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IMPACT OF ADJACENT LAND USE, INFRASTRUCTURE AND URBANIZATION ON WATER QUALITY IN A RIVER FROM HEADWATER TO DOWNSTREAM

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Abstract - Generally, the rivers originate as a pure and clean stream from headwater but are then affected by type of adjacent land use and increased human intervention as they flow downstream. The mixing of surface drainage, pollutants and waste water from modified land use in river basin result broadly in reduced quality of water and increased decay of aqua life. The concentration of pollutants and abundance/ richness of macro invertebrate can be used to determine the impacts on stream quality throughout the course of flow.

Keywords - Localized Impact on River Water Quality, Presence of Pollutants, Physical / Chemical Investigation of Water Quality, Effects of Abundance/ Richness of Macro-Invertebrates.

I. INTRODUCTION

The European Union has declared Water as a natural heritage and a common asset to all humankind in its purest, clean and clear state with all water streams managed in natural way without pollution/ human modifications to preserve for next generations[1]. Tenenbaum has ascertained that the human being has been settling down around the river streams for availability of water for drinking, agriculture, food and fish, good environment and transportation means and has caused tremendous disturbance to ecology of water streams [2]. All these modifications have been made for wishful living of human being along water front to tame the nature for our domestic and commercial benefits, but all have resulted into disastrous consequences[3]. Now enormous efforts are being made to reverse these ecological modifications costing Billions of USD to restore the nature [4]. More and more research is being carried out to conserve the water heritage in its original biodiversity to use it in a sustainable manner [5]. The European Union Water framework Directive 2000 (EU WFD) has legally imposed on member countries to improve rivers quality through sustainable ecology and reduction/ prevention of pollutants to attain good water status by 2015 which has now been extended to 2022 [1].

The rivers are source of fresh water having enormous species of fish, macro-invertebrates and plants[6]. The diversity and abundance of all these categories dictate the water quality using different biomonitoring index such as BWMP/ASPT and South African Scoring System SASS ASPT evaluation 2014 etc[7]. The abundance and richness of biodiversity and physio-chemical properties of water in a stretch of a river have been a main index to check the water quality [8]. However, all these indexes show varying nature of results depending upon the land use type, rock formation/ strata, urbanization, sources of pollution and infrastructure adjacent to each site[7].

This study suggests that there is always a localized effect as the river flows from its headwater to downstream through human habitat/ infrastructures in different towns. The quality of water continues to deplete and biodiversity in the form of macroinvertebrates continue to decrease with an increase in dissolved salts/ minerals, ionization and pollution at different locations.

II.AIM/ OBJECTIVE

The aim of this study is to ascertain the impact of local land use, increasedinfrastructure and urbanization on river water quality from headwater to downstream.

III.METHODS

A. Study Sites

The River Wharfe has been taken as a case study which is a small river flowing through the valley of Wharfe dale in Yorkshire county of United kingdom with a stream length of around 100 Km before its confluence into River Ouse.First site was chosen near river head water in Beckermonds in Oughtershaw2nddown past Kilnsey, 3rd near AddinghamBolton Abbey, 4th near Otley and 5th to the lower reaches around Wetherby.

Figure1: Map of 5 sites on River Wharfe

Figure2: Site1

Figure3: Site2

Figure4: Site3

Figure5: Site4

Figure6: Site5

B. Field Sampling

Kick sampling method was used in collection of samples. The sampling party agitates the river bed for 3 minutes and use a net attached to a rod, dipped vertically downstream of disturbed bed to collect floating macroinvertebrates. Filtered water sample was collected using syringes and filters to collect water in bottles to examine later in the laboratory for chemical testing. Different electronic probes were used to check pH, electric conductivity, temperature and dissolved oxygen.

C. Data Analysis Methodology - All the data collected from all 5 sites was summarized/ formattedinto excel datasets and later on same was transferred into csv files to import to RStudio statistical software[9]. The RStudio software alongwith vegan package was used to calculate, richness, count, BMWP-ASPTwas used for analysis. MS Excel was used to prepare tables and graphs.

