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Evaluation of Seasonal Variation in Water Quality in Agartala City, India Using Principal Component Analysis and Water Quality Index

ATOSHI CHAKMA, Y.V. KRISHNAIAH*, KAUSIK PANJA, MANIKA MALLICK, DEEPA RAI, DEBASIS DAS AND MOUMITA HATI

Department of Geography and Disaster Management, Tripura University (A Central University), Suryamaninagar, 799022, Tripura, India

E-mail: atoc.chakma@gmail.com, yvkrishna09@gmail.com, yvkrishnaiah@tripurauniv.ac.in, kausikpanja89@gmail.com, mnkmlik14@gmail.com, rai09deepa@gmail.com, debasisdas379@gmail.com, moumitahati421997@gmail.com

***Corresponding author**

ABSTRACT

Agartala City is one of the developing cities after Guwahati in north-eastern India. It is rapidly growing with an ever-increasing population and their necessities. The city is exposed to demands more than ever, which gives immense pressure on the natural resources of water. The water resources are limited and essential to sustain life. Population growth and urbanization create great pressure on water resources and further urbanization influences the lack of access to safe water. Water quality decline has nowadays become a serious urban problem globally and Agartala city is not an exception. In order to evaluate the seasonal changes in water quality in Agartala City, India, thirteen different physicochemical parameters were chosen to test twenty-four (groundwater and surface water) samples of pre and post-monsoon collected during 2020-22.

Key words: Agartala City, Principal Component Analysis, Seasonal Variation, Tripura, Water Quality, Water Quality Index

INTRODUCTION

In the last hundred years, most of the global population has been migrating from rural to urban for employment, education, healthcare, basic infrastructure facilities, better economic opportunities to sustain a better life, etc. (Cox et al. 2018). According to the United Nations, groundwater accounts for 30.1% of the total freshwater available on Earth. Groundwater is trapped below the earth's surface in the porous rock formation layers. 97% of the usable freshwater is groundwater (Loucks 2000, Singh et al. 2019). Population pressure on an urban space has a negative impact on the quantity and quality of usable water. Urban morphology and structure of urban spaces most of the time hinder the natural activity of percolation and recharge of the water table which makes the situation more alarming for emerging urban spaces. The groundwater is often overused and altered by various anthropogenic activities. Urban land use changes (infrastructural development and settlement) have been causing the demand for water and its stress on groundwater (Singh and Kumar 2015).

In India, the exponential growth of the population increases the demand for water (Trivedi et al. 2001). In recent decades, numerous cities in India are developing into megacities. Urbanisation often causes degradation of environmental quality such as serious issues like alteration of the quality of water (Cullis et al. 2019, Zhang 2016). Further, urbanisation mainly leads to contaminants in water resources like ponds, streams, lakes, rivers, etc (Wetz et al. 2016). The increasing population demands various developmental activities such as industrialisation, but industrial pollutants were discharged highly into the environment mainly rivers (Mahapatra et al. 2012). Now urban areas have exceeded the natural capacity of mankind's progress and their challenges (Sharma 2018). Overcrowding is causing many cities worldwide to fail in providing essential services to their residents (Stanley and Gunn 2018). It can show an impact on water quality and the well-being of the local ecosystem (Zandbergen 1998, Hall and Ellis 1985).

The main issue is that the water pollution transcends boundaries from national to global level (Shahid and Saba 2018). The presence of heavy metals can be traced from industrial effluents (Wahaab and Badawy 2004). In water quality, the physical characteristic of water includes colour, odour, taste, organic matter, temperature, pH, turbidity, and chemicals, water pollution consisting of atoms and molecules of dangerous substances released by anthropogenic activities (Praveen et al. 2016). Anthropogenic activities are accountable for the release of these chemical substances, including agricultural activities, industrial discharges, sewage generation from households, etc (Taghinia et al. 2011). In 2015, it was estimated that 1.8 million people died from the consequences of water pollution (Biswas and Tortajada 2019). It has been observed that human interference is being inflicted on the urban watercourse (Gomes et al. 2016).

Water sources need protection from adverse effects of anthropogenic activities (Saleem 2017). The quality of groundwater once deteriorated it becomes difficult to restore the quality (Singh et al. 2018). Water Quality Indexes can inform mainly the common people regarding the quality of water (Smith 1990). A planned and systematic, sustainable approach to surface and groundwater uses is the need of the hour for urban spaces around the world. It is critical for water conservation in all countries (Jiang et al. 2019).

STUDY AREA

Agartala City is the capital of Tripura state which is situated in northeast India. It is a growing city which consists of 51 wards in Agartala Municipality Corporation. Over the years the city has been growing with the merging of new sub-urban localities to accommodate the growing population and their needs. The city extends between 23°45′ to 23°55′ N latitude and 91°15′ to 91°20′ E longitude. The climate of the city falls on the type of 'Aw' (tropical wet and dry climate) by Köppen-Geiger. The total area of the city is more than 76 km², and its elevation is 12.8 meters above msl. The city is situated on the banks of the river Haora. The city has a border with the neighbouring country Bangladesh (Fig. 1). The total population of the city is 578,577 and the population density is 5,200/km² (Anonymous 2022).

MATERIALS AND METHODS

Water samples are collected from pre- and post-monsoon to know the seasonal variation in the water quality of Agartala City. The total number of collected water samples was 24, each season 12 water samples (8 are surface water and 4 are groundwater) from pre and post-monsoon (Table 1). The purposive

