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Investigating the effects of anthropogenic land use on water quality of drinking water sources in Barak Valley, Assam, North East India

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ABSTRACT

Anthropogenic land use can potentially impact the water quality of different drinking water sources. However, the degree of impact in different watersheds remains largely unknown. We hypothesized that a heterogeneous environment created due to diverse land uses can have a substantial effect on the water properties of different drinking water sources. We tested this hypothesis using data on drinking water parameters collected following standard methods at seasonal intervals for a period of two years from selected surface water sources in the Barak Valley region of Assam in North East India. The study showed that drinking water from different sources viz., pond, river and tap water, located under different land use types viz., rural area, semi-urban area, urban area, and tea-garden area, have their distinctive characteristic features. Water properties of different sources varied within as well as across different land use types. Upon comparing the water properties of various surface water sources utilized for drinking purposes with the relevant standards, it was found that certain parameters did not fall within the acceptable range for drinking water. The study highlights the significant influence of anthropogenic land use on the quality of drinking water sources in the Barak Valley region of Assam, North East India. The results suggest that the impact of land use on water properties varies between different sources and land use types. The findings underscore the need for sustained efforts to manage land use practices and implement effective strategies to ensure the provision of safe and clean drinking water to the population.

Key words: *Landuse type, Drinking water sources, Water properties*

Introduction

Of all the water on earth, only 2.5–2.75% is fresh water, including 1.75–2% frozen in glaciers, ice and snow, ~0.6% as fresh ground water and less than 0.01% are available as surface water in lakes, swamps and rivers (Levy *et al*., 2011; Abu-Shahba *et al*., 2020; Luijendijk *et al*., 2020). The limited availability of fresh water from surface water sources underscores the crucial need to protect and preserve waterbodies. As civilization has advanced and industrialization, urbanization, and the use of chemical fertilizers in agriculture have increased, along with a surge in human population, especially in developing countries, surface water bodies such as rivers, ponds, and lakes, which also act as drinking water sources, are being overwhelmed with sewage effluents, agricultural, and industrial waste (Dey *et al*., 2021). Although drinking water quality is a relative term that depends on the water's composition and the natural processes involved, as well as the influence of human activities (Meride *et al*., 2016), it is imperative that good quality water for human consumption should be free of harmful substances or microorganisms. Hence, access to clean drinking water remains a major issue worldwide. According to UNO (2003), up to 80% of all diseases are waterborne and can be caused by inadequate sanitation, polluted water, or a lack of high-quality drinking water. Therefore, to enhance confidence in the safety of drinking water, a holistic approach to assessing and managing risks in drinking water supply is crucial (Rizak *et al*., 2003).

In context of the above proposition, an attempt has been made to evaluate the status of drinking water from surface water sources viz., pond, river and tap water, located under different human land use type viz., urban area, semi-urban area, rural area and tea-garden in Barak Valley, Assam through analyses of the water quality. The objectives of the study were: (1) to determine whether there is any variation in the quality of drinking water derived from sources located in different land use types, (ii) if such variation exists, to identify the possible reasons for it, and (iii) to suggest potential solutions for addressing issues related to contaminated drinking water.

Materials and Methods

Study area

The present study was conducted in the Barak Valley, Assam, north-east India. Barak valley comprises three districts viz, Cachar, Hailakandi and Karimganj with varied types of anthropogenic land use viz., rural area (RA), semi-urban area (SUA), urban area (UA) and tea- garden area (TGA), inhabited by the local communities. For the present study drinking water samples from surface water sources were collected from representative drinking water sources located under different anthropogenic land use types. A total of 22 number of drinking water sources from surface water systems comprising 8 ponds, 6 rivers and 8 tap water sources (i.e., water after conventional treatment by Public Health Engineering department, Govt., of Assam, India) were selected which were distributed across different anthropogenic land use types viz., RA, SUA, UA, and TGA (Figure 1). These numbers of sampling points were considered as functions of the representation of drinking water source belonging to surface water, as well as on their availability under different types of land use.

