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Trend Analysis of Water Quality Parameters of Kushiyara River, Bangladesh

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***Abstract*—In water resources, analyzing trends in water quality data is essential for planning streams, tracking changes in water quality parameters, and identifying changes in water quality. The research was undertaken to assess the overall water quality of the Kushiyara rivers on the basis of physico-chemical parameters such as temperature, pH, DO, BOD, COD, TS, TDS and SS in both rainy season and winter season for the years 2010 to 2013. The analysis revealed that temperature, pH, TS and TDS of the Kushiyara rivers in both season lie within the limit of Bangladesh water quality standard. But the average values of BOD, COD and SS cross the limit of Bangladesh water quality standard defined by DoE, Bangladesh. On the other hand, DO of both rivers are strictly below the permissible limit. For the findings of the ultimate goal of this study, several statistical analysis is done with the help of different statistical software. The PCA is used to extract the important parameters for trend analysis. According to trend analysis, it is found that three parameters follow a linear trend, five parameters follow a quadratic trend, and ten parameters follow a cubic trend sequentially. The findings showed that the watershed's overall water quality has been contaminated by a wide range of contaminants due to exposure to different pollutants. These findings may offer practical and efficient information for managing and controlling watershed contamination.**

***Index Terms*—Cubic Trend, Linear Trend, PCA (Principal Component Analysis), Quadratic Trend, Water Quality Parameters, Adjusted R squared value.**

I. Introduction

Protecting water resources is essential to the multi-barrier approach to ensuring safe drinking water [32], as water is vital for all life forms ([36] & [3]). While humans can survive without food for about two months, they can only last three or four days without water[13]. However, rapid industrialization and population growth have led to a surge in demand for freshwater [34], resulting in increased water pollution from various sources ([10] & [45]). Rivers, crucial for assimilating effluents, are heavily impacted by anthropogenic pollutants ([24] & [38]). Livestock and agriculture contribute significantly to river contamination, with livestock waste containing high levels of pollutants ([12] & [15]). This pollution leads to environmental degradation, including oxygen depletion and increased algae production [1]. Effective management strategies are imperative for addressing these challenges ([41] & [7]). As sewage and industrial effluents from human activity continue to damage the Kushiyara river basin, which is essential for a variety of uses, it is essential for water quality parameters be continuously monitored [9].

Trend is characterized as a consistent, steady rise or fall in the parameter's mean value. The standard definition of a trend is long-term variations in studied elements [26]. In time series analysis and climate change investigations, there are generally several parametric and nonparametric statistical techniques to determine if a trend exists or not. However, nonparametric methods are utilized more frequently in hydrometeorological studies [46]. A number of researchers, including ([47], [19], [22], [11]) and others, investigated into trends in a variety of hydrological and hydro-meteorological parameters, including air temperature, precipitation, stream flow, concentration of water pollutants, characteristics of drought, Pan evaporation, and evapotranspiration of reference crops, across the world.

Using a variety of multivariate statistical approaches, including principal component analysis (PCA), this study uses statistical analysis to evaluate the quality of the water. As stated by ([17], [23], [48], [35], [39], [40] and [29]) the method enhances comprehension of water quality and ecological status, identifies sources of pollution, and facilitates effective management of water resources. All across the world, surface and freshwater quality has been extensively studied and assessed using multivariate statistical approaches. For example, [49] used factor analysis and cluster analysis to identify geochemical zones within a Brazilian watershed, whereas [50] used a dynamic factor model to identify trends in time series. In Ontario, Canada, [42] used GIS and multivariate statistical analysis to investigate relationships between landscape features and water quality. Similar methods were applied by ([41] & [42]) to investigate temporal and regional fluctuations in the water quality of the Gomti River in India. They were used by [51] to evaluate the surface water quality in the Fuji River Basin in Japan. According to [28], PCA has been especially helpful in assessing water quality monitoring stations. Furthermore, factor and discriminant analysis have been used to examine long-term hydrochemical data from shallow water bodies ([25], [43] and [30]). Significant tools for water quality management have been made available by water quality modeling, which makes use of hydrochemical data and a variety of analytical techniques like multiple linear regression, structural equation modeling, predictability, trend, and time-series analysis ([2], [8], [42], [44], [33] and [37]). PCA assists in interpreting correlations between observations in terms of underlying factors by decreasing variables while explaining the same amount of variation with fewer

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components ([53] & [52]). Important water quality parameters are taken into consideration, with some being removed from further analysis owing to data availability constraints. Significant parameters related to water quality, such as temperature, pH, dissolved oxygen (DO), chemical and biochemical oxygen demand (BOD, COD), total solids (TS), total dissolved solids (TDS), and suspended solids (SS) [16], are taken into account. Certain parameters are not included in the analysis further because of limitations in data availability.

