

Seasonal Variation of Water quality and Heavy Metal Pollution Index: A case study

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ABSTRACT

Pond as an ecosystem plays crucial role in growing cities, not only to recharge ground water but also facilitate urban residents in terms of ensuring livelihood. Leading urbanisation and continuous anthropogenic activities pollute water sources and affect human and aquatic lives. Due to lack of opulent research studies in Indian cities on water quality of ponds in different seasons and subsequent effect on the ecosystem, the current study attempted to answer contagion conditions of HPI and its affect. It also aims to suggest new evidence-based recommendation to get included in the sustainable water policies against the SDG target 6.3. The longitudinal study was conducted in one of the rapidly growing cities of India, where around 30 big ponds exist. Eight Heavy metals i.e., Iron, Zinc, Manganese, Copper, Cadmium, Cobalt, Lead and Nickle, were investigated during 2016-17 spreading up all seasons, in a standard laboratory testing for 5 selected aquatic ponds. Testing was done for all round of sample in ICP-MS.7700 method and data were processed in SPSS. Descriptive statistics and correlation were tested, and HPI are estimated to interpret the water quality. Results shows that iron, manganese, copper content in the water was more in monsoon and pre-monsoon seasons in all studied ponds. Zn, Cd, Co, Pb, Ni were reported less than permissible limit. Highly positive correlation is found between copper and Zinc ($r \geq 0.993$, $P < .001$), medium for cobalt and cadmium ($r \geq 0.564$, $p < .05$), Lead with Zinc ($r \geq 0.695$, $p < .001$), lead with copper ($r \geq 0.753$, $p < .000$). The HPI index is not good for all the studied ponds in monsoon. Hence, wastewater and stormwater must be contaminated free from heavy metals before adding to the ponds to maintain the water level quality.

Key Words: HPI, Heavy meatal, seasonal variation., water pollution, Aquatic animal health

Mathematics Subject Classification: 62H20, 62H99, 62P12

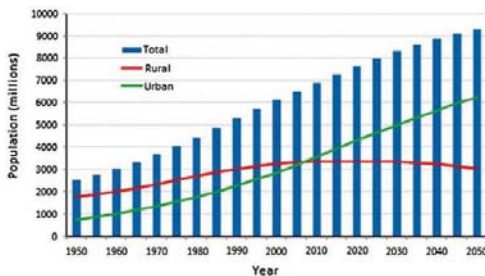
Journal of Economic Literature (JEL) Classification: Q5, I1

1. INTRODUCTION

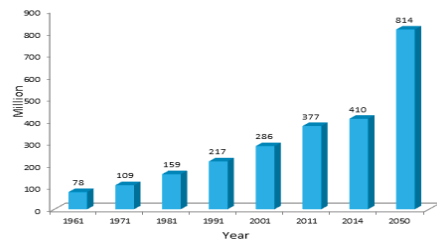
Water contribute to human lives and economic development of any country. However, over a period, it gets contaminated with pollutants added by anthropogenetic activities (Linnik & I, 2000; Lwanga et al., 2003, 2015). This contamination is sometimes done by nature itself, but in specific area where concentration of the elements is found to be more, land use (Nillos et al., 2020), and industries (Koetlisi & Muchaonyerwa, 2019) also reported to be accountable (Bhardwaj et al., 2020; Das & Maiti, 2007). Heavy metals, a natural element which is having high atomic weight and

5 times density than water is present in natural environment and contaminate the surface and ground water (Tchounwou et al., 2012). The modernisation and urbanisation have now polluted world's water bodies and caused many severe diseases through the process of bioaccumulation and biomagnification which are harmful not only for *Homo Sapiens* but for aquatic animals too (Maurya et al., 2018; Mor et al., 2022; Pal & SK, 2018). Earlier literature also revealed that "heavy metals are placed as key leading causes of carcinogenic illness as stated by U.S. Environmental Protection Agency, and the International Agency for Research on Cancer" (Tchounwou et al., 2012) and require research on measuring intensity of trace metals in different bodies such as soil, water, air etc. from time to time. Keeping the aim to understand water contamination, one of such indices is Heavy Metal Pollution Index (HPI) which is used to determine the intensity of pollution of heavy metals (Venkata Mohan et al., 1996). Studies conducted in different cities of India revealed that quality of water and mortality of aquatic animals are interrelated, and physiological parameters are not only the factor accountable (Paul et al., 2019; Yap et al., 2015). But in recent times due to anthropogenic activities these ponds are continuously being polluted in the absence of proper laws, guidance, and strict penalties.

India is growing rapidly in terms of population and economy, both in recent years. As per census 2011, population growth has increased from 27.81 % to 31.16% in last one decade i.e., from 2001-2011, and growth of urban population is reported to be 31.80 % (Figure 1) (Musa et al., 2016). This unplanned urbanisation (R B Bhagat, 2015) resulted in increased demand of water and grew the demand of aquaculture.



Source: (Musa, Hasim and Reba, 2016)



Source: Census of India 1961 to 2011#

#Note: This figure is taken from urban migration trends, challenges, and opportunities in India by Ram B Bhagat, 2015.

Ponds, according to the data, plays a crucial role not only to maintain biodiversity but also contribute to bridge the gap pertaining to depletion of water level. But with gradual increase of urbanisation and industrialisation, these ponds were filled up with soil and very few still remained in the cities. The water quality of the ponds is decreasing day by day as revealed from different studies due to addition of untreated domestic and sewage wastewater through small drains (El-Sayed et al., 2011). According to research conducted by annually 800 x 106 gallons of waste sewage and sullage produced 60,000t NPK and around 250-400 ppm organic carbon and 80-120 ppm total nitrogen could be produced from the domestic sewage. This could be read in terms of carbon and nitrogen ration of 3:1 (Mukhopadhyay, P. K., & Sarangi, 2006). Sreenivasan in 1969, elicits that small amount of addition of organic matter to eutrophic reservoirs can stimulate bloom in the water chain and affect human

life (Sreenivasan A., 1969). Hence, physico-chemical nature of pond's water gets changed in different seasons and cause harm if heavy metals are found more or less in concentration. In context to provide quality water, it is necessary to conduct research as many of the residents are dependent on these pond water and also affecting the health if the polluted aquatic animals and water could be taken by them (Ghaderpoori et al., 2018). Hence, this current paper attempts to understand the water quality of ponds located at different sites of Raipur city in terms of contamination of heavy metal and its toxic waste index so that technical suggestion could be think of by the scientific world on urban bio-diversity management. The findings of this research paper will help the policy makers and urban local bodies to think about possible solutions for encouraging aquatic crops as a livelihood and suggested to manage sewage systems at local level without contaminating the pond water (A.O. et al., 2022).