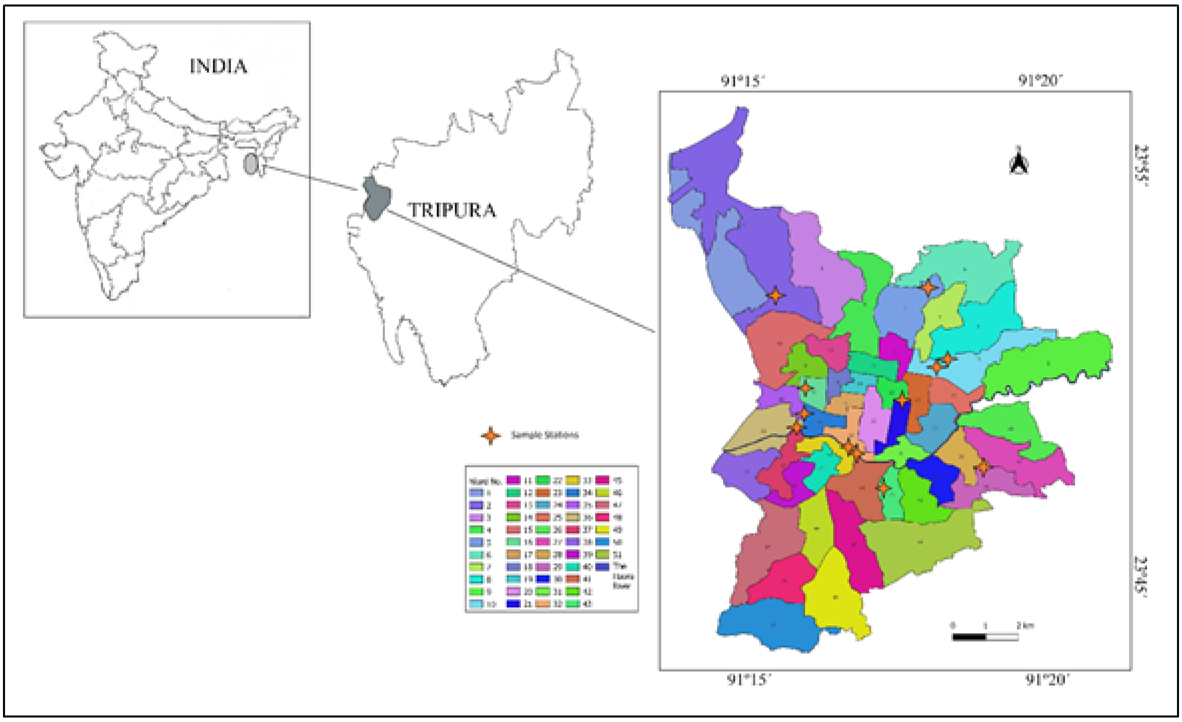

Figure 1. Study area

Table 1. Sample station area and types of water sample in both the seasons

Station no.	Area and types of water sample
Station 1	Chanmari (Ground water)
Station 2	Banamalipur (Surface water)
Station 3	Near Haorah River (Ground water)
Station 4	Haorah River near Pratapgarh (Surface water)
Station 5	College Tilla (Surface water)
Station 6	Katakhal canal (Surface water)
Station 7	Indranagar (Ground water)
Station 8	Barjala (Surface water)
Station 9	Joynagar Haora River (Surface water)
Station 10	Bangeshwar River (Surface water)
Station 11	Joynagar (Surface water)
Station 12	Ramnagar (Ground water)

sampling method was adopted for collecting water samples during 2020-22. The selected thirteen physical and chemical parameters are pH, Turbidity (NTU), Total Dissolved Solids (TDS), Total Alkalinity (H_2SO_4), Total Hardness ($CaCo_3$), Iron (Fe), Chloride (Cl), Nitrate (NO_3), Fluoride (F), Magnesium (Mg), Sulphate (SO_4^{2-}) and Electrical Conductivity (EC). The physical and chemical parameters were tested by PCS multi-parameter handset and even used standard testing kits and lastly, samples were tested at the laboratory. In addition, Dissolved Oxygen (O_2) was tested on the site by DO meter, and turbidity was tested with Nephelometer. Further, a standardized table was prepared for thirteen parameters like mean, median, minimum, maximum, and standard deviation for the analysis of seasonal variation of water quality (Tables 3, 4). A correlation was worked out with an application of Karl Pearson's Correlation Matrix for pre and post-monsoon samples. Principal Component Analysis (PCA) was used to identify the important components through eigenvalues and eigenscales. Eigenvalues, if they are above zero, it means a positive trend. Water Quality Index (WQI) worked out on overall thirteen parameters from the collected twenty-four water samples of groundwater and surface water (Horton 1965). Further, assessed water suitability for use by humans with an adaptation of Weighted Arithmetic Index method postulated by Brown et al. (1972) (Table 2). Water Quality Index is the process that simplifies multiple weighted factors into numerical values to the significance of the water quality

Table 2. Standard table of weighted arithmetic water quality index (WQI) (Brown et al. 1972)

WQI Scale	Water Quality Rating
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unsuitable

(Abdelaziz et al. 2020).

Step I: Calculate the unit weight (W_n)

$$W_n = \frac{K}{S_n} \quad (1)$$

Where,

$$K = \frac{1}{1/S_1 + 1/S_2 + 1/S_3 + \cdots + 1/S_n} = \frac{1}{\Sigma \frac{1}{S_n}}$$

S_n= n^{th} parameter's Standard desirable value

Summation of all the selected parameters, unit weight factor W_n= 1 (unity)

Calculation of the sub-index value (Q_n)

$$Q_n = \frac{[(V_n - V_o)]}{[(S_n - V_o)]} * 100$$

here,

V_n= mean concentrations of the n^{th} parameter

S_n= Standard desirable value of the n^{th} parameter

V_o= Actual values of the parameters in pure water (V_o=0, of most parameters except for pH)

Step II: $$Q_pH = \frac{[(V_pH - 7)]}{[(8.5 - 7)]} * 100 \quad (2)$$

Merging step 1 and step 2, WQI is calculated as follows:

Step III: $$\text{Overall WQI} = \frac{\Sigma W_n Q_n}{\Sigma W_n} \quad (3)$$

RESULTS AND DISCUSSION

Season-wise physicochemical parameters of mean, standard deviation, etc

Pre-monsoon

During the pre-monsoon period, station-1 exhibited a minimum pH of 5.6, whereas station-11 had a maximum pH of 7.18. The average pH was 6.5 with a standard deviation of ±0.41. Turbidity, measured in NTU, was at its lowest (0.12 NTU) at station-1 and highest (556 NTU) at station-10. The mean turbidity across all stations was 130.59 NTU with a SD ±203.06. The wide variation in turbidity values (ranging up to 555.88 NTU) was due to the collection of samples from various ground and surface water sources. In terms of total dissolved solids (TDS), station-10 had the lowest measurement of 39 mg/l, followed by station-1 with 50 mg/l, while station-3 recorded the highest measurement of 240 mg/l. The average TDS was 109.66 mg/l with a standard deviation of ±69.2. Total alkalinity (TA) was found to be low at station-1 (14 mg/l) and high at stations 2 and 3 (98 mg/l). The average total alkalinity across all stations was 60 mg/l with a SD of ±30.6. Regarding total hardness (TH), station-1 had the lowest measurement of 24 mg/l, while station-2 had the highest measurement of 98 mg/l. The mean TH was 60 mg/l with a standard deviation of ±25.52. Iron (Fe) levels were low at station-1 (0.01 mg/l) and high at station-9 (8.799 mg/l). The mean Fe concentration was 2.71 mg/l with a SD ±3.11. Chloride (Cl) levels were high at station-3 (44 mg/l) and low at station-9 (12 mg/l). The average chloride concentration was 25 mg/l with SD ±9.26. Nitrate (NO3) levels were high at station-10 (39.78 mg/l) and low at station-7 (0.509 mg/l). The mean nitrate concentration was 11.33 mg/l with a SD ±14.16. Electrical conductivity (EC) was lowest at station-5 (95 ìmho/cm) and highest at station-3 (303 ìmho/cm). The mean EC value was 171.52 ìmho/cm with a standard deviation of ±62.13. Fluoride (F) levels were lowest at stations 2, 3, and 6 (0.001 mg/l) and highest at station-9 (1.93 mg/l). The average fluoride concentration was 0.41 mg/l with SD ±0.68. Dissolved oxygen (DO) was at its minimum (6 mg/l) at stations 11 and 12, while station-1 recorded the highest DO level of 8 mg/l. The average DO concentration was 6.8 mg/l with a standard deviation of ±0.65. Magnesium (Mg) levels were low at station-5 (0.75 mg/l) and high at station-9 (9.61 mg/l). The average magnesium concentration was 7.33 mg/l with SD ±10.08. Sulphate (SO4) levels were highest at station-10 (100 mg/l) and lowest at station-7 (1.229 mg/l). The average sulphate concentration was 38 mg/l with a standard deviation 51.45 (Table 3).

Post-monsoon

During post-monsoon, the pH was low (5.5) in station-1, but a high value (7) was in station-11. The average pH was 6.4, and the ±SD 0.39. Turbidity was low in station-1 (0.11 NTU) and the highest was in station-9 (324 NTU). The mean of turbidity was 90 NTU, and with the ±SD 124.4, this is due to the high variation between the maximum and minimum value of turbidity. TDS high value was exhibited in station-3 (167 mg/l) and low in station-10 (19 mg/l). The mean of TDS for all the samples where 75.91 mg/l, with ±SD 42. Total Alkalinity (TA) lowest was in station-1 (12 mg/l), but high showed in station-5 (82 mg/l). The mean was 41.83 mg/l with ±SD 21.69. Total Hardness (TH) was lowest in station-5 (18 mg/l), and highest was in station-3 (79 mg/l). The mean of TH was 47 mg/l, ±SD 21.84. Iron (Fe) was shown high (6.851 mg/l) in station-10 and the low occurred in station-1 (0.013 mg/l). The average was 2.08 mg/l with ±SD 2.52. The lowest chloride (Cl) was observed in station-4 (10 mg/l), and the highest was in station-3 (34 mg/l). The mean value of this parameter was 19.16 mg/l and ±SD 8.77. Nitrate (NO_3) was at maximum in station-10 (31.78 mg/l), and the minimum was in station-7 (0.109 mg/l). The mean of NO_3 was 8.66 mg/l, and the ±SD was 12.5.

Table 3. Physicochemical parameters for pre-monsoon

Parameters	pH	Turbidity (NTU)	TDS (mg/l)	Total alkalinity (H_2SO_4 (mg/l)	Total hardness ($CaCO_3$) (mg/l)	Fe (mg/l)	Cl (mg/l)	NO_{3-} (mg/l)	EC (mg/l)	F (mg/l)	DO (mg/l)	Mg (mg/l)	SO_4^{2}- (mg/l)
N	12	12	12	12	12	12	12	12	12	12	12	12	12
Min	5.6	0.12	39	14	24	0.01	12	0.50	95.1	0.001	6	0.75	1.229
Max	7.18	556	240	98	98	8.79	44	39.78	303	1.93	8	38	145.2
Mean	6.5	130.59	109.66	60	61.25	2.71	25	11.33	171.52	0.41	6.8	7.33	38
Median	6.69	40.9	76.5	63	59	0.96	24.5	4.21	160.6	0.1	6.65	4.5	11.54
SD	0.41	203.06	69.2	30.6	25.52	3.11	9.26	14.16	62.13	0.68	0.65	10.08	51.45

Table 4. Physicochemical parameters for post-monsoon

Parameters	pH	Turbidity (NTU)	TDS (mg/l)	Total alkalinity (H_2SO_4 (mg/l)	Total hardness ($CaCO_3$) (mg/l)	Fe (mg/l)	Cl (mg/l)	NO_{3-} (mg/l)	EC (mg/l)	F (mg/l)	DO (mg/l)	Mg (mg/l)	SO_4^{2-} (mg/l)
N	12	12	12	12	12	12	12	12	12	12	12	12	12
Min	5.5	0.11	19	12	18	0.01	10	0.10	95.1	0.001	6	0.4	0.001
Max	7	324	167	82	79	6.85	34	31.78	303	1	7.8	29	121.8
Mean	6.4	90	75.91	41.83	47	2.08	19.16	8.66	172	0.21	6.7	5.67	31.27
Median	6.45	35.5	65	43.5	46	0.71	18	1.97	160	0.03	6.65	3.8	10.05
SD	0.39	124.4	42.58	21.69	21.84	2.52	8.77	12.5	61.45	0.37	0.54	7.67	43.64

Electrical conductivity (EC) was high in station-3 i.e., 303 µmho/cm, but the lowest was 95.1 µmho/cm. The mean of EC was 172 µmho/cm with ±SD 61.45. The fluoride (F) was highest in station-9 and 10 (1 mg/l) whereas, the lowest was detected in several stations (0.001 mg/l). The dissolved oxygen (DO) was tested an average of 6.7 mg/l and the lowest value was 6 mg/l in stations-11 and 12 with the highest was 7.8 mg/l in station-1. The average value of magnesium (Mg) was 5.67 mg/l. The lowest Mg was in station-4 (0.4 mg/l), and the highest was in station-10 (29 mg/l). The sulphate (SO_4) highest value was in station-9 (121.8 mg/l) and the lowest was in station-1(0.001 mg/l). The average of sulphate was 31.27 mg/l with ±SD 43.64 (Table 4).