II. MATERIAL AND METHOD

A. Sampling and Analysis

Sampling is the most significant stage in the testing of water quality. Inadequate sampling is one of the main reasons why water quality analyses go wrong. Thus, to provide a representative sample, water sampling should be carried out carefully. Using pre-sterilized two-liter plastic bottles, water samples were taken from 10–30 feet from the bank and 20–30 cm of the water column along the Kushiyara rivers during two seasons, namely the rainy season and the winter season, at each site. The samples were then repeatedly washed with water from those sites and tested for certain physical and chemical water quality parameters that are necessary for this study. Rainy season data is collected in the months of January through February, while winter season data is gathered in May and June. As a result, water samples were taken in 2010; 2011,; 2012; and 2013. Twenty sample stations are collected along the rivers for both seasons in 2012 and 2013, after 15 sampling sites were collected in the prior two years. Analytical results are guaranteed to be valid when sampling is meaningful and trustworthy. The results are more dependable when the period between data collection and processing is shorter. Between sample collection and analysis, there cannot be any appreciable changes.

B. Statistical Analysis

Principal component analysis (PCA), is a vital method for decreasing the dimensionality of datasets by converting them into orthogonal variables known as principle components (PCs). In this work, PCA is utilized via factor analysis. Eigenvalues and eigenvectors that indicate the dispersion of measured parameters are obtained from PCs that are computed using covariance or cross-product matrices. With its roots in the research of [31], [5], [21] and other scholars, PCA's current form was codified by [18], who also introduced the term "principal component." It is a popular method for data reduction used in many scientific fields that makes it possible to understand complicated datasets. By addressing connections between several variables, PCA simplifies statistical studies by combining multidimensional components into a single system for quantitative research [20]. By calculating new variables as linear combinations of the originals, it shows patterns of similarity between observations and variables. The first PC maximizes inertia and captures the most variance, with succeeding components being estimated to be orthogonal. Factor scores, which are the projections of observations onto principal components, are geometrically analyzed. Although PCA is not intended for classification, it can help identify correlations among data, albeit it cannot ensure that groups on PC score plots are clearly separated from one another.

Scree Plot: R. B. Cattell created the scree test in 1966 [4]. It is predicated on the ideas that meaningful information is larger than random noise and that the number of components appears to have a fairly linear effect on the fluctuation in random noise dimensions. In a scree plot, the number of a component or factor is plotted against the eigenvalues associated with it in descending order. In principle components analysis and factor analysis, scree charts can be used to visually evaluate which components or factors account for the majority of the variability in the data. A helpful visual tool for choosing the right number of principle components is the scree plot. In order to ascertain the proper quantity of components, we search the scree plot for a "elbow". The point at which the remaining eigenvalues are all around the same size and relatively tiny is considered the component number. A scree plot should ideally have a steep slope, a bend, and then a flat or horizontal line. Before the initial point at which the flat line trend begins, hold onto the elements or factors that make up the steep curve. A scree plot may be tough for you to understand. To determine the number of significant components or factors, use your understanding of the data and the outcomes of the previous methods of component or factor selection.

Curve Fitting (Trend Analysis): Curve fitting is the process of using a given set of data to introduce mathematical relationships in the form of an equation between dependent and independent variables. Fitting a mathematical function to a particular collection of data is most commonly accomplished by applying the principle of least squares. A curve that best fits the available data is suggested by the principle of least squares, which offers a distinct set of values for the constants. To fit a unique curve via the provided data points, the least squares method is arguably the most methodical technique.

There are various types of curves that are used to describe the given data in the study as follows:

Straight line: $y_t = a + bt$ (1)

Quadratic line: $y_t = a + bt + ct^2$ (2)

Cubic line: $y_t = a + bt + ct^2 + dt^3$ (3)

III. RESULT AND DISCUSSION

A. Extraction of WQP's using PCA (Principle Component Analysis) methods

Based on the overall variation described by PCA, the first six components account for roughly 95% of the variance. However, the scree plot shows that the first two components were adequate to account for the entire variation.

Table 1: Component Loadings of different variables of the Kushiyara river

Water quality parameters	Component	
	1	2
Temperature of the Kushiyara river in winter season	0.338	0.801
pH of the Kushiyara river in winter season	-0.163	0.603
DO of the Kushiyara river in winter season	-0.280	-0.275
BOD of the Kushiyara river in winter season	0.429	-0.129
COD of the Kushiyara river in winter season	0.074	0.820
TS of the Kushiyara river in winter season	0.958	0.147
TDS of the Kushiyara river in winter season	0.921	0.240
SS of the Kushiyara river in winter season	0.909	-0.111
Temperature of the Kushiyara river in rainy season	0.049	0.903
pH of the Kushiyara river in rainy season	0.180	0.240
DO of the Kushiyara river in rainy season	0.045	-0.256
BOD of the Kushiyara river in rainy season	0.882	-0.206
COD of the Kushiyara river in rainy season	0.903	0.098
TS of the Kushiyara river in rainy season	0.824	0.368
TDS of the Kushiyara river in rainy season	0.580	0.574
SS of the Kushiyara river in rainy season	0.881	-0.173