2. MATERIALS AND METHODS

2.1. Description of the study area

Pond is considered as a small area water source in terms of ensuring water to the urban dwellers however many of the residents are depended on it for getting their livelihood. In the world, a very small number of countries keep the track of water quality of ponds. In India, although no information is published on public portal on pond water quality, it is necessary to broadcast the water quality for two reasons. First, the water quality and its effect must be known to every city dweller and second, government must conduct the water quality test and broadcast the water quality results along with the quality of aquatic products which come from these sources.

Raipur, the capital of Chhattisgarh province is located in latitude of 22°33'N to 21°14'N and longitude 82°6'E to 81°38'E of the globe and well known for its ponds, industrial boom in the twentieth century. According to available literature, once upon a time around 100-154 ponds existed there which is now reduced to 85 ponds (Kumar et al., 2015). Another literature depicts that around 70 ponds were found once upon a time, however it's reduced to 40 by the end of 1997 and subsequently to 22, now (Raghav & Biswas, 2009). These ponds cover around 2800-402000 square meter which is 2 % area of the city. Keeping this decreasing numbers of ponds and water scarcity challenges observed in the city, big ponds basically started to develop livelihood options such as fisheries and the nearby community consume the water for drinking. However, contaminated, and polluted water restricted the growth of the fishes and spread up many diseases unknowingly to its citizens. Raipur is considered as a growing city in terms of general as well as slum population, who are considered to be most vulnerable from health point of view as they consume water from ponds. The pond's water quality influence their health as they consume it directly and indirectly. Secondly, the ponds of the city are well connected to sewage drains and is known for its aquaculture practices. Every year these ponds are given on rent by urban local body to generate revenue through fish production and local people consume these fishes to many extents. During monsoon, runoff water gets mixed with these ponds and affect the water quality. Lots of industrial waste through environment, and several types of waste including bathing, washing clothes are reported to be added to these ponds and contaminate the water. This contaminated water is consumed by community living in nearby area in potable form. As no studies are addressed to these

issues since 2014, the author tried to measure the water quality of the ponds along with HPI in this research study and can suggest the government and scientific world to innovate in the developing urban area in terms of ensuring the SGDs goal related to water.

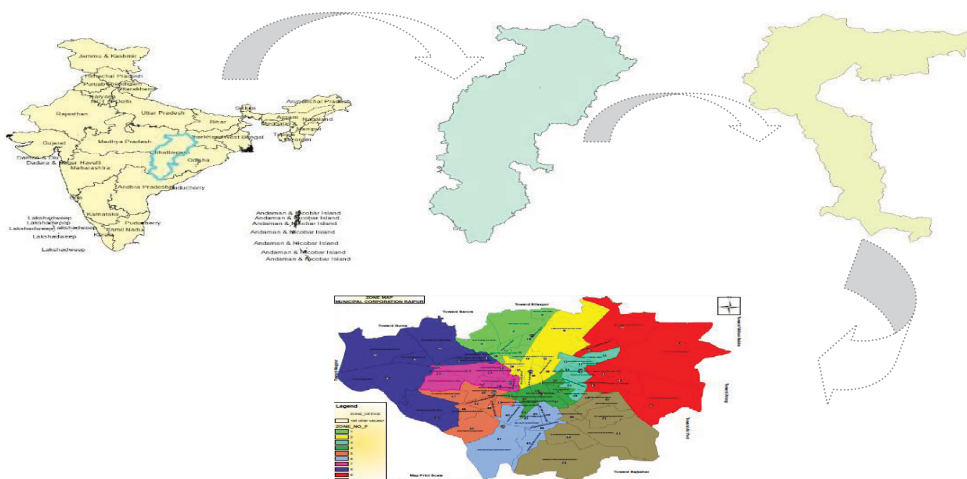
2.2. Sampling

The longitudinal study with descriptive and experimental research design was conducted in Raipur city of India. Out of the listed 85 ponds available in the city, 5 ponds were selected randomly. For sampling, four major ponds were chosen randomly from each direction i.e., North (Budha talab), East (Bhaiyyu Talab), West (Khokho talab), South (Sarjubandh talab), and one pond was chosen from the middle part (Maharaja bandh talab) of the city. After selection of these ponds, sources of contamination in the ponds had been mapped out with the help of local community and google satellite map (Khan et al., 2014; *Raipur Municipal Corporation*, 2015) (Figure 3 exhibit the location of selected ponds in the google map).

