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REVIEW ARTICLE

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Microplastic in freshwater ecosystem: bioaccumulation, trophic transfer, and biomagnification

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Abstract

Plastic wastes in the environment ultimately reach to the aquatic habitats and become available to aquatic organisms. The pathway of microplastic in aquatic ecosystem is very less investigated specially in freshwater. There have been evidences of MPs ingestion by freshwater biota but the fate of these MPs further in the food chain is unexplored. Thus, we reviewed the status of MPs in freshwater biota and tried to compare the studies to merge the available information, concepts, and perspectives in order to draw a conclusion on bioaccumulation potential, trophic transfer possibilities, biomagnification, and trends of ingesting MPs by the biota. In this review, the previously available information about MPs in aquatic biota is arranged, analyzed, and interpreted to understand all possible routes of MPs in freshwater habitats. The review further provides a better understanding about the lack of information and research gaps that are needed to be explored to develop a solution to the problem of MPs in near future.

Keywords Bioaccumulation · Biomagnification · Freshwater ecosystems · Microplastic · Trophic transfer

Introduction

Plastic has played a vital role in the development of modern human lifestyle and changed it for better. Being economical in nature, the consumption of plastic increased everyday but the durability led to a very slow degradation rate. The yearly production of plastic in the year 2020 was about 367 million metric tons (Anonymous 2022b), the world was facing a pandemic, which being contagious in nature encouraged people for using single-use plastics further sky-rocketing the disposal of plastic wastes by 280% (Anonymous 2022a) in the course of this duration. The extravagant usage along with the deficient recycling and helter-skelter dumping advanced toward the heavy plastic load in the environment which underwent physical, chemical, and biological stresses and got crumbed, scraped, or fragmented (Singh and Sharma 2008). The breakdown resulted in the formation of plastic particles of various shapes and sizes, amidst those, the particles ranging from 1 to 5 mm in size are microplastics (MPs) (Browne et al. 2007). MPs produced in industries are primary MPs; they are formed in personal care industry, their byproducts and remains; tires and its remains during the manufacturing; textile industries that majorly include synthetic textile industries; marine coatings, etc., while the broken or degraded fragments of larger plastics (macroplastics) are secondary MPs, which do not have a specific point source (Anonymous 2022b).

MPs are emerging as a major environmental pollutant having serious impact on ecology, environment and organisms. They have invaded almost every ecosystem type and is recorded in air (Gasperi et al. 2015), water (Pivokonsky et al. 2018), soil (Boughattas et al. 2021), and ice (Stefánsson et al. 2021). Recently, MPs have been found in human stool (Schwabl et al. 2019), placenta (Ragusa et al. 2021), and blood (Leslie et al. 2022). MPs are available at all possible locations near or far, and have been reported from a remote place like Antarctica as well (González-Pleiter et al. 2020). Arising from all the ecosystems they pollute, MPs end up in the aquatic ecosystems entering them via

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Journal of Biodiversity Management & Forestry

Research Article

A SCITECHNOL JOURNAL

Exposed Roots of *Salvadora oleoides* in Aravalli Range Addresses Freeways Constraint: Ecological and Management Perspective

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Abstract

The rapid development of industries and modern cities in India coincides with the improved road networking in the last five years or so. An observation on such an effort in the state of Haryana is visualized from 2018-2020, which showed ecologically jeopardizing the pervasiveness of some important endemic vegetation like *Salvadora oleoides* a tree of greatest economic significance. The species is on the verge of decline in the state, where only 3.62% forest area surrounds the state geographical area of 44,212 km^2. This viewpoint highlights wounded and exposed root zones of *S. oleoides* causes deterioration due to one of the key developmental activities, *i.e.*, the construction of roads and the expansions of rural, state and national highways. Further, we provide an overview of various *in situ* and *ex situ* modes of conservation measures for *S. oleoides*. The conclusion is focused on invocation of better land use policy intervention to maintain natural ecosystems with the modernization.

Keywords: Protein-protein interaction; Support vector machine; Feature extraction; Genetic algorithm; Simulated annealing

Key Policy Highlights

Reporting of unethical ways of road development networks leads to the rapid decline in the natural range of *S. oleoides* distribution; ecological impact of lost individuals of *S. oleoides* on native and non-native biodiversity of the country; *In situ* and *ex situ* conservation and management of the species is required at policy level to maintain natural ecosystems with the modernization.

