International Journal of Ecology and Environmental Sciences 48: 399-407, 2022
ISSN: 2320-5199 (Online); https://doi.org/10.55863/ijees.2022.0399

Impact of Physicochemical Status of Wetlands on Marsh Crocodiles (*Crocodylus palustris* Lesson, 1831) in Terai Landscape, Uttarakhand, India

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ABSTRACT
Water is the basic life line of all living organism on this planet. The study revealed that the significance of water quality is good at the Terai Arc Landscape (TAL) rivers which passes through the Terai landscape of Kumaun, Uttarakhand, India. Water is essential for drinking, domestic, irrigation and industrial purposes. The Terai Landscape of Uttarakhand is rich in water resources and which is utilizable for all purposes. Rapid industrialization has led to low quality of water due to wastewater flowing in natural wetlands of the area. Water and their ecosystems are major indicators of the strength of forest and aquatic fauna. This was achieved by analyzing 12 water quality parameters from samples collected at 13 study sites between the Kosi and Sharda river stretch of different water bodies on monthly basis for a period of 12 calendar months. The water physicochemical variables are analyzed using standard methods during May 2015 to April 2016 and its assessment is carried out. The 12 parameters included Average depth, Temperature, pH, Transparency (turbidity), Dissolved Oxygen (DO), Total Hardness, Total Alkalinity, Chloride, Nitrate, Fluoride, Total Iron, Phosphate and presence and absence of Coliforms. We observed that the range of contagion, vicinity of pollution sources and water quality of sites suggest that the species is under threatened category in Terai landscape, Uttarakhand. Amongst the 13 sites chosen for assessment, the physicochemical properties of different water bodies in reference to usage of wildlife such as Marsh crocodile, tiger, leopard, elephant, sloth bear and many species of herbivores at present is acceptable.

Key words: Water, Physicochemical, Parameters, Pollution, Terai Landscape, Dissolve Oxygen, Fluride, Acceptable

INTRODUCTION

Wetlands play an important role in numerous processes such as filtering contaminants, eliminating nutrients, sedimentation and ground water recharge, storing rainwater which stabilises and provide life line to biodiversity (Mitsch and Gosselink 2000). Water plays a vital role in human life, wildlife and forest too. Wetland ecosystem and many water bodies are declining globally due to continuous and unmanaged use of water. Crocodiles, aquatic turtles, fishes and snakes mainly uses the wetlands and its water is utilised by others wildlife. The big aquatic reptilian species *C. palustris* is considered as nationally "Vulnerable" subsequent to an assessment under the IUCN criteria for the threatened species and listed in CITES Appendix I (Molur and Walker 1998) and it has received the greatest legal protection in India as it is listed in the Schedule I of the India Wildlife Protection Act, 1972. Many studies have been completed to analyse the physicochemical parameters of water qualities in India including Uttarakhand (Ramachandra et al. 2006, Mishra et. al. 2008, Gagan 2014, Azmi et al. 2015, Selakoti and Rao 2015, Kamboj et al. 2016, Gagan et al. 2017, Kamboj and Vishal 2019).

Rivers are the vigorous and vulnerable freshwater ecosystems that are critical for the sustenance of all life especially to aquatic species. Therefore, regulatory agencies such as Federal Environmental Protection Agency (FEPA) and United States Environmental Protection Agency (USEPA) recommend that river monitoring should be done continuously either annually or at an interval of 2-5 years (Moshood 2016, Detenbeck 2015). However, Farouk (2015) as well as Jaji et al. (2013) reported that many rivers and tributaries in developing countries are not monitored due to the high cost usually incurred. Many crocodiles, migratory birds and other species have been studied through satellite tracking to understand the impact and movement (Brien et al. 2010 and Kalra et al. 2011). One possible way of doing this is to initially select numerous sampling sites as many as possible and analyse the

water samples obtained from these study sites and then subjecting the laboratory results into cluster analysis. Water quality depends on the bioavailable forms of nutrients, laboratory procedures to separate different phosphorous (P) elements are significant (Worsfold et al. 2016).