Table 1: Selected Ponds details from Raipur city, Chhattisgarh state, India

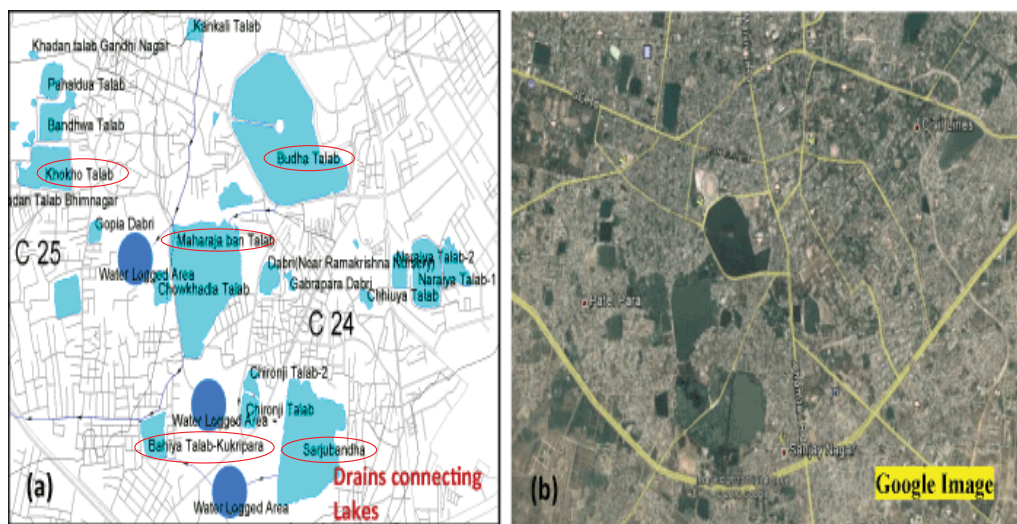
Name of the local water pond	Area of water body in hectare	Latitude	Longitude	Seasonal (S) / Permanent (P)	Fish production	Availability of water (retention months)	Direction
Bhaiyyu Talab (Near Kali temple)	2.984	21.113° N	81.3735°E	P	Yes	12 months	East
Budha Talab	8.141	21.2317°N	81.6344°E	P	Yes	12 months	North
Maharaja Bandh Talab	NA	NA	NA	P	Yes	12 months	Middle
Sarju Bandh Talab	NA	21.2226°N	81.6366°E	P	Yes	12 months	South
Khokho talab (Near Danteswari temple)	5.257	21.2314°N	81.6196°E	P	Yes	12 months	West

Figure 1: Maps showing selection of the study area by India, Chhattisgarh, Raipur District, and Raipur City.



Source: <https://nagarnigamraipur.nic.in/rmcwebsite.aspx?pageid=44> and Primary map prepared by author

Figure 2: Location of the Five selected ponds of the Raipur city, Chhattisgarh State, India



Source: Khan A. A., Ahmad M., (2014) *Integration of Stormwater Drains with Lakes: Expectations and Reality - A Case of Raipur, India. Hydrol Current Res* 5: 166. doi:10.4172/2157-7587.1000166

2.3. Sampling methods and testing process

Monsoon, pre-monsoon, winter, and summer seasons during the year 2016-17 were selected to collect the water sample in 500 ml sterilised plastic bottle. Water samples were collected from central part of the ponds during morning time i.e., 6.00 AM by covering shore to core covering surface and at one feet depth. This was done to get the average quality of water sample for conducting the testing. It was also ensured that no air bubble should be present in the water while collecting the sample. The samples were preserved in fridge without any contamination, before conducting the test for eight heavy metals i.e., Zinc (Zn), Lead (Pb), Nickel (Ni), Iron (Fe), Cobalt (Co), Manganese (Mn), Cadmium (Cd), and Copper (Cu). The authors conducted the test at scientific laboratory based at Central pollution control board (CPCB), Kolkata, India. All the four rounds of sample water were evaluated and analysed in ICP-MS7700 Series method. Through this method, trace elements were easily found in liquid due to modern technology which ensure sensitivity, accuracy, reliable, lower detection limit, and prompt result. The Inductive coupled plasma (ICP) spectroscopy method ionised the samples and Mass Spectroscopy (MS) segregated the ions per second by the mass to charge ratio. Hence, concentration of the metals was found very clearly even in resulted in very negligible amount. Microsoft excel was used to record the measurements of the water samples. Ethical consent was taken from the in-charge of each of the ponds.

2.4. Statistical analysis

To understand the quality of water of the ponds, descriptive and analytical analysis was made. More specifically mean and Standard deviation and correlation was calculated to check the association of heavy metals with each other. Pearson correlation was calculated to measure the association between the heavy metals by the studied season and ponds. Analysis was done in the Statistical

package for social science (SPSS), version 22.0, and p-value was considered to be 0.05 for testing statistical significance.

Further, HPI was calculated by approaching three steps i.e., (i) sub-index value (Q_i), (ii) unit weight of the studied parameters, and (iii) the HPI. Bureau of Indian standard (BIS) 2012 was used to calculate the heavy metals concentration as a comparison in the current study. All the calculations are done with the unit ppb ($\mu\text{g/l}$). Following formula was used to calculate the HPI and result is categorised into two i.e., more than 100 HPI which shows shoddy quality of water and less than 100 i.e., good quality of water. The author used the below formula for calculation of HPI:

$$\text{HPI} = \frac{\sum_{i=1}^n W_i Q_i}{\sum_{i=1}^n W_i}$$

Where, Q_i is the sub-index of the i th parameter and w_i the unit weight of the i th parameter and n is the number of parameters considered for the study. Sub index (Q_i) of the parameter was used by using the below formula

$$Q_i = \sum_{i=1}^n \frac{\{m_i(-)I_i\}}{(s_i - I_i)} \times 100$$

Where monitored value (M_i) is the i th parameter of the heavy metal, I_i is the ideal value (maximum desirable value for drinking water) of the i th parameter; standard value (highest permissible value for drinking water) of the i th parameter is S_i . The negative ($-$) sign shows numerical difference of the two calculated values, ignoring the algebraic sign. Analysis of the available information from water samples were carried out with SPSS 22.0 version and Microsoft excel for calculating HPI.

3. RESULT

Presence of heavy metals in required concentration is good for human and aquatic animal health. However, anthropogenic activities in urban as well as rural area contaminate the water and harm the animal and humans. The current study focused to understand the water quality in terms of presence of heavy metals and its relevance of health from different secondary literature. Hence, the findings are summarised in two different headings such as (i) the distribution of heavy metals with its statistical variations and (ii) the HPI calculation using the formula proposed by Mohan et al, 1996. All the parameters are compared with the BIS, 2012.

