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The impact of human waste hair reprocessing occupation on environmental degradation—A case study from rural West Bengal, India

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Abstract Human hair is considered as a potential biowaste worldwide, and improper disposal of hair can create multiple environmental problems. Due to unique characteristic features, human waste hair can be efficiently utilized for versatile applications, from agricultural industries to fashion industries. There is a huge business of human hair in many multinational countries and also in some rural areas of India. The continuous demand of such keratinous waste for human need in turn is producing residual waste at an alarming rate that causes environmental degradation. Therefore, our study aims to investigate the possible impacts of waste hair reprocessing activity on environmental health in rural India, citing examples from Radhapur village. Physico-chemical parameters of pond water and soil from the dumpsite were assessed. Along with this, elemental profile of waste hair, pond water and soil was estimated. To assess the deterioration of water quality, zooplankton diversity was also measured. Water quality index showed that the studied ponds are unsuitable for drinking purpose and aquaculture. The Shannon index further indicated comparatively lower diversity of zooplankton community in the studied ponds. Due to the presence of total organic carbon and available N–P–K, the soil can sustain the growth and survival of plants; however, the risk of toxic metal accumulation may be persisted. Hence, to enhance the utilization of waste hair in a large scale, a policy framework is extremely required that will incorporate environmental and social well-being and provide necessary support towards sustainable development. Future study needs to be carried out to eliminate the toxic elements from the water and soil using some phytoremediation strategies.

Keywords Waste hair reprocessing · Water quality index · Soil quality · Zooplankton diversity · Elemental profile

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Introduction

Environmental issues have become a major global burden due to the rapid growth of industrialization, urbanization and agricultural advancement. Human development both technologically and socially inextricably yields huge quantity of wastes which leads to environmental degradation. Globally, water pollution is one of the major environmental problems due to the disposal of waste in the soil–water environment. Even open dumpsite can severely affect the surface water quality as well as groundwater quality within its vicinity (Fulekar 2012; Oyelami et al. 2013). Therefore, it is imperative to develop proper waste management and also adequately emphasize involving waste-to-resource conversion. The latter plays a dual role minimizing the waste and simultaneously enhancing the economical support to the society. One of the global trending businesses is reusing keratin waste in a sustainable manner. There is a huge business of human hair in many multinational countries and also in some rural areas of India. The continuous demand of such keratinous waste for human needs and the generation of loads of waste lead to the accumulation of waste in the ecosystem. Pieces of literature reported some Indian case studies on air pollution due to incineration of waste hair and/or water pollution due to improper disposal of waste hair (Gupta 2014; Mishra 2017). Apart from these, the deposition of keratinous wastes in landfills led to some environmental problems and deterioration of valuable resources (Sharma and Gupta 2016).

Human hair is considered as a potential biowaste worldwide as there is no such use of this anywhere in such a huge quantity; therefore, it has been thrown away. Interestingly, while the hair is dumped as waste in most places, its transformation into resource becomes a global challenge. The fundamental constituent of human hair is keratin having 15–18% nitrogen, 2–5% sulphur, 3.20% mineral elements, 1.27% fat and 90% of proteins (Clay and Cook 1940). Keratin is less prone to enzymatic hydrolysis due to high cross-linking by disulphide bonds, hydrophobic interactions and hydrogen bonding and thus resistant to be degraded. In rural areas or areas with low population density, the hair is disposed of in nature which stays in the dumps/waste streams for long occupying large volumes of space due to slow disintegration (Sharma and Gupta 2016). Due to unique characteristic features such as biodegradability, mechanical strength, biocompatibility and natural profusion, human waste hair can be efficiently utilized for versatile applications, from agricultural industries to fashion industries (Gupta 2014; Sharma and Gupta 2016; Mishra 2017).

Extensively focused on fashion industries, a large number of the hair-processing units have been set up in most of the rural areas of India and become a classified source of occupational health problems as well as environmental degradation (Zheljazkov 2005; Sharma and Gupta 2016; Mondal et al. 2018). Some studies reported that value-added chain systems are involved in hair processing from the collection of waste hair to marketing of its products. After collection from different vendors, the raw waste hair is separated according to length, colour, quality and untangled; then, these are washed, dried and finally shaped using different types of *Kanta* (Gupta 2014; Mondal et al. 2018). Workers often use their nearby water bodies during and/or after the hair reprocessing activity, which eventually can contribute to unhealthy water quality (Gupta 2014). To the best of our knowledge, there had been no systemic thinking about environmentally safe management in spite of a large-scale economy running around human hair.

Studies have indicated that the environment in West Bengal has been grossly polluted by heavy metals as well as by toxic substances which thus enter into living organisms through food chain (Banerjee et al. 2010; Kar et al. 2008). On the other hand, these substances affect the geochemical and geotechnical properties of soil and contaminate groundwater table through percolation (Sharma et al. 2018). With the above background in mind, the major objective of this paper is to investigate the possible impacts of waste hair reprocessing activity on environmental health in rural India, especially addressing the surface water quality, productivity of the local ponds by assessing zooplankton diversity, elemental profile of waste hair from the dumpsite and soil quality of the dumpsite.