India is primarily an agriculture nation and the main profession of the people living in this region is agriculture and industries exists in nearest places (Yadav and Kumar 2010). Most of the rivers in the urban to rural areas of the developing countries are the ends of effluents released from the industries. The pollution in the wetlands and its habitat loss is the main reason affecting the Marsh crocodile population in India. The study of water quality has been necessitated to observe the demand and pollution level of water (WHO 1999). The exploitation has taken their toll as evidenced by decline in fisheries, floods, droughts, loss of biodiversity and communities trying to deal with limited water supplies. It is difficult to understand the biological phenomenon fully because the chemistry of water reveals much about the metabolism of the ecosystem and explain the general hydro-biological relationship (Basavaraja et al. 2011).

Water serves to assimilate these impacts by spreading them among the elements within these ecosystems. A clean ecosystem with a healthy biological community will be symbolic of the state of the terrestrial habitat in the watershed. As is apparent from the scientific data bases little is known of the national trends in population diversity of Marsh crocodile, even though they provide basic functions of aquatic ecosystems. The loss of aquatic ecosystem may be difficult to restore. Therefore, the physicochemical parameters of water are most important for the composition, abundance and distribution of living organisms in the aquatic ecosystem. Abundance of animals, diversity and distribution are linked to various physicochemical biotic phenomenon (Dutta and Malhotra 1986).This study highlights the conservation of biodiversity, restoration and management aspects of aquatic ecosystem and richness of Marsh crocodile habitat in Terai Landscape of Kumaun, Uttarakhand. The outcomes of this study may be useful in aquatic habitat improvement and conservation strategy for Marsh crocodile in Terai area. The Terai region consist of many rivers, dams, reservoirs, lake, streams and artificial ponds and these water bodies provide good habitat to Marsh crocodile. These water bodies spread in the Shivalik hills of the Kumaun region of Uttarakhand, India. All water bodies have approximately similar habitat. This study has done to assess water physicochemical parameters and impact on Marsh crocodiles to acceptable levels as recommended by WHO and other institutions. The purpose of this study was done to assess the water quality in Terai landscape and its suitability to Marsh crocodile, human being and its conservation.

MATERIAL AND METHODS

To facilitate counting of Marsh crocodile, thirteen sampling sites were selected based on the presence and composition of soil and vegetation (Bogati 2003). Terai Arc Landscape (TAL) signifies two distinct zones such as Bhabar region and the Terai plains of India (Rodgers and Panwar 1988). The soil composition is mostly rocky, sandy and alluvial and mainly riverine forest (Jamun - *Syzygium cumini*, Sissoo - *Dalbergia sissoo* and Bel - *Agele marmilose*). The study area is located at 28.960111 N and 79.871386 E at an elevation of 209m. Entire study sites falls under districts Nainital and Udham Sigh Nagar of Kumaun, Uttarakhand.

The standard analytical methods were followed for physicochemical assessment (Chang et al. 2014) of water samples in Terai landscape, Kumaun, Uttarakhand. The samples were collected for a period of 12 months from May 2015 to April 2016 from 13 sites (Fig. 1 and Table 1) of the water quality of rivers, dams and its tributaries. The justification for selecting these locations as sampling sites is that they represented the most important point for gaining access to the rivers and also suitable for informal sampling of the present water quality status and have a more progressive pollution pressure (Adie 2008). Sampling methods must be selected by considering into account human, technical and financial assets (Behmel et al. 2016) and the research objectives are important too. Mainly, water sample collection by using manual techniques and automated samples are the two main sampling methods in river, dams, lake