3.1. Content of Iron (Fe) in the sample

Table 1.1 to 1.5 exhibits the statistical variations of the 5 different studied ponds of Raipur city, Chhattisgarh. Analysis from Budha talab shows that average iron content in the water was more in monsoon and pre-monsoon seasons. Similarly, it was also seen from the analysis that for Maharaja bandh talab, the iron content is more in monsoon and winter. Further analysis shows that the Bhaiya talab, Khokho talab and in Sarju bandh talab, the iron content was more in all the studied seasons compared to the BIS acceptable limit (See the table 1.1 to 1.5). On reviewing literature, the author found

that iron was basically added to the ponds water through industries however, no such industries are seen within the city of Raipur.

3.2. Content of Zinc (Zn) in the sample

Zinc is found in contaminated water added through galvanised pipes, and other metal fittings. The rapid urbanisation has increased the contamination of Zinc in the pond water. However, in all the studied ponds contamination of Zinc was reported to be below the acceptable limit of BIS. The mean of the Budha talab with standard deviation (SD) is calculated to be 0.4722 ± 0.5899 mg/l. across all studied seasons. Compared to this, the mean value of Maharaja bandh, Bhaiya talab, Khokho talab, and Sarju Bandh talab is calculated to be 0.2623 ± 0.3409 mg/l, 0.1163 ± 0.0821 mg/l, 0.0867 ± 0.0342 mg/l, 0.086 ± 0.039 mg/l respectively. However, the concentration of Zinc varies within the seasons, the Budha talab, located centrally to the city is more prone to Zinc contamination.

Table 1.1: Assessment of heavy metals in the sample of Budha Talab, Raipur city, India

Indicator	n	Monsoon	Post Monsoon	Winter	Pre-monsoon	Minimum	Maximum	Mean	SD	Mean $\pm$ SD	Acceptance limit of BIS in mg/l	Standard limit of WHO (mg/L)	EPA (mg/L)
Iron	4	0.72	0.13	0.24	0.1072	110721	72000	29930	28639	0.2993 ± 0.2864	0.3	NA	0.3
Zinc	4	0.39	0.07	0.0986	1.3300	713300	707000	1.3300	747219	0.4722 ± 0.5899	5	NA	5
Manganese	4	0.31	0.1642	0.2827	0.0268	1103	31	19	13	0.1949 ± 0.1297	0.1	0.4	NA
Copper	4	0.05	0.0039	0.0065	0.2074	900390	20749	06697	09604	0.067 ± 0.096	0.05	2	NA
Cadmium	4	<0.03	0.0002	0.0000	0.0000	400000	00020	00007	00009	0.0001 ± 0.000	0.003	0.003	0.005
Cobalt	4	<0.05	0.0007	0.0003	0.0001	700000	00078	00032	00033	0.0003 ± 0.000	NA	NA	NA
Lead	4	<0.07	ND	ND	ND	0.0000	02335	00748	01076	0.0075 ± 0.010	0.01	0.01	0.015
Nickle	4	<0.07	ND	ND	ND	0.0000	0.0000	0.0000	0.0000	0 ± 0	0.02	NA	0.07

3.3. Content of Manganese (Mn) in sample

Presence of Manganese was reported in Budha talab across the year in all seasons except in pre-monsoon and in more concentration than the acceptable limit of BIS. It ranges from 0.16426 mg/l in post monsoon to 0.31 mg/l in monsoon. In Sarju bandh Talab the finding is almost same however, in monsoon and winter, concentration was almost reported to be same i.e., 0.52 mg/l and .53176 mg/l respectively. The mean was calculated to be 0.3409 ± 0.2439 mg/l in Sarjubandh compared to 0.1949 ± 0.1297 mg/l in Budha talab. Similarly for Bhaiya talab, Khokho talab and Sarju Bandh Talab the presence of manganese in all seasons is more than acceptable limit and is a concern for both human and aquatic lives.

3.4. Content of Copper (Cu) in sample

Copper is essential for human body as a nutrient and is mainly contaminated through pipes, fittings of valves, and alloys. Sometimes, during distribution of water, the concentration also increases. The sewage water which comes through certain copper mixed pipes also contribute to these and expose daily copper intake as food and water are primary source of all these. Studies show that intake of **copper more than permissible limit may cause gastrointestinal diseases and carries vulnerability to Wilson disease with some more disorder related to metabolism** (Akoto et al., 2021). In the current study the seasonal variation was seen for copper. The data show that in Budha talab and maharaja bandh talab, concentration of copper is more during pre-monsoon reason i.e., 0.02681 mg/l and 0.11761 mg/l respectively, which was less when matched to the standard limit of .05 mg/l.

Table 1.2: Assessment of heavy metals in the sample of Maharaj Bandh Talab, Raipur city, India

Indicator	n	Monsoon	Post Monsoon	Winter	Pre-monsoon	Minimum	Maximum	Mean	SD	Mean $\pm$ SD	Acceptance limit of BIS in mg/L	Standard limit of WHO (mg/L)	EPA (mg/L)
Iron	4	1.02	0.18	0.40	0.06629	.06629	1.02000	.41657	.42547	0.4166 $\pm$ 0.4255	0.3	NA	0.3
Zinc	4	0.15	0.07	0.05911	0.76994	.05911	0.76994	.26226	.34087	0.2623 $\pm$ 0.3409	5	NA	5
Manganese	4	0.52	0.30095	0.53176	0.01193	.01	.53	.34	.24	0.3409 $\pm$ 0.2439	0.1	0.4	NA
Copper	4	<0.05	0.0046	0.0056	0.11761	0.00000	.11761	.03196	.05715	0.032 $\pm$ 0.0572	0.05	2	NA
Cadmium	4	<0.03	0.0000	0.00013	0.00006	0.00000	.00013	.00005	.00006	0.00005 $\pm$ 0.0001	0.003	0.003	.005
Cobalt	4	<0.05	0.00049	0.00049	0.00026	0.00000	.00049	.00031	.00023	0.0003 $\pm$ 0.0002	NA	NA	NA
Lead	4	<0.10	0.00968	0.00447	0.0151	0.00000	.01510	.00731	.00653	0.0073 $\pm$ 0.0065	0.01	.01	.015
Nickle	4	<0.07	ND	ND	ND	0.00000	0.00000	0.00000	0.00000	0 $\pm$ 0	.02	NA	.07

3.5. Cadmium (Cd) in Sample

Presence of cadmium in the water is dangerous as it causes different disease both in humans and aquatic life. The intensity of cadmium in the water increases by addition of waste from steel industries, batteries, polythenes, fertilisers and local air pollution. The current study findings show that concentration of cadmium in all ponds across all seasons are found less than the acceptable limit. The mean amount of cadmium present in the ponds are 0.0001 $\pm$ 0.0001 mg/l, 0.00005 $\pm$ 0.0001 mg/l, 0 $\pm$ 0 mg/l, 0.0001 $\pm$ 0.0001 mg/l, and 0.0001 $\pm$ 0.0001 mg/l for Budha talab, Maharaj Bandh talab, Bhaiya talab, Khokho talab and Sarju bandh talab respectively.