Introduction

Rationale

Haryana, one of the sporting capitals of India, regularly conducts regional and world level summits and events. The state faces several events of rapid urbanization and industrialization in cities, namely Ambala, Bhiwani, Gurgaon, Hisar, Mahendragarh, Najafgarh, Rewari and Rohtak [1]. The advancement is decoded by the Prime Minister Rural Road Development Project (PMRRDP) leading to the construction of large number of National Highways (NHs), besides linking roads to far flung villages and their conversion into the State Highways (SHs) National Rural Roads Development Agency (NRRDA) [2]. The National Highways Authority of India (NHAI) is a leading government organization under Government of India (GoI) for constructing the NHs. The NHAI provides contracts to industries to develop and construct the road, along with guidelines of road safety measures, digging of the lands, creation of dumping zones for the waste, etc. [3]. But these industries often manipulate the power given to them for the monetary benefit [4]. The kind of living standard required is usually not maintained at ground zero, though the developer thinks there is no long-lasting problem arising due to harm posed on the ecosystem [5]. Thus, the viewpoint shed light on the impacts of improper road networking, their repercussions and dire consequences to the arid ecological environments affecting the keystone species *S. oleoides* and finally suggests some management perspective to the policy makers.

Materials and Methods

During 2018-2020, surveys were conducted in the *S. oleoides* dominated forests and community lands in the state of Haryana. Here, we came into foray with the striking observations and ever alarming situations of the road safety measures. This included expansion of highways to remove roadside trees and the topsoil was excavated from the community forest lands of *S. oleoides* in a devastating manner (Figure 1a and Supplementary Figures 1(a-c)). This may cause forest health deterioration in the long run as the majority of desert biomes reside near the periphery of the root zone due to lesser soil moisture availability in the deeper pan of the arid land [6]. Further, it was observed that the stone crushers are built in open zones without any enclosures and safety measures. These were very close in proximity with the agricultural farm lands (Figure 1b and Supplementary Figure 1(d)). This led to the aeration of Suspended Particulate Matter (SPM) and is subjugated to the local cultivated crops and *S. oleoides*, whose impact would be easily visible on vegetations [7].

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RESEARCH ARTICLE

Evidences of microplastics in aerosols and street dust: a case study of Varanasi City, India

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Received: 9 December 2021 / Accepted: 12 June 2022

Abstract

Microplastics (MPs) are ubiquitous in our environment. Its presence in air, water, and soil makes it a serious threat to living organisms and has become a critical challenge across ecosystems. Present study aimed to assess the abundance of MPs in aerosols and street dust in Varanasi, a typical urban city in Northern India. Airborne particulates and street dust samples were collected from various sampling sites around Varanasi City. The physical identification of MPs was conducted by binocular microscopy, fluorescence microscopy, and scanning electron microscopy (SEM), while elemental analysis was made by energy-dispersive X-ray (EDX). Finally, Fourier-transform infrared spectroscopy (FTIR) was used for chemical characterization of MPs. Presence of MPs in both aerosols and street dust from all selected sampling sites was confirmed, however with varying magnitude. MPs of different colors having the shape of fragments, films, spherules, and fibers were recorded in the study while fragments (42%) in street dust and fibers (44%) dominated in aerosols. Majority of the MPs were < 1 mm in size and were primarily polypropylene, polystyrene, polyethylene, polyethylene terephthalate, polyester, and polyvinyl chloride types. The EDX spectra showed the presence of toxic inorganic contaminants like metallic elements on MPs, especially elements like aluminum, cadmium, magnesium, sodium, and silicon found to adsorb on the MPs. Presence of MPs in the airborne particulates and street dust in Varanasi is reported for the first time, thus initiating further research and call for a source-specific management plan to reduce its impact on human health and environment.