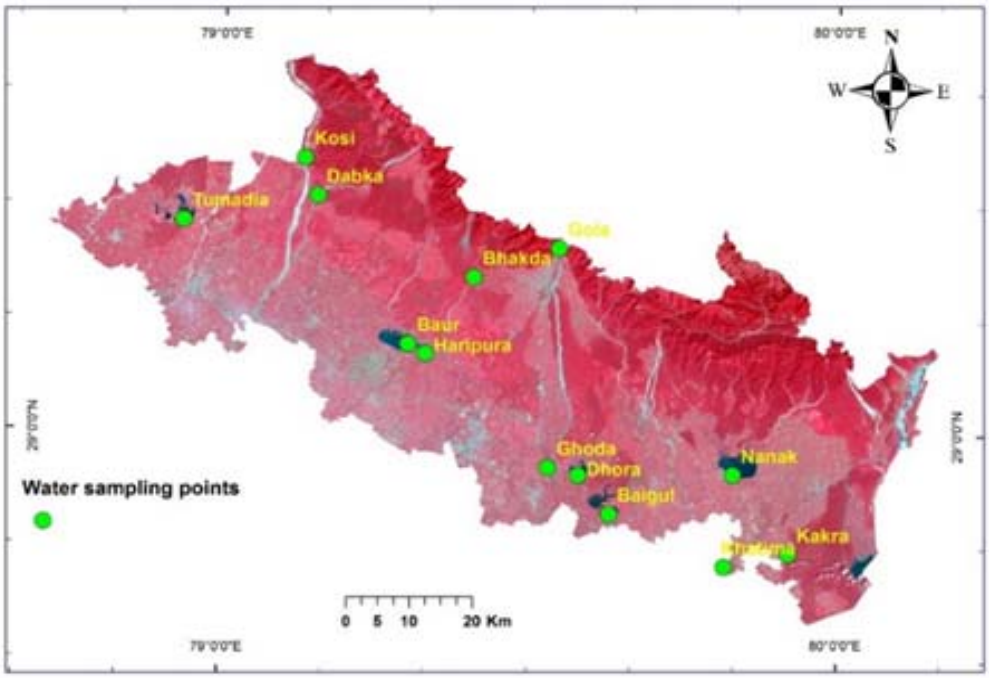

Figure 1. Location of sampling sites in the Terai landscape of Western circle, Uttarakhand

Table 1. Study site characteristics

Site Code	Sampling Sites	Latitude	Longitude	Sources of Pollution
1	Kakra Nala (S1)	28.82547222	79.92216667	Industrial waste and fertilizer
2	Khatima Farm (S2)	28.80636111	79.81833333	Industrial waste and fertilizer
3	Nanak dam (S3)	28.94144444	79.83158333	Solid waste and pesticide
4	Baigul dam (S4)	28.88255556	79.63161111	Solid and domestic waste
5	Dhora dam (S5)	28.93905556	79.58108333	Solid and domestic waste
6	Ghoda Nala (S6)	28.94980556	79.53208333	Solid waste and pesticide
7	Haripura reservoir (S7)	29.11530556	79.33133333	Solid waste and pesticide
8	Baur reservoir (S8)	29.12930556	79.30294444	Solid waste
9	Bhakda river (S9)	29.22578889	79.40708333	Solid waste
10	Gola river (S10)	29.26363889	79.54713889	Solid waste and municipal water discharge
11	Dabka river (S11)	29.34586111	79.15358333	Solid waste
12	Kosi river (S12)	29.40091667	79.13175	Solid waste and municipal water discharge
13	Tumadia Dam (13)	29.30766667	78.9361	Solid waste

and streams monitoring studies. Standard methods of water sample collection, at a single location or at a few locations to represent to minimum bias, were followed (Harmel 2010). Water sampling sites have been selected at three locations in a site to minimize the error in results. Determination of physico-chemical parameters was carried out by standard methods of analysis (APHA, 1989, Trivedy and Goel 1986, Kodarkar 1992).

RESULTS

Average depth of water body is important

phenomenon to presence of Marsh crocodile and other aquatic species. The highest depth was measured of huge Nanak dam and lowest depth observed in Dabka riverbed (Table 2).

Temperature is most important parameters for aquatic body which is directly related to other chemical presence and Marsh crocodile. Temperature is an important variable which is directly impacts on the aquatic species and it will reduces the dissolve oxygen in wetland ecology. During the study, it was observed highest temperature of water found 27.5°C in Kakra and Ghoda nalas and lowest temperature recorded 26.25°C in Haripra Dam (Table 2). pH is very important to determining the acidic and basic nature of water. The higher pH values observed 7.55 in Dabka river and lowest 7.32 in Khatima farm (Table 2). The value of pH observed higher suggests that carbon dioxide, carbonate-bicarbonate equilibrium is influenced more due to change in physicochemical condition (Karanth 1987).

The highest level of turbidity was recorded 5.5 NTU in Ghoda nala during the study and lowest level 4.21 NTU was recorded (Table 2). The turbidity can varyto depend on the inflow of rainwater carrying suspended particles (Nafeesa, et. al 2006). The turbidity in natural wetlands mightprominence a brown colour to water (George 1997).