Table 1.3: Assessment of heavy metals in the sample of Bhaiya Talab, Raipur city, India

Indicator	n	Monsoon	Post Monsoon	Winter	Pre-monsoon	Minimum	Maximum	Mean	SD	Mean $\pm$ SD	Acceptance limit of BIS in mg/l	Standard limit of WHO (mg/L)	EPA (mg/L)
Iron	4	3.15	1.37	1.02	0.3374	.33740	3.15000	1.46935	1.19968	1.4694 $\pm$ 1.1997	0.3	NA	0.3
Zinc	4	0.12	0.05	0.0644	0.23084	.05000	0.23084	0.11631	0.08210	0.1163 $\pm$ 0.0821	5	NA	5
Manganese	4	0.13	0.37098	0.37183	0.1915	.13	.37	.27	.12	0.2658 $\pm$ 0.1239	0.1	0.4	NA
Copper	4	<0.05	0.0032	0.0028	0.03436	0.00000	.03436	.01008	.01625	0.0101 $\pm$ 0.0163	0.05	2	NA
Cadmium	4	<0.03	0.0001	0.00002	0.00004	0.00000	.00010	.00004	.00004	0 $\pm$ 0	0.003	0.003	.005
Cobalt	4	<0.05	0.00112	0.00101	0.00036	0.00000	.00112	.00062	.00053	0.0006 $\pm$ 0.0005	NA	NA	NA
Lead	4	<0.10	0.00721	0.00617	0.00618	0.00000	.00721	.00489	.00330	0.0049 $\pm$ 0.0033	0.01	.01	.015
Nickle	4	<0.07	ND	ND	ND	0.00000	0.00000	0.00000	0.00000	0 $\pm$ 0	.02	NA	.07

3.6. Cobalt (Co) in Sample

Just like cadmium, cobalt was also not reported in heavy quantity in the studied ponds for all seasons. The mean variation for cobalt was reported as 0.0003 $\pm$ 0.0003 mg/l, 0.0003 $\pm$ 0.0002 mg/l, 0.0006 $\pm$ 0.0005 mg/l, 0.0011 $\pm$ 0.0009 mg/l, and 0.0013 $\pm$ 0.0009 mg/l for Budha talab, Maharaj Bandh talab, Bhaiya talab, Khokho talab and Sarju bandh talab respectively.

Table 1.4: Assessment of heavy metals in the sample of Kho-Kho Talab, Raipur city, India

Indicator	n	Monsoon	Post Monsoon	Winter	Pre-monsoon	Minimum	Maximum	Mean	SD	Mean $\pm$ SD	Acceptance limit of BIS in mg/l	Standard limit of WHO (mg/L)	EPA (mg/L)
Iron	4	2.01	2.59	1.83	0.50083	.50083	2.59000	1.73271	.88296	1.7327 $\pm$ 0.883	0.3	NA	0.3
Zinc	4	0.09	0.06	0.0629	0.13376	.06000	.13376	.08667	.03418	0.0867 $\pm$ 0.0342	5	NA	5
Manganese	4	0.39	0.15134	0.15992	0.11269	.11	.39	.20	.13	0.2032 $\pm$ 0.1262	0.1	0.4	NA
Copper	4	<0.05	0.0055	0.0073	0.01823	0.00000	.01823	.00776	.00764	0.0078 $\pm$ 0.0076	0.05	2	NA
Cadmium	4	<0.03	0.0001	0.00023	0.00006	0.00000	.00023	.00010	.00010	0.0001 $\pm$ 0.0001	0.003	0.003	.005
Cobalt	4	<0.05	0.00205	0.00133	0.00096	0.00000	.00205	.00109	.00085	0.0011 $\pm$ 0.0009	NA	NA	NA
Lead	4	<0.10	0.01079	0.01129	0.00681	0.00000	.01129	.00722	.00522	0.0072 $\pm$ 0.0052	0.01	.01	.015
Nickle	4	<0.07	ND	ND	ND	0.00000	0.00000	0.00000	0.00000	0 $\pm$ 0	.02	NA	.07

3.7. Lead and Nickle in Sample

Lead is a harmful heavy metal which causes damage to the nervous system (Sharma et al., 2013). As central part of India is rich in mineral, it is assumed that the soil must be added with lead and may contribute to pond water pollution through runoff (Patel et al., 2006). However, findings from the data revealed that lead and nickel are reported to be less than the acceptable limit of BIS and WHO, which means ponds water is not harmful for the human beings as well as aquatic life. The mean value of lead is reported to be 0.0075 ± 0.0108 mg/l, 0.0073 ± 0.0065 mg/l, 0.0051 ± 0.0034 mg/l, 0.0049 ± 0.0033 mg/l, and 0.0072 ± 0.0052 mg/l for Budha talab, Maharaj Bandh talab, Bhaiya talab, Khokho talab and Sarju bandh talab respectively. However, in the study nickel was not detectable at all in any studied ponds across all the seasons except in less quantity in monsoon season.