Materials and methods

Study area

The present study was conducted at Radhapur village (22.0350° N, 87.7345° E) in Purba Medinipur district of West Bengal, India (Fig. 1). A small community, viz. *Muslim Palli*, in this area is involved in waste hair reprocessing occupation, and the demographic detail of this community was discussed in our previous study

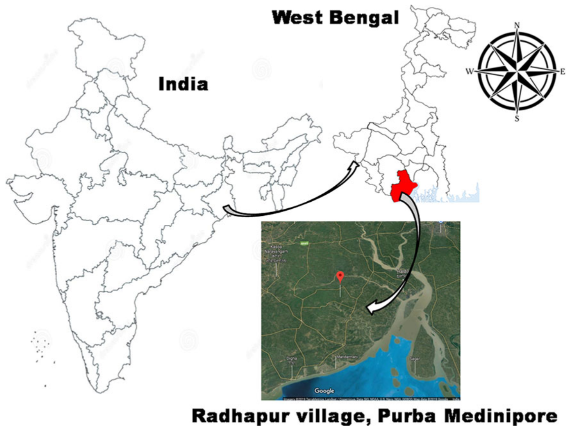

Fig. 1 Location of study area

(Mondal et al. 2018). This study was carried out for a period of January to June 2019.

Radhapur village: a case study for waste hair reprocessing unit

Radhapur is a small village located in Bhagawanpur II block of Purba Medinipur district in West Bengal, India. As per 2011 census, about 3670 people live in this village (approx. 322.64 ha area) among which 52% are male and 48% are female with an average population growth of 16.7%. Within this village, a small waste hair reprocessing unit was set up at *Muslim Palli* area (approx. 150 ha) where 71.43% people are involved in waste hair reprocessing, especially the females of this community (Mondal et al. 2018). A total of 44 ponds are present in this area among which 30 ponds are used for various purposes of waste hair reprocessing since last 10 years. During the washing process, workers generally use a specific hair dye and bleaching agents which contain *p*-phenylenediamine (*p*-PD) and hydrogen peroxide (H_2O_2) are generally used (Mondal et al. 2018). After reprocessing, the unwanted hair wastes are dumped into the environment without any proper management. Though for drinking purpose, this community use tubewell and *Sajal Dhara* water supplied by irrigation department of West Bengal; they solely depend on the ponds for all the domestic purposes such as bathing, washing utensils, washing vehicles, bathing of cattle and washing cattle waste, etc. Apart from this, they also consume some vegetables grown within the near vicinity of the dumpsite.

Assessment of surface water quality

The five water bodies identified for the present study are situated within the study area (Fig. 2) adjacent to the worker's community. The ponds were named as P1 (22° 01′ 26.28″ N, 87° 44′ 26.37″ E, elevation-5 m), P2 (22° 01′ 25.65″ N, 87° 44′ 25.30″ E, elevation-4 m), P3 (22° 01′ 28.09″ N, 87° 44′ 25.21″ E, elevation-4 m), P4 (22° 01′ 28.18″ N, 87° 44′ 26.20″ elevation-5 m) and P5 (22° 01′ 27.49″ N, 87° 44′ 24.09″ E, elevation-4 m). Physicochemical properties such as pH, temperature, acidity, alkalinity, free CO_2 concentration, dissolved O_2, total hardness and BOD_3 were measured using APHA-recommended protocol. Concentration of toxic metal was examined by ICP-OES (Thermo Scientific iCAP 7000 series). The sample was collected from the ponds and preserved with suprapure HNO_3 (HNO_3/sample = 1:25). The sample was filtrated with 0.2 µ syringe filter paper before spectrometry process, and then good linearity was obtained from the calibration curves prepared from a multielement (100 mg/L) standard solution supplied by Merck Pvt Ltd. Details of the instrumental setup are given in Table 1.

Plankton study

Plankton diversity was observed in five water bodies adjacent to the worker's community. The zooplankton in the surface water of five ponds was collected by filtering 50 l of water through a plankton net made by nylon net of 60 µ mesh size fitted to a metallic frame. Immediately after collection of the samples, the plankton was preserved in 4% formaldehyde solution. The counting of preserved samples was done using Sedgwick rafter-type plankton counting cell and was expressed in nos/L. To support the water quality variation, zooplankton diversity was expressed in terms of species richness, species abundance and Shannon–Weiner index (Mukherjee et al. 2010; Ismail and Mohd Adnan 2016; Adhikari et al. 2017).

Fig. 2 Sampling points from study sites. P1, P2, P3, P4 and P5 indicate water bodies; S1, S2, S3 and S4 indicate waste hair dumping sites

Analysis of the elemental composition of waste human hair from the hair dumping site

Waste hair samples were collected randomly from the dumpsite around the hair reprocessing unit. The collected samples were washed according to IAEA recommendation and were kept overnight at 50 °C for drying, and then the dried hair was crushed into fine powder using liquid N_2. The elemental concentrations of human waste hair were estimated using Xenemetrix (Ex-3600) energy-dispersive X-ray fluorescence (ED-XRF) spectrometer consisting of an oil-cooled Rh anode X-ray tube (maximum voltage 50 kV, current 1 mA). The instrument was calibrated using standard reference material (SRM) 2586, 2587, 1646a from National Institute of Standards and Technology (NIST) and certified reference material (CRM) DC 73347 from NCS Testing Technology Co; 150 mg of each dried powdered hair sample was pelletized and measured in triplicates for quantitative analysis.