Keywords Aerosols · FTIR · Microplastics · Particulate matter · Polymer · Street dust

Introduction

Microplastics (MPs) are the emerging contaminant of the environment, ubiquitous in air, water, and soil. Since last decade, the research in the field of MPs has gained momentum. Mostly the studies are conducted for the availability of MPs in the water and rarely for the air medium (Dris et al. 2016). Few studies have documented the existence of MPs in both the indoor and outdoor air (Abbasi et al. 2019; Akhbarizadeh et al. 2021; Cai et al. 2017; Dris et al. 2016; Enyoh et al. 2019; Liu et al. 2019). Synthetic fabrics, abrasion from synthetic rubber tires, erosion, and dust from city and household areas are the most common sources of MPs in the air (Prata 2018; Sol et al. 2022). According to estimates, a single item of clothing might release up to 2000 fibers per wash (Browne et al. 2011). Other major sources of airborne MPs may include construction and waste incineration site, road dust, landfilling area and industrial outflow, particle re-suspension, synthetic particles such as polystyrene (PS) peat (used in horticultural soils), sewage sludge (used as a fertilizer), and exhaust from tumble dryer (Dris et al. 2016; Prata 2018). Anthropogenic activities always influence the abundance of MPs in air (Abbasi et al. 2019). The study conducted by Dris et al. (2016) at urban and suburban sites in Paris observed fibers in most of the atmospheric fallout. Another study by Zhou et al. (2017) detected airborne MPs including fibers, fragments, films, and foams of different colors in a coastal city Yantai, of Shandong Province. Similarly, Liu et al. (2019) studied the airborne MPs in Shanghai City and

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REVIEW ARTICLE

Microplastics removal strategies: A step toward finding the solution

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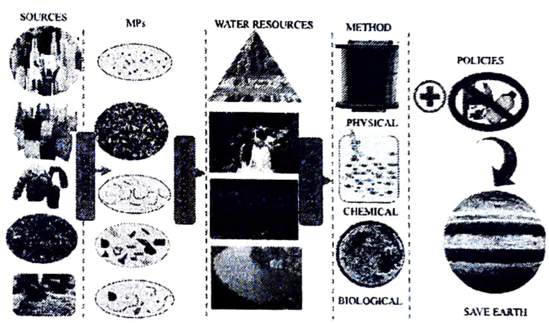
HIGHLIGHTS

- Physical, chemical and biological methods are explored for MPs removal.
- Physical methods based on adsorption/filtration are mostly used for MPs removal.
- Chemical methods of MPs removal work on coagulation and flocculation mechanism.
- MBR technology has also shown the removal of MPs from water.
- Global policy on plastic control is lacking.

GRAPHIC ABSTRACT



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ABSTRACT

Microplastics are an emerging threat and a big challenge for the environment. The presence of microplastics (MPs) in water is life-threatening to diverse organisms of aquatic ecosystems. Hence, the scientific community is exploring deeper to find treatment and removal options of MPs. Various physical, chemical and biological methods are researched for MPs removal, among which few have shown good efficiency in the laboratory. These methods also have a few limitations in environmental conditions. Other than finding a suitable method, the creation of legal restrictions at a governmental level by imposing policies against MPs is still a daunting task in many countries. This review is an effort to place all effectual MP removal methods in one document to compare the mechanisms, efficiency, advantages, and disadvantages and find the best solution. Further, it also discusses the policies and regulations available in different countries to design an effective global policy. Efforts are also made to discuss the research gaps, recent advancements, and insights in the field.

1 Introduction

Plastic waste spreading around our planet has become one of the biggest concerns of this century (Barnes et al., 2009). The global production of plastic is more than 335 million tons per year while recycling is much less than the generated plastic waste and accounts for only 9% of the total plastic waste discarded (Geyer et al., 2017; Lv et al., 2019). Dumped plastic waste gets transported throughout the environment by wind, rivers, tides, storm drains, rainwater, floods, industrial runoff, and sewage disposal to the different aquatic ecosystems (Ryan et al., 2009). These then get converted into smaller size plastic particles by various physical, chemical, and biological actions (Arthur et al., 2009; Dudas et al., 2018). Based on their size, plastic particles are labeled into different categories including viz. macro-plastics (>25 mm), meso-plastics (5–15 mm),

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Investigation of microplastic pollution in river Alaknanda stretch of Uttarakhand

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Abstract

Microplastic pollution research is conducted at a rapid rate throughout the world. However, microplastics (MPs) research in the freshwater ecosystem especially riverine ecosystem is lacking in India. This study is the pioneer to explore the occurrence of MPs in an Indian river. For the present investigation a stretch of river Alaknanda which is a major stream of river Ganga was selected. This stretch was divided into five sampling sites from which five water samples and four sediment samples were collected. The samples were filtered, oxidized, density separated and finally studied under compound microscope and Scanning Electron Microscope. Further, Energy-Dispersive X-ray Spectrum was also conducted to analyze the elemental status of the samples. The result of this research study recorded a total of 955 MPs. Among which 566 particles of the MPs were in water samples while 389 particles were found in sediment samples. In this study threads/fibers were the dominating type, i.e., 412 particles and particle size less than 1 mm was the most abundant type of MPs. Presence of such fine size of plastic particles increases the effect of exposure and interaction of particles with aquatic organisms and possesses a bigger threat for aquatic life. Metals like sodium, potassium, aluminum, calcium, titanium and magnesium were found attached with the MPs, indicating the potential risks to the living organisms.