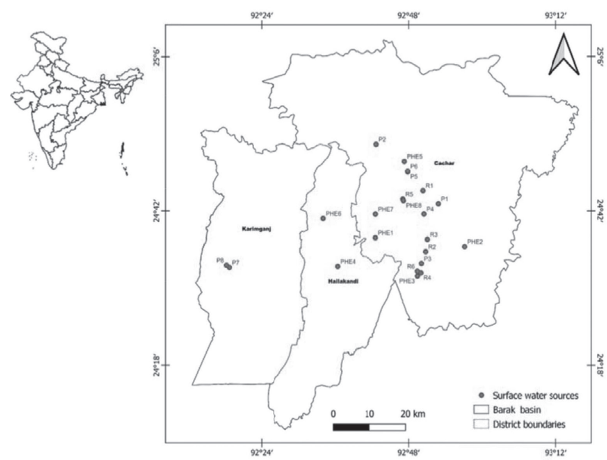

Fig. 1. Map showing sampling locations of different drinking water sources located under different land use types; P indicates pond; R indicates river; PHE indicates tap water source supplied by Public Health Engineering department, Govt. of Assam, India

P1, P2 -ponds located in rural area; R1, R2-rivers located in rural area; PHE1, PHE2- source of tap water in rural area;

P3, P4- ponds located in semi-urban area; R3, R4- rivers located in semi-urban area; PHE3 PHE4- source of tap water in semi-urban area;

P5, P6- ponds located inurban area; PHE5, PHE6- source of tap water in urban area;

P7, P8- ponds located in tea-garden area; R5, R6- rivers located in tea-garden area; PHE7, PHE8- source of tap water in tea-garden area

Methodology

For analyzing the water quality of drinking water from different drinking water sources located under different land use types in the study area, water samples were collected from the selected drinking water sources under the selected anthropogenic land uses at seasonal intervals i.e., pre-monsoon (March-May), monsoon (June-August), and post-monsoon (September to November) for a period of 2 years (2019 and 2021). Air and water temperatures were measured down in situ using a mercury bulb thermometer (0-50 °C). Collection of water samples for analyses of its chemical parameters was done using one liter polyethylene container. For dissolved oxygen, BOD bottle (300 ml) was used to which 2 ml each of alkaline iodide and manganous sulphate was added immediately and mixed in the field to form a precipitate of $Mn(OH)_2$ (so that there is no further alteration in dissolved oxygen of the collected sample). For total and fecal coliforms, sterilized BOD bottle (300 ml) was used. All samples were later brought to the laboratory where all the analysis was performed following standard methods (APHA, 2012).

Statistical analysis

Boxplots were utilized to visualize the data, while the Shapiro-Wilk Test was applied to check for normality. Statistical analyses, such as one-way analysis of variance (one-way ANOVA) with Tukey post-hoc tests, and principal component analysis (PCA) were carried out using SPSS version 20. PAST software (version 4.10) was used to generate group-wise PCA and dendrograms through cluster analyses for the water quality parameters of the drinking water sources located under different land use types.

Results and Discussion

Significant variations in some of the drinking water parameters in different types of drinking water sources located under different types of land use could be observed in the present study. For example, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), total and fecal coliforms showed significant variations in the water of the ponds located under different types of land use (Figures 2D, 2E, 2F, 2J and 2K). Significantly higher value of EC and TDS in ponds located under UA (Figures 2D and 2E) can be attributed to urban runoff and inflow of sewage and wastewaters, which enhances inorganic dissolved solids in water (Chusov *et al.*, 2014). A significantly higher value of DO in ponds located under UA (Figure 2F) can be attributed to algal production (Rodrigues *et al.*, 2022). Significantly higher value of total and fecal coliforms in ponds located under TGA (Figures 2J and 2K) indicates the incidence of open defecation in the riparian region of such ponds.