IV. RESULTS

It was assumed with this study that local conditions of a catchment area in any river stretch greatly

influence the biodiversity and physio-chemical properties of water due to human intervention and infrastructure. During scrutiny of results with RStudio and MS Excel following has been inferred:

A. Family Summary of Macroinvertebrates

The summary of major macroinvertebrates is given in Table I which shows that the most taxonomic richness is for Dytiscidae whose abundance id maximum at site 1 with count of 83 whereas it is decreasing with a continuous trend from site 1 to site 5. The mean value for Chironomidae is 14 at site 1 but decreasing to site 5 except site 3.

Family		Site.1	Site.2	Site.3	Site.4	Site.5
Athericidae	: 1	Min. : 1.0	Min. : 1.000	Min. : 1	Min. : 1.000	Min. :1.000
Baetidae	: 1	1st Qu.: 3.5	1st Qu.: 1.000	1st Qu.: 2	1st Qu.: 1.000	1st Qu.:1.000
Capniidae	: 1	Median : 6.0	Median : 2.000	Median : 6	Median : 2.000	Median :1.000
Chironomidae	: 1	Mean :14.0	Mean : 7.824	Mean :11	Mean : 5.353	Mean :3.667
Chloroperlidae	: 1	3rd Qu.:10.5	3rd Qu.: 8.000	3rd Qu.:22	3rd Qu.: 7.000	3rd Qu.:5.000
Dytiscidae	: 1	Max. :83.0	Max. :51.000	Max. :29	Max. :29.000	Max. :9.000
(Other)	:23	NA's :13	NA's :12	NA's :12	NA's :12	NA's :26

Table I: Family Richness and Abundance Summary of Macroinvertebrates in River Wharfe

B.BMWP-ASPT Results

BMWP-ASPT is used widely by Environmental Agency UK and other river biological monitoring trusts like Ouse and Auder River Trust [7]. RStudio vegan package was used to calculate BMWP-ASPT for the collected data for invertebrates.Site 1 to 3 have highest BMWP and ASPT values whereas site 4 and 5 have lesser BMWP-ASPT values as shown in Table II. A linear decreasing trend is visible from the Table II and Figure 8 of BMWP-ASPT relationship for all 5 sites starting from head to tail of the river.

Site	BMWP	Ntaxa	ASPT
Site1	95	14	6.79
Site2	118	16	7.38
Site3	97	16	6.06
Site4	90	15	6.0
Site5	14	2	6.0

Table II: BMWP-ASPT for 5 Sites on River Wharfe Calculated using Rstudio Vegan Package

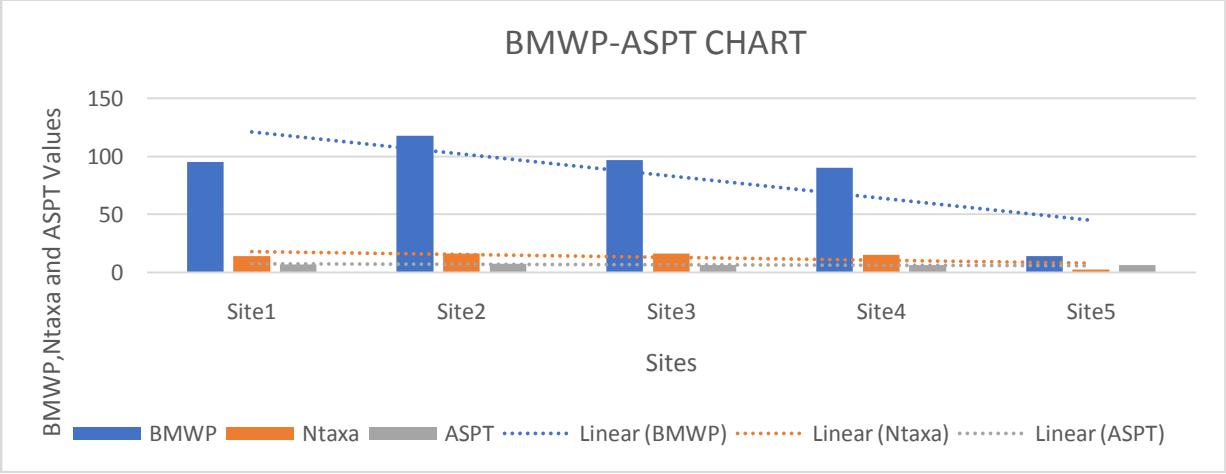

Figure 8: BMWP-ASPT decreasing trends from site 1 to site 5 showing depletion of water quality