Keywords Alaknanda · Heavy metals · Microplastics · Plastic · River ecosystem

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ORIGINAL ARTICLE

Past and future distribution pattern of *Myrica esculenta* in response to climate change scenario

Maneesh S. Bhandari[1] · **Rajeev Shankhwar**[1] · **Rajendra K. Meena**[1] · **Shailesh Pandey**[2] · **Rama Kant**[1] · **Santan Barthwal**[1] · **Harish S. Ginwal**[1] · **Jaspal Singh Chauhan**[3]

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Abstract

The structure and functions of an ecosystem particularly species composition and their distribution are expected to be altered with changing climate, and sustainability can be understood by investigating some key stone species. *Myrica esculenta* is an important medicinal tree of northwestern Himalayas, naturally occurring in hilly regions of northern India, southern Bhutan and western Nepal. In the current study, the species was modeled to estimate its potential distribution pattern under past [late interglacial (LIG), paleoclimate, last glacial maximum (LGM)] and future climate change scenarios of the representative concentration pathways (RCP 2.5–8.0) for 2050 and 2070, using Maximum Entropy (MaxEnt) algorithm. Overall, out-off 1022 geo-tag locations, 450 well distributed species presence points were used to run the model, of which 70% was used for training and rest 30% for validation. The performance and accuracy of the model were checked through an area under curve (AUC) which ranged from 0.846 ± 0.053 (LGM) to 0.924 ± 0.057 (LIG). Among all 9 bioclimatic variables, only 4 viz. temperature seasonality (Bio 4), mean temperature of wettest quarter (Bio 8), precipitation of driest month (Bio 14) and precipitation of warmest quarter (Bio 18), were contributed significantly (75.85%) to all the models used for prediction mapping. The highest 37.73% gain was observed for RCP 4.5_70 from the predicted map, and the future distribution coincided mainly between the districts Almora, Pauri, Chamoli and Bageshwar. Although the current suitable climatic habitat is located in northwestern Almora, the centroid expressed a tendency to shift south-eastward under all the four scenarios of RCPs. Furthermore, the centroid of the climatic habitat suitability will shift maximally 4.39 km southeast under RCP 6.0_2050. By the 2070s, the centroid will shift 3.46 km south-eastward under RCP 2.6. Maxent results revealed an increase in the area of environmentally suitable habitats for *M. esculenta* in northwestern Himalayas, if there is no anthropogenic pressure and evolutionary change occurs in the natural zone of distribution. This research provided past existence of the species and future climatic indications for enhanced distribution, besides suggesting academically for the conservation, protection, management, and sustainable utilization of *M. esculenta* resources.

Keywords Geographical distribution · *Myrica esculenta* · Maxent model · Habitat suitability

Introduction

The ecological niche plays a vital role in species lifecycle, and the bioclimatic factors determine the species survival and perpetuity in particular ecosystems. Owing to the long life-span, trees provide the glossary of seasonal variation particularly through phenology, and are considered as an important indicator of climate change. Phenology actually depicts half-yearly weather conditions, and decade-long study on such aspects describe climatic suitability of the habitat under which the particular species thrives. The effects of climate change are sensed on the local, regional and the global level. Especially, latter half of the twenty-first century evidenced an increased global mean surface temperature (GMST) from 0.3 to 0.6 °C, which has been predicted to rise about 2 to 4 °C above pre-industrial levels by the year 2030 and 2090, respectively (Sharma 2011). Connecting all these facts, the Himalayas, which are known as third pole of the world, having enormous biodiversity, but