Significant variations were observed in DO and Phosphate-P (PO_4-P)in the water of rivers located across different land uses (Figures 2F and 2I). Sig-

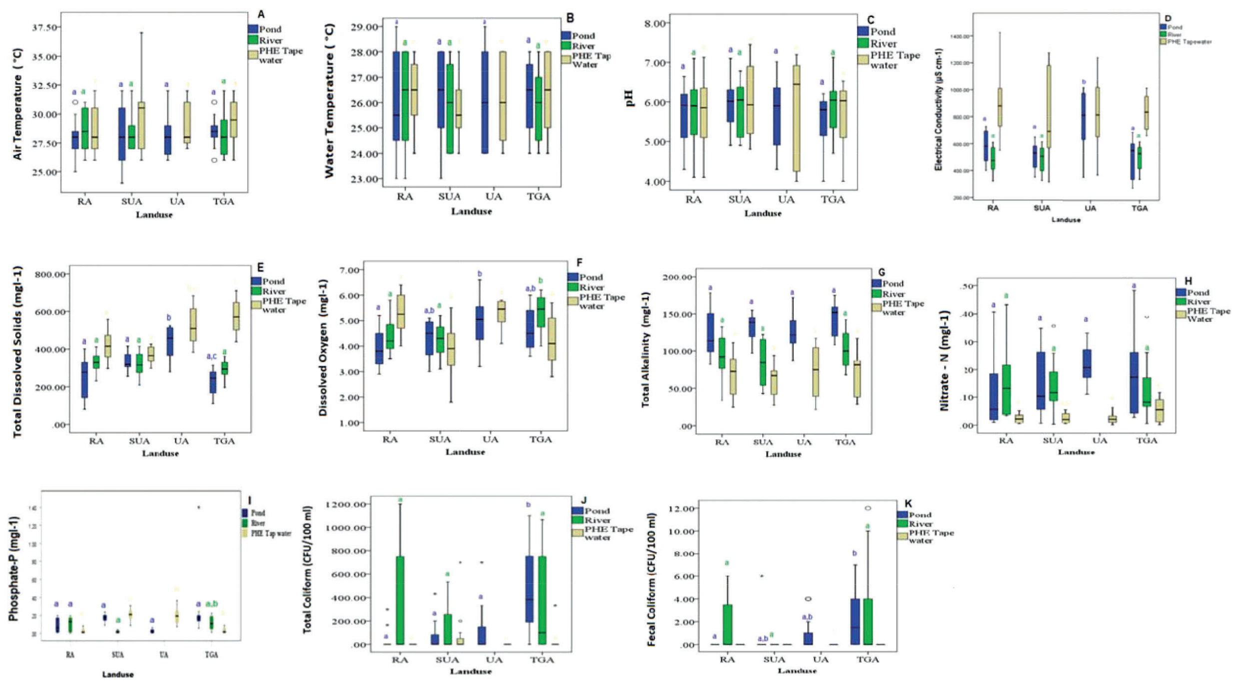

Fig. 2. Variations in physico-chemical properties of drinking water in different surface water sources located under different land use types; RA-Rural area; SUA-Semi-urban area; UA-Urban area; TGA-Tea-garden area
(A) Atmospheric temperature; (B) Water temperature; (C) pH; (D)Electrical conductivity; (E) Total dissolved solids; (F) Dissolved oxygen; (G) Total alkalinity; (H) Nitrate-N; (I) Phosphate-P; (J) Total coliforms; (K) Fecal coliforms
Boxplots with similar colour represents similar type of drinking water source; Similar colored boxplots with alphabet(s)of different type(s) indicate significant variation(s)in the respective water parameter in the drinking water source located across different use types(as per Tukey's post hoc analysis)

nificantly higher value of DO in rivers flowing through TGA (Figure 2F) can be attributed to rapid water flow conditions and fluctuation in temperature as the presence of bushy trees near the river made the region colder and have helped to increase DO concentration (Rajesh *et al.*, 2022). A significantly higher value of PO_4-P in rivers flowing through the TGA (Figure 2I) may be attributed to the deposition of industrial waste from the nearby tea factory and runoff from the nearby catchment area of tea gardens carrying fertilizers used in tea gardens as a management intervention to maintain the productivity of tea plantations.

Besides, significant variations in TDS, DO, and Nitrate-N (NO_3-N) of tap water sources located across different land uses were also observed (Figures 2E, 2F and 2H). The significantly higher value of TDS (Figure 2E) and NO_3-N (Figure 2H) in tap water located under TGA can be attributed either to presence of a large quantity organic matters in the raw water sources from which the PHE department's water treatment plants take the raw water or it might be attributed to the leakage of pipes used for supplying the tap water which lead to input of nutrient-rich organic matters from tea garden area. Significantly greater value of DO in tap water located under RA and UA (Figure 2F) may be attributed to frequent aeration, continuous flow of water and colder reservoirs (Kumar *et al.*, 2012) of the PHE water treatment plants supplying water to such areas.