The correlation between every variable and every component is displayed in the component matrix. Table 1 indicates which variables are most significant based on their high loadings (>= 0.70), i.e., highly correlated variables connected to components 1 and 2. The findings displayed in Table 1 reveal that the 18 variables in total have a strong correlation with Components 1 and 2, which have large loadings. Table 2 displays those variables.

Table 2: Water quality parameters extracted form Principal Component Analysis (PCA)

Kushiyara River			
Rainy season		Winter season	
1	Temperature	6	Temperature
2	BOD	7	COD
3	COD	8	TS
4	TS	9	TDS
5	SS	10	SS

B. Fitting trend of WQP's extracted from PCA

Currently, the question of which trend each variable follows is important. It fits a trend line corresponding to time using these significant variables that were retrieved from principal component analysis and determines which trend best matches each variable. Since they are the most extensively utilized and well-liked techniques for fitting a mathematical function to a given set of data, the linear, quadratic, and cubic trends are the main causes for concern. Fitted trend lines are compared using the Adjusted R Squared value, which is derived from each trend's model summary. The trend with the highest Adjusted R Squared value among the others is chosen. R-squared is often not preferred over corrected R-squared value. An unbiased measure of the fraction of variance explained that accounts for sample size and variable count is the adjusted R-squared. Generally speaking, adjusted R-squared is only marginally less than R-squared; nevertheless, if a model with inadequately informative variables is fitted to an excessively small sample of data, adjusted R-squared could be zero or negative.

1) Test Fitting trend line for Temperature of the Kushiyara river in rainy season

When analyzing the temperature of the Kushiyara River during the rainy season, three trend lines are chosen: a linear one, a quadratic one, and a cubic one. Based on the maximum adjusted R squared value, the cubic model is chosen as the trend line, with equation coefficients that are constant (25.710), time (0.795), time**2 (-0.192), and time**3 (0.013). Figure 1 and Table 3 display the figures of all the models as well as the values of the chosen model coefficients. Equation 4 displays the fitted cubic model for the temperature of the Kushiyara River during the rainy season.

$$Y_t = 25.710 + 0.795t - 0.192t^2 + 0.013\, t^3 \quad (4)$$

Table 3: Coefficients of fitted trend line for Temperature of the Kushiyara river in rainy season

	Coefficients		t	Sig.
	B	Std. Error		
Time	0.795	0.618	1.286	0.246
Time ** 2	-0.192	0.127	-1.507	0.182
Time ** 3	0.013	0.008	1.669	0.146
(Constant)	25.710	0.824	31.183	0.000

2) Fitting trend line for BOD of the Kushiyara river in rainy season

To select the best trend line for BOD of the Kushiyara river in rainy season linear, quadratic and cubic trend lines are analyzed. From the analysis it is observed that adjusted R squared values are 0.80, 0.77 and 0.75 respectively, and studying the maximum adjusted R squared value the linear model is selected as the trend line and the equation coefficients are constant (3.060) and time (0.293). The figure of all models and the selected model coefficients value are shown in figure 2 and table 4. Thus the fitted linear model for BOD of the Kushiyara river in rainy season is shown in equation 5.

$$Y_t = 3.060+ 0.293t \quad (5)$$

Table 4: Coefficients of fitted trend line for BOD of the Kushiyara river in rainy season

	Coefficients		t	Sig.
	B	Std. Error		
Time	0.293	0.049	6.003	0.000
(Constant)	3.060	0.303	10.08	0.000

3) Fitting trend line for COD of the Kushiyara river in rainy season

COD of the Kushiyara river in rainy season is analyzed for the selection of trend line for linear, quadratic and cubic trend lines. From the analysis it is noticed that adjusted R squared values are 0.853, 0.83 and 0.85 respectively and considering the maximum adjusted R squared value the linear model is selected as the trend line and the equation coefficients are constant (5.890) and time (0.119). The figure of all models and the selected model coefficients values are shown in figure 3 and table 5. Hence the fitted linear model for COD of the Kushiyara river in rainy season is shown in equation 6.

$$Yt = 5.890 + 0.119t \quad (6)$$

Table 5: Coefficients of fitted trend line for COD of Kushiyara river in rainy season

	Coefficients		t	Sig.
	B	Std. Error		
Time	0.119	0.016	7.292	0.000
(Constant)	5.890	0.101	58.032	0.000

