RESEARCH REVIEW JOURNALS
Volume-04
Issue-04
April-2019

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com[UGC Listed Journal]

Assessment of Seasonal Influence of Climate on Water Quality of River Damodar from Dishergarh to Bardhaman, West Bengal, India

Rupak Kumar Paul

Assistant Professor, Department of Geography and Applied Geography, University of North Bengal, P.O. NBU. Dist.-Darjeeling. Pin-734013

ARTICLE DETAILS

Article History
Published Online: 15 April 2019

Keywords
Water quality, River Damodar, Seasonal variability of water quality, Spearman's Rank Correlation.

ABSTRACT

The major objective of the present work was to determine whether or not the water quality status of the stretch of river Damodar from Dishergarh to Bardhaman changes in response to seasonality of prevailing climate. Database generated by Central Pollution Control Board which include 20 parameters with monthly frequency from 10 monitoring stations for the period of 4 years between 2014 and 2017 was used for statistical analysis by applying hierarchical cluster and Spearman's Rank Correlation. The result shows that changing pattern of water quality status round the year forms four specific hydrogeochemical seasons which almost correspond to 4 climatological seasons which are defined by India Meteorological Department i.e., pre-monsoon, monsoon, post-monsoon and winter but with a lag of one month. The correlation result suggests that man-induced parameters (e.g., BOD) do not follow the seasonality while geogenic parameters (e.g., TDS, TSS etc.) are very much affected by precipitation which is a seasonal phenomenon controlled by climate.

1. Introduction

Water quality simply refers to the suitability of the water for a particular use and it is manifested in various physical, chemical and biological properties of the water which are obviously the dynamic phenomena governed by both natural and anthropogenic processes. Anthropogenic activities like urbanization, industrial and mining activity, agricultural chemical in agricultural field etc. affect the water quality differently over the space due to their own spatial variability in terms of their magnitude while the natural processes like contamination of geogenic substance e.g., eroded soil, weathered rock etc. occur through precipitation and resultant runoff which are the seasonal phenomena governed by climate (Shrestha & Kazama, 2007).

Seasonal fluctuation of rainfall causes variation of runoff and resultant discharge which affects water quality of a river (Khadka & Khanal, 2008; Mtethiwa et al., 2008; Pejman et al., 2009; Vega et al., 1998) in two different ways. The increased runoff washes out the land to stream resulting in increase in concentration of geogenic contaminants and agricultural runoff encourages the contamination of chemical fertilizer in river water. This is one way the runoff affects stream water quality while the same runoff dilutes the concentration of urban and industrial sewage contaminants (the anthropogenic substance) which constitute the constant polluting sources of a river (Pejman et al., 2009).

For proper management of water quality of a stream it is essential to know how the water quality parameters at any given point on space respond to the seasonality of the prevailing climate since the seasonal influence makes the hydrogeochemical systems a more complex entity. The present study focuses on such issue i.e., the major objective of the present investigation is to trace how seasonality of prevailing climate governs the stream water quality in the stretch of river Damodar from Dishergarh to Bardhaman, in Indian state of West Bengal.

Since Damodar Valley has long been known as the area of intensive industrial and mining activities almost all the previous works, so far reported from the region, focus on the issues of pollution with mainly two approaches thereby. One group of studies intended to observe the water quality status in view to judge its suitability for a specific purposeful use (Chatterjee & Raziuddin, 2007; Haldar et al., 2016; Kumari, 2016; Mukherjee, 2012; Saha, 2010; Verma et al., 2013), while in other group of studies the main objective was to investigate the role of industrial and mining activities in polluting the concerned river (Banerjee & Ghosh, 2012; S. K. Chatterjee et al., 2010; George et al., 2010; Ghosh & Banerjee, 2012; Singh et al., 2014; Sinha et al., 2013).

Some authors, however, incorporated seasonal influence into their observation but with qualitative perspective in a very descriptive manner and that is why they cannot be referred to formulation of strategic plan for avoiding future contamination for protecting the aquatic environment form ill effect of pollution. Present study is intendent to explore two specific aspects of seasonality of water quality of river Damodar: first, determining whether or not there is presence of the specific seasonal pattern in the quality of flowing water and second, quantifying the influence of seasonality of climate on water quality status using statistical approach.