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ORIGINAL ARTICLE

Wastewater ferti-irrigation: an eco-technology for sustainable agriculture

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Abstract
Water is essential for economic growth of a nation, sustained environmental development and for the survival of every living organism on earth. Due to rapid population growth the freshwater resources are receding at an alarming rate, creating a crucial condition of water shortage worldwide. Further, the unregulated industrial and agricultural expansion is also imparting the pressure on fresh water resulting in huge amount of wastewater. Disposal of this untreated wastewater in an aquatic ecosystem (like river, ponds, ocean, etc.) results in serious impairment of that system. However, with proper treatment it may be utilized for various fruitful activities like industrial processing, landscape irrigation, agricultural irrigation (Wastewater ferti-irrigation), etc., and can help in overcoming water shortage. Wastewater is a low expense option for irrigation in areas where water availability is very limited. The high nutrient content in wastewater can be utilized as nutrients for crops, reducing the extra cost of fertilizers. Moreover, the rivers and other aquatic ecosystems will also be spared from wastewater disposal. To reuse wastewater, proper treatment is essential which require a suitable, ecofriendly, cost-effective and efficient method usable by the small scale industries or by small towns/villages. Since there is lack of awareness among farmers, they don't accept the approach of utilizing wastewater for irrigation fearing to lose yield both quantitatively and qualitatively. This review paper will focus on the various aspects of wastewater reuse that may help government to formulate proper policies for the effective utilization of wastewater in agriculture.

Keywords Ferti-irrigation · Recycle · Wastewater reuse · Soil contamination

Background

Water collected after industrial, agricultural and domestic use is referred as wastewater and is generally dumped into the nearby river or landmass polluting the ecosystem (Ghosh 2005). About 75% of freshwater utilized in domestic and industrial areas ends up as domestic sewage and wastewater, which is discharged into the aquatic bodies like groundwater, rivers, lakes, affecting the quality of their water (Rahmani 2007). An estimate says that about 1.8 billion people will be living in regions with utter water shortage by 2025 with two-third of the population of the world facing water-stressed conditions (UNEP 2008). Therefore, to minimize water pollution and conservation of depleting water resources, reuse of wastewater becomes crucial (Butler and MacCormick 1996). The wastewater has the potential to be used for various non-drinking purposes like agricultural irrigation (Ferti-irrigation).

In general, ferti-irrigation is the process of adding supplements to irrigation water used in agriculture. The supplements include anything (mainly carbon, nitrogen, phosphorus and potassium) which can improve growth of crops. Most commonly, fresh water is used for ferti-irrigation and is applied with surface irrigation or drip irrigation method.

Another way of doing ferti-irrigation is by using industrial and domestic wastewater (wastewater ferti-irrigation) which is a rich source of nutrients potentially beneficial for plant growth. Ferti-irrigation using wastewater can be utilized as a sustainable agricultural approach as it not only saves drinkable freshwater but can also reduce fertilizer dependence. Moreover, if used judicially, it also helps in reducing the burden of wastewater on environment.

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ORIGINAL ARTICLE

Assessment of potability of spring water and its health implication in a hilly village of Uttarakhand, India

Jaspal Singh Chauhan[1] · Tarun Badwal[2] · Neha Badola[1]

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Abstract

Water quality assessment of different sources of water in a village was carried out by taking selected significant parameters, namely temperature, pH, conductivity, total dissolved solids (TDS), dissolved oxygen (DO), free carbon dioxide (free CO_2), alkalinity, hardness, calcium, phosphate, nitrate, chloride and coliform count. All these parameters were analyzed as per the standard protocol of American Public Health Association. Further, seven parameters (pH, TDS, alkalinity, hardness, calcium, nitrates and chloride) were used to calculate water quality index for assessing overall drinking water status of sampling sites. A survey of health status of population of the village was also conducted with the help of questionnaire and interview method to draw the relationship of water quality and health. All selected physicochemical parameters were found under prescribed limits as stated by Indian Standard 10500 and Central Pollution Control Board guidelines. The values for most probable number count were found above the permissible limit of drinking water indicating contamination of coliform at all sites. Further, water quality index for SN1, SN2, SN3, SN4 and SN5 was 17.61, 30.11, 69.73, 25.60 and 47.15, respectively. As per the water quality index, the water samples of natural springs which were away from village were classified under 'excellent' category as compared to supply water samples. The result of survey recorded 38% population suffered from dysentery, 23% from diarrhea and 17% from typhoid. The report of the survey and the presence of coliform suggest that drinking water contamination is leading to waterborne diseases like cholera, dysentery and typhoid. It is also suggested that water quality of all sites except SN3 was suitable for drinking purpose, but disinfection of coliform before use is warranted.