4) Fitting trend line for TS of the Kushiyara river in rainy season

For the choice of trend line for TS of the Kushiyara river in rainy season linear, quadratic and cubic trend lines are analyzed. From the analysis it is found that adjusted R squared values are 0.81, 0.81 and 0.96 respectively, and considering the maximum adjusted R squared value the cubic model is selected as the trend line and the equation coefficients are constant (120.367), time (50.282), time**2 (-9.612) and time**3 (0.621). The figure of all models and the selected model coefficients values are shown in figure 4 and table 6. Therefore the fitted cubic model for TS of the Kushiyara river in rainy season is shown in equation 7.

$$Y_t = 120.367 + 50.282t – 9.612t^2 + 0.621\ t^3 \quad (7)$$

Table 6: Coefficients of fitted trend line for TS of the Kushiyara river in rainy season

	Coefficients		t	Sig.
	B	Std. Error		
Time	50.282	10.234	4.913	0.003
Time ** 2	-9.612	2.111	- 4.55	0.004
Time ** 3	0.621	0.127	4.908	0.003
(Constant)	120.367	13.654	8.815	0.000

5) Fitting trend line for SS of the Kushiyara river in rainy season

SS of the Kushiyara river in rainy season is analyzed for linear, quadratic and cubic trend lines for the selection of best trend line. From the analysis it is found that adjusted R squared values are 0.78, 0.85 and 0.89 respectively and considering the maximum adjusted R squared value the cubic model is selected as the trend line and the equation coefficients are constant (58.578), time (-1.905), time**2 (2.056) and time**3 (-0.157). The figure of all models and the selected model coefficients values are shown in figure 5 and table 7. Hence the fitted cubic model for SS of the Kushiyara river in rainy season is shown in equation 8.

$$Y_t = 58.578 – 1.905t + 2.056t^2 – 0.157\ t^3 \quad (8)$$

Table 7: Coefficients of fitted trend line for SS of the Kushiyara river in rainy season

	Coefficients		t	Sig.
	B	Std. Error		
Time	-1.905	7.036	-0.271	0.796
Time ** 2	2.056	1.451	1.417	0.206
Time ** 3	-0.157	0.087	-1.798	0.122
(Constant)	58.578	9.386	6.241	0.001

6) Fitting trend line for Temperature of the Kushiyara river in winter season

Temperature of the Kushiyara river in winter season is analyzed for linear, quadratic and cubic trend lines to choose the best trend line. From the assessment it is found that adjusted R squared values are 0.14, 0.11 and 0.35 respectively and considering the maximum adjusted R squared value the cubic model is selected as the trend line and the equation coefficients are constant (23.201), time (1.282), time**2 (-0.287) and time**3 (0.019). The figure of all models and the selected model coefficients values are shown in figure 6 and table 8. Thus the fitted cubic model for Temperature of the Kushiyara river in winter season is shown in equation 9.

$$Y_t = 23.201 + 1.282t - 0.287t^2 + 0.019\ t^3 \quad (9)$$

Table 8: Coefficients of fitted trend line for Temperature of the Kushiyara river in winter season

	Coefficients		t	Sig.
	B	Std. Error		
Time	1.282	0.801	1.599	0.161
Time ** 2	-0.287	0.165	-1.738	0.133
Time ** 3	0.019	0.010	1.904	0.106
(Constant)	23.201	1.069	21.697	0.000

7) Fitting trend line for COD of the Kushiyara river in winter season

COD of the Kushiyara river in winter season is analyzed for linear, quadratic and cubic trend lines to choose the best trend line. From the analysis it is found that adjusted R squared values are -0.093, 0.087 and 0.77 respectively and considering the maximum adjusted R squared value the cubic model is selected as the trend line and the equation coefficients are constant (5.664), time (0.669), time**2 (-0.168) and time**3 (0.011). The figure of all models and the selected model coefficients values are shown in figure 7 and table 9. Therefore the fitted cubic model for COD of the Kushiyara river in winter season is shown in equation 10.

$$Y_t = 5.664 + 0.669t - 0.168t^2 + 0.011\ t^3 \quad (10)$$

Table 9: Coefficients of fitted trend line for COD of the Kushiyara river in winter season

	Coefficients		T	Sig.
	B	Std. Error		
Time	0.669	0.197	3.404	0.014
Time ** 2	-0.168	0.041	-4.134	0.006
Time ** 3	0.011	0.002	4.644	0.004
(Constant)	5.664	0.262	21.601	0.000