2. The Study Area

The stretch of river Damodar from Dishergarh to Bardhaman traverses for a distance of approximately 122 km

RRIJM 2015, All Rights Reserved

through Paschim and Purba Bardhaman districts of West Bengal, India. Damodar basin is a part of lower Ganga basin and it is further divided 60 small watersheds (Coded as 1 to 60) and out of which five such areal units together covering the area of 3620.81 sq. km are drained by present stretch (India-WRIS, 2012).

The area has popularly known Damodar Valley which includes India's most important coal and mica mining fields and has long been an area of active industrial development (Britannica, 2017). The region presently hosts 10378 registered industrial units of diversified categories including Iron and Steel, Paper Pulp, Cement, Power Plant, Agro-based, Rubber Plastic & Petro-based, Cotton Textile and many others (MSME, 2012).

Coal is the dominant mining materials among many others including iron, limestone, bauxite, baryte, mica, fire clay, china clay, etc. Apart from industry, urban sewage is another source of pollution in the defined stretch of river Damodar on the bank of which two urban agglomerations (UA) namely Asansol UA and Durgapur UA and four Municipalities are located (MSME, 2012). .

All these constitute the constant pollution source for river Damodar though concentration of contaminants varies across the seasons under the influence of prevailing climate. The seasonality is well defined by alternate appearance of two distinct dry and wet seasons with mean annual rainfall of 1250 mm, more than 80% of which occurs during wet season, the period between June and September. This seasonality along with spatial variation of human activity have made the hydrogeochemical system a complex entity which needs to be explored.