Principal component analysis (PCA) was performed for water variables of different drinking water sources located in different land use types to extract and identify the factor(s) playing a significant role in creating variation in the observed variables (Johnson and Wichern, 2002). To uncover the potential reasons for variations in the physico-chemical properties of water among the same types of drinking water sources located across different land use types, group-wise principal component analysis (PCA) was performed. This approach allowed for the identification of underlying factors that contributed to the observed differences in water properties.Variance factor (VF) having eigen values greater than one was considered to explain the data while the VFs representing a correlation greater than or equal to 0.70 were considered significant (Shrestha, 2021).

In case of ponds, PCA explained ~ 82% of the total variance of water parameters (Table 1). It revealed that water parameters like pH, EC, TA followed by AT, WT, and, total coliforms, fecal coliforms, TDS, nitrate-N, and phosphate-P are mainly responsible for characterizing the water properties in ponds (Table 1). This suggests that anthropogenic activities, such as occasional liming, along with the influence of riparian vegetation that

Table 1. Loading of variables on principal components rotated according to the varimax method for physico-chemical properties of drinking water from different surface water sources located under different land use types

Water properties		Types of drinking water sources												
		Pond					River				Tap water			
		VF1	VF2	VF3	VF4	VF5	VF1	VF2	VF3	VF4	VF1	VF2	VF3	VF4
Loading scores	Water temperature	**0.179**	**0.912**	0.014	0.033	0.135	0.101	0.157	**0.886**	-0.151	**0.929**	0.025	-0.135	0.094
	pH	**0.808**	-0.248	0.113	-0.304	-0.132	**-0.907**	0.15	-0.135	-0.196	-0.096	**0.919**	0.024	0.085
	Electrical conductivity	**0.832**	0.123	0.106	0.289	-0.198	**-0.778**	0.303	0.369	-0.227	0.325	**0.819**	0.201	0.104
	Total dissolved solid	-0.006	0.188	-0.175	**0.857**	0.000	0.69	-0.188	0.467	0.141	0.444	-0.654	0.29	0.375
	Dissolved oxygen	-0.693	-0.336	-0.106	0.415	-0.081	0.09	-0.185	-0.127	**0.90**	-0.206	0.132	**0.834**	-0.19
	Total alkalinity	**-0.859**	-0.263	0.076	-0.074	-0.210	0.424	-0.208	-0.503	0.526	-0.512	-0.549	0.457	-0.038
	Nitrate-N	-0.115	-0.243	0.172	0.429	**0.729**	**0.813**	0.146	-0.061	-0.144	0.001	0.093	-0.264	**0.918**
	Phosphate –P	0.044	0.297	0.036	-0.231	**0.792**	-0.212	0.6	0.573	0.288	**0.858**	0.037	-0.106	0.162
	Total coliforms	0.084	0.042	**0.809**	-0.271	0.152	-0.121	**0.858**	0.182	-0.327	0.107	0.054	**-0.82**	0.066
	Fecal coliforms	0.044	0.093	**0.916**	0.049	-0.002	-0.056	**0.907**	0.151	-0.126	**0.769**	0.006	-0.191	-0.294
	Eigen value	2.622	2.106	1.613	1.419	1.308	2.829	2.387	2.295	1.557	2.819	2.274	1.837	1.165
	% of Variance	23.841	19.142	14.667	12.896	11.889	25.715	21.702	20.864	14.153	28.192	22.74	18.368	11.649
	% of Cumulative variance	23.841	42.982	57.649	70.545	82.434	25.715	47.417	68.281	82.434	28.192	50.932	69.3	80.949

VF, Variance factor; bold values indicate strong loading causes shade, and the influx of organic matter and fecal contamination from the surrounding riparian region, play a significant role in determining the water properties of the selected ponds in general.