Table 1 Details of the instrumental setup conditions of inductively coupled plasma-optical emission spectrometer (ICP-OES)

Radio frequency power	1150 W
Purge gas flow	Normal
Auxiliary gas flow	0.50 L/min
Coolant gas flow	12 L/min
Nebulizer gas flow	0.50 L/min
Nebulizer gas pressure	0 kPa
Pump speed	50 RPM

Assessment of soil quality

Soil (at 12-inch depth) was collected from four locations of the dumpsite of the study area (Fig. 2). The dumpsites were named as S1 (22° 01′ 27″ N, 87° 44′ 27″ E), S2 (22° 01′ 31″ N, 87° 44′ 34″ E), S3 (22° 01′ 31.21″ N, 87° 44′ 19.44″ E) and S4 (22° 01′ 27.18″ N, 87° 44′ 26.76″ E). Among these four sites, S1 and S2 are used by majority of the community. The soil samples were dried and crushed into fine powder. Physicochemical properties such as pH, electrical conductivity, total organic carbon (TOC), available N_2, phosphorus and potassium were measured (NABL-accredited laboratory). The elemental concentrations of soil from the waste hair dumpsite were measured using ED-XRF using standard reference material (SRM) 2586, 2587, 1646a from National Institute of Standards and Technology (NIST).

Data analysis

Results were interpreted after statistical analysis by InStat tool and Microsoft Excel 2007. Elemental profile of water was analysed by comparing with national (BIS 2012) standards, while analysis of human hair and soil was done by comparing with reference material as well as background data. In addition to this, the water quality index (WQI) was calculated to determine the suitability of water for drinking purposes (Kankal et al. 2012; Batabyal and Chakraborty 2015; Sajitha and Vijayamma 2016). Soil quality indices were measured by geo-accumulation index (I_{geo}), enrichment factor (EF) and enrichment index (EI) to compare metal pollution at different locations (Das and Chakrapani 2011; Nowrouzi and Pourkhabbaz 2014; Odat 2015). Observations from Roychowdhury et al. (2002), Rahman and Naidu (2010) were used as background data of our study.

Results

The present study focused on the effects of waste hair reprocessing activity on the environment in respect to variation in soil and water quality. Recently, Public Health Engineering Department (Govt. of West Bengal) proposed a project on drinking water improvement with a brief water quality baseline data of Purba Medinipur district (unpublished work). According to their report, the average annual temperature varied from 10° to 34° C with an average annual rainfall of around 1666 mm and interestingly the selected area of our study belongs to one of the salinity-affected blocks of this district.

Pond characteristics

The description of the ponds is given in Table 2. It has been found that most of the people of this community use the water of P1 for their domestic and waste hair washing purpose. Among these five water bodies, only P5 shows colourless water and P2 and P3 showing brownish colour indicate the presence of dissolved organic materials, especially plant materials; P1 and P3 showing greenish colour indicate eutrophication. No major and/or minor carp were found in these ponds. However, few indigenous air-breathing fish were found in these ponds except P1.

Water quality of the pond

The physicochemical properties of the studied ponds are given in Table 3. It has been found that average pH, temperature and TDS of the pond water were 7.2 ± 0.689, 22.06 ± 1.487 °C and 821 ± 220.713 ppm, respectively (ESM_1.pdf). Other physical characteristics including average conductivity, acidity, alkalinity and hardness were found as 1064 ± 305.59 µmhos cm^{-1}, 55.09 ± 51.86, 191.29 ± 93.38 and 174 ± 67.70 ppm, respectively (ESM _2.pdf). On the other hand, major chemical properties such as average Cl^{-} content, nitrate, phosphate and salinity were 243.105 ± 138.68, 1.39 ± 0.239, 0.622 ± 0.397 ppm and 0.437 ± 0.249 parts per thousand, respectively (ESM _3.pdf).

Table 2 An overview of the studied ponds describing the general characteristics

	P1	P2	P3	P4	P5
Appearance	Turbid	Turbid	Turbid	Turbid	Turbid
Colour	Greenish	Brownish	Brownish	Greenish	Colourless
Odour	Yes	Yes	Yes	Yes	No
Type	Perennial	Perennial	Perennial	Perennial	Perennial
Source	Rain fed, surface runoff	Rain fed, surface runoff	Rain fed, surface runoff	Rain fed, surface runoff	Rain fed, surface runoff
No. of users	136	14	21	35	12
Sunlight	Partially	Fully	No	No	Fully
Use for cooking	Yes	Yes	No	Yes	Yes
Use for drinking	No	No	No	No	No
Waste hair wash	Yes	Yes	Yes	Yes	Yes
Waste hair dumping	Yes	Yes	Yes	Yes	Yes

