

Water quality and land use land cover analysis of Pawna River: Lifeline of sister city of Pune, India

Patil SS^{1*}, Gabale S², Padade G³, Durugkar T⁴, Jalamkar S⁵, Mawal S⁶

^{1,4,6} Department of Environmental Sciences, Savitribai Phule Pune University, Pune, Maharashtra, India

^{2,3} Unity Geospatials LLP, Kothrud, Pune, Maharashtra, India

Abstract

River Pawna is the major river with historical background flowing through the jurisdiction of Pimpri-Chinchwad (PCMC), also known as a sister city of Pune, one of the fastest growing metropolitan cities of India. Rapid urbanization and industrialization is putting huge pressure on the existing limited environmental resources and infrastructure. Discharge of tremendous untreated domestic sewage, industrial waste is further deteriorating the quality of river Pawna. In this study for the first time, we aimed to map the discharge inlets into river Pawna using geographical information system (GIS) using advanced softwares. This has led to the information about the pollution load entering the river Pawna at various points (stations) along its flowpath, the information which is non-existent till date. We believe, this information will lead to the better understanding of pollution sources, their pollution load and remedial methods. This information will also help the local city corporation such as PCMC to plan the preventative and control measures to curb the pollution and levy strict regulatory actions against the culprits. Likewise this first-of-its-kind of GIS based maps created for river Pawna will guide the River Rejuvenation program outlined under Swatchha Bharat Mission by Government of India.

Keywords: River Pawna, Land Use, Land Cover, Pollution

1. Introduction

Water is one of the precious and very useful natural resources present on the surface of the earth as all life depends on water for its survival. The most important role of water in our daily life is known to all of us and Water is also an important aspect of socioeconomic and ethnic development of the civilization of the earth. Out of the 70% of the water that is available only 2.5% water is freshwater out of which only 1% of the freshwater is easily assessable rest is trapped in glaciers and snowfields.

The biggest concern of every developing country is the availability of the safe drinking water to every individual. According to the UN report 2019 the use of water has been increasing worldwide by about 1% every year since 1980's due to population growth, socioeconomic development and changing consumption patterns. This is expected to grow at the same rate till 2050 accounting for an increase of 20 to 30% above the current level of water use, mainly due to rising demand in industrial and domestic sectors. Over 2 billion people live in countries experiencing high water stress, and about 4 billion people experience severe water scarcity during at least one month of the year. Stress levels will continue to increase as demand for water grows and the effects of climate change intensify (UN Report 2019).

According to UN report (2019) three out of ten people (2.1 billion people, or 29% of the global population) did not use a safely managed drinking water service in 2015, whereas 844 million people still lacked even a basic drinking water. Of all the people using safely managed drinking water services, only one out of three (1.9 billion) lived in rural areas (WHO/UNICEF, 2017a).

The main use of water apart from drinking and domestic is for agriculture purpose as 69% water is used for irrigation, out of which 15-35% of irrigation withdrawals are

unsustainable. With an increase in demand of water in past few decades it is observed that most of the population is shifting from surface water to groundwater thereby increasing the stress of water in every aspect.

Rivers are the most important sources of the surface water as most of the agricultural practices still depend on river water as it is cheap and convenient for irrigation. As per the current scenario on river pollution in India has reached a point of crisis due to unplanned urbanization and rapid growth of industrialization. The surface water quality mainly the river water is very important as it is generally used for multiple purpose such as drinking, domestic, agriculture (irrigation), hydroelectric power plants, infrastructure development, etc. so the assessment of water quality is an important aspect. The assessment of water quality includes various physiochemical parameters and monitoring of this parameter is of utmost important to quantify the danger and the risk of water borne diseases. Sustainable development and healthy aquatic ecosystems depend on the quality and quantity of fresh water. The physicochemical properties will also help in the identification of pollution sources, for conducting further investigations on the eco-biological impacts and also for initiating necessary steps for remedial actions in case of polluted water bodies.

This study will shed light on Pawna River which flows through the cities of Pimpri and Chinchwad (known as sister Cities of Pune, a metropolitan city of India) and carries a huge load of sediments, chemicals, and various industrial discharges. Considering the urban sprawl and rapid industrial growth of the area in past few decades it is necessary to monitor the water quality of the river periodically; therefore, present investigation aims at insight about the level of contaminants of surface water of selected locations at Pawna river of Pimpri-Chinchwad area of Pune

2.2. Water quality analysis

Table 1: Details of Pawna River and Nalas water sample location points

River Location				Nalas Location		
Sr No	Location	Latitude	Longitude	Location	Latitude	Longitude
1	NH 4	18°38'42.81"N	73°44'20.79"E	Udyognagar stream	18°37'42.77"N	73°47'23.51"E
2	Ravet Bandhara	18°38'24.79"N	73°44'50.93"E	Kasarwadi stream	18°36'19.74"N	73°48'56.96"E
3	Ganesh Ghat	18° 38' 28.08" N	73° 45' 14.61" E	Ambedkar nagar Stream	18°37'29.38"N	73°47'44.18"E
4	Kesubai Ghat	18°37'31.22"N	73°46'12.98"E	Dapodi stream	18°35'21.72"N	73°49'44.19"E
5	Morya Gosavi Ganesh	18°37'31.11"N	73°46'41.45"E	Sanghvi	18°34'46.68"N	73°49'14.06"E
6	Kalewadi RD	18°37'2.79"N	73°47'8.93"E	Ravet stream	18°38'29.98"N	73°44'56.97"E
7	Kalewadi Bridge	18°37'35.05"N	73°47'33.96"E	Tathawade stream	18°37'31.33"N	73°45'52.27"E
8	Kasarwadi	18°36'7.83"N	73°49'18.16"E	Pimpri goan stream	18°36'35.07"N	73°47'42.69"E
9	Pimple Gurav	18°35'16.33"N	73°49'45.19"E	Walhekarwadi stream	18°37'37.97"N	73°46'20.04"E
10	Sanghvi	18°34'32.72"N	73°49'31.53"E	Thergoan	18°37'4.02"N	73°46'55.81"E
11	Kranti Nagar	18° 36' 18.69" N	73° 48' 51.89" E	Pimple gurav stream	18°35'50.58"N	73°49'5.21"E