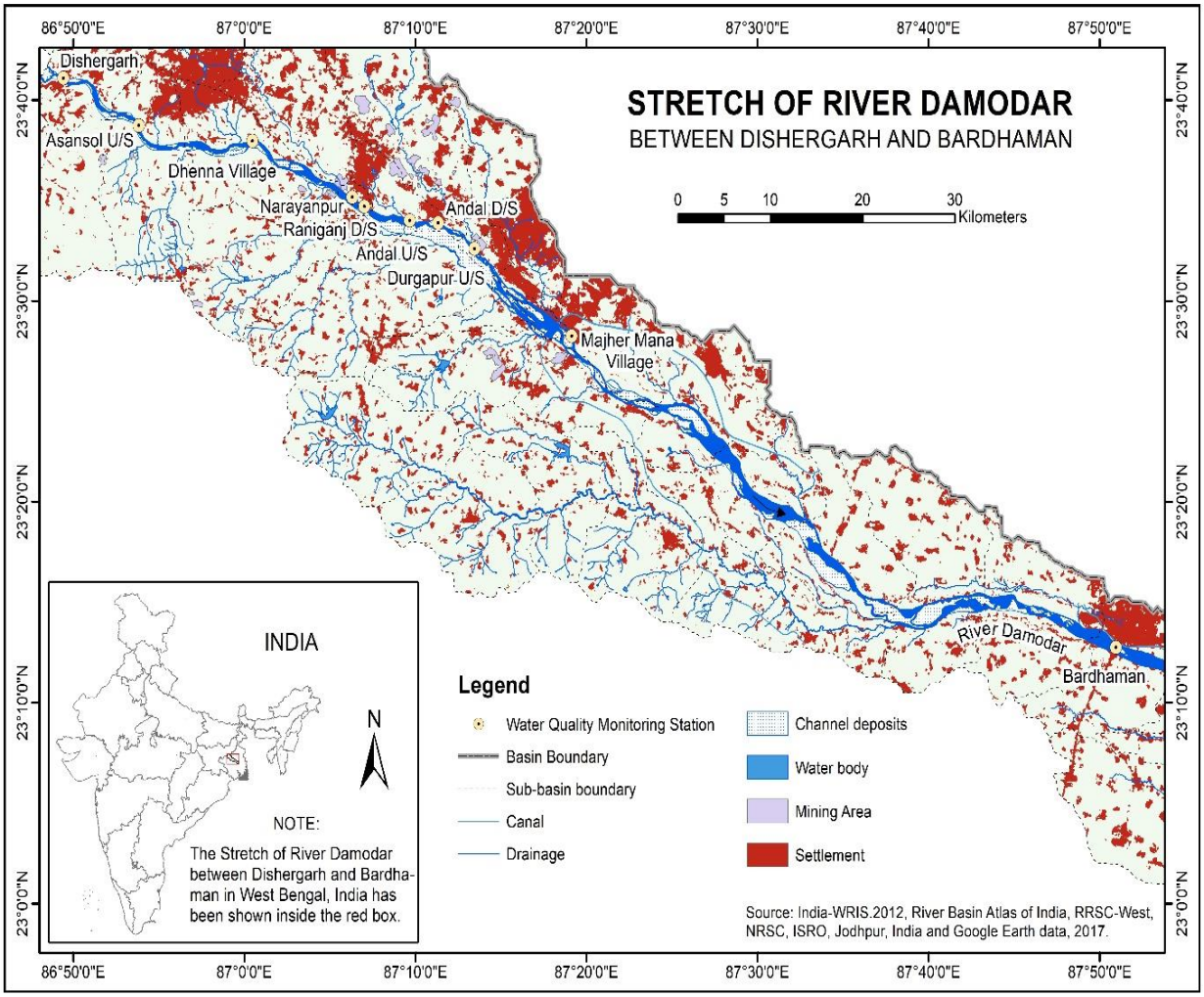

Fig. 1: Location of river Damodar from Dishergarh to Bardhaman. The water quality monitoring stations shown, here, are monitored regularly by West Bengal Pollution Control Board. U/S and D/S, here, refers to Upstream and Downstream respectively.

3. Database and Methodology

The study was done using the database which was generated by West Bengal Pollution Control Board (WBPCB), Department of Environment, Govt. of West Bengal as a part of National Water Monitoring Program (NWMP) started by Central Pollution Control Board (CPCB), Govt. of India in 1978 under Global Environmental Monitoring System (GEMS) (CPCB, 2007).

Twenty water quality parameters were observed every in pair from ten monitoring stations (See Fig. 1) located on the concerned river reach from Dishergarh to Bardhaman

with monthly frequency for the period of 4 years between 2014 and 2017. The water quality parameters which were selected for the present study include Faecal Coliform (F. Coli), Total Coliform (T. Coli), Turbidity, Total Suspended Solid (TSS), Chlorine (Cl^-), Total Alkalinity (TA), Nitrate Nitrogen (NO_3-N), Calcium (Ca^{2+}), Total Fixed Solid (TFS), Total Hardness (TH), Temperature, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Dissolved Solid (TDS), Electrical Conductivity (EC), Fluoride (F^-), Sodium (Na^+), Sulphate (SO_4^{2-}), and pH.

As stated by CPCB (2007), all the sampling stations are located upstream and downstream of significant pollution outfalls like city sewage drains and industrial effluent outfalls. All samples have been collected from well-mixed zone in order to make them well representative and a homogeneity test was performed by the concerned authority to identify the well-mixed zone.

Station No. 2: Asansol U/S had missing value for all parameters for March 2017 while Station No. 10: Burdwan Town had one missing value for Total Suspended Solids for July, 2015 and in the cells of all these missing data the average value of the concerned parameter for concerned month and station were used.

Four data points were found to be censored (Below Detectable Limit, BDL) and these occurred for Nitrate for February, April and June, 2017 for Station No. 2: Asansol U/S and for Fluoride for June, 2015 for Station No. 8: Durgapur U/S. Such 'BDL' of concerned cells for concerned parameter was replaced by 1/10th of detectable limit of concerned parameter.

Agglomerative Hierarchical Clustering technique was applied to determine the seasonal pattern of the water quality status while Spearman's Rho was used to evaluate influence of seasonality of prevailing climate.

According to Wenning & Erickson (1994) as cited in Wunderlin et al. (2001), Hierarchical Cluster analysis is the unsupervised pattern recognition technique wherein samples or variables are classified based on inter-sample or inter-variable similarities and in water quality study the technique uses similarities in magnitudes or variations in chemical and physical constituents of water to detect a definite pattern over the time or space. Whenever the technique is applied using monthly or seasonal time series data on water quality parameter the definite pattern if formed will ensure the presence of seasonal influence on water quality status (Shrestha & Kazama, 2007; Vega et al., 1998; Wunderlin et al., 2001).

The technique can be used either in R-mode or Q-mode. R-mode Cluster Analysis reveals the classification of the variables while Q-mode reveals the classification of cases (Reghunath et al., 2002). In the present study Q-mode clustering has been applied to classify the months (cases) to reveal the seasonal pattern of observed water quality parameters.