Table 3 Physicochemical characteristics of studied ponds

Parameters	Standard references		Present study	Comparable evidences	
	BIS (2012)	Sayato (1989)	Average water quality of the pond (P1–P5)	Swarnakar and Choubey (2016)	Mukherjee et al. (2010)
Temperature (°C)	–	40 + 5	22.06 ± 1.487	–	25.9
pH	6.5-8.5	5.5-9	7.2 ± 0.689	8.29	9.1
Conductivity (μmhos cm^{-1})	–	–	1064 ± 305.59	–	827
Acidity (ppm)	–	–	55.09 ± 51.86	8	–
Alkalinity (ppm)	200	–	191.29 ± 93.38	300.66	6
TDS (ppm)	500	1000	821 ± 220.713	–	–
Hardness (ppm)	300	500	174 ± 67.70	151.78	–
Cl^- content (ppm)	250	250	243.105 ± 138.68	15.01	184.8
Salinity (ppt)	0.5	–	0.437 ± 0.249	–	–
Phosphate (ppm)	2.2	5	0.622 ± 0.397	–	2.37
Nitrate (ppm)	45	20	1.39 ± 0.239	–	3.7
Free CO_2 (ppm)		–	14.08 ± 4.81	–	–
DO (ppm)	5	> 5	1.816 ± 0.50	5.41	9.9
BOD (ppm)	5	5	50.6 ± 22	0.62	60
COD (ppm)	5–10	0	132.02 ± 49.42	0.93	130

In addition to these, average free CO_2, DO, BOD and COD were found to be 14.08 ± 4.81, 1.816 ± 0.50, 50.6 ± 22 and 132.02 ± 49.42 mg/L, respectively (ESM _4.pdf).

The elemental profile of the studied ponds is given in Table 4. The maximum amounts of K (42.508 ppm), Mn (1.195 ppm), Mg (24.525 ppm) and Na (88.274 ppm) were observed in P1, while maximum amounts of Al (12.332 ppm), Cu (0.153 ppm), Fe (2.328 ppm) and Ti (4.393 ppm) were observed in P5. However, the average concentrations of Al, Cr, Cu, Fe, K, Mn, Mg, Na, Zn and Ti were found to be 4.497 ± 4.594, 0.149 ± 0.002, 0.148 ± 0.004, 1.357 ± 0.654, 26.085 ± 12.936, 0.69 ± 0.389, 16.954 ± 5.083, 65.089 ± 21.223, 0.365 ± 0.005 and 1.683 ± 1.544 ppm, respectively.

Zooplankton diversity of pond

The species richness of zooplankton was studied in the present study. It has been found that the number of zooplankton taxa is higher in P3 (24 species/L). With regard to abundance, the highest value of 357 individuals/L in P5 and the lowest value of 100 individuals/L in P1 were recorded. However, the Shannon–Weiner diversity index suggested that the indices value lie between 1.07 and 2.206; i.e. the diversity is very low in all the ponds (Fig. 3a). The diversity index of five water bodies was shown in ascending order: P1 > P4 > P3 > P2 > P5. The zooplankton assemblage of our study is given in online resource (ESM_5.pdf) and graphically represented in Fig. 3b. It has been found that cladocerans were the most abundant species followed by copepods and rotifers. In the present study, when stratified into individual ponds, copepods were the most dominant group in P1 and P4; rotifers, protozoans and cladocerans were dominant in P2, P3 and P5, respectively.

Composition of elemental profile in waste hair

The concentrations of element in waste human hair along with their mass percentages are depicted in Table 5. The concentration of K, Mn, Fe, Cu, Br was significantly ($p < 0.05$) higher in waste hair compared to the CRM value, whereas P, S, Zn concentrations were significantly lower and there was no significant change found in Ca, Se concentration. S concentration was found to be maximum (28,874.17 ± 4349.25 ppm) in waste hair.

Mass percentage of metals showed S (~ 82%) as the most dominant element in the composite mixture

Table 4 Elemental profile in the water of the studied ponds

Trace metal	Reference	Present study	Comparable evidences		
	BIS standard (ppm)	The observed value in our study (ppm)	Kar et al. (2008)	Cuculić et al. (2018)	Edokpayi et al. (2016)
Al	0.03	4.497 ± 4.594	–	–	2.083 ± 1.19
Ca	75	23.141 ± 1.403	–	–	–
Cd	0.003	0.139	0.003	11.3 + 6.0	0.001 ± 0.001
Ni	0.02	0.138 ± 0.011	–	310 + 28	–
Cr	0.05	0.149 ± 0.002	0.020	–	0.015 ± 0.02
Cu	0.05	0.148 ± 0.004	0.006	306 +195	0.0463 ± 0.03
Fe	0.3	1.357 ± 0.654	1.520	–	0.702 ± 0.23
K	–	26.085 ± 12.936	–	–	–
Mn	0.1	0.69 ± 0.389	0.423	–	0.256 ± 0.21
Mg	30	16.954 ± 5.083	–	–	–
Na	–	65.089 ± 21.223	–	–	–
Pb	0.01	0.139 ± 0.003	0.024	61.1 + 74.2	0.01 ± 0.01
Zn	5	0.365 ± 0.058	0.085	1408 + 983	0.031 ± 0.03
As	0.05	0.009 ± 0.003	–	–	–
Ti	–	1.683 ± 1.544	–	74 +11	–

of waste hair. Followed by this, Ca and Si showed similar mass percentages (~ 6%), Fe ~ 3% and K ~ 2%. However, the percentages of Si, P, Ti, Cr, Mn, Zn, As and Br were detected.

