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Neutrosophic Statistical Approach to Water Quality Assessment and its Environmental Health Implications

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Abstract

Accurate assessment of surface water quality is essential for sustainable water resource management and protection of environmental and human health. Conventional statistical approaches, however, often struggle to adequately handle uncertainty, variability, and incomplete information inherent in water quality monitoring data. To address these limitations, the present study employs a neutrosophic statistical approach to assess surface water quality and its environmental health implications using data from the National Water Monitoring Programme (NWMP) collected by the Maharashtra Pollution Control Board (MPCB) in September 2025. The analysis is based on monitored surface water samples from selected stations including Godavari River at Jayakwadi Dam (Paithan), Godavari River at Vishnupuri (Nanded), and Manjra River downstream of Latur, representing major river systems in Maharashtra. Key water quality parameters such as pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Turbidity were considered due to their direct relevance to aquatic ecosystem health and drinking water safety. Each parameter was transformed into neutrosophic numbers characterized by degrees of truth, indeterminacy, and falsity, allowing explicit representation of measurement uncertainty and environmental fluctuations. Neutrosophic descriptive statistics and aggregation operators were applied to compute a Neutrosophic Water Quality Index (NWQI), which was subsequently compared with the conventional Water Quality Index (WQI) and evaluated against WHO and BIS drinking water standards. The results demonstrate that the neutrosophic framework provides a more flexible and informative assessment of water quality by capturing indeterminacy that is ignored in classical methods. Elevated indeterminacy levels associated with BOD and turbidity at certain monitoring stations indicate potential environmental stress and increased health risks, even when average values appear to be within permissible limits. The study concludes that neutrosophic statistical modelling enhances water quality assessment and offers a robust decision-support framework for environmental monitoring, public health protection, and sustainable water management.

Keywords: Neutrosophic Statistics; Water Quality Assessment; Neutrosophic Water Quality Index; Environmental Health Implication

Introduction

Water is a fundamental resource required for human health, ecological balance, and sustainable development. However, increasing urbanization, industrial discharge, and agricultural activities have led to the degradation of surface water quality, posing serious environmental and health risks (Tyagi et al., 2013; Singh et al., 2013).
Water quality is commonly evaluated using the Water Quality Index (WQI), which combines multiple physicochemical parameters into a single value for simplified interpretation (Horton, 1965). Drinking water standards provided by the World Health Organization are widely used to assess water suitability for human consumption (WHO, 2017).

Despite their usefulness, classical statistical methods are limited in handling uncertainty and variability in environmental data. To overcome this limitation, neutrosophic statistical approaches incorporate indeterminacy, allowing a more flexible and realistic representation of water quality conditions (Bera and Mahapatra, 2020).
Therefore, this study applies both classical and neutrosophic methods to assess surface water quality and examine its environmental health implications.

Methodology

The study is based on secondary data obtained from the National Water Monitoring Programme (NWMP) conducted by the Maharashtra Pollution Control Board (MPCB) for September 2025.

Key physicochemical parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Nitrate-N, and Total Dissolved Solids (TDS) were analysed.

Descriptive statistical measures were used to summarize the data, including:

$$\bar{X} = \tfrac{1}{n}\sum X_i, \quad SD = \sqrt{\tfrac{1}{n}\sum (X_i - \bar{X})^2}, \quad CV = \tfrac{SD}{\bar{X}}$$

The Water Quality Index (WQI) was calculated to assess overall water quality using:

$$Q_i = \tfrac{(V_i - V_{ideal})}{(S_i - V_{ideal})} \times 100, \quad WQI = \tfrac{\sum (W_i \cdot Q_i)}{\sum W_i}$$

The Neutrosophic Water Quality Index (NWQI) was computed as:

$$NWQI = \frac{\sum (W_i \cdot Q_{iN})}{\sum W_i}$$

Correlation analysis was performed using Karl Pearson's coefficient:

$$r = \frac{\sum (X - \bar{X})(Y - \bar{Y})}{\sqrt{\sum (X - \bar{X})^2 \sum (Y - \bar{Y})^2}}$$

Regression analysis was applied using:

Classical model:

$$Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_n X_n + \epsilon$$

$$Y_N = \beta_0 + \beta_1 X_{1N} + \cdots + \beta_n X_{nN}$$

Principal Component Analysis (PCA) was used to identify major pollution factors:

$$PC = a_1 X_1 + a_2 X_2 + \cdots + a_n X_n$$

All computations and visualizations were performed using Python software.