Dessolve Oxygen (DO) is one of the most important parameter. DO in sample is measured titrimetrically by Winkler's method after 5 days incubation. The difference in initial and final DO give the amount of oxygen consumed by the bacteria during this period. This procedure needs special BOD bottles which seal the inside environment from atmospheric oxygen. The highest level of DO was recorded from collected sample was 6.82 mg/l in Ghoda nala and Kosi river and lowest level 6.0 mg/l of Tumadia dam (Table 2).

Alkalinity is the highest level of was observed 59.08 mg/l in Ghoda nala and 49.75 mg/l of Dabka river during the study (Table 2). Hardness: The highest level of hardness was observed 128.16 mg/l in Gola river and lowest level 101.66 mg/l was observed in Kosi river (Table 2).

The highest level of chloride was observed 34.46 mg/l in Bhakda river during the study and lowest level 19.31 mg/l was observed in wetland of Khatima Farm (Table 2). The nitrate content of water bodies was observed highest 0.33 in Gola river and lowest 0.21 mg/l in Baur reservoir (Table 2). Iron was observed highest value 0.37 mg/l in different water bodies of studied sites and lowest 0.31 mg/l of Kakra nala (Table 2). The phosphate contented of water bodies was recorded highest value 1.34 mg/l in Haripura dam and lowest value 0.73 in Khatima Farm (Table 2). The fluoride content in water is found highest level 0.69 mg/l in Dhora dam and lowest value 0.55 mg/l in Haripura dam (Table 2).

DISCUSSION

We observed, Marsh crocodile mostly existing in marshes and stagnant water body and tributaries of major rivers where water flow is gentle.The major

Table 2. Water physicochemical average results of one year at study sites of Terai landscape, Uttarakhand from May 2015 to April 2016

Sites	Depth	Temp	pH	Turb.	DO	Alkalinity	Hardness	Chloride	Nitrate	Iron	Phos.	Fluoride
S1	7.05	27.5	7.36	4.46	6.31	58.42	108.66	31.98	0.28	0.31	1.12	0.59
S2	12.33	26.42	7.32	4.5	6.26	55.08	122.08	19.31	0.25	0.35	0.73	0.64
S3	43.27	27	7.51	5	6.78	52.83	119.16	30.65	0.28	0.37	0.86	0.66
S4	15.58	26.5	7.46	4.92	6.14	55.25	113.75	30.19	0.32	0.36	0.86	0.58
S5	20.35	26.83	7.5	4.92	6.5	57	112.42	26.84	0.24	0.32	0.96	0.69
S6	7.93	27.5	7.36	5.5	6.82	59.08	107.92	30.36	0.24	0.32	1.21	0.62
S7	7.09	26.25	7.36	4.5	6.35	55.08	125	31.36	0.27	0.37	1.34	0.55
S8	7.09	27.33	7.46	4.92	6.73	55.16	114.66	26.39	0.21	0.36	0.85	0.58
S9	9.92	26.66	7.4	4.25	6.55	53.33	123.75	34.46	0.26	0.37	1.15	0.61
S10	10.35	26.58	7.52	4.21	6.56	52.42	128.16	31.73	0.33	0.34	0.94	0.57
S11	5.88	27.25	7.55	4.66	6.2	49.75	126.92	28.76	0.27	0.33	0.95	0.56
S12	11.08	26.42	7.33	4.58	6.82	57.33	101.66	32.87	0.26	0.36	0.82	0.62
S13	8.93	27.42	7.44	4.75	6	58.25	115.75	28.52	0.31	0.34	1.12	0.62

natural habitats of crocodiles are small or large ponds (palustrine) with deep enough water as well as vegetation cover around the water bodies. Maximum of these ponds have features that are similar and provide suitable habitats including very dense vegetation along and banks with clay or sand as the main fragments; some have a depth of more than 6-7 meters (Mobaraqi 2015). Usually, crocodiles avoid from shallow and running parts of the rivers.