Soil quality

The basic physicochemical properties of soil from the waste disposal site are given in Table 6. Our result found (ESM_6.pdf) the soil as neutral to alkaline (7.03 ± 0.86) with an average conductivity of 2381.75 ± 1704.59 µmhos cm^{-1}. In addition to this, averages of 1.84 ± 1.37% TOC as well as 108 ± 44.218 mg/kg available nitrogen, 500.75 ± 120 mg/kg phosphorus content and 2356.25 ± 1911.17 mg/kg potassium content (ESM_7.pdf) were found at the study site. On the other hand, the concentrations of element in soil from waste hair dumpsite along with their mass percentages are depicted in online resources (ESM_8.pdf). It has been observed that the maximum amount of Mg, Ni, Fe, V, Pb, Sr, Si was found at S1 and maximum amount of Na, Ca, K, Ti, Cr, Ba, Al was found at S2, while S4 contained maximum level of Zn, Cu, Mn, As. However, on an average of Zn (190.207 ± 96.286), Cu (61.452 ± 8.282), Ni (60.222 ± 4.276), Cr (148.875 ± 7.829), V (134.22 ± 9.301), As (6.992 ± 0.033), Pb (44.65 ± 13.962) and Sr (159.015 ± 15.003) levels were comparatively lower among the overall elemental profile (Fig. 4).

Data analysis

Water quality index

The WQI value of these water bodies is shown in Fig. 5. It has been found that the WQI value ranges from 240.70 to 422.08, which indicates the water of these ponds as very poor to unsuitable for drinking purpose. However, P1 and P3 showed extremely high WQI value compared to others.

Soil quality indices

Soil quality has been assumed by calculating enrichment factors (EF), geo-accumulation factors (I_{geo}) and enrichment index (EI). The EFs of the soil from dumpsite were (in increasing order) as follows: As < Mn < V<Ni < Al < Cu < Cr < Pb < Zn < Fe < Mg. Only As (EF < 1) was found to be level I

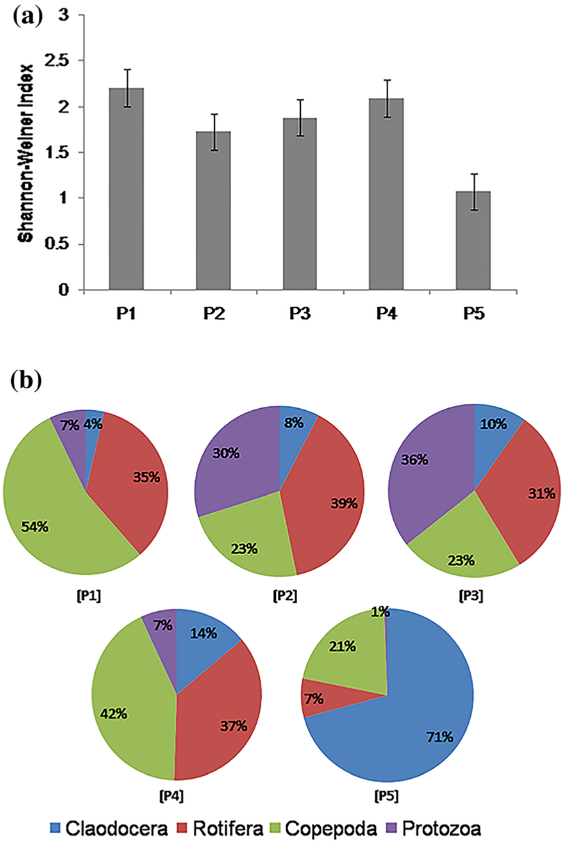

Fig. 3 Zooplankton diversity of the ponds studied

(no enrichment). Ni, Mn, V (EF = 1–3) were found as level II (minor enrichment); Zn, Cu, Cr, Pb, Al (EF = 3–5) were found as level III (moderate enrichment); Fe (EF = 5–10) was found as level IV (moderately severe enrichment), and Mg (EF = 10–25) was found as level V (severe enrichment). On the other hand, I_{geo} of Ni, Mn, V showed Grade 1 (unpolluted); Zn, Cu, Cr, Pb, Al showed Grade 2 (very lightly polluted); Fe showed Grade 3 (lightly polluted) and Mg showed Grade 4 (moderately polluted). Apart from these, EI for Cr, Cu, Ni, Zn was found as 0.43 because except Ni, all the elements were not too close to the permissible/threshold level.