C. Physical Properties Results

The physical properties of river Wharfe water were recorded in all the sites as shown in Table III. It was assessed that temperature of water is increasing from site 1 to site 5 by almost 2.5 degrees centigrade between a 100 Km length of river which shows a climatic effect from mountainous headwater location to comparatively plain areas in populated towns/ city of Leeds. pH is increasing from 7.754 to 8.9 which shows conversion of neutral water status to alkaline nature of water and conductivity is increasing from 54 (at site 1) to 319 µS/cm (at site 5)due to increased mixing of salts mainly from farm land chemical fertilizers, surface runoff from urban polluted roads and more organic material from sewage leakages in the water[10].

Site	Water temp (deg C)	pH	DO (mg/L)	Elec. Conductivity (µS/cm)
1	5.4	7.574	11.542	53.9
2	6.3	8.52	11.78	148.7
3	6.4	8.404	11.934	257.5
4	6.9	8.906	15.59	297
5	6.6	8.76	14.33	319

Table III: Physical Properties of Water in River Wharfe

D. Chemical Properties

Water samples taken from each site were tested in laboratory and different metals/ minerals/ ions have been found in the water as shown in Table IV. The cells shown in green show very meager amount of salts/ minerals and can be considered negligible/ non-impacting.The values in yellow have little impact but the values highlighted with light red to sharp red are of more significance to ascertain the presence of salts/ minerals/ pollution in the water. A noticeable concentration of nutrients like Nitrates, Phosphates and dissolved organic/ inorganic Carbons. The nutrients like Nitrates, Phosphates and Sulphates are present in the water in the form of Ammonia NH4_ ion, N2, NO_2 _, NO_3 _, PO4_ and SO4_. Similarly, noticeable concentration of metals like Calcium, Sodium, Magnesium, Silicon and Potassium. All these have been found in all sites which have increasing abundance trend from site 1 to site 5. The main sources of these salts/ metalsare increased pollution from urbanization, population, fecal bacteria, sewage mixing, industrial wasteand fields/ crops using chemical fertilizers[11].

Site	NH4_N	?(NO2_N + NO3_N)	NO2_N	PO4_P	DOC	DIC	DC	Suspended Solids	Al 396.152 {85} (Radial)	Ca 317.933 {106} (Radial)	Fe 238.204 {141} (Radial)	Mg 279.553 {120} (Radial)	Mn 259.373 {130} (Radial)	Na 589.592 {57} (Radial)	Si 212.412 {458} (Radial)	Ni 231.604 {445} (Axial)	Pb 216.999 {455} (Axial)	Cu 324.754 {104} (Axial)	Zn 213.856 {457} (Axial)	K 766.490 {44} (Radial)	Cl	NO3	SO4	NO3_N
2018site_1	0.031	0.02	0.001	0.006	23.6	4.3	27.9	4.6	0.049	6.2	1.05	1.68	0.06	3.58	1.35	0.001	0.002	0.003	0.002	0.17	4.7	0.1	4.3	0.019
2018site_2	0.03	0.04	0.001	0.006	27.7	18.4	46.1	3.3	0.033	29.1	0.57	2.58	0.01	3.89	1.22	0	0.001	0	0.002	0.4	4.6	0.3	5.1	0.039
2018site_3	0.029	0.49	0.01	0.014	6.1	32.4	38.6	1.2	0.012	44.6	0.07	7.06	0.01	6.66	2.23	0	0.001	0	0.003	2.02	8.3	2.6	12.3	0.48
2018site_4	0.022	0.86	0.005	0.011	7.1	34.3	41.3	1.9	0.016	57	0.1	4.96	0.01	8.97	0.84	0	0.002	0.001	0	1.68	12.4	4.6	12.1	0.855
2018site_5	0.028	0.96	0.003	0.007	28.2	33.2	61.4	4.7	0.014	56.3	0.08	5.65	0	9.17	1.17	0	0.002	0.001	0	1.58	12.8	5	14	0.957