For study purposes, the water samples were collected from 22 locations as 11 samples of river water and 11 natural streams (Nalas) from different locations along Pawna flow path. The GARMIN GPS was used to locate the exact coordinate of sample collection for monitoring purposes. Samples were collected from the river and natural stream channels during post-monsoon (December) in the year 2018-19. Methods of collection and analysis of water samples followed are essentially the same given by (APHA 1998). Samples were collected in polythene bottles (2L). Prior to the collection, bottles were thoroughly washed with diluted HNO₃ acid and then with distilled water in the

laboratory before filling bottles with samples. Each bottle was rinsed to avoid any possible contamination and every other precautionary measure was taken. Calcium (Ca⁺²) and magnesium (Mg⁺²) were determined trichromatically using standard EDTA. Chloride (Cl⁻) by standard AgNO₃ titration. Sodium (Na⁺) and potassium (k⁺) were determined by flame photometry. Sulfate (SO₂⁻), Nitrate (NO₃⁻), phosphate (PO₄⁻) were determined by spectrophotometer. Electrical conductivity (EC), PH and total dissolved solids (TDS) measurements were performed *in situ* with potable pH, EC and TDS meter and also it was carried out inside the lab to check the accuracy of results.

2.3. Land use land cover analysis

Table 2. The area and percentages of the different classes within the 1km radius of the Pawna River

Classified Data of Pawna River within 1 Km Statistics			
Class	Area Sq_m	Area Sq_Km	Percentage of Total Area
Built-up	12230075	12.230075	30%
Barren	9075350	9.07535	22%
Low dense Vegetation	7618375	7.618375	19%
Agriculture	5715050	5.71505	14%
Fallow	5098050	5.09805	13%
Water	920450	0.92045	2%
Total	40657350	40.65735	100%

The Land use land cover classification of the area within the 1Km radius was done using the LISS IV imagery. Two Scenes of LISS IV with 5.8 meter resolution, dated 5th April 2018 and 12th March 2018 is used to prepare the LU/LC map of the given area. The imagery was taken from NRSA Hyderabad. Both scenes were georeferenced and mosaic and the LU/LC categories were identified on the basis of standard image interpretations key like tone, texture shape, pattern and association etc. using a supervised classification. The purpose of the land use land cover classification is to identify and understand the impact of pollution based on the land categories. Considering the different aspects six different Categories of LU/LC have been identified in the area those are Water, Low Dense Tree Cover, Agriculture, Fallow, Built-up and Barren. The data classification is based on National Natural Resources Information System (NNRIS) scheme of classification. For the analysis purpose the 1 km buffer area is considered from the river as majority of the sample points are located along the river.

3. Results and Discussion

Surface water quality assessment is an important aspect to find out the best suitability practices. River water of Pawna has been used for various purposes. The irrigation practices put serious pressure on available resources. The literature review by Eknath *et al.*, (2013) ^[4] explain that water has the ability of adverse effect on health and fish population at the reservoir. The current study helps to identify, assessment of the Pawna River which gives a preliminary idea of water quality how water quality fluctuates with the different station and anthropogenic sources. The surface water sample was examined for the assessment of water quality. The study elucidates that water is getting polluted due to many points and non-point sources of area. Majorly untreated sewage and agricultural runoff are the causative factors for pollution in the study area. The village residing around the river bank does not have proper sanitation facilities and many of the population have open drainage. As the sample points are more or less evenly scattered the

Inverse Distance Weighting (IDW) interpolation was used assuming closer values are more related than father values with its function. The IDW is convex interpolation method that fits only the continuous model of spatial variation, which helps to derive the value of a variable at some new

location using values obtained from known locations (ESRI, 2005). All the measured points (water quality data) were used in the calculation of each interpolated cell (water quality grid).