Discussion

Surface water quality, especially pond ecosystem in rural areas, has been threatened by a multitude of anthropogenic disturbances as these ponds are generally used for domestic, agricultural and industrial use, as well as providing food (Kumar and Padhy 2015). Therefore, water quality assessment is an important requirement for identification of the degree of pollution due to anthropogenic activity. However, a number of studies have been conducted on the assessment of water quality at different zones in India (Mukherjee et al. 2010; Kankal et al. 2012; Dhanalakshmi et al. 2013; Swarnakar and Choubey 2016; Sajitha and Vijayamma 2016; Kisku et al. 2017; Bhattacharyya 2018). In the case of limnological aspect, temperature and pH play a pivotal role in the survival of aquatic organisms (Bhateria and Jain 2016). In the present study, though these two parameters lie within the safe limit, other chemical parameters show significant deviation from their permissible limit which in turn causes an adverse impact on the overall water quality and aquatic community. Due to close proximity from the coastal line, saltwater intrusion towards the inland water resulting salinity may be one of the major problems in this study area (Chowdhury and Gupta 2011; Akter et al. 2016). However, salinity may also indicate human waste contamination, particularly in the rural areas (Bhattacharyya 2018). Interestingly, the results of our study found a relatively high amount of TDS, chloride content, nitrate, phosphate, total hardness, acidity, electrical conductivity and salinity. These observations clearly imply an increased load of organic as well as inorganic substances, and the presence of multivalent metallic ion concentration affects the hardness of the water (Swarnakar and Choubey 2016). Accumulating evidences indicated an increased electrical conductance for our studied ponds resulting in moderate to very hard water quality, which cannot be used for drinking as well as irrigation purpose (Chowdhury and Gupta 2011; Bhateria and Jain 2016). While most of the studies in Indian pond showed DO level ranging from 3 to 13 ppm (Dhanalakshmi et al. 2013; Bhattacharyya 2018) and free CO_2 concentration ranging from 2 to 10 ppm, this study showed DO concentration highly depleted with increased free CO_2. According to Pantle and Buck index, such a high level of BOD and COD classified these ponds as meso-polysaprobic, which indicates that these water bodies are strongly polluted with dissolved organic and inorganic matter (Mukherjee et al. 2010; Dhanalakshmi et al. 2013). Despite having a strong significance of geophysical characteristics, our study suggests that anthropogenic activities have immense contribution towards water quality

Table 5 Elemental composition of human hair measured by ED-XRF

Element	Dombovári and Papp (1998)	Zheljazkov (2005)	Indian hair		Present study			
			Samanta et al. (2004)	Malepfane and Muchaonyerwa (2017)	CRM value (ppm)	Observed conc. (ppm) $N = 9$	p value	Mass%
Sulphur (S)	–	8900	–	33,000	43,000 ± 3000	28,874.17 ± 4349.25	< 0.0001	82.144 ± 1.03
Potassium (K)	–	72	–	601	20	965.581 ± 98.69	< 0.0001	1.318 ± 0.15
Calcium (Ca)	598 ± 39	2450	–	1576	2900 ± 300	2384.97 ± 1051.85	0.1769	5.698 ± 0.39
Manganese (Mn)	1.02 ± 0.10	2	6.03 ± 0.19	3.4	6.3 ± 0.8	66.64 ± 24.01	< 0.0001	0.302 ± 0.09
Iron (Fe)	17 ± 4.7	39	51.76 ± 4.45	318.4	54 ± 10	525.17 ± 348.45	0.0009	3.034 ± 0.19
Copper (Cu)	11.9 ± 0.24	19	9.17 ± 0.78	20.2	10.6 ± 1.2	23.97 ± 9.26	0.0006	–
Zinc (Zn)	164 ± 8	217	198.79 ± 11.22	142.6	190 ± 9	167.02 ± 11.82	0.0123	0.68 ± 0.04
Selenium (Se)	–	–	0.63 ± 0.05	–	0.60 ± 0.04	0.68 ± 0.42	0.5774	–
Bromine (Br)	–	–	–	–	0.36	5.41 ± 3.15	0.0002	0.022 ± 0.05
Silicon (Si)	–	–	–	–	870 ± 80	–	–	5.686 ± 0.48
Chromium (Cr)	–	–	–	–	0.37 ± 0.06	–	–	0.258 ± 0.03
Arsenic (As)	–	–	–	–	0.28 ± 0.05	–	–	0.016 ± 0.06
Titanium (Ti)	–	–	–	–	2.7 ± 0.6	–	–	0.306 ± 0.03

Table 6 Basic physicochemical characteristics of the soil from waste hair dumpsite

Properties	Observed value	Deshmukh and Aher (2017)	Akinbile et al. (2016)
pH	7.03 ± 0.86	8.4 ± 0.23	7.09 ± 0.07
Conductivity (μmhos cm^{-1})	2381.75 ± 1704.59	3200 ± 2850	87.165 ± 1.417
TOC (%)	1.84 ± 1.37	4.2 ± 3.83	2.42 ± 0.05
Available N (mg/kg)	108 ± 44.218	180.9 ± 71.61 kg/ha	8650 ± 775
Available P (mg/kg)	500.75 ± 120	40.3 ± 18.46 kg/ha	7.592 ± 0.04
Exchangeable K (mg/kg)	2356.25 ± 1911.17	167.5 ± 71.49 kg/ha	13.292 ± 0.127