Pearson's correlation matrix for season-wise physicochemical parameters

Pre-monsoon

During the pre-monsoon season, there was a stronger correlation between pH and Total Alkalinity (r=0.49) followed by Total Hardness (r=0.42) compare to other parameters. Turbidity correlated with Iron (r=0.93), F (r=0.89), Mg (r=0.71), Sulphate (r=0.69), and Nitrate (r=0.68). Total Dissolved Solids parameter was positively correlated with EC (r=0.87), TA and TH (r=0.60). Total Alkalinity was significantly higher in correlation with Toral Hardness (r=0.96), EC (r=0.74) and Chloride (r=0.60). Total Hardness correlated with EC (r=0.78) and Chloride (r=0.63). Iron was highly correlated positively with F (r=0.76) and followed by Sulphate (r=0.58), Magnesium (r= 0.53) and Nitrate (r=0.54). Chloride was shown a positive correlation with EC (r=0.57). Nitrate was in positive correlation with Fluoride (r=0.72) and Magnesium (r=0.69). Fluoride was positively correlated with Sulphate (r=0.79) and Magnesium (r=0.76). Magnesium was shown positive correlation with Sulphate (r=0.56). Turbidity, TDS, TA, TH, Iron, Nitrate, Fluoride, Magnesium and Sulphate showed a positive correlation while other parameters remain negatively correlated. Strongly correlated physicochemical parameters are highlighted, these are, Turbidity with Fe, TDS with EC, TA with TH, TH with EC, Iron with Fluoride, Fluoride with Sulphate, Nitrate with Fluoride, and Mg with Sulphate (Fig. 2a)

Post-monsoon

In the Post-monsoon season, pH positively correlated with TA (r=0.68) and TH (r=0.59) like as same in the pre-monsoon season. Turbidity was in positive correlation with Iron (r=0.90), Fluoride (r=0.76), Nitrate (r=0.59), Magnesium (r=0.60) and Sulphate (r=0.58). TDS exhibited high correlation between EC (r=0.88) and followed by TH (r=0.53). Total Alkalinity was highly correlated with Total Hardness (r=0.88) and followed by EC (r=0.55). TH was also shown to have positive correlation with EC (r=0.69). Iron was positively correlated with Fluoride (r=0.80), Nitrate and Magnesium (r=0.62) and Sulphate (r=0.57). Chloride was shown insignificantly correlated with other parameters in the post-monsoon. Nitrate was shown high positive correlation with Fluoride (r=0.91), Magnesium (r=0.69) and Sulphate (r=0.51). Fluoride had positive correlation with Magnesium (r=0.77) and Sulphate (r=0.67). DO was shown insignificantly correlated with other parameters. Magnesium had positive correlation with Sulphate (r=0.48). Most of the parameters are correlated with other parameters like pre-monsoon but few have changed due to seasonal variations in temperature, rainfall etc. In post-monsoon, three parameters showed negative correlation (Cl, EC and DO) and one was negligible.

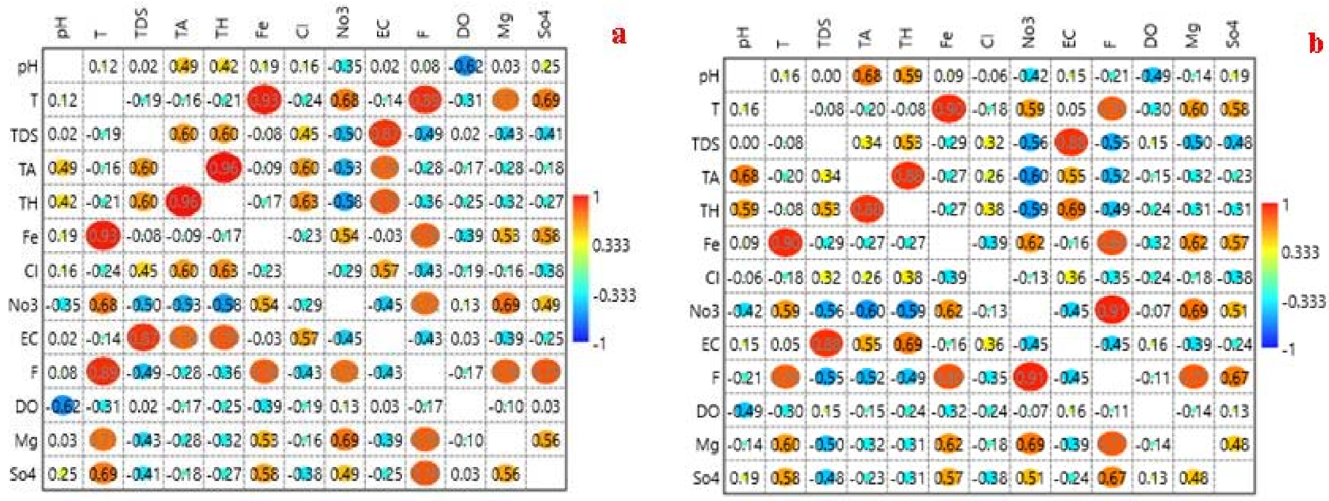

Figure 2. Pearson's correlation matrix for (a) pre- and (b) post-monsoon season

Turbidity was correlated with more parameters (Fe, NO_3, F, Mg and SO_4) in both seasons (Fig. 2b).

Principal component analysis (PCA) for water quality

PCA is a multivariate statistical technique that could be used for large-scale geochemical data (Gomes et al. 2019). PCA can determine the important water quality components (Yang et al. 2020). The management of water quality is important all over the world. Lately, the awareness of water quality has increased, and new harvesting techniques are employed for better sustainable water management. With the application of PCA, large and complex data can be simplified. The most important thirteen physicochemical parameters which can be used to evaluate the variation in water quality can be extracted by Principal Component Analysis and it is useful to identify the important principal components of water quality (Mishra 2010).