Group-wise PCA of the physico-chemical properties of water in ponds located under different land use types revealed that total coliforms, fecal coliforms, TA, AT, WT, and pH were closely associated with the first axis while nitrate-N, TDS and EC were closely associated with the second axis, which together explained 82.86% of the total variance in the dataset. This suggests that the water quality of ponds located in various land use types is differentially impacted by variations in anthropogenic interventions and the quality of runoff carrying organic and inorganic matter, as well as fecal contamination from the adjacent riparian region. Furthermore, the effects of variations in canopy cover on ponds, particularly on water temperature, due to riparian vegetation could also be observed in ponds located under different land use types (Figure 3A).

The cluster analysis of drinking water quality in ponds located under different types of land use (Figure 4A) showed formation of a separate group for the ponds located in TGA indicating some distinctive characteristics of drinking water in ponds located in TGA, while the ponds located in RA, SUA and UA formed a group of clusters indicating more similarity in the drinking water quality of the ponds located in RA, SUA, and UA.

In the case of rivers, PCA explained ~ 82% of the total variance of water parameters (Table 1). It revealed that water parameters such as pH, nitrate-N, total coliforms, fecal coliforms followed by WT, and DO are mainly responsible for characterizing the water properties in rivers. This highlights the significant impact of runoff carrying organic and fecal matters from the surrounding riparian region in shaping the water properties of rivers. Furthermore, the quality of drinking water in rivers is influenced by the effect of riparian vegetation on water temperature, as well as the water flow conditions that impact the dissolved oxygen content. These factors collectively contribute to the overall characterization of drinking water quality in rivers.

Group-wise PCA of the physico-chemical properties of water in rivers located under different land use types revealed that EC, DO, and TA were closely associated with the first axis while WT was closely associated with the second axis, which all together explained 100% of the total variance in the dataset. This implies that the drinking water quality of rivers located in varying land use types is differentially impacted by variations in the quality of runoff carrying organic and inorganic matter, as well as water flow conditions. In addition, the effects of variations in canopy cover on the river banks, particularly on water temperature, due to riparian vegetation, were also observed in rivers flowing through different land use types (Figure 3B).

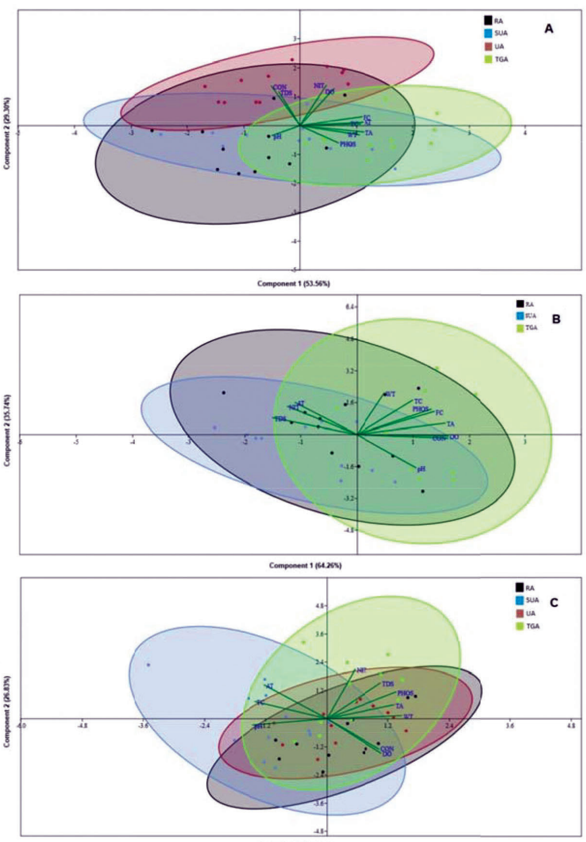

Fig. 3. Group-wise PCA to identify and differentiate characteristic features of drinking water in different drinking water sources located under different land use types viz.,
(A) Pond, (B) River, (C) Tap water
RA-Rural area; SUA-Semi-urban area; UA-Urban area; TGA-Tea-garden area; AT- Atmospheric Temperature; WT- Water Temperature; CON- Electrical conductivity; TDS- Total dissolved solid; DO- Dissolved oxygen; TA- Total alkalinity; NIT- Nitrate-N; PHOS- Phosphate–P; TC- Total coliforms; FC- Fecal coliforms
Here, the size of the ellipse is directly proportional to the overall variability in the water properties, while overlapping regions amongst the ellipse show similarity in conditions

The cluster analysis of drinking water quality in rivers located under different types of land use (Figure 4 B) showed formation of a separate group for the rivers located in SUA, indicating some distinctive characteristics of drinking water in the rivers located in SUA while the rivers located in RA and TGA formed another cluster indicating more similarity in drinking water quality of the rivers located in RA and TGA.