3.1 pH and electrical conductivity

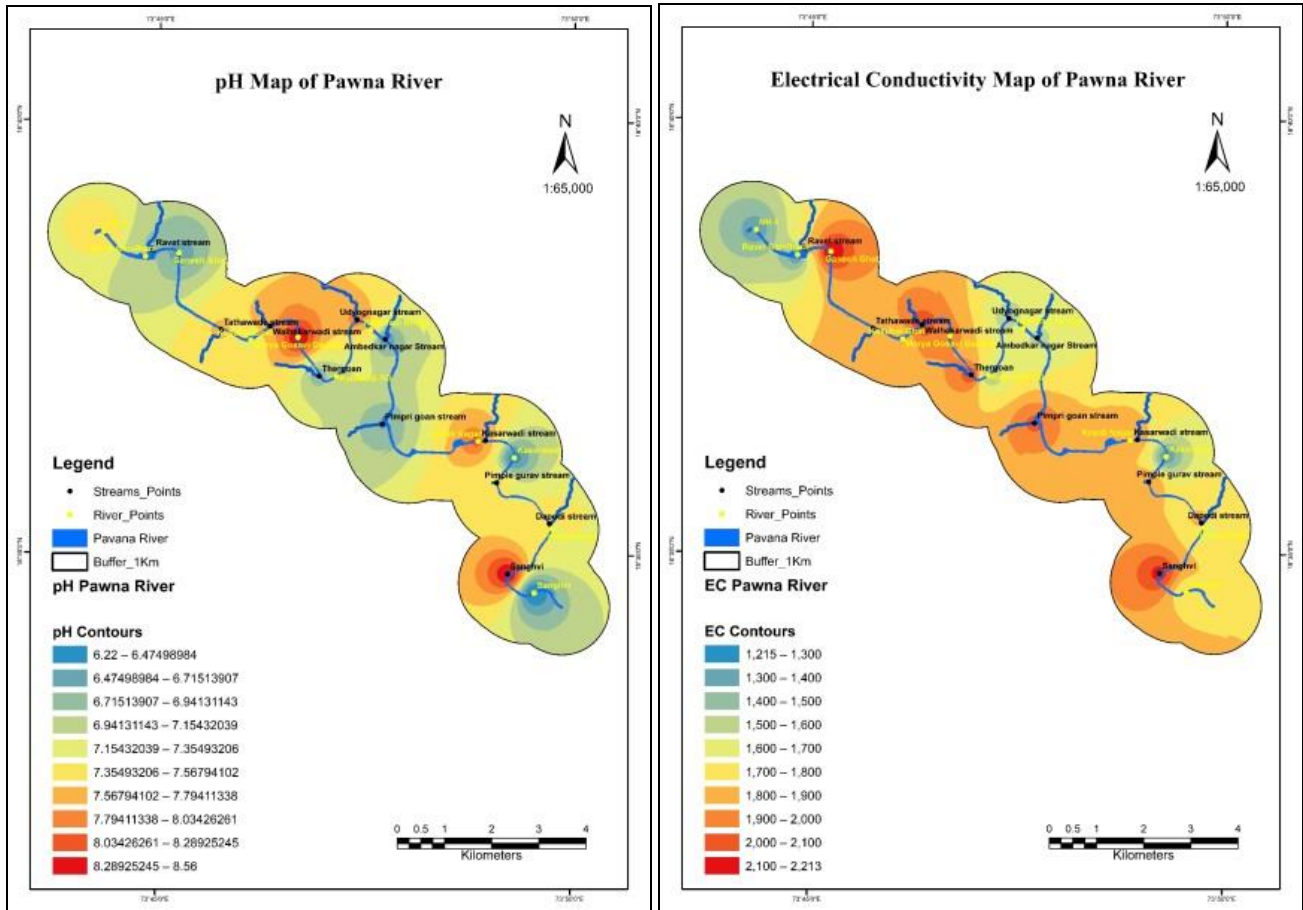


Fig 2: a. and 2b. Ph and E.C Map of

Pawna River within 1 Km Buffer from Pawna River

Permissible limits for pH is 6.5-8.5 there is no relaxation for this value if it is below 6.5 it is acidic and above 7.5 is basic so there is no relaxation for pH value. The pH map of the study area (Fig 2a) indicates the high value of pH at Morya Gosavi Ganesh (8.56) and Sanghvi (8.5) which is nearly at the boundary of the permissible limit. In the study area the value ranges for the pH for river samples is between 6.22 at Sanghvi location and 8.56 at Morya Gosavi Ganesh whereas at stream location value ranges from 6.5 at Ambedkar Nagar stream to 8.5 at Sanghvi location. Based on the pH value it indicates that the Sanghvi Stream is contribution for the higher value of pH as the pH of the Sanghvi at river location is low. The common cause for increase or decrease in pH is the point source and depends on the chemicals involved.

The permissible limit for electrical conductivity is 2000 µS/Cm. Electrical conductivity values in the area (Fig 2b) ranges from 1215 µS/Cm which is at Ravet Bandhara location to 2213 µS/Cm at Ganesh Ghat. The electrical conductivity from the river location ranges from 1215 µS/Cm at Ravet Bandhara to 2213 µS/Cm at Ganesh Ghat which is found to be above permissible limit. Whereas the electrical conductivity value for stream location varies from 1522 µS/Cm at Udyognagar stream to 2133 µS/Cm Sanghvi stream location. In case of stream Location the electrical conductivity is found to be above permissible limit at Sanghvi (2133), Pimprigaon Stream (2021), Walhekarwadi Stream (2100), Thergaon (2101) locations, a higher conductivity value indicates that there are more chemicals dissolved in water.