8) Fitting trend line for TS of the Kushiyara river in winter season

To choose the best trend line for TS of the Kushiyara river in winter season linear, quadratic and cubic trend lines are analyzed. From the analysis it is found that adjusted R squared values are 0.987, 0.984 and 0.982 respectively, and considering the maximum adjusted R squared value the linear model is selected as the trend line and the equation coefficients are constant (131.955) and time (11.618). The figure of all models and the selected model coefficients values are shown in figure 8 and table 10. Hence the fitted linear model for TS of the Kushiyara river in winter season is shown in equation 11.

$$Y_t = 131.955 + 11.618t \quad (11)$$

Table 10: Coefficients of fitted trend line for TS of the Kushiyara river in winter season

	Coefficients		T	Sig.
	B	Std. Error		
Time	11.618	0.471	24.681	.000
(Constant)	131.955	2.921	45.178	.000

9) Fitting trend line for TDS of the Kushiyara river in winter season

TDS of the Kushiyara river in winter season is analyzed for linear, quadratic and cubic trend lines for the selection of best trend line. From the analysis it is observed that adjusted R squared values are 0.941, 0.94 and 0.942 respectively, and considering the maximum adjusted R squared value the cubic model is selected as the trend line and the equation coefficients are constant (47.443), time (19.355), time**2 (-2.444) and time**3 (0.163). The figure of all models and the selected model coefficients values are shown in figure 9 and table 11. So the fitted cubic model for TDS of the Kushiyara river in winter season is shown in equation 12.

$$Y_t = 47.443 + 19.355t – 2.444t^2 + 0.163\ t^3 \quad (12)$$

Table 11: Coefficients of fitted trend line for TDS of the Kushiyara river in winter season

	Coefficients		t	Sig.
	B	Std. Error		
Time	19.355	10.466	1.849	0.114
Time ** 2	-2.444	2.159	-1.132	0.301
Time ** 3	0.163	0.129	1.258	0.255
(Constant)	47.443	13.963	3.398	0.015

10) Fitting trend line for SS of the Kushiyara river in winter season

To choose the best trend line for SS of the Kushiyara river in winter season linear, quadratic and cubic trend lines are analyzed. From the analysis it is found that the adjusted R squared values are 0.76, 0.79 and 0.81 respectively and considering the maximum adjusted R squared value the cubic model is selected as the trend line and the equation coefficients are constant (76.648), time (-1.359), time**2 (1.113) and time**3 (-0.081). The figure of all models and the selected model coefficients values are shown in figure 10 and table 12. Therefore the fitted cubic model for SS of the Kushiyara river in winter season is shown in equation 13.

$$Y_t = 76.648 – 1.359t + 1.113t^2 – 0.081\ t^3 \quad (13)$$

Table 12: Coefficients of fitted trend line for SS of the Kushiyara river in winter season

	Coefficients		T	Sig.
	B	Std. Error		
Time	-1.359	5.043	-0.270	0.797
Time ** 2	1.113	1.040	1.069	0.326
Time ** 3	-0.081	0.062	-1.303	0.240
(Constant)	76.648	6.728	11.392	0.000

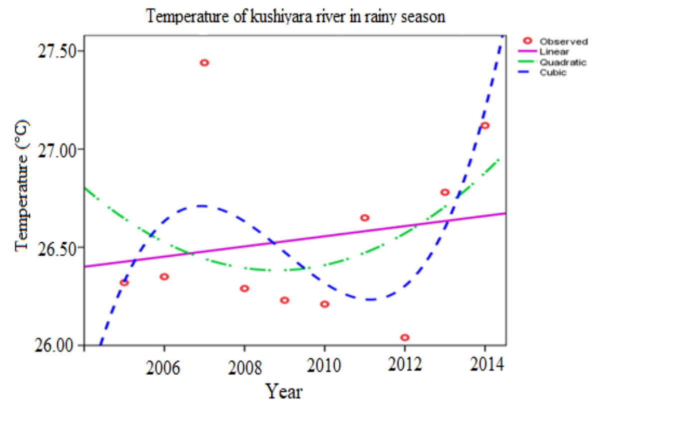

Figure 1: Trend line for Temperature of the Kushiyara river in rainy season ($R^2_{a,L} = -0.091, R^2_{a,Q} = -0.121, R^2_{a,C} = 0.107$)

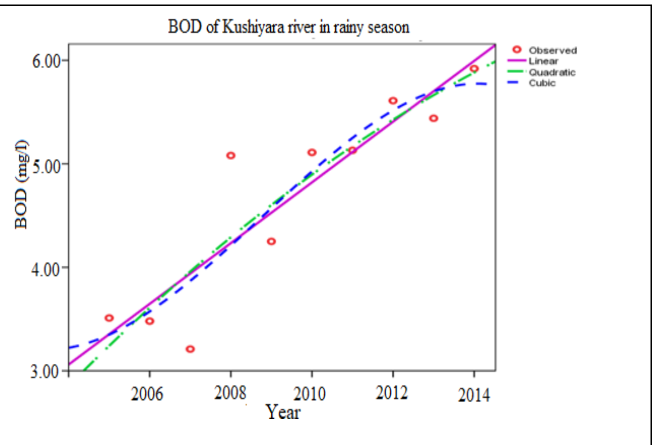

Figure 2: Trend line for BOD of the Kushiyara river in rainy season ($R^2_{a,L} = 0.80, R^2_{a,Q} = 0.77, R^2_{a,C} = 0.75$)