In the case of tap water, PCA explained ~ 81% of the total variance of water parameters (Table 1). It revealed that AT and water parameters like WT, phosphate-P, fecal coliforms followed by pH, Cond, DO, total coliforms and nitrate-N are mainly responsible for characterizing the water properties in tap water sources in general. This highlights the significant variations in the sources of untreated water, which are impacted by inorganic and organic inputs as well as fecal contamination from the surrounding riparian region, that are utilized by the PHE department for water treatment and the subsequent supply of treated water through pipes as the major contributing factors to the observed variations in water properties of tap water in general.

Group-wise PCA of the physico-chemical properties of tap water located under different types of land use revealed that WT, TA, and pH were closely associated with the first axis while nitrate-N was closely associated with the second axis, which together explained 89% of the total variance in the data set. This shows that drinking water quality of tap water located under different land use types are affected due to variations in quality of intake raw water and its subsequent treatment and supply through distribution pipes by the PHE department (Figure 3C).

The cluster analysis of the quality of drinking water from tap water sources located under different types of land use (Figure 4 C) showed the formation of a separate group for the tap water sources located in SUA indicating some distinctive characteristics of drinking water in tap water located in SUA while tap water in RA, TGA, and UA formed a group of clusters indicating more similarity in their drinking water quality.

Although differences were observed in the water properties of similar types of drinking water sources located in different land use types, there were also similarities found among them. Overlapping regions were revealed by the ellipse, which indicated that the drinking water sources located under different land use types occupied a common environmental space in the study area (Figure 3) which was also reflected in the cluster analyses (Figure 4). Nonetheless, the effect of various anthropogenic land uses on the quality of drinking water in different surface water sources cannot be ignored (Figures 2D, 2E, 2F, 2H, 2I, 2J, and 2K).

On comparing the water properties of ponds located under different land use types with the relevant drinking water standard (Tables 2 and 3) we observed that during some part of the year EC in ponds under UA exceeded the standard indicating incidence of pollution in the riparian region of ponds located in UA and subsequent entry of polluted runoff in such systems. DO was less in the RA-restricted ponds, indicating contamination from organic sources. Phosphate-P exceeded the limit in TGA-regulated ponds, indicating the effect of runoff from the surrounding tea garden area undergoing fertilizer application. Fecal coliforms were present in ponds under SUA, UA, and TGA which indicate the effect of fecal contamination in the pond water due to defecation on the surrounding riparian region of

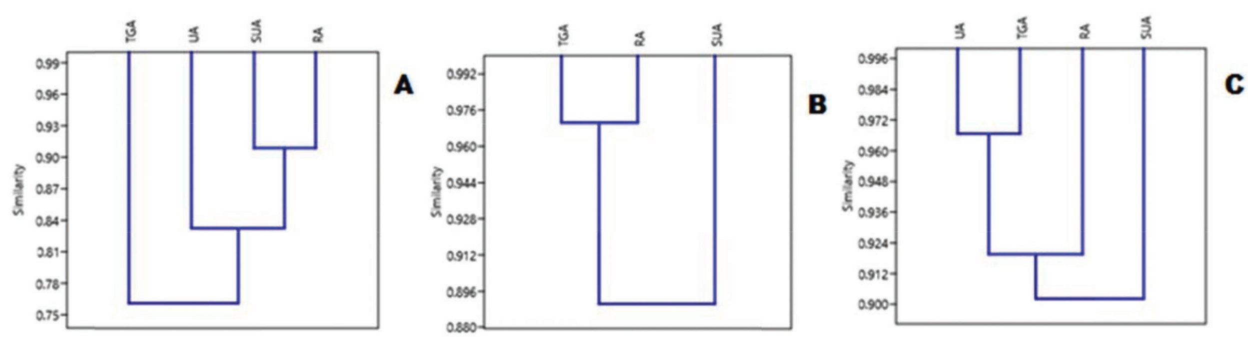

Fig. 4. Dendrogram showing similarity of drinking water quality in respective drinking water sources viz., (A) Pond, (B) River,and(C)Tapwater located under different land use types viz., Rural area (RA); Semi-urban area (SUA); Urban area (UA); Tea-garden area (TGA)