Ward's clustering procedure was used since it is considered to be the best method in the present context because (according to Sharma, 1996 as cited in Reghunath et al., 2002) it yields a larger proportion of correct classified observations than do most other methods and as a measure of similarity, the Squared Euclidean Distance was used since it is one of the most commonly adopted measures. However, prior to applying the technique, the original database was transformed into the standardized variables (z-score) with zero mean and unit variance since z-score based analysis helps avoiding the misclassifications arising from the different order of magnitude of both numerical value and variance of the input parameters (Vega et al., 1998).

Spearman's Rank Co-relation was applied to estimate the association between seasons and water quality parameters in view to trace the seasonal influence on individual water quality parameter. Following the procedure mentioned in Wunderlin et al. (2001), here, wet and dry i.e., monsoon and non-monsoon seasons respectively were coded by numerical value and then correlation between these values and individual water quality parameters was estimated. Same technique was followed to know the influence of month on water quality considering each month as the smallest seasonal unit.

4. Result and Discussion

The dendrogram (Fig. 2) clearly shows that 12 months can be grouped into four clusters if the rescaled Euclidean Distance for determining number of clusters is considered to be very close to 10 while the number of clusters will be 3 at the value very close to 11. Since there are four climatological seasons in the country as defined by India Meteorological Department (IMD, 2011), here, number of clusters has been fixed at 4 so that interaction between seasonality of climate and the water quality can be interpretated better and in Four-Cluster scheme (Table 1) it is observed that (i) January, February and March are forming Cluster 1, (ii) April, May and June are forming Cluster 2, (iii) Third Cluster is consisting of July, August, September and October and (iv) November and December comprise Cluster 4. Each cluster category, here, can be considered as hydrogeochemical season.

RRIJM 2015, All Rights Reserved

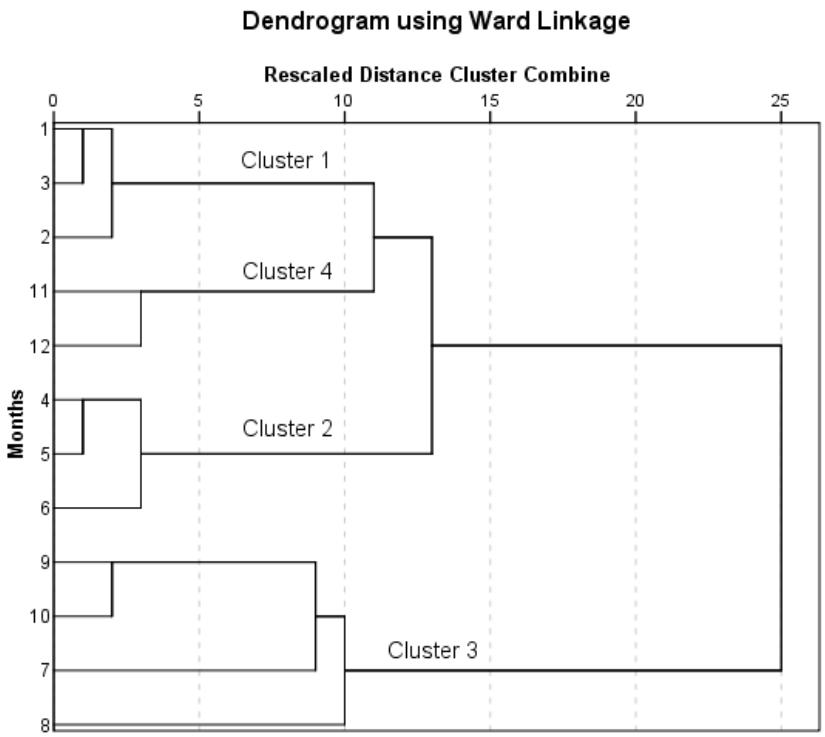

Fig. 2: Grouping of months to form cluster

As per the IMD given definition, four climatological seasons in India include (i) Pre-monsoon consisting of March, April and May (ii) Monsoon comprising June, July, August and September (iii) Post-monsoon which include October, November and December and (iv) Winter consisting of January and February. It is clearly observed that water quality of river Damodar responds to the change in climatological seasons but with a lag of one month.