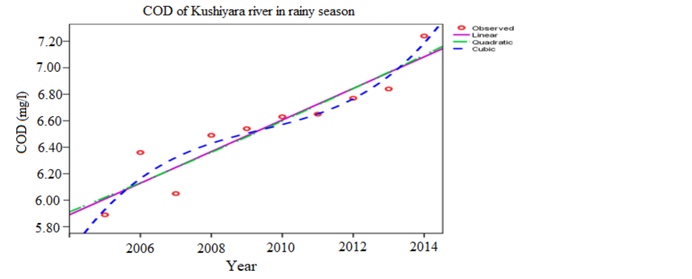

Figure 3: Trend line for COD of the Kushiyara river in rainy season ($R^2_{a,L} = 0.853, R^2_{a,Q} = 0.83, R^2_{a,C} = 0.85$)

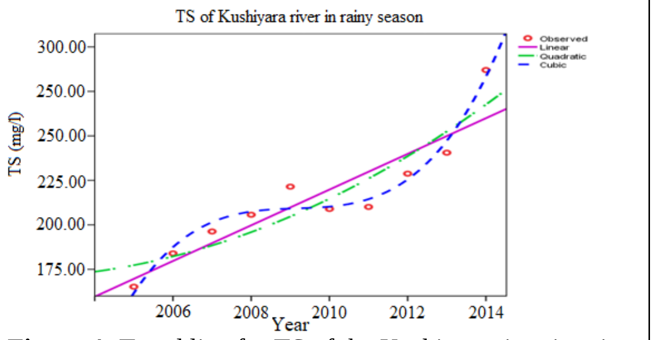

Figure 4: Trend line for TS of the Kushiyara river in rainy season ($R^2_{a,L} = 0.81, R^2_{a,Q} = 0.81, R^2_{a,C} = 0.96$)

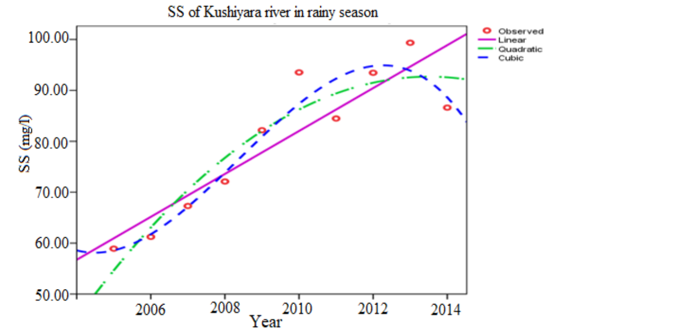

Figure 5: Trend line for SS of the Kushiyara river in rainy season ($R^2_{a,L} = 0.78, R^2_{a,Q} = 0.85, R^2_{a,C} = 0.89$)

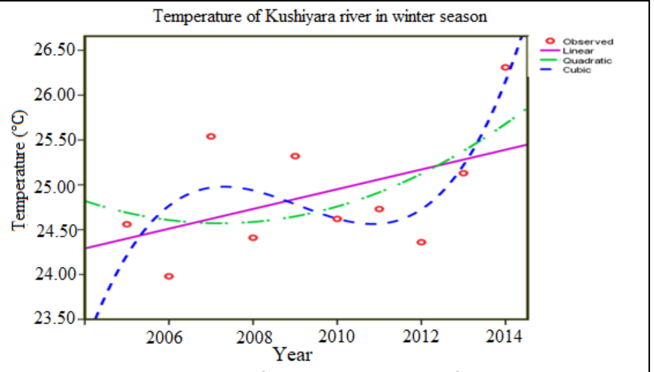

Figure 6: Trend line for Temperature of the Kushiyara river in winter season ($R^2_{a,L} = 0.14, R^2_{a,Q} = 0.11, R^2_{a,C} = 0.35$)