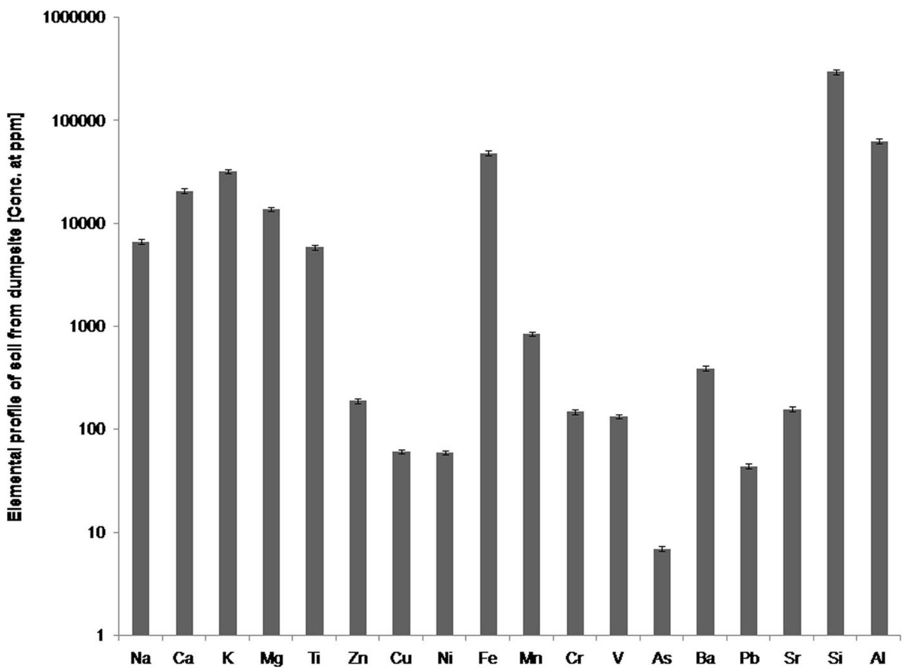

Fig. 4 Elemental profile of soil from the dumpsites

deterioration, which is further uplifted by some kinds of occupation like waste recycling.

Among the most harmful contaminants of surface water, metals are getting importance for their unique characteristics. Though the element profile of water bodies partially depends on the geology of soil, anthropogenic activities such as improper waste disposal containing toxic metals and their chelates also result in deterioration of water quality portraying serious environmental problems posing threat on human beings as well as nourishing aquatic biodiversity (Edokpayi et al. 2016). In the present study, the concentration of identified elements except Ca, Mg and Zn lies within the BIS-recommended desirable limit for drinking purpose. The presence of dissolved Cu, Pb, and Zn indicates an association of organic matter, while dissolved Ti and Ni indicate the association of some kind of inorganic complexes (Cuculic et al. 2018). However, some studies revealed that elements possess toxicity generally in acidic medium, while they remain less toxic or inert in alkaline condition (Edokpayi et al. 2016; Zhang et al. 2018). The levels of elements may be higher due to less nutrient upwelling during the pre-monsoon season (Kar et al. 2008; Edokpayi et al. 2016). Hence, the level of element may not directly affect the living organisms; rather, this is considered to be one of the major factors for degradation of the overall water quality.

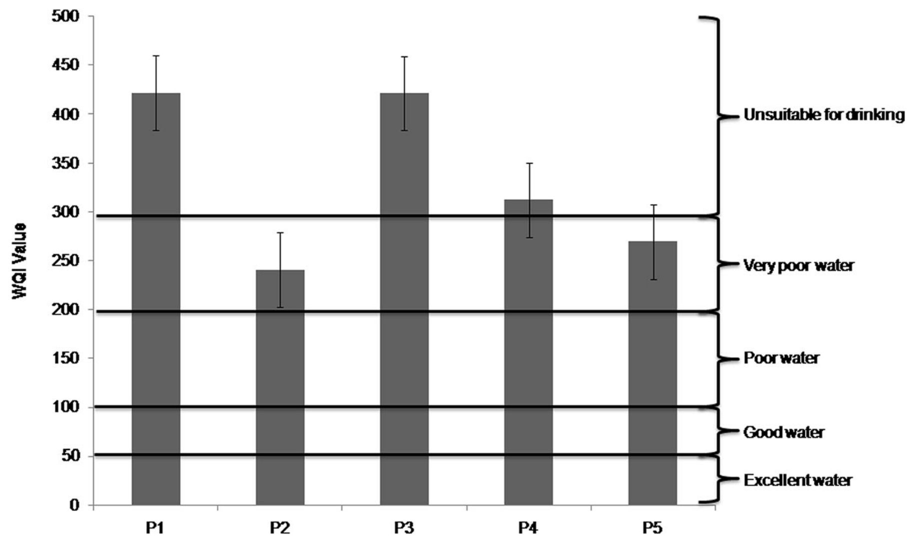

Fig. 5 Water quality index (WQI) of the pond water studied

Zooplanktons are considered to be one of the most important bioindicators for the determination of the ecological status of surface water reservoirs. The characteristics of zooplankton assemblage are made up of several intrinsic factors including surface area, depth, trophic level, the colour of water and the biological community of the lake (Ismail and Mohd Adnan 2016). However, zooplankton diversity mostly depends on seasonal variation, which increases in pre-monsoon and drops at monsoon (Adhikari et al. 2017; Maity et al. 2017; Midya et al. 2018). Literature suggested that cladoceran population distribution is positively associated with DO concentration and salinity, while it is negatively affected by temperature, pH, TDS (Maity et al. 2017). But our study did not find similarity with this observation. Nonetheless, the distribution of rotifers and copepods also depends on the environmental variables such as DO concentration, salinity, nitrate and phosphate concentration, etc. (Mukherjee et al. 2010; Maity et al. 2017). It can be suggested that the overall zooplankton diversity decrease may be due to extreme water quality deterioration and also indicate a decreasing rate of fish growth and survivability.