The previous studies suggest that crocodiles keep their mouths open while basking so as to maintain control over their body temperature. They basked exterior of the water track in the winter season when the water temperature is low. The average temperature level between 27.5ºC and 26.25ºC. They have a "preferred" body temperature of around 30°C to 33°C (Webb and Manolis 1989). We observed, mostly number of Marsh crocodile were basked by orienting themselves in such a way that the maximum amount of body is open to the sun. When the body is heated, they in front of the sun and open their mouth to allow the brain to cool through evaporative heat loss. This is known as the 'mouth gaping' posture (Webb and Manolis 2000). However, in the summer season they spent most of their time underwater. The water body temperature maintains the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to fish. The variation is mainly related with the atmosphere temperature and weather conditions. Higher temperature during June was due to greater heating (Adebowale et al. 2008). The basking was influenced by water temperature (Venugopal and Prasad 2003). pH is most influential in determining the scarring nature of water. Lower the pH value higher is the acidic nature of water. pH was certainly linked with electrical conductance and total alkalinity (Guptaa 2009, Deepshikha 2008). The average pH level was found in different water bodies from 7.55 to 7.32 mg/l. It is between the permissible levels in Table 3. The turbidity is a remarkable feature to know the physical status of a river. The suspended particles, soil particles, discharged effluents, decomposed organic matter, total dissolved solids as well as the microscopic organisms increase the turbidity of water, which interferes with the penetration of light. The average values are 5.5 to 4.12 NTU and it is permissible Table 3. The average value of DO was recorded as 6.82 mg/L (Ghoda nala) to 6.0 mg/l (Tumadia dam) found in all study sites. The highest values of DO contents of water samples were above the permissible the standard limit (6 mg/L) as per WHO (1984) and lowest value is accepted Table 3. The dissolved oxygen in water is habitually recognised to the fact that the oxygen is dissolved more during the period of high catabolic activity by photosynthesis. Alkalinity is composed mainly of carbonate and bicarbonate, it acts like stabilizer for pH. Alkalinity, pH and hardness affect the toxicity of many substances in the water. The observed average values 59.08 mg/l to 49.75 mg/l during the study. The study sites have low carbonate rock. So

Table 3. Physicochemical parameters of WHO (2008), BIS (2004) and EPA (2001) guidelines

S.No.	Parameters	Technique used	Unit	WHO standard	BIS standard	EPA guidelines
1	Av. Depth	Measuring tape	Feet	-	-	-
2	Temperature	Mercury thermometer	°C	-	30-33°C	-
3	pH	pH meter (Digital)	pH unit	6.5-9.5	6.5-9.5	6.5-9.5
4	Turbidity	Nephlometric turbidity	NTU	<1-5NTU	-	-
5	Dissolve Oxygen (DO)	Winkler method	Mg /L	6 mg/l	6.6 mg/l	-
6	Alkalinity	Titration (Silver nitrate)	Mg /L	200-600 mg/l	20-200 mg/l	-
7	Hardness	Titration (Silver nitrate)	Mg /L	200 ppm	300 ppm	<200 ppm
8	Chloride	Titration (Silver nitrate)	Mg /L	250 ppm	250 ppm	250 ppm
9	Nitrate	Spectrometer	Mg /L	45 ppm	45 ppm	50 mg/l
10	Iron (Fe)	Spectrometer	Mg /L		>0.3 mg/l	
11	Phosphate	Spectrometer	Mg /L			1 mg/l
12	Fluoride	Spectrometer	Mg /L		>1.5 mg/l	
13	Fecal coliform bacteria	Membrane Filter	Colonies/100ml	Nil	Nil	Nil

the all values are within the permissible level Table 3.The observed average hardness range from 128.16 mg/l to 101.66 mg/l. It is under the permissible level. That means very good quality of water of all wetlands Table 3. Chloride is a most common anions found in water. However chloride is not harmful at low levels. High chloride value may damage the vegetation of water bodies or use for gardening or irrigation and drinking water an unpleasant taste and smell. The salinity of water osmotic stress on biotic communities is controlled through Chlorides (Banarjee, 1967). Human drinking water standards require chloride level not to exceed 250 mg/l. If chloride level is high, may have problems. The chloride range observed from 34.46 mg/l to 19.31 mg/l Table 3. All water bodies are very good and acceptable level and indicating non pollution level. Nitrate is most common ground water chemicals is rural area. The excess value is harmful to human. Below 10 mg/l is safe. Our all recorded range is too low to permissible level. If is the presence of high level of nitrate, indicates that polluted water body. The nitrate content of water bodies was observed from 0.33 to 0.21 mg/l during study in all wetlands (Table 3). It was observed average value of iron 0.37 mg/l in different water bodies of studied sites to 0.31 mg/l of Kakra nala**.** The permissible level of iron is 0.3 mg/l and most of studied sites were within this permissible level (Table 3). Phosphate can arise in surface water as a result of contamination from domestic sewage, detergents, and agricultural and industrial effluents. The average value of recorded phosphate from 1.34 mg/l to 0.73 during in all 13 study sites. All values are closely from the permissible level of water Table 3. Some water body have above the permissible level. Algae and aquatic weeds may develop when the more value of phosphate present in water bodies. It would be very harmful for a good wetland, human and aquatic biodiversity. The Fluoride contents varied from 0.69 mg/l to 0.55 mg/l. It's indicated that non pollution status of all water bodies of study site Table 3. The maximum and minimum both values were recorded in Dam water during study period. Results of bacteriological parameter show that all water bodies have extent of total coliform.