The pre-monsoon seasons starts in the month of March and prevails till the end of May but water quality starts changing in the month of April and this changing status caused by pre-monsoon persists up to June (Cluster 2). In this month (June) Monsoon season already starts and it prevails till September while water quality starts changing in the month of July in response to monsoon and this changing status continues up to the month of October (Cluster 3) which means that the same water quality status under the influence of monsoon rain continues for another month even after the end of the Monsoon. So, Cluster 4 begins a month after the post-monsoon starts but both of them at the same time i.e., in the month of December which means that the effe Cluster 3 - monsoon season on water quality does not last long. Winter and Cluster 1 begin at the same time i.e., with the beginning of January but Cluster 1 ends one month after winter.

If only two climatological seasons are identified based on rainfall occurrences i.e., Wet Season (Monsoon Season) and Dry Seasons (Non-Monsoon season) and compared with Two-Cluster scheme (Table 1), the one-month lag, again, becomes clearly visible. Here, water quality seasons begins in the month of July and persists up to October. In Three-Cluster scheme also, the Cluster 3 (water quality season) which coincides with monsoon (climatological season) begins one month after monsoon starts and ends one month after the monsoon ends. So, with all these evidences it can be said that change in temperature a bit does not affect the stream water quality in the concerned stretch and the rainfall is the major driving force in controlling water quality status but it takes almost a month to cause noticeable change in the environment which leads alteration of stream water quality. It is obvious that a few spells are required for wetting the land cover before it makes response mechanical or chemical processes become active to cause change in stream water quality and that might be the reason for existence of one month lag between climate season and water quality season.

Table 1: Cluster membership of months

Month	4 Clusters	3 Clusters	2 Clusters	Month	4 Clusters	3 Clusters	2 Clusters
Jan	1	1	1	Jul	3	3	2
Feb	1	1	1	Aug	3	3	2
Mar	1	1	1	Sep	3	3	2
Apr	2	2	1	Oct	3	3	2
May	2	2	1	Nov	4	1	1
Jun	2	2	1	Dec	4	1	1

Note: 4-Clusters scheme has been accepted but the membership of 3 & 2 clusters scheme has also been mentioned.
Source: Computation was done by author using CPCB database.

RRIJM 2015, All Rights Reserved

The result of Spearman's Rank Correlation between month and individual water quality parameter (Table 2) shows that 7 parameters (BOD, COD, TA, Na^+, NO_3-N, SO_2^{-4} and EC) are not significantly related to months ($p > 0.05$) while rests i.e., 13 parameters show significant relationship ($p < 0.05$). Same result was found (Table 3) while evaluating the relationship of water quality parameter with hydrogeochemical seasons (i.e., cluster group of Four-Cluster scheme). Out of those parameters which show significant relationship with both month and cluster group, Turbidity and DO have maximum effect size. Turbidity shows 10.82% and 12.85% while DO shows 8.35% and 9.18 respectively for their relation with month and cluster group. This is clearly indicative of the fact that more seasonal effects are observed for both the parameters. Minimum effect size, on the other hand, is observed for TDS and TA for both the cases i.e., their relationship with month and cluster group (R square < 1%).

Table 2: Result of Spearman's Rank Correlation between month and individual water quality parameters

Parameters	Spearman's rho	*p-Value*	Remarks	Parameters	Spearman's rho	*p-Value*	Remarks
TDS	-0.091	0.047	Significant	Temperature	0.140	0.002	Significant
TSS	0.264	0.000	Significant	Turbidity	0.329	0.000	Significant
TFS	-0.148	0.001	Significant	DO	-0.289	0.000	Significant
F. Coli	0.106	0.020	Significant	BOD	-0.043	0.351	Not
T. Coli	0.114	0.012	Significant	COD	-0.046	0.314	Not
Ca^+	-0.170	0.000	Significant	TA	-0.021	0.653	Not
Cl^-	0.166	0.000	Significant	Na^+	0.007	0.887	Not
TH	-0.091	0.046	Significant	NO_3-N	0.030	0.514	Not
F^-	-0.280	0.000	Significant	SO_2^{-4}	0.026	0.569	Not
pH	-0.261	0.000	Significant	EC	-0.080	0.080	Not

Source: Computation was done by author based on CPCB data.