Table 1.5: Assessment of heavy metals in the sample of Sarju Bandh Talab, Raipur city, India

Indicator	n	Monsoon	Post Monsoon	Winter	Pre-monsoon	Minimum	Maximum	Mean	SD	Mean $\pm$ SD	Acceptance limit of BIS in mg/L	Standard limit of WHO (mg/L)	EPA (mg/L)
Iron	4	3.46	1.49	1.56	1.76324	1.49000	3.46000	2.06831	.93500	2.0683 ± 0.935	0.3	NA	0.3
Zinc	4	0.08	0.07	0.05195	0.14187	.05195	.14187	.08596	.03904	0.086 ± 0.039	5	NA	5
Manganese	4	0.37	0.19975	0.28079	0.17171	.17	.37	.26	.09	0.2556 ± 0.0892	0.1	0.4	NA
Copper	4	<0.05	0.0042	0.0051	0.01999	0.00000	.01999	.00733	.00873	0.0073 ± 0.0087	0.05	2	NA
Cadmium	4	<0.03	0.0001	0.00003	0.00013	0.00000	.00013	.00007	.00006	0.0001 ± 0.0001	0.003	0.003	.005
Cobalt	4	<0.05	0.00126	0.00167	0.00207	0.00000	.00207	.00125	.00090	0.0013 ± 0.0009	NA	NA	NA
Lead	4	<0.10	0.00667	0.0074	0.00616	0.00000	.00740	.00506	.00341	0.0051 ± 0.0034	0.01	.01	.015
Nickle	4	<0.07	ND	ND	ND	0.00000	0.00000	0.00000	0.00000	0 ± 0	.02	NA	.07

3.8. Correlation between Heavy metals of all ponds for all season

To understand the association between the 8 studied metals such as Zinc, Manganese, Cadmium, Iron, Cobalt, Lead, Copper, and Nickel with each other, correlation was tested for all ponds, all seasons and summarized in the Table 1.6. Correlation coefficient results envisaged both negative and positive result for some heavy metals. More clearly the data shows positive correlation between Copper and Zinc ($r \geq 0.993$, $P < .001$), however, a negative correlation shows for manganese and zinc ($r \geq -0.550$, $P < .05$). Further it also shows, a positive correlation between cobalt and cadmium ($r \geq 0.564$, $p < .05$), Lead with Zinc ($r \geq 0.695$, $p < .001$), lead with copper ($r \geq 0.753$, $p < .000$) and shows negative correlation

lead with Manganese ($r \geq 0.600$, $p < .005$). It also exhibits positive correlation of cobalt with Cadmium ($r \geq 0.564$, $p < .010$).

Table 1.6: Correlation between heavy metals i.e., Lead, Cadmium, Manganese, Iron, Zinc, Copper, Cobalt, and Nickle in the studied ponds in different seasons

Heavy Metals	Iron	Zinc	Manganese	Copper	Cadmium	Cobalt	Lead	Nickle
Iron	1							
Zinc	-.388	1						
P value	.091							
Manganese	.097	-.512*	1					
P value	.683	.021						
Copper	-.419	.993**	-.550*	1				
P value	.066	.000	.012					
Cadmium	-.083	-.156	-.252	-.091	1			
P value	.728	.510	.285	.703				
Cobalt	.175	-.331	-.223	-.252	.564**	1		
P value	.460	.154	.344	.284	.010			
Lead	-.366	.695**	-.600**	.753**	.221	.259	1	
P value	.112	.001	.005	.000	.349	.270		
Nickle	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a	. ^a

3.9. Heavy Metal Pollution index in studied samples

The overall impact of traces of heavy metals on water quality can be computed by HPI concept given by (Venkata Mohan et al., 1996). Many researchers had revealed that the intensity of heavy metals is caused due to anthropogenic activities and is natural in some cases. This leads to ground water and surface water contamination and becomes harmful to the human beings and animal kingdom also up-to many extents, including the social and economic development. Currently, surface water contamination is a concern not only in rural areas but also in urban areas because ponds and wetlands in urban areas are considered as livelihood options for many urban residents.

The location of the Budha talab of Raipur city is towards west corner of the city. Table 1.7 depicts that HPI was calculated to be 1035.00 i.e., around 9 times more in monsoon season when compared to pre-monsoon season. But it was also seen that in the post monsoon and winter seasons the HPI was calculated to be very low. Hence, the author puts efforts to compute individual heavy metal pollution index for Fe, Zn, Mn, Cu, Cd, Co, Pb and Ni. The result shows that heavy metals such as cadmium, iron, and lead are contributing more for the heavy metals contamination compared to rest heavy metals. The findings also highlight that the scenario was almost same for the pre-monsoon period. However, contamination of iron was supposed to be takes place in every period i.e., pre-monsoon, post-monsoon, winter, and monsoon (Table 1.6). The table also described the HPI for Bhaiya talab of the city. It shows that heavy metal contamination was more in i.e., 210.299. Further to identify individual contribution of metals to contamination, it was found that Copper (5539.83) followed by lead (2357.37), cobalt (1178.68), and nickel (235.73) in monsoon. However, the contribution of iron, lead and cadmium is reported to be more in rest of the seasons such as post monsoon, winter, and pre-monsoon.

Further, the HPI of Bhaiya talab was found to be contaminated from heavy metals specially in monsoon whereas the water quality is good in rest of the season. In monsoon, the prominent heavy metals which pollute the water are Copper, lead, Cobalt, Nickle, and Magnesium. Further in-depth analysis also shows that in rest season although water quality is good but intensity of heavy metals such as iron, cadmium, and lead are more. Similarly, the HPI index of Khokho talab, Maharaj bandh and Sarju bandh talab was reported to be more in monsoon season when compared to rest of the season. The analysis also shows that although in rest seasons the HPI is reported to be good and drinkable, the sub-index value of Iron, cadmium, lead is estimated to be more in Khokho, maharaja bandh and Sarju Bandh talab. If we summarise the analysis in a nutshell, we could say that the ponds of Raipur city are more prone to heavy metals such as cadmium, lead, and iron in all the studied period.

To understand the issue, the study tried to pinpoint the resources of heavy metals in the local geographical areas near to the pond and found that Budha talab is well connected with sewage system of the city and wastewater is directly dumped into it.