Results

Descriptive Statistics

Index	pH	Dissolved O2	BOD	Nitrate N	Total Dissolved Solids
count	221.0	214.0	221.0	204.0	221.0
mean	7.8779	5.8126	6.7927	1.3779	2568.82
std	0.3966	1.0783	7.9511	1.2160	7885.6549
min	7.0	1.0	2.2	0.31	38.0
25%	7.5	5.1	3.2	0.6675	135.0
50%	7.9	6.0	4.0	0.915	221.0
75%	8.2	6.7	7.2	1.6925	448.0
max	9.5	7.6	65.0	9.7	36528.0

Table 1: Descriptive Statistics of Selected Water Quality Parameters

Interpretation

This table presents the basic statistical characteristics of key water quality parameters such as pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Nitrate-N, and Total Dissolved Solids (TDS) for the collected samples. The mean pH (≈7.88) indicates that the water is slightly alkaline but mostly within the acceptable range. The mean DO value (≈5.81 mg/L) suggests moderate oxygen availability; however, the minimum value of 1.0 mg/L indicates severe pollution at some locations. BOD shows a high maximum value (65 mg/L) and a large standard deviation, indicating strong organic pollution at several sites. Nitrate-N values vary considerably, reflecting agricultural runoff and sewage influence. TDS has extremely high maximum values (36528 mg/L), indicating severe salinity or industrial discharge at certain locations. The wide range and high variability confirm uneven and poor water quality conditions across monitoring stations.

Neutrosophic Mean with Indeterminacy

Parameter	Lower Mean	Upper Mean	Neutrosophic Mean	Indeterminacy
pH	7.48402	8.27181	7.87792	0.1
Dissolved O2	5.52199	6.10325	5.81262	0.1
BOD	6.45312	7.1324	6.79276	0.1
Nitrate N	1.30904	1.44684	1.37794	0.1
TDS	2440.39	2697.27	2568.83	0.1

Table 2: Neutrosophic Mean with Indeterminacy of Selected Water Quality Parameters

Interpretation

This table represents the neutrosophic statistical analysis, which accounts for uncertainty and data indeterminacy. The neutrosophic mean lies between the lower and upper mean values, capturing uncertainty in real environmental data. An indeterminacy level of 0.1 reflects unavoidable sampling and measurement uncertainty. TDS again shows a very large range, highlighting its dominant role in water quality degradation. This approach provides a more realistic representation of environmental uncertainty compared to classical statistics.

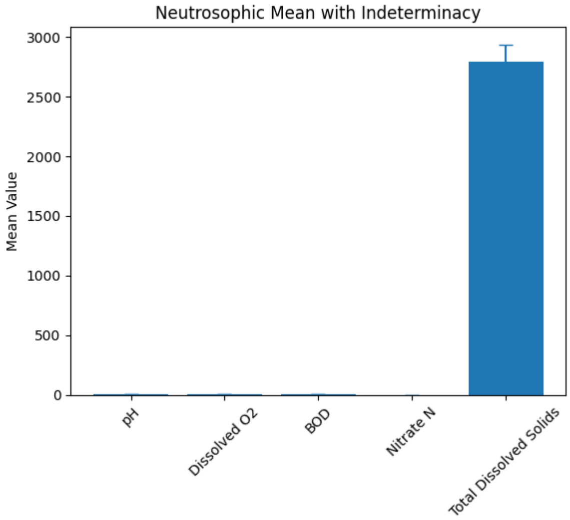

Fig. 1. Bar Chart Neutrosophic Mean with Indeterminacy of Selected Water Quality Parameter

The graph shows that Total Dissolved Solids (TDS) has a much higher neutrosophic mean than all other parameters, indicating it is the major contributor to water pollution. The large error bar for TDS reflects high uncertainty and variability across locations. pH remains relatively stable, while DO, BOD, and Nitrate-N show moderate values with some uncertainty, indicating organic and nutrient pollution. Overall, the graph confirms that TDS dominates water quality degradation, and the neutrosophic approach effectively captures data uncertainty.