Table 5. Eigenvalue and percentage of the variance of principal components

Pre-Monsoon			Post-Monsoon		
PC	Eigenvalue	% Variance	PC	Eigenvalue	% Variance
1	5.81517	44.732	1	5.77965	44.459
2	3.04809	23.447	2	2.6181	20.139
3	1.48798	11.446	3	1.53556	11.812
4	0.861821	6.6294	4	1.27037	9.772
5	0.800091	6.1545	5	0.743759	5.7212
6	0.307266	2.3636	6	0.476271	3.6636
7	0.281854	2.1681	7	0.246918	1.8994
8	0.181149	1.3935	8	0.136901	1.0531
9	0.102769	0.79053	9	0.0866118	0.66624
10	0.0921646	0.70896	10	0.064922	0.4994
11	0.0216467	0.16651	11	0.040943	0.31495

Pre-monsoon

In the Principal Component Analysis, the eigenvalue percentage of PC1 was >44%, PC2 was >23%, PC3 was >11% and remains were negligible (Table 5). As per physicochemical parameters of PC1 loadings for six physicochemical components were found to have been more significant i.e., Fluoride (0.87), Nitrate (0.83), Turbidity, and Magnesium are 0.74, Sulphate (0.70) and Iron (0.62). In PC2, five physicochemical components were more prominent than the rest, they are pH, TA and Fe (0.63), Turbidity (0.60), and TH (0.58). In PC3, two physicochemical parameters were found to have more significance than the rest that is DO (0.58) and EC (0.50), and PC4 components were not significant. In PC1 parameters, Turbidity, Iron, Nitrate, Fluoride, Magnesium, and Sulphate are positively significant, but pH, Total Dissolved Solids, Total Alkalinity, Total Hardness, Chloride, DO, and Electrical Conductivity are negatively correlated (Table 6). The variation of the factors such as temperature, amount of rainfall, and human activities have been influenced to a certain degree by the water sources. In the pre-monsoon season, the parameters found to have been significant in PC1, and PC2 are Turbidity and Iron only. Station-3 was a groundwater source located nearby the river and a populated area. Thus, physiochemical parameters indicated that groundwater was unsuitable for drinking and domestic purposes (Fig. 3).

Table 6. Season-wise principal components analysis of physicochemical parameters

Parameters	Pre-monsoon				Post-monsoon			
	PC 1	PC 2	PC 3	PC 4	PC 1	PC 2	PC 3	PC 4
pH	-0.11715	**0.63957**	-0.67163	0.20722	-0.26918	**0.75094**	-0.51705	0.21969
Turbidity	**0.74121**	**0.60073**	0.22257	-0.060479	**0.63366**	**0.64743**	0.35511	-0.00308
TDS	-0.7026	0.31554	0.44278	0.025973	-0.68915	0.13922	**0.63376**	0.04709
TA	-0.67647	**0.63026**	0.054647	0.17135	-0.67738	**0.5596**	-0.1872	0.12977
TH	-0.73446	**0.58424**	0.027973	0.074538	-0.70808	**0.61749**	0.02173	-0.02555
Fe	**0.62356**	**0.63372**	0.17776	-0.039547	**0.74658**	**0.52514**	0.17798	0.053191
Cl	-0.60866	0.34186	0.12756	-0.4983	-0.43991	0.070336	0.21255	-0.71752
NO_3 -	**0.83139**	-0.00713	0.35255	-0.25032	**0.88664**	-0.01588	0.20521	-0.246
EC	-0.70338	0.4436	**0.5042**	0.085202	-0.63673	0.37691	**0.63793**	0.13259
Fl	**0.87585**	0.38855	0.067453	0.093889	**0.94209**	0.19714	0.14548	-0.032457
DO	-0.02425	-0.58969	**0.58575**	0.4181	-0.06373	-0.5645	0.3923	**0.61464**
Mg	**0.74513**	0.30305	0.1099	-0.2162	0.76669	0.23261	0.060258	-0.15824
SO_4 ^{2}-	**0.70228**	0.36632	0.037771	0.47904	0.66982	0.29415	-0.01829	0.45028

Post-monsoon

In post-monsoon, the percentage of eigenvalue of PC1 was >44%, PC2 was >20%, PC3 was 11%, PC4 was 9%, and the other components remained negligible (Table 5). In PC1 of Loading scores, six physicochemical components were more significant than others (F=0.94, NO_3 -= 0.88, Mg=0.76, Fe=0.74, SO_4=0.66 and Turbidity=0.63). The five components were more prominent than the rest in PC2 (pH=0.75, Turbidity=0.64, TH=0.61, TA=0.55 and Fe=0.52). In PC3, two parameters (TDS=0.63 and EC=0.63), and in PC4, only one parameter was more prominent (DO=0.61) than the rest. Out of all the parameters for PC1, in post-monsoon, Turbidity, Iron, Nitrate, Fluoride, Magnesium, and Sulphate have positive scores but in the case of pH, TDS, TA, TH, Cl, EC and DO values were negative. In the Post-monsoon season, Turbidity, and Iron are shown significantly in PC1 and PC2. Sample station-wise, the PC1 score of station-10 was high followed by station-9. Station-10 water sample was collected from the stream which is influenced by agricultural activity, and other human activities such as bathing, washing clothes, wastes from domestic animals, funeral rites, runoff from soil erosion due to urban developmental activities, wastes from the nearby market, rail tracks, etc. The station-9 water sample was collected near Haora River in Joynagar area, this station sample was influenced by various human activities. And it was a popular place for Idol immersion, the place is locally named 'Dashami ghat.' Station-3 sample was a groundwater source located adjacent to the Haora River. It was influenced by river siltation and effluences around the market area where it was situated (Table 1, 6, Fig. 4).

Season-wise Water Quality Index (WQI)

Water Quality Index (WQI) is an overall influence on the quality of water (Horton 1965). WQI for 24 water samples were analysed with Brown et al. (1972) index (Table 2). The selected water samples are four groundwater and eight surface water samples for each season.

Pre-monsoon

According to the water quality index, only two samples fell in the excellent category (0-25 according to WQI) these were station-1 and 7 (both are groundwater sources), only one sample falls in between 51-75, a poor rating which was station-8 (surface water source (pond)), remaining nine water samples had water quality ranging above >100 (unsuitable). Among these, station-3 and 12 are groundwater sources, and the rest are all surface water samples (Rivers, Lakes, and Ponds) (Table 7, Fig. 5).