Table 1.7: Heavy metals pollution index for 5 studied ponds of Raipur city, Chhattisgarh, India

Heavy metals concentration and HPI	Monsoon (Slot 1)	Post Monsoon (Slot 2)	Winter (Slot 3)	Pre-monsoon (Slot 4)
HPI Overall (Budha Talab)	1035.99901	66.57900343	75.0105	118.4677585
Fe (Iron)	565.770863	102.7974226	186.822	84.24485306
Zn (Zinc)	-344.41301	-352	-351.27	-322.2536539
Mn (Magnesium)	-11.786893	-159.9952852	-353.25	-322.0179161
Cu (Copper)	0	7.501341267	7.07376	25.6043831
Cd (Cadmium)	3182.4611	335.9264498	351.249	348.8920321
Co (Cobalt)	-294.67232	-352.6874116	-353.23	-353.3710514
Pb (Lead)	2357.3786	42.43281471	112.683	550.4479019
Ni (Nickle)	1650.16502	0	0	1.650165017
HPI Overall (Bhaiya Talab)	210.299008	84.99657839	83.0249	80.35212081
Fe (Iron)	-279.34936	1076.795537	799.843	265.1265127
Zn (Zinc)	-212.16407	-352.334512	-352.09	-348.1650165
Mn (Magnesium)	13.0062267	-83.66336634	-84.665	-127.8877888
Cu (Copper)	5539.8397	7.608642638	7.6818	2.542717326
Cd (Cadmium)	-318.24611	344.1772749	351.249	348.8920321
Co (Cobalt)	1178.6893	-352.2866572	-352.42	-353.1824611
Pb (Lead)	2357.3786	169.9669967	145.45	145.6859972
Ni (Nickle)	235.73786	0	0	0
HPI Overall (Khokho Talab)	210.860795	96.19270683	91.4814	79.38874698
Fe (Iron)	-306.22348	2033.820525	1441.36	393.5486406
Zn (Zinc)	-247.52475	-352.0975955	-352.12	-350.4479019
Mn (Magnesium)	55.2764636	-175.223951	-165.11	-220.7685054
Cu (Copper)	5893.44649	7.234713619	6.94207	5.165097791
Cd (Cadmium)	-318.24611	346.5346535	326.497	346.5346535
Co (Cobalt)	1178.6893	-351.1904762	-352.04	-352.4281

Heavy metals concentration and HPI	Monsoon (Slot 1)	Post Monsoon (Slot 2)	Winter (Slot 3)	Pre-monsoon (Slot 4)
Pb (Lead)	2357.3786	254.3611504	266.148	145.6859972
Ni (Nickle)	235.73786	0	0	0
HPI Overall (MaharajBandh Talab)	1034.30842	89.9320943	72.9065	98.08889359
Fe (Iron)	801.508722	140.9633821	140.963	52.09020902
Zn (Zinc)	-350.07072	-352.0487977	-352.05	-335.4549741
Mn (Magnesium)	-259.31165	-1.119754833	-1.1198	-339.5803866
Cu (Copper)	0	7.213578501	7.21358	11.00814515
Cd (Cadmium)	3182.4611	351.2494107	351.249	346.5346535
Co (Cobalt)	-294.67232	-353.0292315	-353.03	-353.2531825
Pb (Lead)	2357.3786	228.194248	228.194	355.9641678
Ni (Nickle)	1650.16502	0	0	0
HPI Overall (Sarju Bandh Talab)	210.704125	84.16493919	87.7431	81.70607983
Fe (Iron)	-272.04149	1170.776363	1227.84	1385.541411
Zn (Zinc)	-259.31165	-352.0473833	-352.38	-350.2623762
Mn (Magnesium)	52.0249069	-118.1636021	-22.643	-151.21405
Cu (Copper)	5539.8397	7.450942139	7.29487	4.878960802
Cd (Cadmium)	-318.24611	346.5346535	350.071	338.2838284
Co (Cobalt)	1178.6893	-352.1216407	-351.64	-351.1669024
Pb (Lead)	2357.3786	157.2371523	174.446	145.2145215
Ni (Nickle)	235.73786	0	0	0

Source: Primary research data collected for Doctoral of Philosophy, 2017-18

Environment pollution has been a concern for all the countries now as it is affecting human and aquatic life. The recent boom in urbanisation has significantly affected the water quality of ground and surface water. Although, government has designed strict laws related to pollution, but lack of monitoring system, effective system and unskilled manpower totally make these policies worthless.

4. DISCUSSION

Aquaculture has been adopted by many urban residents in India including Raipur city as a livelihood option and the urban local government lease these ponds to get revenue. However, in many smart cities including Raipur, the government has not been able to mitigate the water contamination in the lack of regular testing or water or monitoring. In the current study, few conclusions are derived which is necessary to understand by the local government and policy makers. First, the HPI was calculated to be more in monsoon seasons as reported in many other studies of Ponds. However, it was also seen that in Budha Talab, HPI was reported to be more in pre-monsoon season, Khokho talab in Post monsoon, Maharaja bandh talab in post monsoon. This means maximum quantity of heavy metal contamination occur during the monsoon period due to mixing of rainwater with other sewage and grey water coming from the domestic uses, industries, immersion of idols and from air pollution (Reddy et al., 2011). If we look at the recent developments, many of the sewerage systems are connected to the ponds directly or indirectly in Raipur city. This needs to be stopped by inculcating proper management mechanism on sewage water management. Second, a strict need of monitoring of heavy meal

contamination is required on regular basis by the urban local bodies, so that strict preventive measure regarding contamination may looked. Third, the urban residents must be sensitised regarding the ill effects of heavy metals through proper training and ward counsellors and fish producers must be oriented towards this. A study conducted at Dhanbad city of India shows that the heavy metals are found more in pre-monsoon season in that area and within muscles of *L. Bata*, in the presence of heavy metals is seen in the sequence of $Zn > Mn > Pb > Cr > As > Cd$ (Pal & SK, 2018). On contamination of heavy metals, similar kind of findings is reported on Sunyani, Ghana (Saah et al., 2021). Locally compared to earlier studies among the ponds of Raipur city, envisaged that the intensity of heavy metals has been increase in last decades. This may be due to more anthropogenic activities and fly-ash discharged to water (Swarnakar et al., 2019; Swarnakar & Choubey, 2016). The same kind of findings was revealed by a researcher that heavy metal such as Mn and Cr contamination was more than permissible limit during pre-monsoon and Mn, Cr, and Fe was found more in post monsoon season. The findings are similar with present research findings which shows less intensity of Cu and Pb in the tested water (Tiwari et al., 2015). Not only the contamination affects human, but it also affects fishes also (Karimi et al., 2020). A study suggested that fishes are also prone to infectious diseases, if water gets polluted and indirectly harm the consumers while consuming them (Boyd, 2017).