Table IV: Chemical Properties of Water in 5 sites on River Wharfe

V. DISCUSSION

The hypothesis that adjacent land use and increased infrastructure/ urbanization cause localized impact on water quality in river Wharfe from headwater to downstream has been supported by the results. The samples have been taken from Site 1 near headwater to site 5 downstream in increased populated areas. The samples have been tested in laboratory and results have been analyzed using RStudio, MS Excel and different parameters/ standards set by water monitoring organizations. An overall good standard of water quality has been assessed in River Wharfe.

A. Biodiversity in River Wharfe

The decreasing trend has been observed from site 1 to site 5 in family richness and abundance in almost all the macro invertebrates which clearly show the quality of water is decreasing from site 1 to site 5. This decreasing trend support the hypothesis that biodiversity decreases with downstream stretch as the river flows through areas of human intervention/ population. The graph in Figure 9 and 10 below show the decreasing trendlines in count of macroinvertebrates from headwater site 1 to site 5 in most populated catchment area.

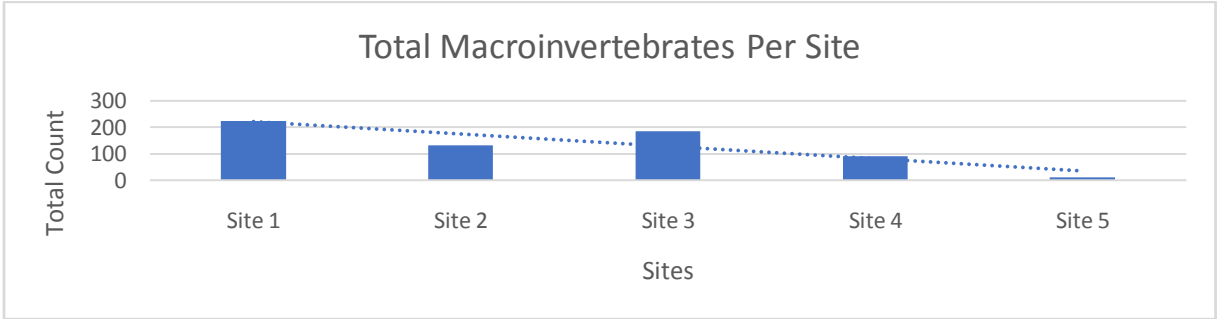

Figure 9: Decreasing Trend for Total Macroinvertebrates Per Site from Site 1 to Site 5 - River Wharfe