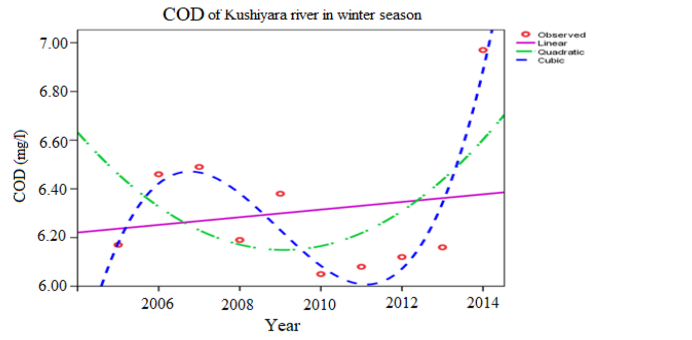

Figure 7: Trend line for COD of the Kushiyara river in winter season ($R^2_{a,L} = -0.093, R^2_{a,Q} = 0.087, R^2_{a,C} = 0.77$)

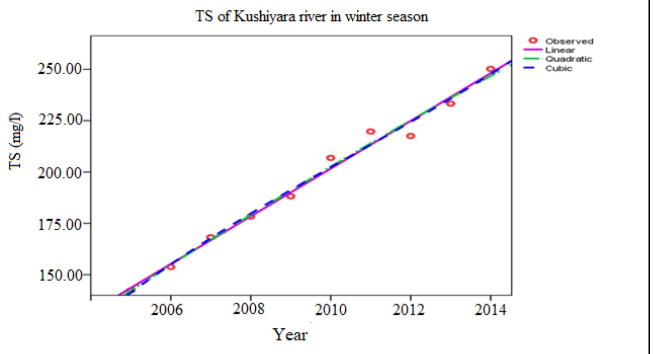

Figure 8: Trend line for TS of the Kushiyara river in winter season ($R^2_{a,L} = 0.987, R^2_{a,Q} = 0.984, R^2_{a,C} = 0.982$)

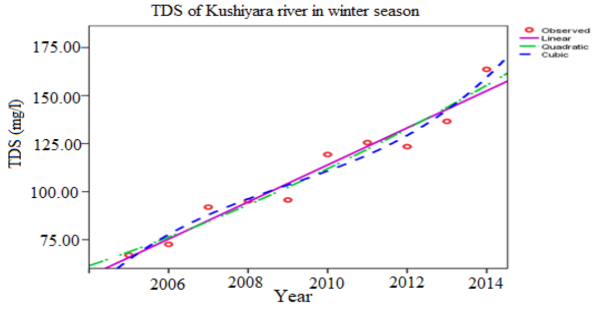

Figure 9: Trend line for TDS of the Kushiyara river in winter season ($R^2_{a,L} = 0.941, R^2_{a,Q} = 0.94, R^2_{a,C} = 0.942$)

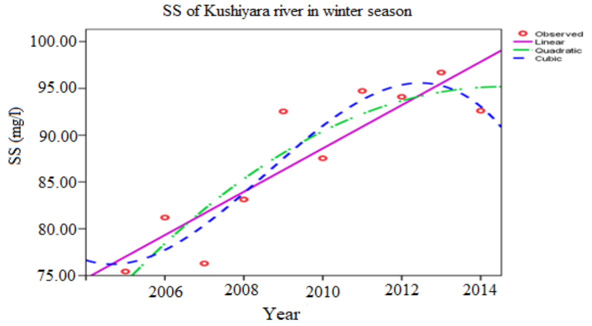

Figure 10: Trend line for SS of the Kushiyara river in winter season ($R^2_{a,L} = 0.76, R^2_{a,Q} = 0.79, R^2_{a,C} = 0.81$)

Table 13: Water Quality parameters which follow Linear trend

Serial No	Parameter	River	Season	Trend Estimates (B)	Trend	Adjusted R^2
1	BOD	Kushiyara	Rainy	0.293	Increasing	0.800
2	COD	Kushiyara	Rainy	0.119	Increasing	0.085
3	TS	Kushiyara	Winter	11.618	Increasing	0.990

Table 14: Water Quality parameters which follow Cubic trend

Serial No	Parameter	River	Season	Trend Estimates (B)	Trend	Adjusted R^2 value
1	Temperature	Kushiyara	Rainy	0.795* -0.192** 0.013***	Overall Increasing	0.11
2	TS	Kushiyara	Rainy	50.282* -9.612** 0.621***	Overall Increasing	0.96
3	SS	Kushiyara	Rainy	-1.905* 2.056** -0.157***	Overall Decreasing	0.89
4	Temperature	Kushiyara	Winter	1.282* -0.287** 0.019***	Overall Increasing	0.34
5	COD	Kushiyara	Winter	0.669* -0.168** 0.011***	Overall Increasing	0.77
6	TDS	Kushiyara	Winter	19.355* -2.444** 0.163***	Overall Increasing	0.94

From table 15, it is shown that TS of the Kushiyara river in winter season, BOD of the Kushiyara river in rainy season and COD of the Kushiyara river in rainy season data follow linear trend. Cubic Trend Model is followed by Temperature of the Kushiyara river in winter season, COD of the Kushiyara river in winter season, TDS of the Kushiyara river in winter season, SS of the Kushiyara river in winter season, Temperature of the Kushiyara river in rainy season, TS of the Kushiyara river in rainy season and SS of the Kushiyara river in rainy season.