5. CONCLUSION

Water for all, is a priority for all government across the globe. However, lack of proper execution of effective policies and political willingness to bring change, have continuously contaminated water sources and affected lives. Pond as an ecosystem not only bridge the issue of water depletion level in urban and rural areas, but it acts as a source of income for many of the urban resident including uses of water for drinking and other purpose. In this perspective, water contamination is reported much more in industrial belt as compared to general region by many researchers (Saravanan et al., 2019). The research carried out across the globe has raised concern for taking initiative to reduce contamination in many forms, however, this needs to be regulated through local intervention and policies, now. This is because most of the slum dwellers are residing nearby these water bodies and uses contaminated water for bathing, drinking, washing clothes and cleaning utensils. The poor quality of water affects their health extremely and brining loss to a nation in terms of Gross Domestic Production.

Raipur, a growing city in developing country like India need more concern as population has been showing 2-3-4-5 syndrome and more dependency is seen on livelihood and domestic purposes through ponds. The result from current paper would help the government to take necessary steps to ensure good health of its citizens and could be replicated in other developed and developing cities by establishing water quality improvement strategies. It revealed many new trends in the ponds that Iron and Magnesium content in Budha Talab was more across all seasons and is more than permissible limit. Not only this, Copper was also reported to be more in pre-monsoon period only. Rest of the metal traces are less and within permissible limit. The corelation between metal traces like Copper and Zinc, Cobalt and Cadmium, Lead and Zinc, and Lead with Copper were reported to be positive whereas

Manganese and Zinc exhibit negative correlation. The quality of water through HPI in Budha Talab conclude that, the contamination was more in terms of Cadmium, Iron, and Lead. Iron was a identify as a major contributor. However, HPI was estimated to be more in monsoon period then Premonsoon period only. This means the metal traces may add to the ponds water through runoff and through air pollution. In monsoon, the key heavy metals which pollute the water are Copper, lead, Cobalt, Nickle, and Magnesium for Bhaiya Talab. Similarly, the HPI index of Khokho talab, Maharaj bandh and Sarju bandh talab was reported to be more in monsoon season, compared to rest of the season. The analysis also shows that although in rest season, the HPI is reported to be good and drinkable, the sub-index value of Iron, Cadmium, Lead is estimated to be more in Khokho, Maharaja bandh and Sarju Bandh Talab. If we summarise the analysis in a nutshell, we could say that the ponds of Raipur city are more prone to heavy metals such as Cadmium, Lead, and Iron in all the studied period.

Hence, every local government must conduct regular seasonal monitoring and developed a data base to measure the effectiveness of the policies and testing and display the result in the public places to create awareness regarding the water contamination and its ill effect on aquatic and human life (Umeogaju et al., 2021). Further, the sewage management system at city level needs to be improved along with the industrial waste management (Dietler et al., 2019). Much research is also proposed to manage the storm and sewage water by adding to the ponds. There isa a need to make an amendment. Before adding to pond water, the government must try to purify the water with the standards of BIS, WHO and other standards. A study conducted by GIZ suggested that interconnectivity of stormwater drains with ponds of the city (Khan et al., 2014), however, the author did not agree to this completely and suggested that wastewater and stormwater must be contaminated free from heavy metals before adding to the ponds to maintain the water level. This paper highlights that seasonal variation is seen in heavy metal contamination; hence the aquatic business system must develop a mechanism to check the quantity of heavy metal pollution effect on the aquatic animals before sending them to the consumers, directly or indirectly as human life is precious. This could be used as a baseline information on pond water contamination in India. Addition to this, effluent conformation of industrial products discharged into sewage or ponds must be registered, so that wastewater management instruction should be given to different industries.

6. DECLARATIONS

6.1. Ethical Approval and Consent to participate

To conduct the research study, individual written and verbal consent to test the quality of water was taken from the in-charges of the ponds. Before collecting the water sample, purpose of the study was cleared to all these in-charges and all questions of them were addressed. Raipur Municipal corporation (RMC) gave these large, studied ponds to conduct fishery cultivation to individual contractors.

6.2. Human and Animal Ethics

No human or animal are tested or involved in this research work, directly or indirectly. Hence, this section is not applicable.

6.3. Consent for publication

Not applicable

6.4. Availability of supporting data

The supporting data will be provided to the reader and journal on request.

6.5. Competing interests

The authors declared that they do not have any known conflict of interest in conducting and publishing this original article.

6.6. Funding

Not applicable as no one has funded to conduct this research.

6.7. Authors' contributions

DD, the first author collected the water samples, analysis, prepared the tables and conduct the review. HKM, the second author conceptualises the paper, conducted the analysis and write the paper. SKP, the third author edited the paper and checked the statistical validation of the data and its scientific interpretation. SKP guided the co-authors to complete the paper.

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The authors of the paper acknowledge the contribution of the in-charge of the studied ponds for providing support to collect the water sample by taking them into the mid-area of these ponds. The discussion with these officials also helps to understand the sources of contamination of these ponds.

6.9. Authors' information

The first author DD is a scholar in the department of Environmental Science of Sambalpur University whereas HKM is working as an assistant professor in the School of Development Studies. and is facilitating the student in the Department of Environmental Sciences, sambalpur University, Odisha, India.

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