Lower and Upper Standard Deviation

Parameter	Lower SD	Upper SD
pH	0.37683	0.41649
Dissolved O2	1.02441	1.13225
BOD	7.55364	8.34875
Nitrate N	1.15521	1.27681
TDS	7491.37	8279.94

Table 3: Standard Deviation of Selected Water Quality Parameters

Interpretation

This table shows the uncertainty range of variability for each parameter. BOD and TDS have the widest SD range, indicating unpredictable pollution sources. pH has the narrowest SD range, confirming its stability. The results further emphasize that organic pollution and dissolved solids vary significantly across sites.

Classical vs Neutrosophic Mean Comparison

Parameter	Classical Mean	Lower Mean	Upper Mean	Neutrosophic Mean	Indeterminacy Width
pH	7.9031	7.50795	8.29826	7.9031	0.79031
Dissolved O2	5.7325	5.44588	6.01913	5.7325	0.57325
BOD	5.96	5.662	6.258	5.96	0.596
Nitrate N	1.32635	1.26003	1.39267	1.32635	0.13264
TDS	2794.62	2654.89	2934.35	2794.62	279.46

Table 4: Comparison of Classical and Neutrosophic Mean of Water Quality Parameters

Interpretation

This table compares classical statistical means with neutrosophic means.The neutrosophic mean closely matches the classical mean, validating the reliability of the neutrosophic method.The indeterminacy width quantifies uncertainty, which is highest for TDS, again confirming its unstable nature. Thus, neutrosophic analysis enhances interpretation without contradicting classical results.

Coefficient of Variation

Parameter	CV
pH	0.05035
Dissolved O2	0.18552
BOD	1.17054
Nitrate N	0.88248
TDS	3.06975

Table 5: Coefficient of Variation of Water Quality Parameters

Interpretation

The coefficient of variation indicates the relative variability of each parameter. TDS shows the highest CV, indicating very high spatial variation and strong anthropogenic influence. BOD and Nitrate-N also show high CV values, suggesting inconsistent pollution loads. pH has the lowest CV, showing that pH remains relatively stable across locations. This confirms that TDS and BOD are the most unstable and critical pollutants affecting water quality.

Correlation analysis

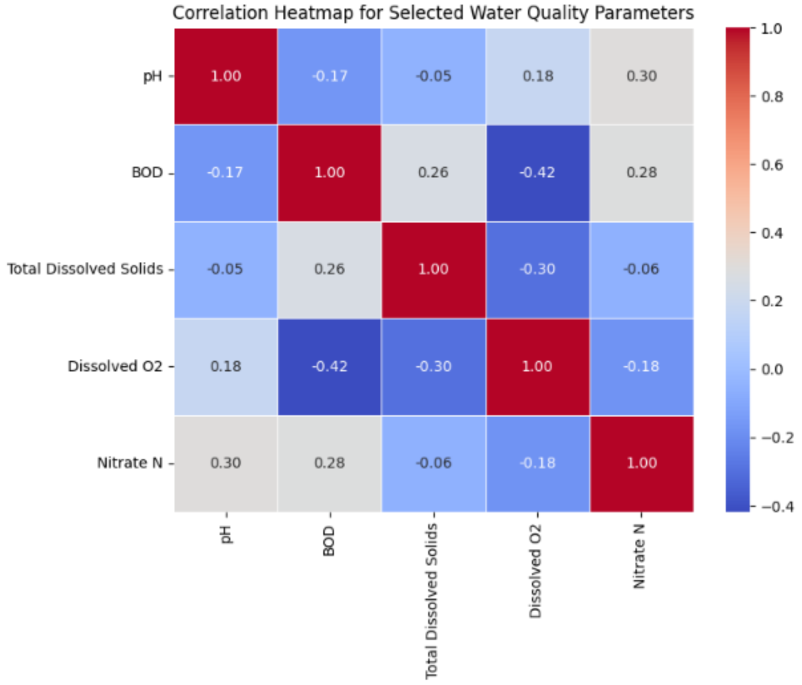

Fig. 2. Heatmap

Correlation analysis revealed a moderate negative relationship between BOD and Dissolved Oxygen (r = -0.42), indicating that increased organic pollution reduces oxygen levels. Total Dissolved Solids also showed a negative correlation with Dissolved Oxygen (r = -0.30). Weak positive correlations were observed between BOD and Nitrate-N (r = 0.28) and between pH and Nitrate-N (r = 0.30).