In the crocodile sites observed that the process of eutrophication was higher due to shallowness of basin, stagnant water and some range of the physicochemical parameters was gone up high, beyond the permissible limits and some low from recommended by world health organization (WHO, 1984). Marsh crocodiles which typically focuses their attention on of important issue is related with water pollution that is directly apprehensive with the health of human beings (Chang et al. 2012). The quality of water is the major grounds to determine the aquatic biodiversity associated with their health (Gachal et al. 2006). The Marsh crocodile sites are challenged by many shortcomings such as effluents of factories and agricultural within its impacts and prediction on crocodile population (Chang et al. 2013). 341 Marsh crocodiles exists in these wetlands (Belal et al. 2021). The Marsh crocodile population is threatened by water quality and insufficient space of many study sites such as Kakra nala, Ghoda nala and others also. We observed many values of different water bodies are low and above from permissible level were recorded during the study period in laboratory analysis which causing the direct harmful effects on Marsh crocodile population and aquatic biodiversity. Tremendously threatened within the large number of people and many villagers disturb them and contract of fishing from dams and its quality and insufficient food amounts and usually reduces the suitability of the habitat for increasing population of Marsh crocodile. The space of crocodile sites is not sufficient for increasing population of Marsh crocodile and they required a large sized pond for their healthy growth and survival. During our study the water quality and waterbody status are not suitable for their healthy growth in all 13 water bodies except the Kakra nala (tributary). Although the dams and tributaries provide good habitats for the Marsh crocodiles, they are not present in major rivers of Uttarakhand (Gola and Kosi) as they are subjected to very excessive water flow and risk of pollutant exposures. On the other hand, the low water quality in future may decrease the population of Marsh crocodiles. Thus monitoring of water quality of a river helps in identifying high deficiency areas within a river (Ouyang et al. 2016). The surface water quality is declining due to anthropogenic activities such as urbanization, industrialization, transportation, farming, disposal of animal and human defecations and domestic wastes into river and dams (Siamak and Srikantaswamy 2009).

CONCLUSION

Wetland ecosystems have different problems in Terai Landscape, due to increased human population on the fringe of rivers, unwanted use of water, industrialisations, different developmental activities, lack of solid and sewage waste management leading to sever crisis to degradation of water bodies.It is a matter of serious issue to aquatic animals. The encroachments are alarming in dam's area and it is hazardous for aquatic species. At Present, most of wetlands have excellent water quality except Ghoda (S5) and Kakra nala (S1). S1 and S5 wetlands have been started to pollution due to the effluents of local industries (SIDCUL) fell and others pressure. S1 and S5 wetlands have maximum Marsh crocodile population of all these sites (Belal et al., 2021). The work related to water physicochemical parameters impact on Marsh crocodile which makes it an interesting, permissible and excellent aquatic habitat. S1 site and included all other sites would be as conservation reserve in future.

ACKNOWLEDGEMENT

We would like to thank Dr. Parag Madhukar Dhakate, CCF and Mrs. Kalyani (IFS), Deputy Director, Corbett Tiger Reserve, Uttarakhand for her valuable support. We are thankful to Uttarakhand Forest Department and Kumaun University, Nainital. We extend our humble gratitude to Mr. Naresh Chandra, Environmental Manager and Mr. MP Srivastava of Century pulp and paper mill, Lalkuan, Uttarakhand for their support and laboratory work.

Authors' contributions: All authors contributed equally on different aspects.

Conflict of Interest: Authors declare that they do not have any conflict of interest.

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Received:28th July 2021
Accepted:23rd January 2022