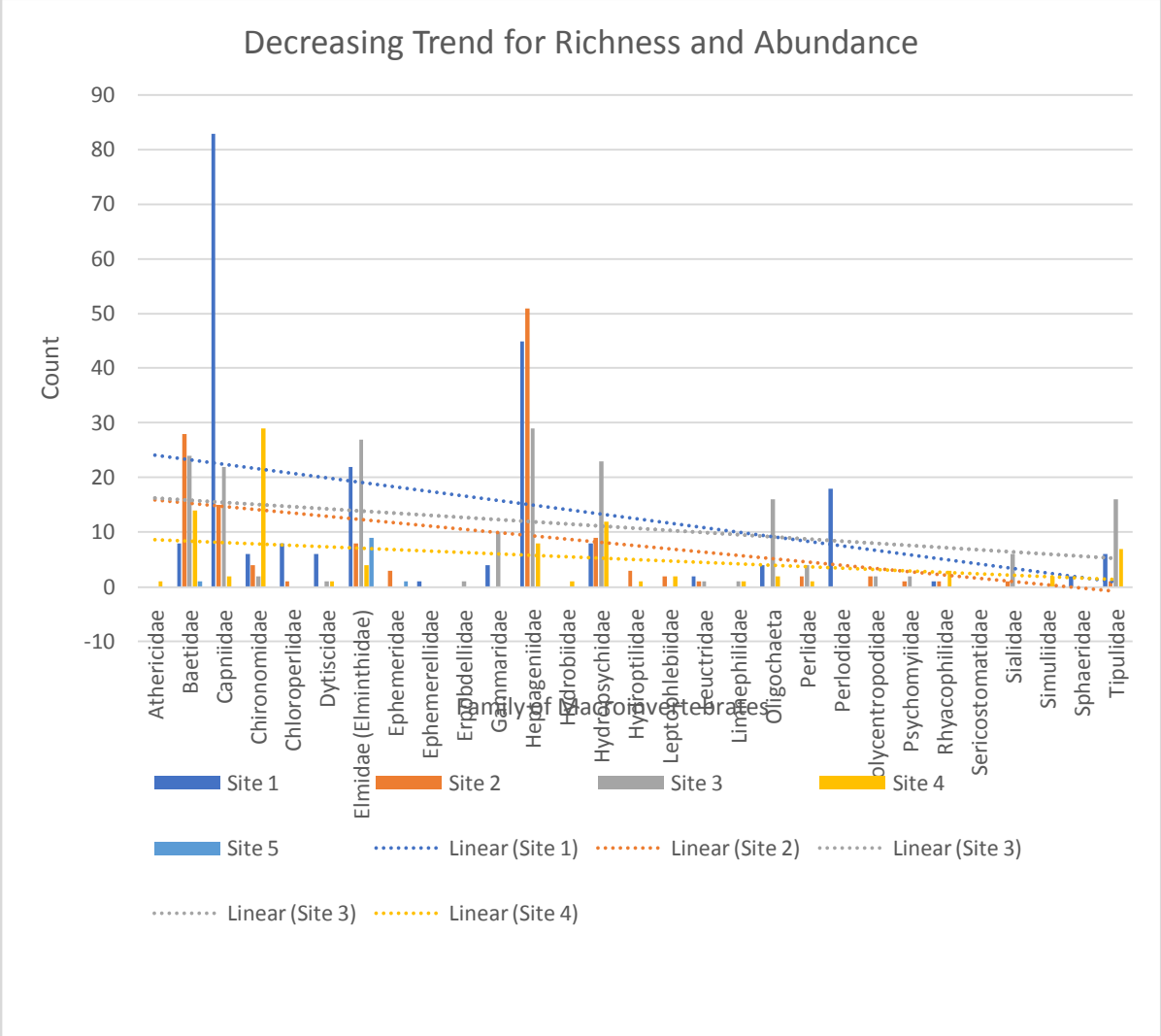

Figure 10: Decreasing Trend for Richness & Abundance of Macroinvertebrates from Site 1 - Site 5

B.BMWP-ASPT Values

Quality of water monitored by abundance and family richness of macroinvertebrates in River Wharfe shows that overall quality of water is good (BMWP>80 and ASPT >=6) as given in Table V[7]. However, first 2 sites in Dale National Park with excellent preserved sheep grazing land around and meager urbanization/ infrastructure are better in water quality followed by site 3, 4 and 5.

BMWP		ASPT	
BMWP Score	**Biological Quality**	**ASPT**	**Water quality**
Over 130	A. Very good biological quality (natural)	Over 7	Very good (natural)
81 – 130	B. Good biological quality	6.0 – 6.9	Good
51 – 80	C. Fair biological quality	5.0 – 5.9	Fair
11 – 50	D. Poor biological quality	4.0 – 4.9	Poor
0 – 10	E. Very poor biological quality	3.9 or less	Very poor

Table V: Biological quality index [11]

C. Physical Properties

The graph in Figure 11 shows an increased worsening trend in physical properties of river Wharfe water especially in electric conductivity (increased by 6 times from site 1 to site 5) due to mixing of salts and waste. Physical properties are deteriorating as the

population/ urbanization and misuse of farm land with chemicals is increasing along the river stream. Due to small flow, shallow water and uneven beds in site 1 and 2, dissolved oxygen is comparatively lesser here as compared to site 3 to 5 where water flow is wavier with rocky deep beds. The overall water quality is good and within permissible parameters for fresh water pH 6.5 – 8, DO more than 5 mg/L and electric conductivity less than 600 µS/cm [12],[13], [14].