Soil is the basic natural resource on which the existence of mankind depends and a major source of nutrients needed by plants for growth. Unfortunately, lack of knowledge on scientific land use management may affect the natural land use pattern and cause deterioration of soil quality and decrease in vegetation abundance (Mondal 2013; Ali et al. 2014). In developing countries, open dumpsites for solid wastes are common, due to the low budget for waste disposal and nonavailability of trained manpower, which become one of the major causes of deterioration of soil (Ali et al. 2014). Apart from this, soil quality often varies from place to place due to some unique geophysical and geochemical properties. Our study location is one of the vast expanses of younger alluvial soil in India, and the texture of the soil is clayey to silt clayey (Biswas and Das 2014; Sahu 2014). Literature on soil quality of Purba Medinipur suggested that the pH is moderately acidic and electrical conductance of our study area is greater than 1500 μmhos cm^{-1} which is critical for seed germination (Sahu 2014). Contrastingly, our result found the soil as neutral to alkaline with extremely high electrical conductivity. The effective change in pH of our studied soil may be due to the decomposition of biowaste (Tripathi and Misra 2012; Deshmukh and Aher 2017; Joardar and Rahman 2018) like human waste hair but the conductivity hike indicates the metal contamination as well as dissolved salts which is supported by our elemental analysis with ED-XRF. Comparing with the existing literature (Biswas and Das 2014; Sahu 2014), high percentages of TOC, available N, P and exchangeable K were found in the dumpsite, which may contribute to the alteration in pH, conductivity by release of exchangeable cations during mineralization of organic matter (Ali et al. 2014; Biswas and Das 2014).

Previous study suggested that disposal of human waste hair was considered as a major source of keratin, which has been used as a nutrient in the agricultural land (Zheljazkov 2005). But during the hair recycling process, waste hair generally gets exposure of multiple synthetic chemicals which after decomposition remain in the soil and long-term effect of improper disposal of the waste hair eventually alters the elemental profile of the dumping area.

Strength and limitations of the present study

Although waste hair reprocessing is a growing industry worldwide because of the versatile nature of hair, improper disposal of this waste actually causes environmental nuisances which eventually affect the health of the particular community. To the best of our knowledge, this is the first study to reveal the degree of water and soil quality degradation due to waste hair reprocessing activity and its improper disposal to the open environment. Not only the basic physicochemical property, this study depicts the elemental profile of the surface water and soil and also assesses the productivity of pond and soil. Moreover, the overall observation of this study can be considered as a model for other waste hair reprocessing industries and/or related occupations.

However, the limitation of this study is that the physicochemical property of water and the plankton diversity analysis were conducted only in pre-monsoon (January–March) season; thus, seasonal variation might have some impacts on the overall water quality. Another drawback is that water samples and hair samples were not collected at the same time, thus impeding a closer comparison between both results. In addition to these, due to dependence on self-reporting, the details of chemicals used by the workers are little known.

Policy relevance and research needs

There is a very huge scope of expanding the utilization of human hair in different critical areas of social importance such as medicine, construction materials, pollution control and agriculture. To expand the human hair utilization, a policy framework is being needed that must incorporate two simultaneous tasks: ensuring environmental and social well-being and building necessary support system for developing local and large-scale uses. Previous studies suggested the potential areas of hair utilization (Gupta 2014; Mishra 2017), and our study concerned about the waste hair produced after recycling processes. It has been suggested that the waste hair can be used for reinforcement of construction materials, removal of pollutants, testing materials for hair-care products, etc. If the hair is free from toxic contamination, these can be used for traditional medicines, keratin protein isolation, fertilizer, engineering biomaterials, etc. To minimize the environmental and human health impacts due to occupation, intensive research is indeed important to identify the harmful agents that are generated due to recycling process and/or after disposal.

Conclusion

Waste burden is growing at a shocking rate, and the worldwide challenge lies in the conversion of waste to resource. The management of keratin-based waste biomass by reconversion into commercially used product will not only save the ecosystem from large amount of sludge but also economically boost up the pharmaceutical as well as cosmetic industry. This study has shown the adverse impacts of waste hair reprocessing activity on environmental health in rural India. Due to improper disposal of waste hair, the water quality of the surrounding ponds were deteriorated which eventually affect fish productivity by decreasing the plankton diversity. Also, the water of the pond is not suitable for drinking purpose due to quality deterioration. It has been found that decreasing zooplankton community indicates less survival and mortality of fish. On the other hand, disposal of waste hair into land causes improvement in nutrient source that can help with growth of crops. However, element analysis of waste hair suggested the presence of certain toxic elements which after deposition into water and soil may leach out and contaminate the environment and these toxic elements can enter into living organisms through food chain. Therefore, future study is needed to eliminate the toxic elements from the water and soil using some phytoremediation strategies. In addition to this, community-based outreach programs should be conducted to spread awareness to the people and provide knowledge with proper training on expanding utilization of hair waste.

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Author contributions KM was involved in sample collection. KM and SB conducted the experiment. SD contributed to manuscript writing and data analysis. MS and PB were involved in manuscript editing and experiment-related supervision.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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