Table 15: Showing overall results and fitted model of trend

S.N.	Variables	Fitted Model Type	Fitted Model	Adjusted R^2 value
1	Temperature of the Kushiyara river in rainy season	Cubic (overall increasing)	$Y_t = 25.710 + 0.795t - 0.192t^2 + 0.013\ t^3$	0.11
2	BOD of the Kushiyara river in rainy season	Linear (increasing)	$Y_t = 3.060 + 0.293t$	0.80
3	COD of the Kushiyara river in rainy season	Linear (increasing)	$Yt = 5.890 + 0.119t$	0.85
4	TS of the Kushiyara river in rainy season	Cubic (overall increasing)	$Y_t = 120.367 + 50.282t – 9.612t^2 + 0.621\ t^3$	0.96
5	SS of the Kushiyara river in rainy season	Cubic (overall decreasing)	$Y_t = 58.578 – 1.905t + 2.056t^2 – 0.157\ t^3$	0.89
6	Temperature of the Kushiyara river in winter season	Cubic (overall increasing)	$Y_t = 23.201 + 1.282t - 0.287t^2 + 0.019\ t^3$	0.34
7	COD of the Kushiyara river in winter season	Cubic (overall increasing)	$Y_t = 5.664 + 0.669t - 0.168t^2 + 0.011\ t^3$	0.77
8	TS of the Kushiyara river in winter season	Linear (increasing	$Y_t = 131.955 + 11.618t$	0.99
9	TDS of the Kushiyara river in winter season	Cubic (overall increasing)	$Y_t = 47.443 + 19.355t – 2.444t^2 + 0.163\ t^3$	0.94
10	SS of the Kushiyara river in winter season	Cubic (overall decreasing)	$Y_t = 76.648 – 1.359t + 1.113t^2 – 0.081\ t^3$	0.81

Table 16: Trends of WQP's of the Kushiyara rivers extracted by PCA important for both seasons

Sr. No	WQP's selected for forecasting	Rainy Season	Winter Season
1	Temperature of Kushiyara river	Cubic (overall increasing)	Cubic (overall increasing)
2	COD of Kushiyara river	Linear (increasing)	Cubic (overall increasing)
3	TS of Kushiyara river	Cubic (overall increasing)	Linear (increasing)
4	SS of Kushiyara river	Cubic (overall decreasing)	Cubic (overall decreasing)

Table 17: Trends of WQP's of the Kushiyara rivers extracted by PCA important for only one season

Sr. No	WQP's selected for forecasting	Rainy Season	Winter Season
1	TDS of Kushiyara river	-	Cubic (overall increasing)
2	COD of Kushiyara river	Linear (increasing)	-

IV. Conclusion

The results demonstrate total 18 variables are highly correlated with component 1 and 2. For the Kushiyara river, rainy season temperature, BOD, COD, TS and SS are important. In winter season, temperature, COD, TS, TDS and SS are found important in case of the Kushiyara river. From trend analysis it is found that the river does not follow quadratic trend, with certain parameters showing linear and cubic trends over the years. The study found that TS of the Kushiyara river in winter season, BOD of the Kushiyara river in rainy season and COD of the Kushiyara river in rainy season data follow linear trend. Cubic Trend Model is followed by Temperature of the Kushiyara river in winter season, COD of the Kushiyara river in winter season, TDS of the Kushiyara river in winter season, SS of the Kushiyara river in winter season, Temperature of the Kushiyara river in rainy season, TS of the Kushiyara river in rainy season and SS of the Kushiyara river in rainy season. The Kushiyara river experiences an increasing trend in water temperature during the rainy season, with exceptions in 2007 and 2012. Winter temperatures are less due to higher upstream water temperatures and abrupt changes in effluents from various sources. The surface water's pH is lower in winter, which is harmful to immature fish and insects. The amount of dissolved oxygen (DO) decreases with the exception of 2011 due to atmospheric temperature and waves. High BOD indicates a heavy load of organic matter, reducing the water's dissolved oxygen supply. The COD of water shows an increasing trend, indicating deteriorating water quality. Total solids increase due to industrial discharges, sewage, fertilizers, road runoff, and soil erosion. TDS and SS changes abruptly in both seasons, possibly due to agricultural and residential runoff, clay-rich upstream waters, soil contamination, and point sources of water pollution. Therefore it is recommended that the Kushiyara river management authority should be established, to work under the administration of the Ministry of Environment (MOE). This agency could be allocated with legislative power and would hold individual responsibility to manage and coordinate all activities related to pollution control and conservation of the Kushiyara river.

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