Post-monsoon

Station-1 and station-7 were identified as having excellent water quality. Station-8 exhibited good water quality, station-5 displayed very poor water quality and remaining all the samples have values above 100 rendering unsuitable for drinking purposes. Notably, station-5 was a surface water

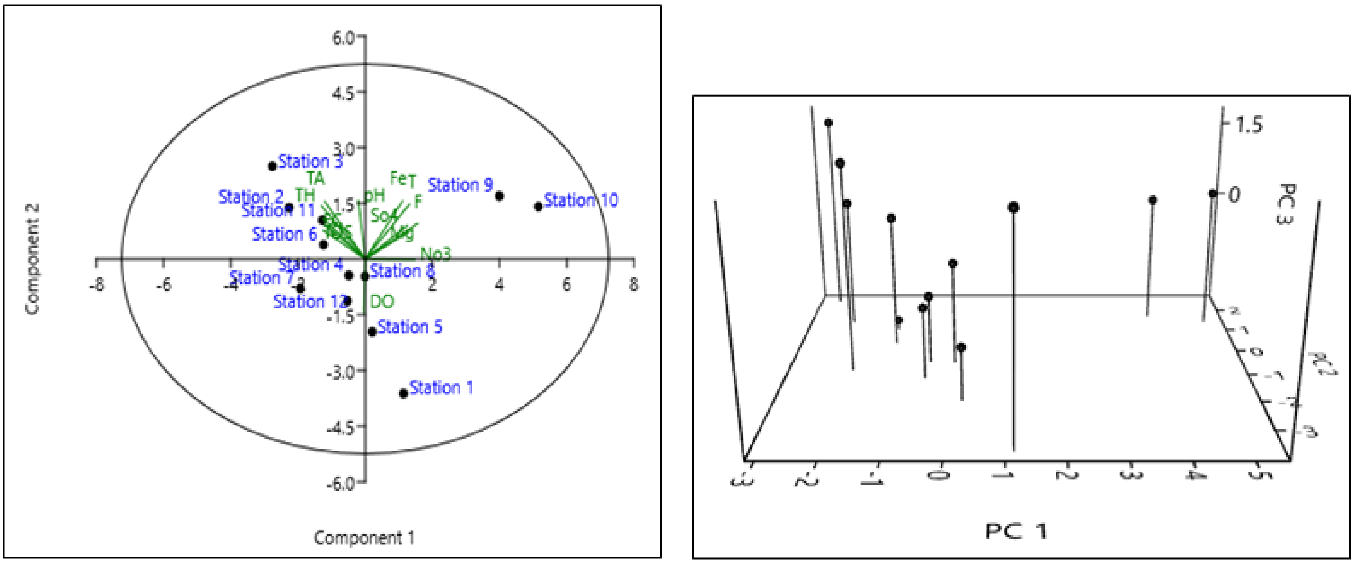

Figure 3. PCA in eigen scale: Loadings of PCA (Pre-monsoon)

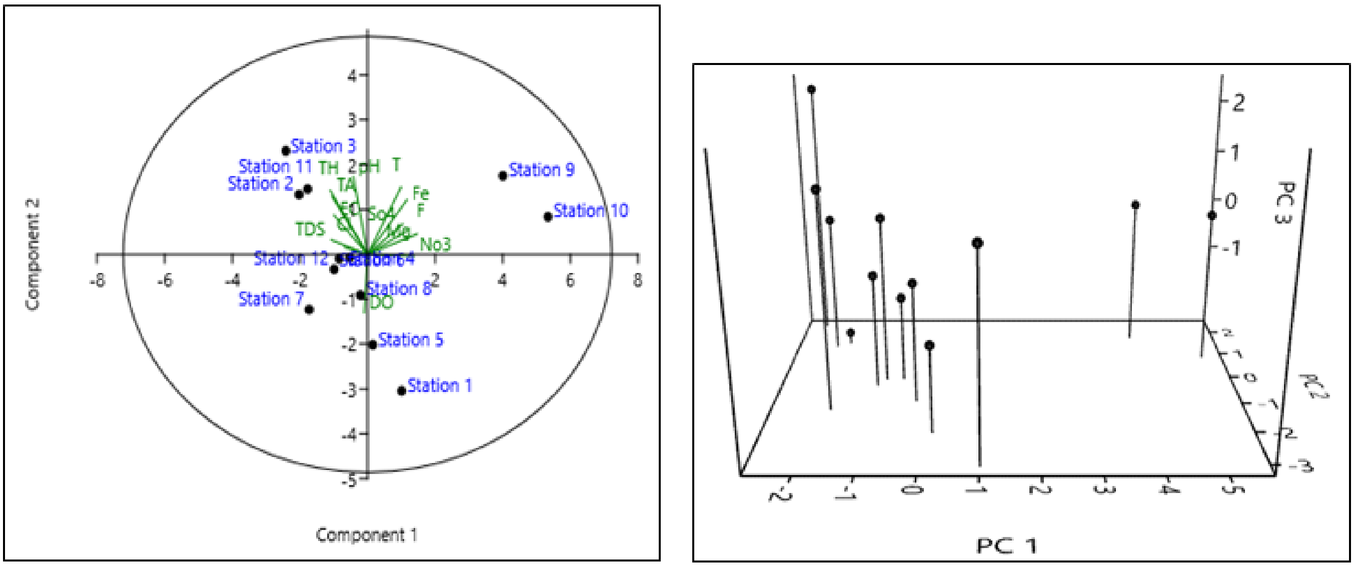

Figure 4. PCA in eigen scale: Loadings of PCA (Post-monsoon)

sample that shows variation in pre and post-monsoon (Table 7, Fig. 5).

The WQI reveals that station-1 (Chanmari) and station-7 (Indranagar) both are groundwater samples excellent for drinking purposes in both pre and post-monsoon. The amount of turbidity and iron were found very less amount and further, these stations are in less urbanised areas which means less pollution and population pressure. Station-8 (Barjala) was a surface water sample and it showed seasonal variation, in pre-monsoon it had poor water quality but in post-monsoon season it was good water quality. This is because in post-monsoon the value of parameters has changed due to rainfall and human activities, also it is situated in a less populated area with less pollution stress. Station-5 (College tilla) was a surface water sample, this sample as well showed seasonal variation like the post-monsoon sample shows very poor water quality but the pre-monsoon sample was shown as not suitable. This station is situated in populated place and it is a popular destination for Siberian migratory birds. The

Table 7. Season-wise water quality index

Station number, area and source of sample	Water Quality Index	
	Pre-monsoon	Post-monsoon
Station 1: Chanmari (Ground water)	Excellent water quality(0-25)	Excellent water quality (0-25)
Station 2: Banamalipur (Surface water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)
Station 3: Near Haorah River (Ground water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)
Station 4: Haorah River Near Pratapgarh (Surface water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)
Station 5: College Tilla (Surface water)	Unsuitable water quality (>100)	Very poor water quality (76-100)
Station 6: Katakhal River (Surface water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)
Station 7: Indranagar (Ground water)	Excellent water quality(0 – 25)	Excellent water quality(0 – 25)
Station 8: Barjala (Surface water)	Poor water quality (51 – 75)	Good water quality (26 – 50)
Station 9: Joynagar Haora River (Surface water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)
Station 10: Bangeshwar River (Surface water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)
Station 11: Joynagar (Surface water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)
Station 12: Ramnagar (Ground water)	Unsuitable water quality (>100)	Unsuitable water quality (>100)

remaining eight stations were found to be unsuitable for drinking water purposes subsequently the amount of iron and turbidity was high in these water samples. Among all the sites, station-12 had the least seasonal variation of WQI (Fig. 5). Surface water bodies are more susceptible to exposure to anthropogenic activities. And half of the groundwater samples in the city have the presence of a high amount of iron which makes water not suitable for drinking purposes. Water samples collected from Haora River and Bangeshwar River showed high levels of Turbidity in both seasons and the amount of nitrate and iron were found relatively higher than other elements.