Figure 11: Physical properties worsening trend from site 1 to site 5 – River Wharfe

D.Chemical Properties – Nutrients, Metals and Dissolved Organic/ Inorganic Matter

The increasing trends in metal particles have been shown with moving line trends for each site in graph in Figure 12. The graph and trend line show maximum concentration of metal particles for site 3 to 5. The nutrients like Nitrates, Phosphates and Sulphates are present in the water in the form of Ammonia NH4_ ion, N2, NO_2 _, NO_3 _, PO4_ and SO4_ with main sources from runoff from fields using chemical fertilizers, roads runoff, sewage leakages, human/ animal secretes and dissolved nutrients in soil as shown in the figures 13 and Figure 14[15]. Dissolved organic/ inorganic carbon have their sources from dead plants, organism, human/ animal secrets, pollution from surface runoff from roads, industries, soil, smelting of minerals/ mines and chemical fertilizers used by farmers in adjacent farm lands in the catchment areas[10]. The metals are coming from sources like natural erosion of sediments, rocks, smelting of mines, runoff from polluted roads/ surfaces/ garages/ industry. These metals are useful ingredients of ecosystem but their excess causes toxicities in fish, aqua organism, transported to agriculture by irrigation water and consumed by human being causing grave consequences for all users[11].

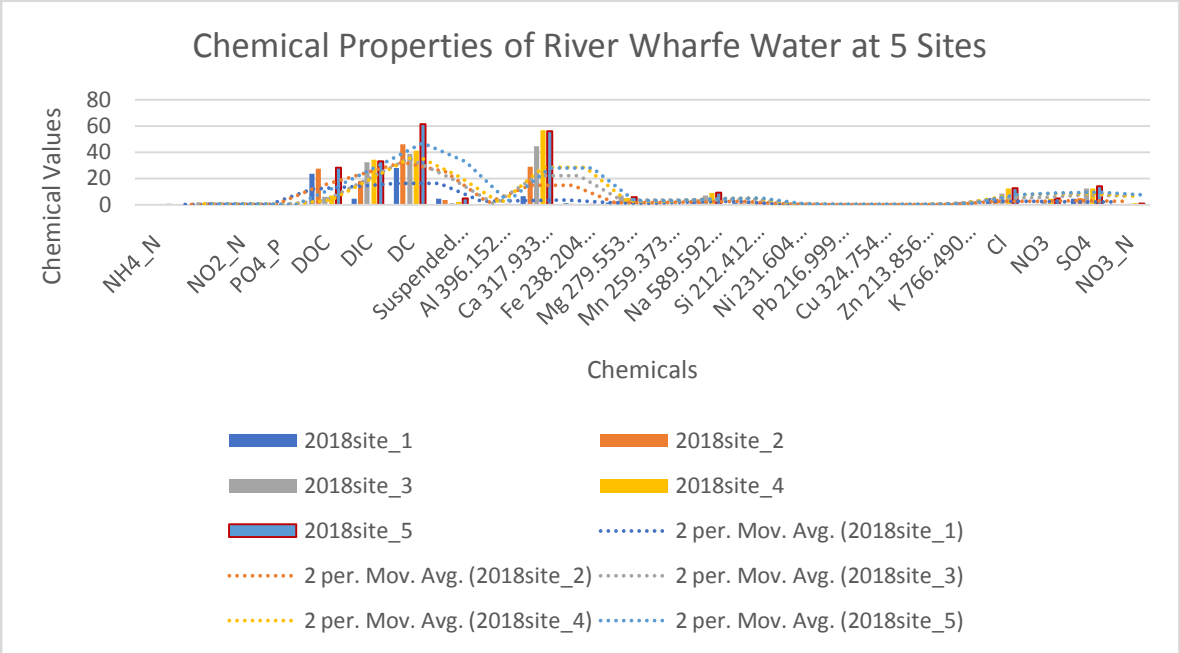

Figure 12: Chemical Properties of River Wharfe Water at 5 Sites

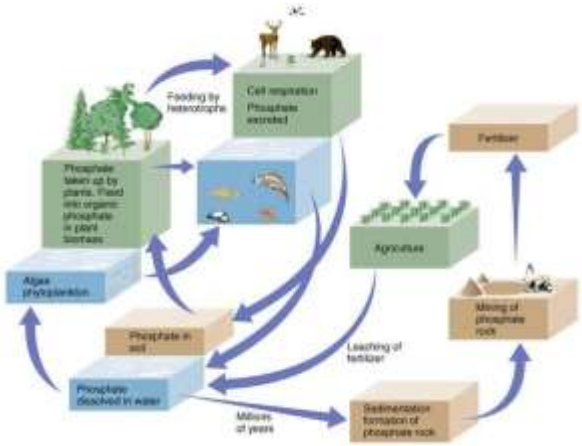

Figure 13: The phosphorus cycle. [15]

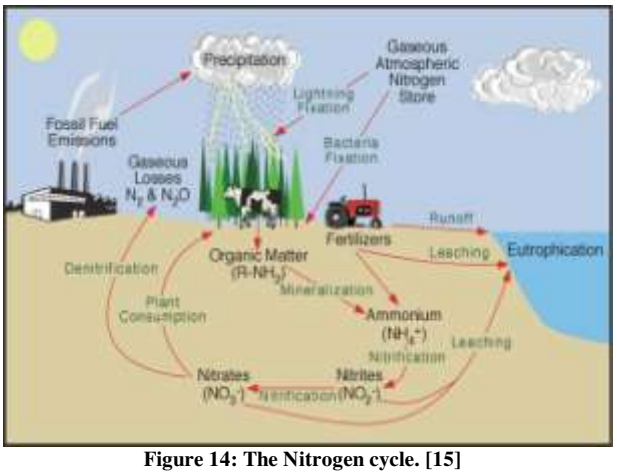

Figure 14: The Nitrogen cycle. [15]

Site 1 having very less intervention is best in quality, site 2 has some impacts from Cool Scar Quarry and tourist attraction parks/ waterfall and shows a little deterioration[16]. Site 3 is better in some respects but overall getting more deterioration in water quality due to local impact of urbanization and pollution. Site 4 and 5 are the most affected sites. The increasing trend of total dissolved minerals/ metals/ salts in Figure 15 support this finding of deterioration by localized impacts.

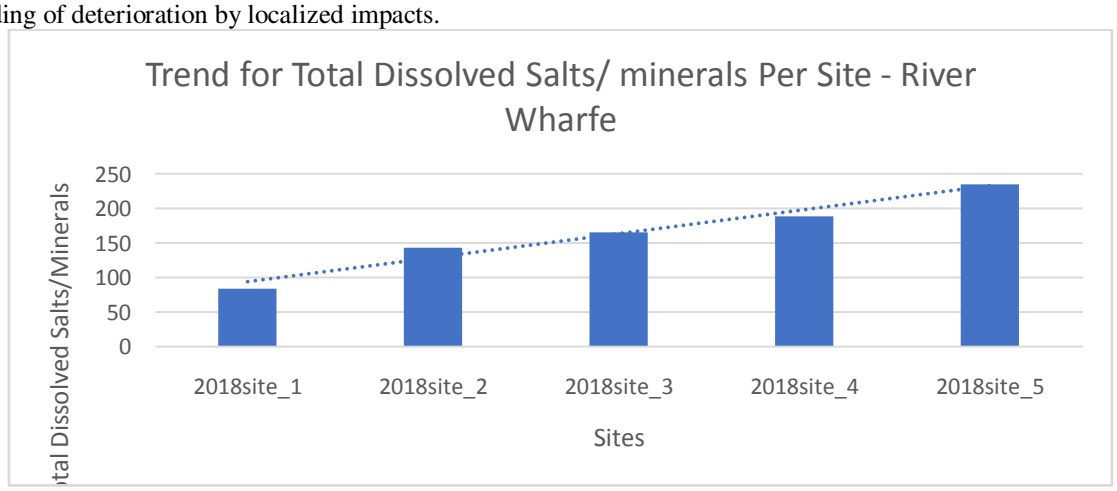

Figure 15: Increasing Trend for Total Dissolved Salts/ minerals Per Site - River Wharfe