Table 3: Result of Spearman's Rank Correlation between hydrogeochemical season and the individual water quality parameters

Parameters	Spearman's Rho	p-Value	Remarks	Parameters	Spearman's Rho	p-Value	Remarks
DO	-0.303	0.000	Significant	TH	-0.090	0.049	Significant
Temperature	0.118	0.010	Significant	F^-	-0.269	0.000	Significant
TDS	-0.097	0.033	Significant	pH	-0.296	0.000	Significant
TSS	0.274	0.000	Significant	BOD	-0.029	0.523	Not
TFS	-0.148	0.001	Significant	COD	-0.017	0.711	Not
Turbidity	0.350	0.000	Significant	TA	-0.015	0.751	Not
F. Coli	0.131	0.004	Significant	NO_3-N	0.024	0.598	Not
T. Coli	0.131	0.004	Significant	SO_2^{-4}	0.062	0.177	Not
Ca^+	-0.167	0.000	Significant	EC	-0.067	0.143	Not
Cl^-	0.159	0.000	Significant	Na^+	0.006	0.888	Not

Source: Computed by author

DO, because of its chemical property, is inversely related to temperature. BOD on the other hand reflects the pollution caused by organic waste and DO depletes in the environment if BOD increases due to pollution i.e., both are negatively related to each other (Vega et al., 1998). But the noticeable fact, here, is that DO shows significant relation with both month and hydrogeochemical season while BOD does not. This indicates that DO, here, is solely controlled by temperature and not affected by BOD. The negative value of Spearman's Rank Correlation coefficient of DO also supports the view that its concentration decreases with the increase in water temperature.

Finally, it is observed that those parameters (e.g., BOD, COD etc.) which are indicative of human interference in water quality which usually happens by means of contamination of urban sewage and/or the industrial effluents do not show the relationship with seasons while the geogenic parameters (e.g., TSD, TSS etc.) which are mainly governed by rainfall and subsequent runoff are found to be affected by seasonality of the climate.

5. Conclusion

Evidences are strong enough to say that water quality status of the stretch of Damodar from Dishergarh to Bardhaman obviously follows the seasonality of the climate but with a lag of one month. Precipitation which is the seasonal phenomenon in prevailing monsoon climate is the dominant factor leading to alteration of stream water quality status. After onset of rainy seasons a few spells are required to cause the chemical alteration and mechanical translocation of the

RRIJM 2015, All Rights Reserved

geogenic substances which determine the water quality and that is why one month lag does exist between change in seasons and corresponding response in stream water quality.

The seasonality affects those individual water quality parameters which reflect the environmental contamination while sewage contamination that occurs owing to human activities like urban culture, industrial activity etc. does not make noticeable seasonal pattern in the water quality status.

Acknowledgment: The author thankfully acknowledges Mr. Raj Kumar Roy, M. Phil student, Department of Geography and Applied Geography, University of North Bengal for his assistance in collecting the database and preparing master table.