such ponds. All these indicate the necessity of taking safety measures by local communities of SUA, UA, and TGA while consuming pond water, especially during the rainy season, when the chances of contamination are maximum due to inflow of runoff from the surrounding riparian region. Interestingly, ponds in RA were free from fecal contamination (Table 2). This indicates the awareness of some section of rural communities in the study area about the importance of clean and uncontaminated water in ponds for drinking purposes.

We observed fecal contamination in water of rivers flowing through RA and TGA (Tables 2 and 3) indicating the incidence of defecation on the surrounding riparian region of such rivers thereby indicating the necessity for disinfecting the drinking water of rivers flowing through RA and TGA before its consumption. The results also highlight the necessity for awareness regarding proper sanitation measures to the local authorities and also the communities of RA and TGA.

Comparison of the water properties of the tap water supplied by the PHE department located in different land use types with the relevant drinking water standard (Tables 2 and 3) revealed that during most period of the year EC exceeded the standard limit, indicating contamination of the treated water from inorganic sources,particularly during rainy season. This also shows the necessity of upgrading the water treatment methods for removing the excess EC by the PHE department by employing one of the several approaches like reverse osmosis, distillation, ion exchange, electrodialysis, or activated carbon filtration. However, to ensure the effectiveness and safety of the treatment method for drinking water, the PHE department must carefully select the appropriate method. The level of Phosphate-P in tap water in UA has exceeded the standard limit during certain periods of the year. This suggests that there may be sewage or wastewater containing high levels of phosphorous-rich organic matter in the sources of the raw water that is used by the PHE water treatment plants. Alternatively, it could be due to contamination of the treated water from wastewater and sewage, possibly due to cracks in the water supply pipes. This highlights the importance of managing urban waste and sewage systems in a scientific and sustainable manner. DO was less in tap water sources under SUA and TGA indicating either presence of organic contamination in such sources or insufficient aeration in the water treatment plants supplying water through tap in such areas or possibly due to contamination of the treated water due to cracks in the water supply pipes. Al-

Table 2. Ranges in different physico-chemical properties of drinking water from different surface water sources under different land use types

Range of drinking water parameters in different drinking water sources under different land use types		Types of drinking water sources under different land use types										
		Pond				River			Tap water			
		RA	SUA	UA	TGA	RA	SUA	TGA	RA	SUA	UA	TGA
Water temperature	Minimum	23	23	24	24	23	24	24	24	24	24	24
(WT; °C)	Maximum	29	28	29	28	28	28	28	28	28	28	28
pH	Minimum	4.3	4.9	4.3	4	4.1	4.9	4.7	4.1	4.8	4	4
	Maximum	6.64	7.1	7.02	6.21	6.7	6.78	7.13	7.13	7.45	7.11	6.53
Electrical conductivity	Minimum	401	352	351	269	322	326	335	551	315	368	658
(EC; µS cm^{-1})	Maximum	728	650	1016	684	611	615	613	1425	1274	1238	1012
Total dissolved solid	Minimum	81	255	328	110	231	213	196	297	298	383	439
(TDS; mgl^{-1})	Maximum	401	416	525	315	412	415	362	559	427	684	711
Dissolved oxygen	Minimum	2.9	3	3.2	3.6	3.5	3.1	4	4	2.8	4.1	2.8
(DO; mgl^{-1})	Maximum	5.2	5.1	6.6	6	5.8	5.2	6.2	6.4	5.5	5.8	5.7
Total alkalinity	Minimum	82	97	87	108	33	43	68	24	27	21	28
(TA; mgl^{-1})	Maximum	178	155	172	175	132	122	142	111	94	117	112
Nitrate-N(NO_3-N;	Minimum	0.01	0.01	0.11	0.03	0.03	0.003	0.01	0.01	0.01	0.001	0.001
mgl^{-1})	Maximum	0.41	0.35	0.33	0.48	0.43	0.36	0.39	0.05	0.05	0.06	0.12
Phosphate-P	Minimum	0.01	0.09	0.002	0.06	0.002	0.002	0.01	0.002	0.09	0.07	0.002
(PO_4-P; mgl^{-1})	Maximum	0.2	0.24	0.07	1.4	0.2	0.04	0.22	0.08	0.30	0.37	0.09
Total coliform	Minimum	0	0	0	0	0	0	0	0	0	0	0
(CFU/100 ml)	Maximum	300	433	700	1100	1200	533	1066	0	700	0	333
Faecal coliform	Minimum	0	0	0	0	0	0	0	0	0	0	0
(CFU/100 ml)	Maximum	0	6	4	7	6	0	12	0	0	0	0