3.2 Total Suspended Solids (TSS) and Total Dissolved Solids (TDS)

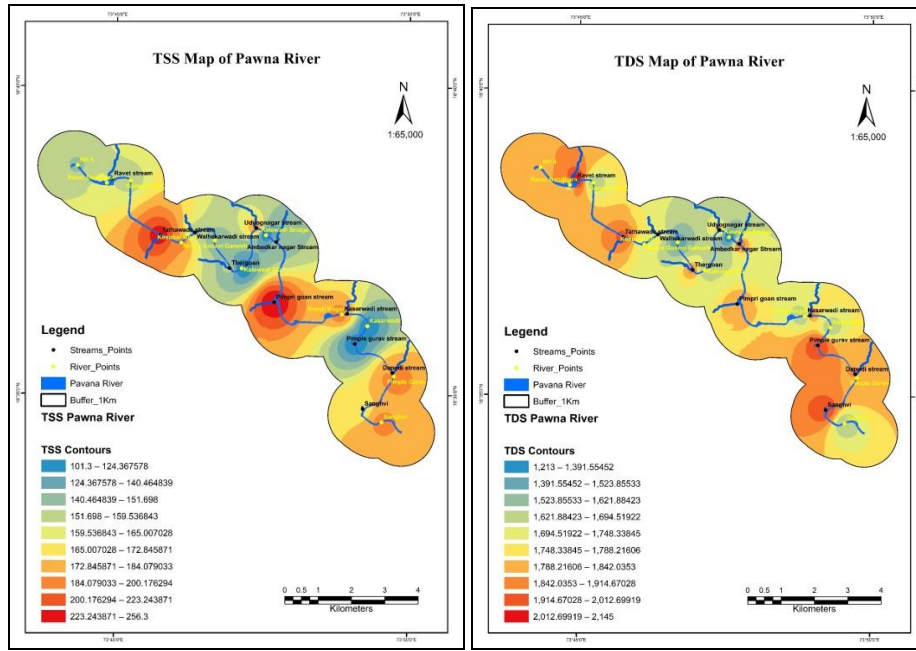


Fig 3: a. and 3b TSS and TDS Map of

Pawna River within 1 Km Buffer from Pawna River

A total suspended solid (TSS) is the dry-weight of suspended particles that are not dissolved, in a sample of water that can be trapped by a filter that is analyzed using a filtration apparatus. The TSS value for River sample location (Fig 3a) ranges from 101.3 mg/l at Kalewadi Road to 203.2 mg/l at Kranti Nagar whereas the value for stream location ranges from 104.3 mg/l at Pimple Gurav to 256.3 mg/l at Pimprigaon Stream. The higher level of TSS will increase the water temperature as suspended particle will absorb more heat which on contrary decrease the dissolve oxygen level.

The carbonate, bicarbonate, chlorides, Sulfate, phosphate, nitrates, calcium, magnesium and sodium and potassium contribute to total dissolved solids (TDS). In addition to these organic matters and anthropogenic pollutants also support to increase in TDS of water. Therefore, TDS is an important parameter to determine water quality. The value of TDS for river location (Fig 3b) ranges from 1213 mg/l at Kalewadi Bridge to 1822 at NH4 whereas for stream location value ranges from 1750 mg/l at Walhekarwadi Stream to 2145 mg/l at Ravet Stream. A higher concentration of TDS may influence the toxicity of heavy metals and organic compounds in fish and other aquatic life.

3.2 Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO)

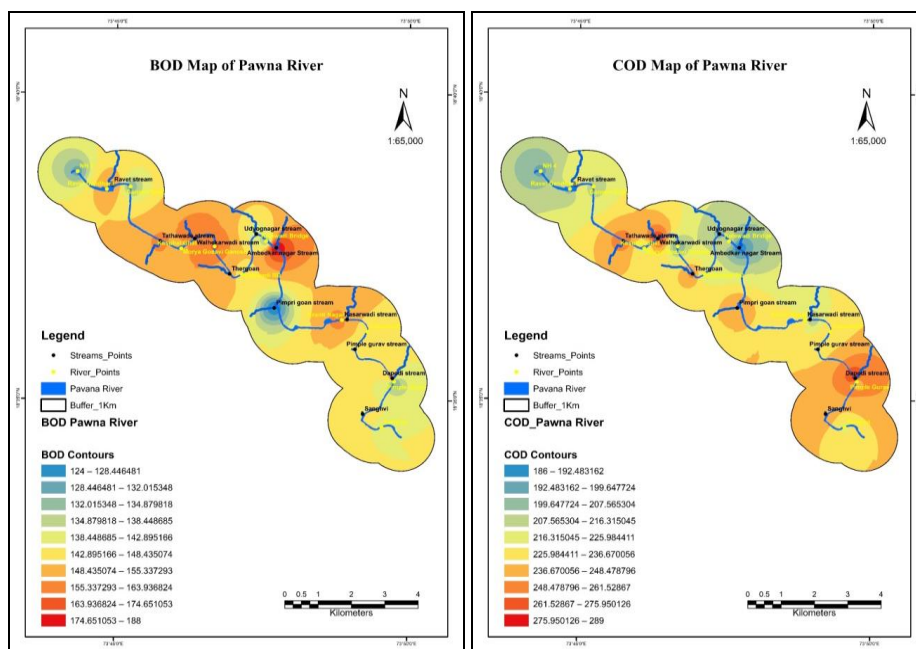


Fig 4: a.and 4b BOD and COD map of Pawna River within 1 Km Buffer from Pawna River

Biological oxygen demand (BOD) is the amount of oxygen that requires for bacteria to degrade the organic components present in water/ waste water. BOD is an important water quality parameter because it provides an index to assess the effects of discharged wastewater on the receiving environment. The BOD values at river location (Fig 4a) ranges from 124 mg/l at Pimple Gurav to 165 mg/l Morya Gosavi Ganesh whereas at stream location the value ranges from 126 mg/l at Pimprigaon Stream to 188 mg/l at Ambedkar Nagar Stream. As per the Environmental Status Report of PCMC (2012-2013) and recorded readings in the study area the BOD level is above 30 mg/l which indicates that water is much polluted with organic waste. Higher the values of BOD, the greater the amount of organic matter or the “food” available for oxygen consuming bacteria. Higher

value of BOD can also be due to high nitrate which may cause oxygen depletion from water. Chemical Oxygen Demand (COD) is another important water quality parameter because similar to BOD, it provides an index to assess the effect discharged wastewater will have on the river. Higher COD levels mean a greater amount of oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher aquatic life forms. The COD test is often used as an alternate to BOD due to the shorter length of testing time. The COD values for river location (Fig 4b) ranges from 198 mg/l at NH4 to 240 mg/l at Kranti Nagar whereas the COD value for stream ranges from 186 mg/l at Ambedkar Nagar Stream to 289 at Dapodi stream.