River-wise NWQI Values

Sr. No.	River / Location	NWQI	Sr. No.	River / Location	NWQI
1	AMRAVATI	NaN	46	MORNA	0.92
2	ARNALA	0.97333	47	MUCHKUNDI	0.94667
3	BASSEIN	0.86667	48	MULA	0.94667
4	BHAGWATI BUNDAR	0.86667	49	MULA MUTHA	0.92
5	BHAYANDER	0.97333	50	MUTHA	0.98667
6	BHIMA	0.87667	51	NARIMEN POINT	0.97333
7	BINDUSARA	0.76	52	NAVAPUR	0.84
8	BORI	0.84	53	NIRA	0.82667
9	BPT NAVAPUR	1	54	PANCHGANGA	0.89333
10	BURAI	0.78667	55	PANVEL	0.94667
11	CHANDRABHAGA	0.81333	56	PANZARA	0.76
12	CHIKHALI NALLA	1	57	PATALGANGA	0.99619
13	CHURNI ROAD	0.84	58	PAWANA	0.96
14	COLOUR CHEM	0.97333	59	PEDHI	0.94667
15	DAHANU	0.78667	60	PEHLAR	1
16	DANDI	0.81333	61	PENGANGA	0.76
17	DARNA	0.80267	62	PIMPAL PANERI	0.86667
18	ELEPHANTA ISLAND	0.97333	63	PURNA	0.82667
19	ERAI	0.76	64	RABODI	1
20	GANPATIPULE	0.86667	65	RANGAVALI	0.73333
21	GATEWAY OF INDIA	0.92	66	SANDOZ	0.94667
22	GHOD	0.81333	67	SARWALI	0.92
23	GIRNA	0.78667	68	SAVITRI	0.99467
24	GIRRNA	0.81333	69	SAVTA	0.84
25	GODAVARI	0.80267	70	SHIVAJI PARK	0.92
26	GODAVRI	0.85667	71	SINA	0.76
27	GOMAI	0.81333	72	SURYA	0.91111
28	HAJI ALI	0.94667	73	TANSA	0.92
29	HIWARA	0.78667	74	TAPI	0.81333
30	INDRAYANI	0.92	75	TARAPUR MIDC NALLA	0.99111
31	JUHU BEACH	0.92	76	THANE	0.97333
32	KALU	0.92	77	TITUR	0.84
33	KAN	0.73333	78	ULHAS	0.99667
34	KANHAN	0.86667	79	UNKNOWN	0.90222
35	KARAMBAVANE	0.97333	80	URMODI	0.81333
36	KHAREKURAN MURBE	0.84	81	UTTAN	1
37	KOYNA	0.84	82	VAITARNA	0.92
38	KRISHNA	0.8163	83	VASHISTHI	0.98222
39	KUNDALIKA	0.98827	84	VELU	0.78667
40	MAHIM CREEK	0.94667	85	VENNA	0.84
41	MALABAR HILL	0.92	86	VERSOVA BEACH	1
42	MANDVI	0.94667	87	WAGHUR	0.84
43	MANJARA	0.78667	88	WAINGANGA	0.88267
44	MITHI	0.92	89	WARDHA	0.75333
45	MOR	0.78667	90	WENA	0.88

Table 6: River-wise NWQI Values of Water Quality Parameters

Interpretation

The Neutrosophic Water Quality Index (NWQI) values for different rivers and coastal locations range from 0.73 to 1.00, indicating moderate to extremely poor water quality across most sites. NWQI 1.00 Extremely polluted / Severe health risk. NWQI between 0.90 0.99 Very high pollution / Severe health risk NWQI between 0.75 0.89 High pollution / High health risk; NWQI < 0.75 Relatively lower pollution, but still not safe

