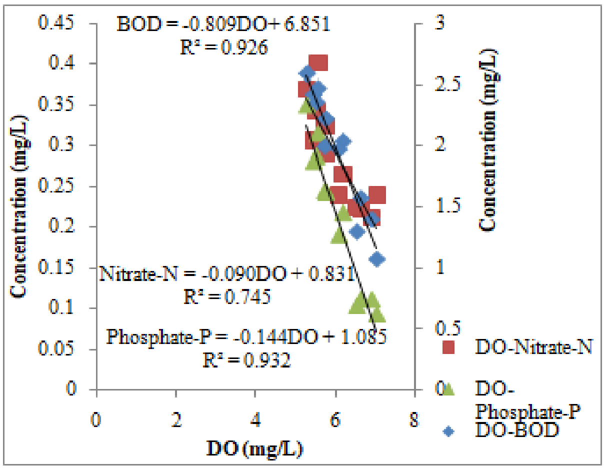

Figure 9 (b)

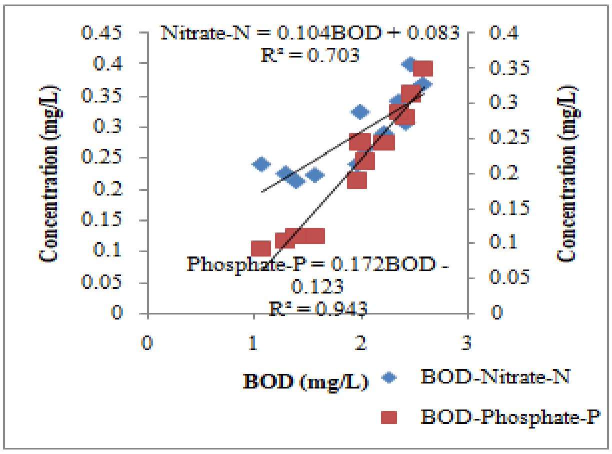

Figure 9 (c)

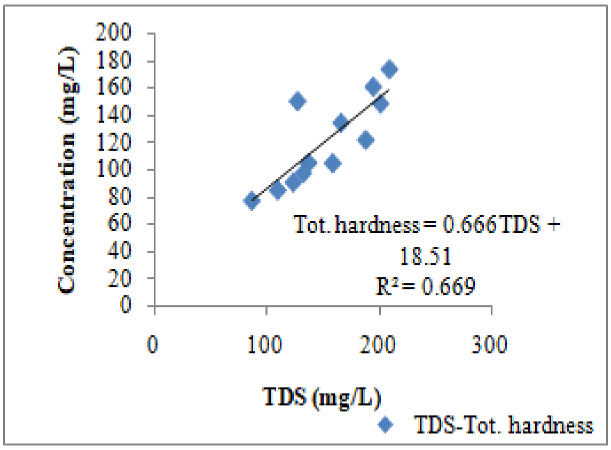

Figure 9 (d)

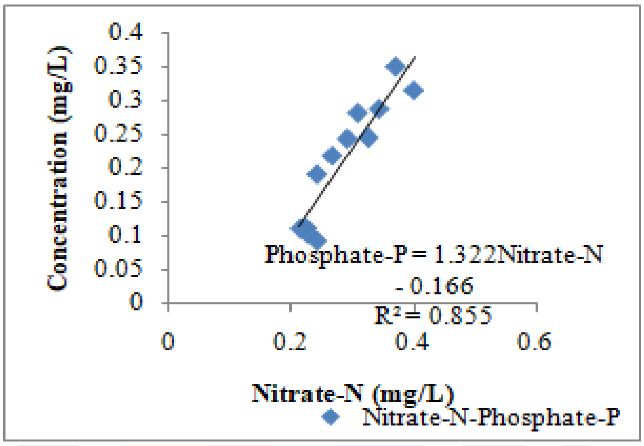

Figure 9 (e)

Figure 9 (a) – 9 (e): Parameter plots for the linear regression model of the water quality

Figure 9(a) illustrates that as pH rises, DO rises while Phosphate-P and BOD fall, while Figure 9(b) illustrates that as DO rises, Nitrate-N, Phosphate-P and BOD fall; Figure 9(c) illustrates that Nitrate-N and Phosphate-P rise along with BOD; Figure 9(d) illustrates that as TDS rises, total hardness rises; and Figure 9(e) demonstrates that Phosphate-P increases as Nitrate-N increases.

CONCLUSION

The investigation demonstrates the extent to which significant anthropogenic activities, such as disposal sewage, disinfectants, trash, shoddy drainage systems, waste disposal, bathing and washing clothes directly in water sources, have polluted the disturbed regions (site 1 and site 2). The levels of DO, BOD and phosphate-P content were discovered to be higher than the legal restrictions imposed by various agencies. Most of the parameters under study showed a strong and significant relationship, as shown by the linear regression and correlation coefficient analysis. Due to heavy rainfall that flushes surrounding fertilised agricultural fields, city trash, and other pollutants into headwaters water bodies during the rainy season, the majority of the metrics under research have higher values. More in-depth analyses of water resources as well as the creation and implementation of efficient water management strategies could result from this research.

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