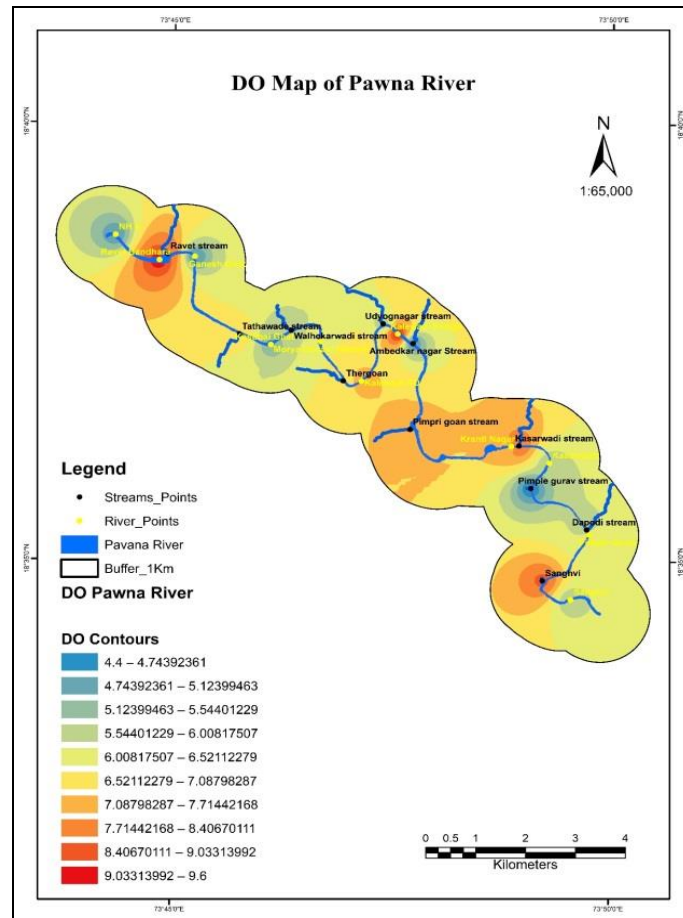


Fig 4c: DO map of Pawna River within 1 Km Buffer from Pawna River

Dissolved oxygen (DO) is considered as one of the most important indicators of water quality. Oxygen dissolves in surface water due to the aerating action of winds. When dissolved oxygen becomes too low, fish and other aquatic organisms cannot survive. For the study area, the DO values for river (Fig 4c) ranges from 4.6 mg/l at Ganesh Ghat to 9.6 mg/l at Ravet Bandhara, whereas the values range for stream location is 4.4 mg/l at Pimple Gurav Stream to mg/l at Sanghvi. The availability of DO in river

depends on the rate and period of photosynthesis, its consumption by aquatic flora, fauna and microorganism, water temperature etc. Since lower levels of DO were available in surface waters of rivers during day time, there is a possibility of development of anaerobic condition during night hours due to absence of photosynthesis by phytoplankton resulting in no production of oxygen. Such condition in bottom as well as surface water leads to mass mortality of fish.

3.3 Calcium and Magnesium Analyses

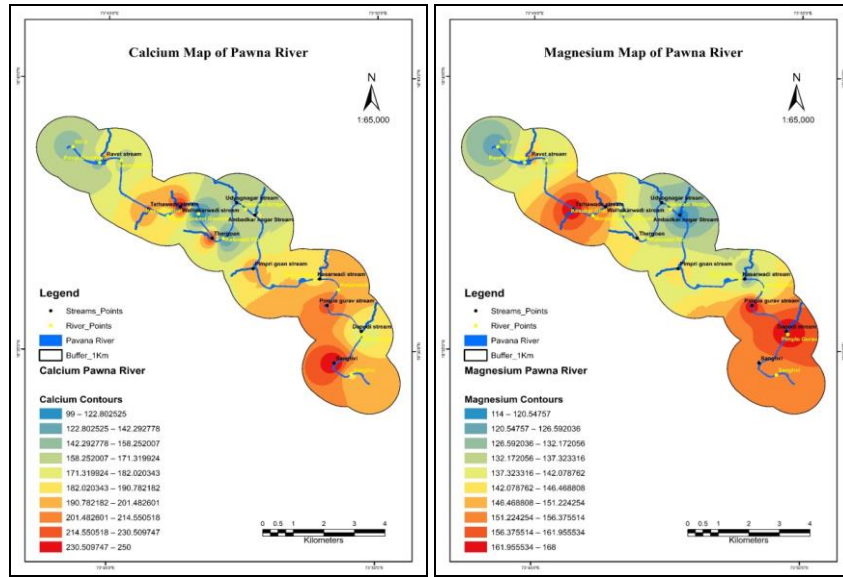


Fig 5: a and 5b. Calcium and Magnesium map of Pawna River within 1 Km Buffer from Pawna River

Calcium and magnesium are important parameters contributing to water hardness as it comes in contact with a soluble divalent metallic cation such a carbonate, sulphates and chloride of calcium (Jain *et al* 2010). According to Indian Standard Specification for drinking water the desirable limit is 75 mg/l and the permissible limit is 200 mg/l. The Calcium value for river location (Fig 5a) ranges from 99 mg/l at Morya Gosavi Ganesh to 201 mg/l at Kasarwadi whereas the calcium values for stream ranges from 156 mg/l at Udyognagar Stream to 250 mg/l at Sanghvi location. In the complete study area the calcium value ranges from 99 mg/l at Morya Gosavi Ganesh Location to 250 mg/l at Sanghvi stream location. The main sources of calcium in natural water are various types of rocks, industrial waste and sewage. Deficiency of calcium causes severe rickets while excess amount helps for

formation of concentration in body part causing kidney stone or bladder stone and irritation in the urinary tract (Mangesh and Chandrashekhar 2013) Magnesium is the fourth most abundant cation in the body and the second most abundant cation in intercellular fluid (WHO, 2009). According to Indian Standard Specification for drinking water the desirable limit is 30 mg/l and the permissible limit is 100 mg/l. In the study area the value of Magnesium for river samples (Fig 5b) ranges from 121 mg/l at NH4 to 165 mg/l at Pimpri Gurav, whereas for stream location value ranges from 114 mg/l at Ambedkar Nagar to 168 mg/l at Tathawade stream. In the entire study area the value of magnesium ranges from 114 mg/l at Ambedkar Nagar Stadium to 168 mg/l at Tathawade Stream with an average value of 145 mg/l at Kranti Nagar.