CONCLUSION

The current paper reveals seasonal variation in water quality through the physicochemical parameters with an application of Karl Pearson's Correlation, PCA, and WQI. Pearson's correlation was observed high between total hardness and total alkalinity, iron and turbidity, and electrical conductivity and total dissolved solids in both seasons. Turbidity and iron are shown more significant in PC1 and PC2 and the remaining parameters appear individually either in PC1 or PC2 in pre- and post-monsoon. The WQI explained that Chanmari and Indranagar area's groundwater samples are excellent and followed by Barjala area's surface water sample is good for drinking purposes in both pre and post-monsoon seasons respectively. In the remaining stations most of surface water samples are not suitable for drinking purposes including two groundwater sample (bank of Haorah River and Ramangar) in both seasons. Turbidity is an important parameter of overall water quality, the amount of Turbidity in rivers and canals is higher compared to ponds, and lakes. The presence

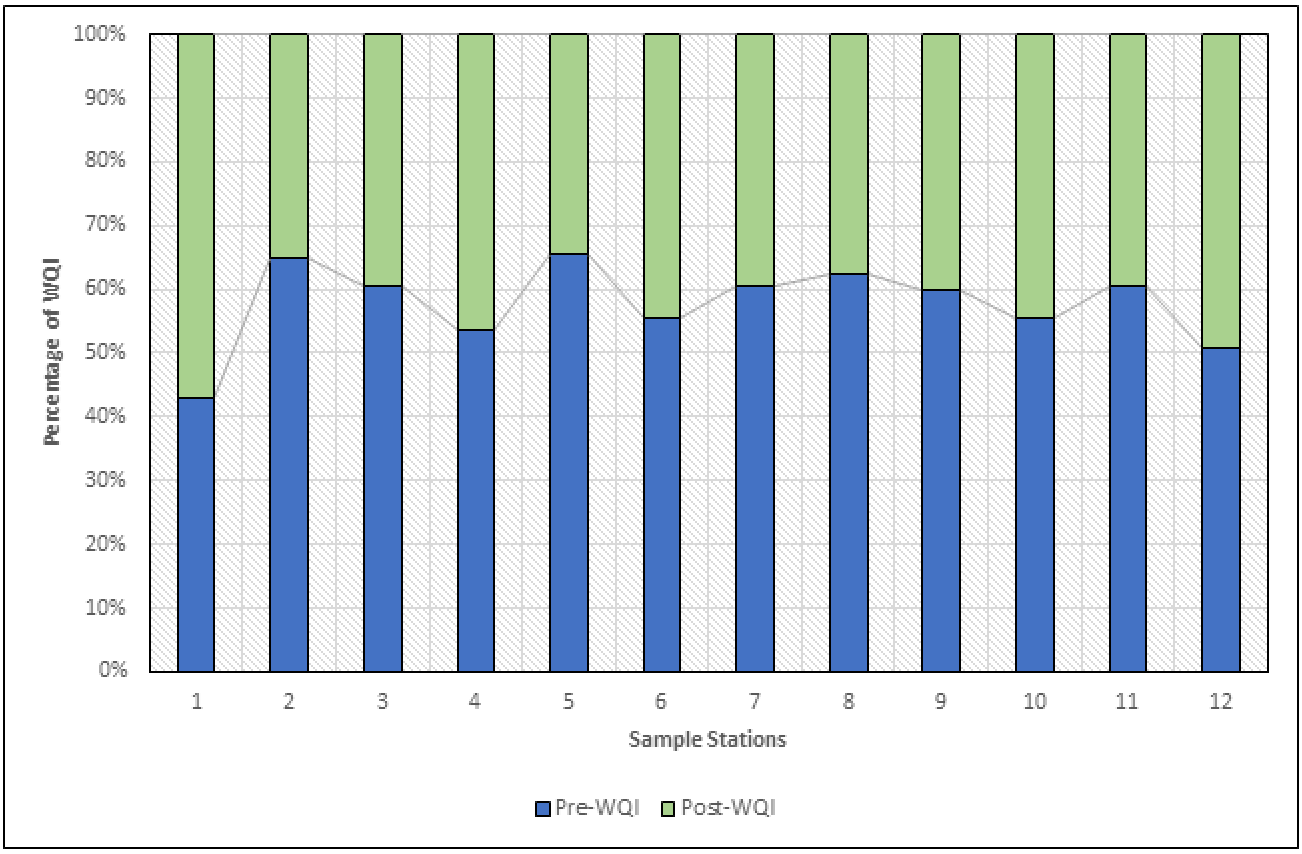

Figure 5. Water Quality Index of Pre and Post-monsoon

of Turbidity can lower the amount of TDS. In the study area, Iron has been found naturally in high amounts. The presence of Nitrate could be indicated by runoff from agricultural activities. The surface water sources that are vulnerable to more anthropogenic activities are found unsuitable for drinking and domestic usage. The effluents in the city largely derive from non-point sources pollutants that are causing alteration in water quality.

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REFERENCES

Abdelaziz, S., Mohamed, I., Gad, M.I., Abdel Hamid, A.M.H. and Tahan, E. 2020. Groundwater quality index based on PCA: Wadi El-Natrun, Egypt. Journal of African Earth Sciences, 172, 103964. https://doi.org/10.1016/j.jafrearsci.2020.103964.