RA-Rural area; SUA-Semi-urban area; UA-Urban area; TGA-Tea-garden area

Table 3. Drinking water standards as per different relevant organization

Parameters	Standards as per					
	WHO		ICMR		BIS	
	*HDL	**MPL	*HDL	**MPL	*HDL	**MPL
pH	6.5-8.5	6.5-9.5	7.0-5.0	6.5-9.2	6.5-8.5	No relaxation
Electrical conductivity (EC; µS cm^{-1})	300	-	300	-	800	-
Total dissolved solid (TDS; mgl^{-1})	500	-	500	-	500	2000
Dissolved oxygen (DO; mgl^{-1})	ˆ 5	>5	>6	3.0-6.0	-	-
Total alkalinity (TA; mgl^{-1})	120	250	120	250	200	600
Nitrate-N(NO_3-N; mgl^{-1})	50	No relaxation	45	-	45	No relaxation
Phosphate-P(PO_4-P; mgl^{-1})	0.3	-	-	-	-	-
Total coliforms (CFU/100 ml)	Must not be detectable in any 100 ml sample	-	-	-	Must not be detectable in any 100ml sample	-
Fecal coliforms (CFU/100 ml)	Must not be detectable in any 100 ml sample	-	-	-	Must not be detectable in any 100 ml sample	-

WHO: World Health Organization
ICMR: Indian Council for Medical Research
BIS: Bureau of Indian Standards
*HDL: Highest Desirable Limit
**MPL: Maximum permissible Limit

though all tap water sources were free from fecal contamination, indicating the efficiency of the PHE water treatment plant in treating raw water before its supply to the general masses however, the presence of total coliforms in such sources during some part of the year in SUA and TGA indicates the possibilities of contamination of drinking water perhaps due to breakage of the water supply pipelines in such areas. Therefore, this indicates the necessity of disinfection of tap water in SUA and TGA, which may be done by boiling the water prior to its consumption. The occasional detection of contaminated tap water supplied by the PHE department in SUA, UA, and TGA also suggests that the department should investigate the water supply pipelines in those specific locations for any cracks or damages.

It may be noted that in all the drinking water sources located under different anthropogenic land uses, the water pH and total alkalinity was lower than the standards during most periods of the year. This might be ascribed to the fact that the study area (Barak valley) has acidic soil condition due to its typical geological character (Borah *et al*., 2016; Shyam *et al*., 2022) or it might be attributed to presence of organic pollution in such water sources, particularly during rainy season. Such lower range of pH and total alkalinity in the respective drinking water source may be adjusted by treating the collected water using little amount of lime [Ca $(OH)_2$].

Conclusion

The study findings indicate that the quality of drinking water in various drinking water sources, located in different land use types, exhibit unique characteristics. The study highlights that the water properties in these drinking water sources are determined by a combination of natural processes across the catchments, different anthropogenic interventions based on the type of riparian land use, and human interferences within the drinking water sources. Effective management interventions, coupled with awareness campaigns for both local authorities, policy makers, and consumers settled across all land uses, are necessary to ensure the quality of drinking water. These measures may include individual-level and collective-policy-level water treatment strategies.

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Conflict of interest statement

The authors declare no conflict of interest.

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