3.4 Sodium and Potassium

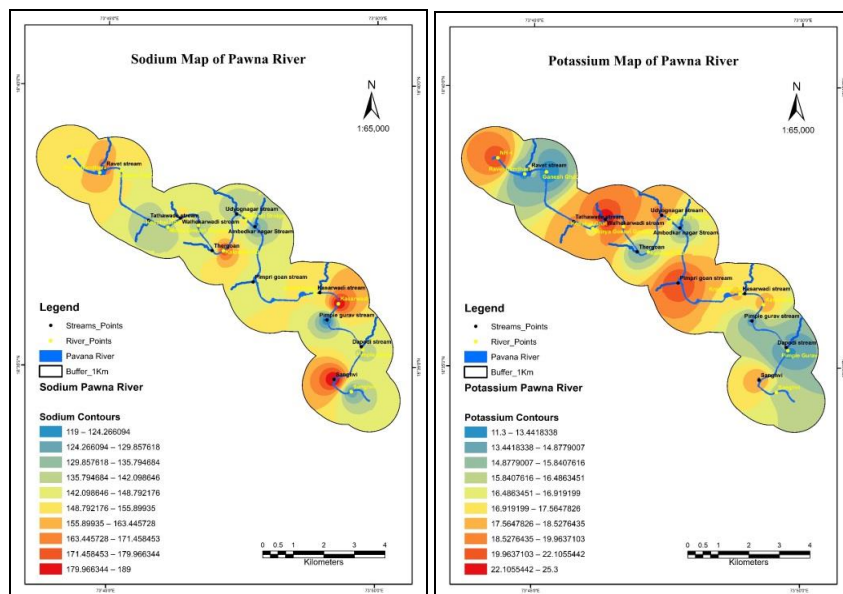


Fig: 6a and 6b. Sodium and Potassium map of Pawna River within 1 Km Buffer from Pawna River

In action, sodium has a dominant role and highly soluble in nature. The atmospheric deposition, evaporate dissolution and silicate weathering are the important source of sodium as well as potassium in surface water (Singh et. al 2008; Sajil Kuma.et.al 2014) in addition to this as sodium has high solubility, it gets replace with available Ca and Mg and with Cl to form rock salt NaCl (El- Sayed and Salem 2015). In the study area the Sodium value for river (Fig 6a) ranges from 126 mg/l at Sanghvi to 189 mg/l at Kasarwadi, whereas for streams it ranges from 119 mg/l at Pimple

Gurav Stream to 189 mg/l at Sanghvi. The potassium alkaline earth cation occurs naturally in water. The excess use of potassium fertilizer increases the concentration of potassium in water. In the study area the Potassium value for river location (Fig 6b) ranges from 11.3 mg/l at Pimple Gurav to 21.3 mg/l at NH4 location, whereas for stream location value ranges from 14.5 mg/l at Ambedkar Nagar Stream to 25.3 mg/l at Walhekarwadi Stream.

3.5 Sulphate, Phosphate and Nitrate analyses

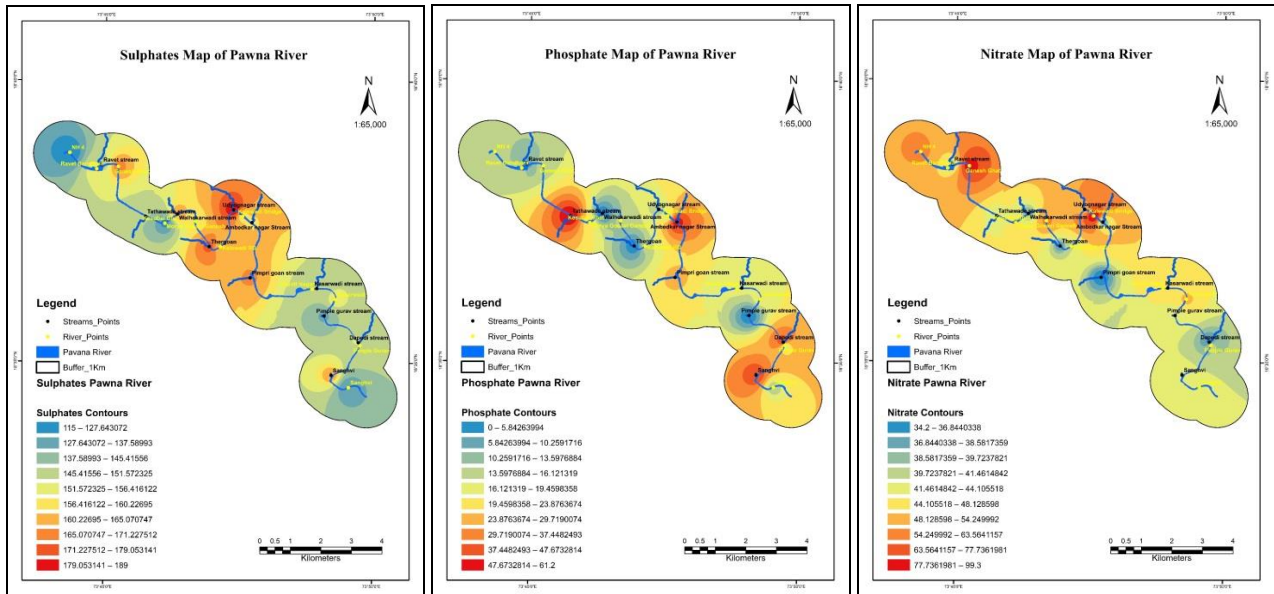


Fig 7: a.7b and 7C Sulphates, Phosphate and Nitrate map of Pawna River within 1 Km Buffer from Pawna River

Sulphate mainly perceived in the water due to the presence of gypsum and the common minerals (Facture and Mane 2007; Allam et. al 2012)^[7]. The values of sulphates for river location (Fig 7a) ranges from 115 mg/l at NH 4 to 169 mg/l at Ganesh Ghat, whereas in case of stream sample location value ranges from 135 mg/l at Pimple Gurav stream to 189 mg/l at Udyognagar Stream. In the entire study area it is found that at most of the location the Sulphate values area above desirable limit.