VI. CONCLUSION

The overall water quality of River Wharfe is well within the parameters/ standards as it has been declared a "good river" with excellent quality in UK as per EU WFD 2000 as shown in Figure 16 [15],[17], however decreasing trend of water quality is visible from headwater to downstream areas with the impacts from increased urbanization/ population and adjacent land use by farmers, industries and other man-made facilities. Therefore, there is an immediate need to control/ monitor the different types of land uses in the light of regulations like EU water framework directive to avoid disturbing the river quality and ecology.

The world now, needs to pay attention to maintenance of natural assets in their purest forms for the future use by coming generations along with survival of aqua life in befitting ecological balance.

Figure 16: Quality Status of Wharfe River. [15].
Notes: River water quality classification: Blue = 'excellent'; Green = 'good'; Yellow = 'fair'

REFERENCES

[1] European Union Water framework Directive 2000.
[2] Tenenbaum, David J. (2010). River health: Finding fixes published in The why files: the science behind the news by University Of Wisconsin Board Of Regents in 2010 available at https://whyfiles.org/2010/river-health-finding-tonics/
[3] NMRMR,2018. National Mississippi River Museum Report , 2018 available at http://www.shootforthemoon.com/our_work/river-museum-expansion/
[4] Birch, J.C., Newton, A.C., Aquino, C.A., Cantarello, E., Echeverría, C., Kitzberger, T., et al.,2010. Cost-effectiveness of dryland forest restoration evaluated by spatial analysis of ecosystem services. Proc. Natl. Acad. Sci. 107, 21925–21930.
[5] Allison, S.K., 2012. Ecological Restoration and Environmental Change: Renewing Damaged Ecosystems. Routledge.
[6] Walther, John V., 2013. Earth's Natural Resources. Published by Jones & Bartlett Publishers on 15 February 2013, ISBN 978-1-4496-3234-2.
[7] Smith Jim,2018. Jims's Diary: Monitoring changes in habitat over time: Biological Monitoring - Ouse and Adur Rivers Trust available at https://oart.org.uk/our-work/projects/water-quality/biological-monitoring
[8] Gonzalez, E., Rochefort, L., Boudreau, S., Hugron, S., Poulin, M., 2013. Can indicator species predict restoration outcomes early in the monitoring process? A case study with peatlands. Ecol. Indic. 32, 232–238.
[9] RStudio Development Core Team, 2018. RStudio: A Language and Environment for Statistical Computing R Software Foundation for free open source Statistical Computing.
[10] EPA. (2014, February). Sediments. In Water:Pollution Prevention & Control. Retrieved from http://water.epa.gov/polwaste/sediment
[11] USGS, 2018. Water Qualities Indicators by South Atlantic Water Science Center (SAWSC), US Geological Survey available at http://ga.water.usgs.gov/edu/characteristics.html,
[12] RAMP,2018. Water Quality Indicators: Conventional Variables. Published online by Regional Aquatics Monitoring Program (RAMP) Alberta, Canada available at http://www.rampalberta.org/river/water+sediment+quality/chemical/conventional.
[13] EPA. (2012). 5.9 Conductivity. In Water: Monitoring and Assessment. Retrieved from http://water.epa.gov/type/rsl/monitoring/vms59.cfm
[14] Talling, J.F. and I.B. Talling. 1965. The chemical composition of African lake waters. Rev. ges. Hydrobiol. 50: 421-463
[15] Hime, S., Bateman I.J., Posen, P. and Hutchins, M. (2009) 'A transferable water quality ladder for conveying use and ecological information within public surveys, ChREAM project, Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia.
[16] McCarthy Michael,1998. Quarrying in beauty spots to end published by Independent on Monday 29 June 1998 available at https://www.independent.co.uk/news/quarrying-in-beauty-spots-to-end-1168374.html
[17] EFTEC, 2010. Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal Case Study 4 – Valuing Improvements in River Water Quality Submitted to Department for Environment, Food and Rural Affairs in February 2010 available at www.eftec.co.uk