NWQI and Health Impact Classification

index	Stn Name	NWQI	Health_Impact
0	Arnala sea, Village. Arnala, Taluka. Vasai, District. Thane.	201.16310572474012	Severe health risk
1	Asna River, Dist- Nanded	141.12712932668208	Severe health risk
2	BPT, Navapur, Village. Navapur, Taluka. Palghar, District. Thane.	608.9704394925972	Severe health risk
3	Bassein creek at VasaiFort , Village. Bassein, Taluka. Vasai, District. Thane.	164.66026949063942	Severe health risk

4	Bhatsa River at D/s of Liberty Oil Mills, Satnel, Shahapur, Thane.	82.14047801891682	High health risk
5	Bhatsa river at D/s of Pise Dam, Village. Pise, Taluka. Bhiwandi, District. Thane.	82.29400077870059	High health risk
6	Bhayander creek at D/s of Railway bridge at Jasal park choupathy, Village. Navghar, Taluka. Bhayander, District. Thane.	164.12982875040063	Severe health risk
7	Bhima river after confluence with Mula.Mutha at Pargaon near Vasant Bandara,Village. Pargaon,Taluka. Daund, District. Pune.	172.62940885438513	Severe health risk
8	Bhima river at D/s of Bundgarden, Village . Yerwada,Taluka. Haweli, District. Pune.	184.06965778044517	Severe health risk
9	Bhima river at Koregaon near Koregaon bridge, Village. Koregaon,Taluka. Shirur, District. Pune.	114.81687048402048	Severe health risk
10	Bhima river at Narsingpur near Sangam bridge after confluence with Nira, Village. Narsingpur, Taluka.Malshiros, District. Solapur.	118.55457249982254	Severe health risk
11	Bhima river at Pune (Mutha river) at U/s of Vithalwadi near Shankar Mandir, Village. Vithalwadi, Taluka. Haweli, District. Pune.	155.41884519991308	Severe health risk
12	Bhima river at Takli near Karnataka border, Village. Takali, Taluka. South Solapur, District. Solapur.	123.08025950950469	Severe health risk
13	Bhima river. Backwater of Ujani Dam, near raw water pump house, Village. Kumbargaon, Taluka. Indapur, District. Pune.	90.84192549857275	High health risk
14	Bhogawati River water sample at Haldi KT Weir, Tal. Karveer, Dist. Kolhapur	86.91508549573327	High health risk
15	Bindusara river at Beed, near intake water pump house at Dam, Village. Paligaon, Taluka. Beed, District. Beed.	93.85647214209351	High health risk
16	Bori river, D/S of Amalner, Village. Amalner, Taluka. Jalgaon, District. Jalgaon.	111.17656197230666	Severe health risk
17	Burai river before confluence to Tapi river, Village. Mukudas, Taluka. Dhule, District. Dhule.	106.34963269854177	Severe health risk
18	Chandrabhaga river at D/s of Pandharpur town rear Vishnupant Mandir, Village. Gopalpur,Taluka. Pandharpur,District. Solapur.	130.29078444405724	Severe health risk
19	Chandrabhaga river at U/s of Pandharpur town, Village. Gursale,Taluka. Pandharpur, District. Solapur.	114.99989007845083	Severe health risk
20	Chandrabhaga river at chandur jahanpur thesil daryapur Dist-Amravati	93.37083249977951	High health risk
21	Chikhali nallah meets Godavari river, Village. Chikhali, Taluka. Nashik, District. Nashik.	190.82487582736934	Severe health risk
22	Colour chem Nalla, Village. Majiwada,Taluka. Thane,District. Thane.	339.0902931313014	Severe health risk
23	Dahanu Creek at Dahanu Fort, Village. Danugaon, Taluka. Dahanu, District. Thane.	179.45469016535557	Severe health risk
24	Dandi Creek, Village. Dandi, Taluka. Palghar, District. Thane.	273.807972001196	Severe health risk

Table 7: NWQI and Health Impact Classification of Water Quality Parameters

Interpretation:
This table presents station-wise Neutrosophic Water Quality Index (NWQI) values and associated health risks Most stations fall under "Severe health risk" category. Very few locations show "High health risk", and none fall in safe categories. Extremely high NWQI values at locations like Lonar Lake, BPT Navapur, and industrial nallas indicate alarming pollution levels.