Phosphate is an active element and so it occurs in the form of phosphate in igneous rock, sediments, and minerals. The mechanical and chemical weathering and erosion of rock releases phosphate into nearby water bodies. The other source of phosphate is sewage, animal waste and detergents (Hem 1985). In the study area the phosphate value for river

location (Fig 7b) ranges from 7.1 mg/l at Pimple Gurav to 20.1 mg/l at Kesubai Ghat, whereas the values for Stream ranges from 7 mg/l at Ravet Stream to 61.2 mg/l at Tathawade Stream. The high value of phosphate may cause the excessive growth of algae and aquatic plant.

The value of nitrate for the river location ranges from 41.3 mg/l at Pimple Gurav to 99.3 mg/l at Kalewadi Bridge, whereas the value for stream sample ranges from 34.2 mg/l at Ambedkar Nagar Stream to 46.7 mg/l at Udyognagar Stream (Fig 7c). The nitrate concentration in the entire study area is observed in the range of 34.2 mg/l at Ambedkar Nagar Stream to 99.3 mg/l at Kalewadi Bridge with an average of 47.2 at Kranti Nagar. The average explains that the concentration of nitrate is high over the permissible limit.

3.6 Land use land cover analysis

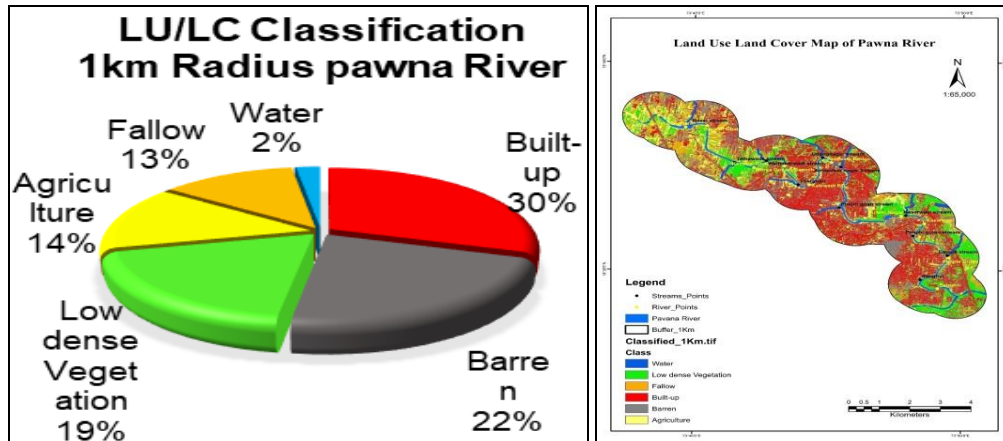


Fig 8a: Classified image of the Pawna River different land use classes (area 1km radius from Pawna River and Figure 8b). The percentage of the land use classes of River Pawna

The land use classification clearly shows that Built-up land covers the majority of the area (Fig 8a). Land use is the major factor affecting the river water quality as the runoff that discharges into river are implicitly from land surfaces (Rosana *et al.* 2007). Land use classification map shows that the agriculture land and the low dense vegetation land is scattered throughout the area and the use of fertilizers may contribute significantly to water resource impairments and general environmental pollution (Chaosheng 2006). It is clear from the maps and graphs (Fig 8b) that in 1km radius around the Pawna River area the dominant land use/ land cover is Built-up land covering an area of 30% of total land which is followed by barren land forming 22% of the total area followed by Low dense vegetation which forms 19 % of the total area. Agriculture area accounts for 14% while water bodies form about 2 % of the area. Fallow land forms 13% of the land use land cover in the area.

4. Concluding Remarks

The selected study area was identified to find out the interaction between sewage and river water and the impact of land use pattern contributing to the river pollution. As per the land use land cover classification the higher values of the pH at Morya Gosavi Ganesh Location might be from the agriculture runoff or the influx of the waste water discharged directly into the river, whereas at Sanghvi location it might be due to waste water discharge that contains detergents and soap-based products causing a water source too basic. The electrical conductivity value clearly indicates that water from the stream locations is considerably ionized and has the higher level of ionic concentration due to higher dissolved solids. The Land use land cover map indicates that the higher Electrical conductivity value can be due to built-up area and agriculture land. The highest concentration of the BOD is observed within the location of Built-up area and may be related to influx of waste water discharge in the river.

For the entire study area the COD value ranges from 186 mg/l at Ambedkar Nagar Stream to 289 mg/l at Dapodi Stream and as per the average values, COD of Pawna river is found to be above MPCB limit of 150 mg/l. The DO values are above 2 mg/l and as per the Maharashtra Pollution Control Board (MPCB) limits the DO with values

greater than 2 mg/l there are meager chances of fish propagation. In case of TDS as per the Indian Standard Specifications for drinking water the acceptable limit is 500 mg/l and it is found that all the location in the given area exceeds the value of the acceptable limit. It is recorded that Calcium and Magnesium at all the sample location points are above desirable limits. The calcium at few locations showed higher values than the permissible limit, whereas in case of magnesium all the location values recorded were above permissible limit.

Considering the Land use pattern of the area the higher value of sulphate is mostly in the built-up area and these values might be due to municipal or industrial discharge. Whereas the higher level of phosphate might be due to phosphate based fertilizers and waste water discharge into the river. On the other hand, the higher values of nitrate might be due to impact of urban land use as well as peri urban agriculture activities within the area which may lead to high level of eutrophication.

The GIS based IDW maps clearly shows the hot spots in relation to the spatio-temporal characteristics of pollutants influx and also enable the estimate of level of pollutants in the Pawna River. The Built up and the agriculture land and the influx of waste water into river seem to be responsible for elevated levels of pollutants as observed in the maps.