Anonymous. 2011. Tripura Profile. Retrieved February 02, 2020 from http://censusindia.gov.in

Anonymous. 2012. Indian Standard, Drinking Water Specification (Second Revision), Bureau of Indian Standards, New Delhi. India. Retrieved January 20, 2020 from: http://cgwb.gov.in/Documents/WQ-standards.pdf

Anonymous. 2022. Population data of AMC (2012 to 2022). Retrieved March 10, 2023 from https://agartalacity.tripura.gov.in/sites/default/files/Population-year-wise-22.pdf

Biswas, A. K. and Tortajada, C. 2019. Water quality management: a globally neglected Issue. International Journal of Water Resources Development. 35, 913- 916, DOI: 10.1080/07900627.2019.1670506

Brown, R. M., McClelland, N I., Deininger, R.A. and Tozer, R.Z. 1972. A water quality index do we dare? Water and Sewage Works. 117, 339-343.

Cox, D.T.C., Shanahan, D.F., Hudson, H.L., Fuller, R. A. and Gaston, K.J. 2018. The impact of urbanisation on nature dose and the implications for human health. Landscape and Urban Planning, 179, 72-80.

Cullis, J. D. S., Horn, A., Rossouw, N., Fisher-Jeffes, L., Kunneke, M. M. and Hoffman, W. 2019. Urbanisation, climate change and its impact on water quality and economic risks in a water scarce and rapidly urbanising catchment: case study of the Berg River Catchment.

H2Open Journal, 2(1). 146–167.

Dharankar, Chandrashekhar. 2018. Re: Can Standard Deviation (SD) be greater than MEAN? . Retrieved April 12, 2023 from: https://www.researchgate.net/post/Can-Standard-Deviation-SD-be-greater-than-MEAN/5a4b0bc7217e20f1fc231788/citation/download

Gomes, C., Sperandio, D., Borges, N., Barbosa, A., Viçozzi, A. and Dias.G.P. 2019. Water quality assessment through PCA analysis. International Journal of Advanced Engineering Research and Science, 6(3), 202-210.

Gomes, R.C., Longo, R.M., Ribeiro, F.H.S., Bettine, S.D.C., Demanboro, A.C. and Ribeiro, A.I. 2016. Water quality index in an urban watershed. International Journal of Sustainable Development and Planning, 11, 1037-1043.

Hall, M.J. and Ellis, J.B. 1985. Water quality problems of urban areas. Geo Journal, 11(3), 265-275.

Horton, R.K. 1965. An index number system for rating water quality. Journal of the Water Pollution Control Federation, 37, 300-306.

Jiang, J., Ri, T., Pang, T., Wang, Y. and Wang, P. 2019. Water quality management of heavily contaminated urban rivers using water quality analysis simulation program. Global Journal of Environmental Science and Management, 5(3), 295-308.

Loucks, D. P. 2000. Sustainable Water Resources Management, Water International, 25(1), 3-10. https://doi.org/10.1080/02508060008686793

Mahapatra, S. S., Sahu, M., Patel, R. K. and Panda, B. N. 2012. Prediction of water quality using principal component analysis. Water Quality, Exposure and Health, 4(2), 93-104.

Mishra, A. 2010. Assessment of water quality using principal component analysis: A case study of the river Ganges. Journal of Water Chemistry and Technology, 32, 227-234.

Praveen, P.K., Ganguly, S., Kumar, K. and Kumari, K. 2016. Water pollution and its hazardous effects to human health: A review on safety measures for adoption. International Journal of Science, Environment and Technology, 5(3), 1559-1563.

Saleem, M. 2017. Analysis of ground water quality of Greater Noida Region along Yamuna River using water quality index. Cogent Engineering, 4(10), 404-408.

Shahid, A. and Saba, I. 2018. Water Pollution and its Sources, Effects & Management: A Case Study of Delhi. International Journal of Current Advanced Research, 07(2), 10436-10442.

Sharma, S. 2018. Behavioral study of urban watersheds in Bhopal-city of lakes, International Journal of Hydrology, 4(3), 111-115. https://doi.org/10.15406/ijh.2020.04.00234

Singh, M.K., Paul, R. and Karmakar, B. 2018. Studies on the seasonal variations of groundwater quality in Lefunga block of West Tripura District, Tripura, India. International Research Journal of Environment Science, 7(6), 25-33.

Singh, A.K. and Kumar, S.R. 2015. Quality assessment of groundwater for drinking and irrigation use in semi-urban area of Tripura, India. Ecology, Environment and Conservation, 21(1), 97-108.

Singh, S., Hassan, S. M. T., Hassan, M. and Bharti, N. 2019. Urbanisation and water insecurity in Hindu Kush Himalaya: Insights from Bangladesh, India, Nepal and Pakistan. Water Policy Corrected Proof, 1-19. https://doi.org/10.2166/wp.2019.215

Smith, D. G. 1990. A better water quality indexing system for rivers and streams. Water Research, 24(10), 1237-1244.

Stanley, M. and Gunn, G. 2018. Using Technology to solve today's water challenges, IISD-ELA Report. International Institute for Sustainable Development.

Taghinia Hejabi, A., Basavarajappa, H.T., Karbassi, A.R. and Monavari, S.M. 2011. Heavy metal pollution in water and sediments in the Kabini River, Karnataka, India. Environmental Monitoring and Assessment, 182, 1-13.

Trivedi, S.M., Yadav, B.R., Gupta, N., Chandrasekharan, H. and Ramachandran, K. 2001. Effects of urbanization on changes in groundwater quantity and quality in Delhi State, India. Proceedings of Sixth IAHS Scientific Assembly Symposium at Maastricht, IAHS Publication, 269, 147-153.

Wahaab, R.A. and Badawy, M.I. 2004. Water quality assessment of the River Nile system: An overview. Biomedical and Environmental Sciences, 17(1), 87-100.

Wetz,M .S., Hayes, K.C., Fisher, K.V., Price, L. and Sterba-Boatwright, B. 2016. Water quality dynamics in an urbanizing subtropical estuary (Oso Bay, Texas). Marine Pollution Bulletin, 104(1-2), 44-53.

Yang. W., Zhao. Y., Wang. D., Wu, H., Lin. A. and He, L. 2020. Using principal components analysis and IDW interpolation to determine spatial and temporal changes of surface water quality of Xin'anjiang River in Huangshan, China. International Journal of Environmental Research and Public Health, 17(8), 2942. https://doi.org/10.3390/ijerph17082942

Zandbergen P. A., 1998. Urban watershed ecological risk assessment using GIS: a case study of the Brunette River watershed in British Columbia, Canada. Journal of Hazardous Materials, 61(1-3), 163.

Zhang, X. Q. 2016. The trends, promises, and challenges of urbanisation in the world. Habitat International, 54(13), 241–252.

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