Classical Regression Results

```
                  OLS Regression Results
Dep. Variable:            WQI   R-squared:                 0.984
Model:                    OLS   Adj. R-squared:            0.983
Method:           Least Squares   F-statistic:             3928.
Date:             Sun, 05 Apr 2026   Prob (F-statistic):   9.90e-175
Time:                  09:52:46   Log-Likelihood:         -731.81
No. Observations:          200   AIC:                      1472.
Df Residuals:             196   BIC:                       1485.
Df Model:                 3
Covariance Type:          nonrobust
coef    std err       t     P>|t|     [0.025     0.975]
const           52.1616     1.297    40.213    0.000    49.604    54.720
BOD              14.9055     0.156    95.319    0.000    14.597    15.214
```

```
Nitrate N               -1.0117    0.637   -1.588    0.114    -2.268     0.245
Total Dissolved Solids  -9.637e-06  9.26e-05  -0.104    0.917    -0.000     0.000
Omnibus:                315.117  Durbin-Watson:          1.797
Prob(Omnibus):           0.000  Jarque-Bera (JB):     53951.526
Skew:                    7.284  Prob(JB):              0.00
Kurtosis:               82.132  Cond. No.              1.76e+04
```

High Predictive Power (R-squared = 0.984): The model explains a substantial 98.4% of WQI variability.
Significant Predictor: BOD is a highly statistically significant positive predictor of WQI.
Non-Significant Predictors: Nitrate N and Total Dissolved Solids are not statistically significant predictors of WQI in this model.
Multicollinearity Warning: A high condition number suggests multicollinearity among predictors, which may affect the reliability of individual coefficient estimates for Nitrate N and Total Dissolved Solids, despite the strong

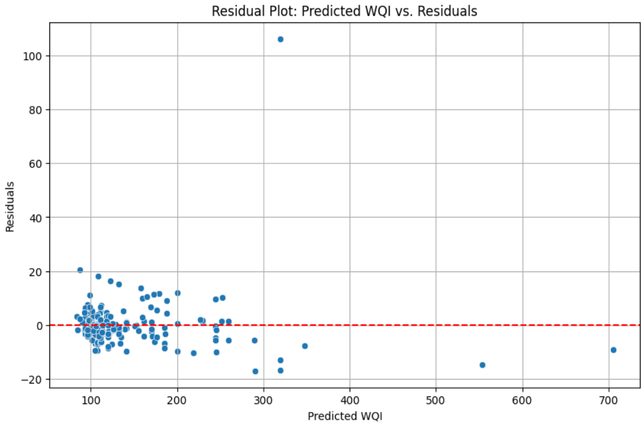

Fig. 3. Residual Plot

Randomness
Residuals should be randomly spread around zero. Here, they show a pattern, so the model may not be appropriate.
Homoscedasticity (Constant Variance)
The spread of residuals should be equal. Here, the spread changes (fanning shape), so this condition is not satisfied.
Outliers
Some points are far from others, which may affect the model.
Normality
High Skew (7.284) and Kurtosis (82.132), and p-values = 0.000
→ Residuals are not normally distributed.
Neutrosophic Regression Results
R-squared = 0.6486

This means the model explains about 64.86% of the variability in the dependent variable.
It indicates a moderate to good fit, but some variation is still unexplained.

Mean Absolute Error (MAE) = 16.9994
On average, the model's predictions deviate from actual values by about 17 units.
This shows a moderate level of prediction error.
Root Mean Squared Error (RMSE) = 20.5832
RMSE is slightly higher than MAE, meaning larger errors are present in some predictions.
It penalizes large errors more, indicating some variability in prediction accuracy.