The significant use of surface water for local people is for irrigation and drinking, and the research has helped to identify the appropriate use of river water. The study indicates that the water is of poor quality and is not suitable for use by the local people as sodium, calcium and magnesium value are quite higher.

We believe that this is first of its kind of GIS based study conducted on major River Pawna under PCMC jurisdiction. Considering the growing concerns of river pollution and proposed smart city plans for the PCMC, this study will prove beneficial in implementing remedial measures for river Pawna restoration. We hoped that the researcher objectives have been successfully achieved with the help of the study of pollution indices and environmental impact and probable sources of pollutant discharge. The physiochemical assessment gives adequate information about water quality, its current status and probable contributory factor for fluctuation in the quality of water. The complete study

makes understand the impact of the polluted body on the nearby environment. Overall, this study will pave the path towards achieving river rejuvenation scheme under smart city goals and maintaining sustainable environment and healthy ecosystem.

5. References

- Maheshwari A, Sharma M, Sharma D. Hydro chemical analysis of surface and ground water quality of Yamuna River at Agra, India. *Sci.* 2011; 2(4):373-378
- Ogbozige FJ, Adie DB, Abubakar UA. Water Quality Assessment and Mapping using Inverse Distance Weighted Interpolation: A Case of River Kaduna, Nigeria. *Nigerian Journal of Technology (Nijotech)*. 2018; 37(1):249-261.
- Environmental Status Report (2012-2013) Kumar M., Puri A. Pimpri Chinchwad Municipal Corporation (PCMC) A review of permissible limits of drinking water. https://www.pcmcindia.gov.in/pdf/esr_eng_2013.pdf
- Eknath CN. The seasonal fluctuation of physico chemical parameter of a Mula -Mutha at Pune, India and their Impact on Fish Biodiversity. *J Environmental Health Science Engineering*. 2013; 1:11-16.
- El-Sayed m, Salem WM. Hydrological assessment of surface Nile water and groundwater in an industry area – South West Cairo. *Egypt J Pet.* 2015; 24:277-288.
- Etteieb S, Cherif S, Tarhouni J. Hydrochemical assessment of water quality irrigation: A case study of the Medjedra River in Tunisia. *Appl water Sci.* 2017; 7(1):469-480
- Fadtare VV, Mane TT. Studies on water pollution of Mula – Mutha and Pawna Rivers in the summer season in the Pune city region. *Nature Environment and Pollution Technology*. 2007; 6(3):499-506.
- Ge KY. The Status of Nutrient and Meal of Chinese in the 1990s. Beijing People’s Hygiene Press, 1992, pp. 415-434.
- Gulis G, Czompolyova M, Cerhan JR. An ecological study of nitrate in municipal drinking water and cancer incidence in Trnava District, Slovakia, *Environ. Res. A sect.* 2002; 88:182-187.
- Hakanson L. An Ecological risk index for aquatic pollution control: *Water Res.* 1980; 14:975-1001.
- Hariprasad NV, Dayananda HS. Environmental impact due to agriculture runoff containing heavy metal – A Review. *International J of Scientific Research*. 2013; 3(5):2250-3153.
- Hem D. Study and Interpretation of the Chemical of Natural of Characteristics water.
- Hem JD. Study and Interpretation of Chemical Characteristics of Natural Water, US Geological Survey, Water Supply Paper No.2254, 1985. <https://pubs.usgs.gov/wsp/wsp2254/pdf/wsp2254a.pdf>
- Islam MS, Shamsad SZKM. Assessment of Irrigation Water Quality of Bogra. *Bangladesh J Agril. Res.* 2009; 34(4):597-608.
- Kawaguchi M, Misaki K, Sato H, Yokokawa T, Itai T, Nguyen M. *et al.* Interdisciplinary studies on environmental Chemistry- Environmental pollution and Ecotoxicology, 2009, Pp. 141-150.
- Kumar S, Nayak B, Environmental studies on river water quality with reference to suitability for agricultural purposes: Mahanadi River Estuarine system, India- A case study. *Environmental Monitoring and Assessment*. 2009; 155(1-4):227-243.
- Maigari AU, Ekanem EO, Garba IH, Harami A, Akan JC. “Health Risk Assessment for Exposure to Some Selected Heavy Metals via Drinking Water from Dadinkowa Dam and River Gombe Abba in Gombe State, Northeast Nigeria.” *World Journal of Analytical Chemistry*. 2016; 4(1)1-5. doi: 10.12691/wjac-4-1-1.
- Satyanarayana E, Ratnakar D, Murlidhar M. Major ion chemistry of surface water and groundwater in part of Muluga – Venkatpur Mandal, Warangal District, Telangana State, India, *Hydrol Current Res.* 2016; 7(3):253. DOI: 10.4172/2157-7587.1000253
- Siriwong W. Organophosphate pesticide residue in the aquatic ecosystem and health risk assessment of the local agricultural community. Thesis. Chulalongkorn University, Thailand, 2006.
- US EPA. Risk assessment guidance for superfood, Human health evolution manual (part), report EPA /540/1-89/002 (volume 1) United State Environmental Protection Agency, Washington, DC, USA, 1989.
- US EPA IRIS. (US Environmental Protection Agency) Integrated risk information system. Environmental Protection Agency Region I, Washing – ton DC 20460. US EPA, 2012.
- The US. EPA Drinking water and human health effects information, 1999. <https://www.epa.gov/dwstandardsregulations/drinking-water-contaminant-human-health-effects-information>. Accessed on June 2019.
- Vasanth Kumar B, Vijaykumar K. Diurnal variation of physicochemical properties and primary. *Recent Research in Science and Technology*. 2011; 3(4):39-42.
- WHO. World Health Organization: Environmental health criteria, 1998. <https://www.who.int/ipcs/publications/ehc/en/> Accessed on June 2019.