Reference

1. Banerjee, R., & Ghosh, A. R. (2012). Assessment of physicochemical attributes of River Damodar from Barakar its upstream zone to Burdwan the downstream zone. *Int J Current Res*, *4*(5), 26–31.
2. Britannica. (2017). *Damodar River, India*. https://www.britannica.com/place/Damodar-River#ref109293
3. Chatterjee, P. R., & Raziuddin, M. (2007). *Studies on the Water Quality of a Water Body At Asansol*. *6*(2), 289–292.
4. Chatterjee, S. K., Bhattacharjee, I., & Chandra, G. (2010). Water quality assessment near an industrial site of Damodar River, India. *Environmental Monitoring and Assessment*, *161*(1–4), 177–189. https://doi.org/10.1007/s10661-008-0736-1
5. CPCB. (2007). *Guidelines for Water Quality Monitoring, Central Pollution Control Board, Govt. of India.*
6. George, J., Thakur, S. K., Tripathi, R. C., Ram, L. C., Gupta, A., & Prasad, S. (2010). Impact of coal industries on the quality of Damodar river water. *Toxicological and Environmental Chemistry*, *92*(9), 1649–1664. https://doi.org/10.1080/02772241003783737
7. Ghosh, A. R., & Banerjee, R. (2012). Qualitative Evaluation of the Damodar River water flowing over the Coal mines and Industrial area. *International Journal of Scientific and Research Publications*, *2*(10), 1–6. www.ijsrp.org
8. Haldar, D., Halder, S., Das (Saha), P., & Halder, G. (2016). Assessment of water quality of Damodar River in South Bengal region of India by Canadian Council of Ministers of Environment (CCME) Water Quality Index: a case study. *Desalination and Water Treatment*, *57*(8), 3489–3502. https://doi.org/10.1080/19443994.2014.987168
9. IMD. (2011). *CLIMATE OF JHARKHAND, Climatological Series of State Series No. 17*. Climatological Publication Section, India Meteorological Department.
10. India-WRIS. (2012). *River Basin Atlas of India*. RRSC-West, NRSC, ISRO, Jodhpur, India.
11. Khadka, R. B., & Khanal, A. B. (2008). Environmental management plan (EMP) for Melamchi water supply project, Nepal. *Environmental Monitoring and Assessment*, *146*(1–3), 225–234. https://doi.org/10.1007/s10661-007-0074-8
12. Kumari, J. (2016). *Assessment of water quality index of damodar river in dhanbad, jharkhand*. 1–5.
13. MSME. (2012). *Brief Industrial Profile of BURDWAN DISTRICT, West Bengal, Ministry of Micro, Small and Medium Enterprises, Govt. of India.*
14. Mtethiwa, A. H., Munyenyembe, A., Jere, W., & Nyali, E. (2008). Efficiency of oxidation ponds in wastewater treatment. *International Journal of Environmental Research*, *2*(2), 149–152.
15. Mukherjee, D. (2012). Evaluation of Water Quality Index For Drinking Purposes In The Case of Damodar River, Jharkhand and West Bengal Region, India. *Journal of Bioremediation and Biodegradation*, *03*(09). https://doi.org/10.4172/2155-6199.1000161
16. Pejman, A. H., Nabi Bidhendi, G. R., Karbassi, A. R., Mehrdadi, N., & Esmaeili Bidhendi, M. (2009). Evaluation of spatial and seasonal variations in surface water quality using multivariate statistical techniques. *International Journal of Environmental Science and Technology*, *6*(3), 467–476. https://doi.org/10.1007/BF03326086
17. Reghunath, R., Murthy, T. R. S., & Raghavan, B. R. (2002). The utility of multivariate statistical techniques in hydrogeochemical studies: An example from Karnataka, India. *Water Research*, *36*(10), 2437–2442. https://doi.org/10.1016/S0043-1354(01)00490-0
18. Saha, P. (2010). Assessment of water quality of damodar river by water quality index method. *Indian Chemical Engineer*, *52*(2), 145–154. https://doi.org/10.1080/00194506.2010.485967
19. Shrestha, S., & Kazama, F. (2007). Assessment of surface water quality using multivariate statistical techniques: A case study of the Fuji river basin, Japan. *Environmental Modelling and Software*, *22*(4), 464–475. https://doi.org/10.1016/j.envsoft.2006.02.001
20. Singh, A., Deo, B., & Singh, S. P. (2014). Risk Analysis on the use of Damodar River Water for Drinking Purposes. *International Journal of Current Engineering and Technology*, *4*(1), 405–410. http://inpressco.com/category/ijcet
21. Sinha, D. K., Kumar, V., & Kumar, A. (2013). *Physiochemical qualities of Damoder river water and turbidity control studies in monsoon season*. *1*(2), 49–54.
22. Vega, M., Pardo, R., Barrado, E., & Debán, L. (1998). Assessment of seasonal and polluting effects on the quality of river water by exploratory data analysis. *Water Research*, *32*(12), 3581–3592. https://doi.org/10.1016/S0043-1354(98)00138-9
23. Verma, R. K., Murthy, S., Tiwary, R. K., & Verma, S. (2013). Evaluation of water quality index of Damodar River for drinking purpose using computer programming. *Asian Journal of Water, Environment and Pollution*, *10*(2), 27–40.
24. Wunderlin, D. A., María Del Pilar, D., María Valeria, A., Fabiana, P. S., Cecilia, H. A., & María De Los Ángeles, B. (2001). Pattern recognition techniques for the evaluation of spatial and temporal variations in water quality. A Case Study: Suquía River basin (Córdoba-Argentina). *Water Research*, *35*(12), 2881–2894. https://doi.org/10.1016/S0043-1354(00)00592-3

RRIJM 2015, All Rights Reserved