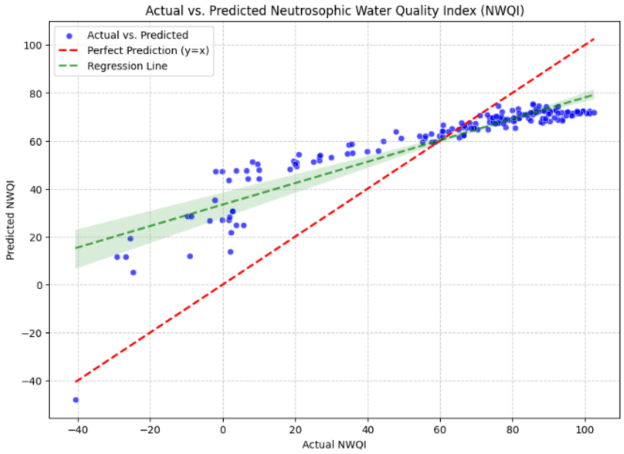

Fig. 4. Residual Plot

Overall Relationship
The scatter points show a positive linear relationship between actual and predicted NWQI values.
This means the model is capturing the general trend correctly.
Closeness to Perfect Line (y = x)
The red dashed line represents perfect prediction.
Many points are close to this line, especially in the middle range (50–80), indicating good prediction accuracy in this region.
Deviation from Perfect Prediction
Some points are far from the red line, especially:
At low NWQI values
A few outliers (e.g., extreme negative prediction)
This indicates higher prediction errors in certain cases.
Regression Line (Green Line)
The green line shows the fitted regression trend.
It is slightly flatter than the perfect line, suggesting:
The model underestimates higher values
Slight bias in prediction
Confidence Band (Shaded Area)
The shaded region shows uncertainty.
Wider spread at lower values indicates less confidence in predictions there.

Model Comparison

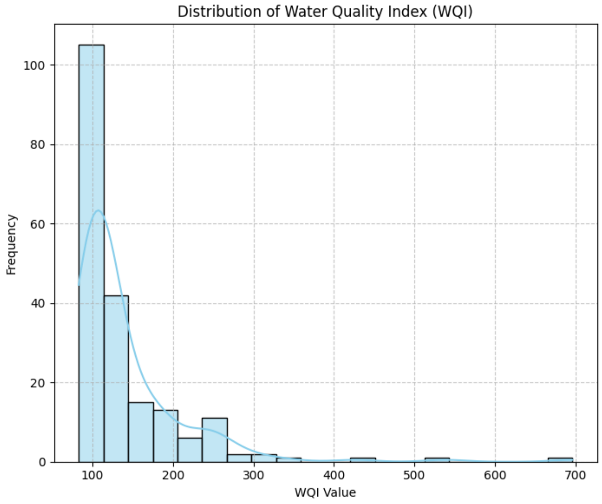

Fig. 5. Frequency vs WQL

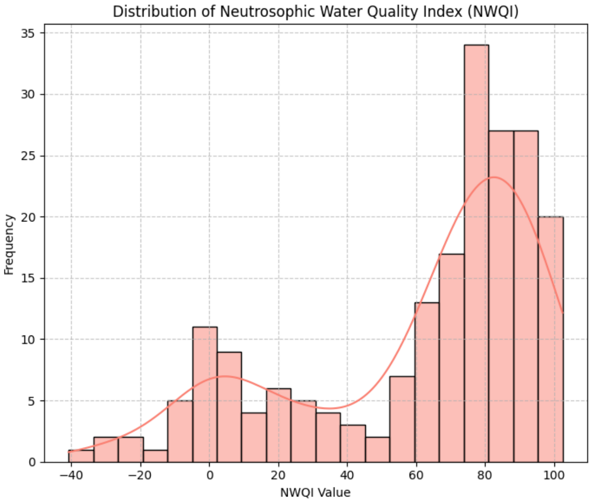

Fig. 6. Frequency vs NWQI

Shape and Spread:
The distributions of WQI and NWQI may look different.
WQI shows overall water quality based on values, while NWQI also considers uncertainty (Indeterminacy) and falsity, so its spread can be wider or slightly different.

Central Tendency:
The average (mean/median) of NWQI may be lower than WQI.
This is because NWQI is more strict and reduces values when uncertainty or error is present.

Outliers / Extremes:
NWQI may show more extreme values (long tails), especially when there is high uncertainty or incorrect data in some parameters.

Index	Model	R_squared	Adj_R_squared	AIC	BIC
0	Classical	0.984	0.983	1750.10	1763.30
1	Neutrosophic	0.648	0.647	1605.85	1644.04

Table 8: Model Comparison of classical and neutrosophic regression
Interpretation
R² (Model Fit)
Classical = **0.984** Very high fit

Neutrosophic = 0.648 Moderate fit
Classical model explains more variation

Adjusted R^2:
Classical = 0.983 (better)
Neutrosophic = 0.647

AIC & BIC (Model Quality – lower is better):
Neutrosophic has lower AIC (1605.85) and BIC (1644.04)
Indicates better model in terms of penalty + simplicity

Principle Component

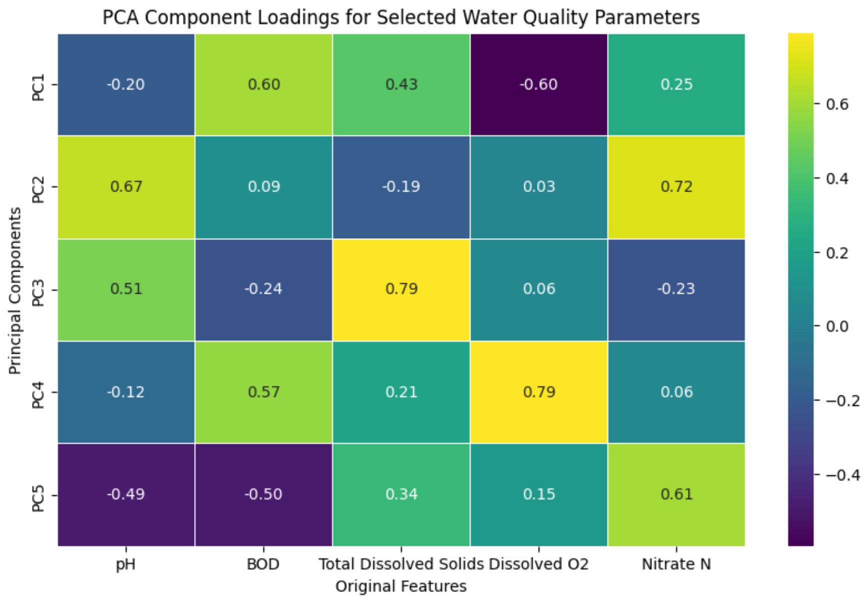

Fig. 7. PCA Plot

Principal Component Analysis revealed that water quality variation is mainly controlled by organic pollution, nutrient enrichment, and dissolved solids. PC1 represents the impact of organic pollution (BOD–DO relationship), PC2 reflects nutrient influence (Nitrate-N and pH), and PC3 indicates mineral/salinity variation (TDS). Thus, these factors are the major contributors to overall water quality variation in the study area.

Discussion

The analysis of physicochemical parameters indicates noticeable variation in water quality across the selected monitoring locations. High values of Total Dissolved Solids (TDS) and Biological Oxygen Demand (BOD) suggest significant pollution levels, mainly due to anthropogenic activities such as industrial discharge and agricultural runoff. Lower Dissolved Oxygen (DO) levels at certain sites further indicate deteriorating water conditions. The computed Water Quality Index (WQI) reflects poor water quality in several locations, confirming that conventional methods are effective in identifying pollution levels. However, classical approaches rely on precise values and do not account for uncertainty in environmental data. The Neutrosophic Water Quality Index (NWQI) provides a more flexible assessment by incorporating truth, indeterminacy, and falsity components. The obtained NWQI values indicate high to severe pollution levels, which align with the WQI results but offer additional insight into data variability and uncertainty. Regression analysis shows a strong relationship between selected parameters and water quality, with TDS and BOD contributing significantly to pollution. Principal Component Analysis (PCA) identifies these parameters as major influencing factors, supporting the results obtained from WQI and NWQI. The findings demonstrate that the neutrosophic approach enhances the reliability of water quality assessment by addressing uncertainty, making it more suitable for complex environmental data.

Conclusion

The study assessed surface water quality using classical and neutrosophic statistical methods based on key physicochemical parameters. The results reveal poor water quality conditions in several locations, with TDS and BOD identified as major contributors to pollution. The comparison between WQI and NWQI shows that while both methods effectively evaluate water quality, the neutrosophic approach provides a more comprehensive assessment by incorporating uncertainty and variability in the data. This leads to more realistic and reliable results. The study highlights the importance of continuous monitoring and the application of advanced statistical techniques for effective water quality management. The findings can support decision-making in environmental protection and public health. In conclusion, neutrosophic statistical methods offer a robust framework for water quality assessment and can be effectively applied to improve environmental analysis under uncertain conditions

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SSS, DDG and SND conceived the concept, wrote and approved the manuscript.

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