Keywords Coliform · Spring · Water quality · Water quality index

Introduction

The quality of water governs life of an organism on the earth. Hence, researchers around the world are engaged on framing the systematic approach and policy for the long-term conservation of good-quality water. Historical evidences show that change in water quality and quantity due to anthropogenic pressure has lead to vanish many settlements of human beings. Quality of water always depends on the source of water, the storage technique and the treatment opted (Lim et al. 2012; Kumpel and Nelson 2013; Wright et al. 2004). Water pollution affects water quality and harms human health, slows economic development and reduces social wealth (Milovanovic 2007). Water quality represents the purity of water and expresses the suitability of water for various uses like drinking, industrial water supply, and irrigation, propagation of aquatic organisms and generation of hydro power. The water quality is assessed in order to determine its potability, safety of human contact and ecosystem health. Poor quality of water is due to high level of organic and inorganic substance that does not fit in the standard limits given by the government. Biological organism like bacteria, viruses and protozoan is also involved in deteriorating the quality of water and further resulting in many diseases (Grabow 1996). The outburst of epidemics in the form of diseases like cholera and diarrhea, which are major waterborne diseases and a global health problem, is the results of

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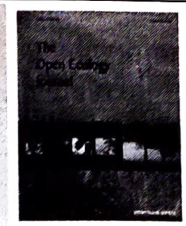

CASE REPORT

Natural and Anthropogenic Impacts on Forest Structure: A Case Study of Uttarakhand State

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Abstract: Forests are among the most important natural resources in Uttarakhand as they occupy 71% of the geographic area and contribute a good share in state economy. They are rich repositories of biodiversity and are providers of ecosystem goods and services to both regional and global community. People are dependent on forests for fuel wood, grass and other biomass. But unfortunately recent trend of data shows a huge degradation of forestland due to natural and anthropogenic activities. Variations in climatic condition and natural disasters are triggering rate of degradation of forests in Uttarakhand. The present paper reviews the status of forest in Uttarakhand and discusses the major natural and anthropogenic factors responsible for its degradation.

Keywords: Biodiversity, Climate Change, Forest fire, Forestland, Global warming, Uttarakhand.

1. INTRODUCTION

1.1. Geographical Location of Study Area

Uttarakhand is the 27^{th} state of Republic of India which lies between 28 44' & 31 28' N Latitude and 77 35' & 81 01' E longitude. It was carved out of Uttar Pradesh on 9th November 2000 and was divided into two divisions of Garhwal and Kumaon with total of 13 districts namely Pithoragarh, Bageshwar, Champawat, Nainital, Pithoragarh, Udham Singh Nagar, Dehradun, Haridwar, Tehri Garhwal, Uttarkashi, Chamoli, Pauri Garhwal, Rudraprayag. It has a total geographical area of 53,483 km^2, of which large area is mountainous with under snow cover and steep slopes. It shares an international boundary with Nepal in the East and China in the North. In the West, it touches state Himachal Pradesh, and in the South, Uttar Pradesh. The human population of the state is 101.167 lakhs (2011census) out of which approximately 70 percent lives in rural areas. There are four major river systems *viz*. Ganga, Yamuna, Ramganga and Sharda originating from the state along with their tributaries serving as the prime source of water for drinking, irrigation and hydropower. A brief statistics of Uttarakhand state is mentioned in Table 1.

1.2. Classification of Study Area

The major wealth of the state is its rich biodiversity forests. Based on altitude different climate zones are classified as warm temperate (900 m-1800 m), cool temperate (1800 m-2400 m), cold zones (2400 m-3000 m), alpine zone (3000 m-4000 m), glacier zone (4000 m-4800 m), and frozen zone (above 4800 m). The average annual rainfall is about 1550 mm. Based on land elevation, the State is classified as terrain region (less than 300 m above msl), lower hilly region (300-600 m), upper hilly region (600- 2400 m) high altitude region (2400-4500 m) and upper high altitude region (above 4500 m). Udham Singh Nagar and Haridwar are the only plain districts in the State. The state comprises of five lithotectonically and physiographically distinct subdivisions namely, the Outer Himalaya (comprising the Tarai and

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RESEARCH PAPER

Monitoring the self-purification capacity of the River Alaknanda stretch at Srinagar, Uttarakhand, India

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ABSTRACT

After six months from Uttarakhand's biggest flood tragedy that took place at Kedarnath, a rapid investigation was conducted to assess the water quality and purification capacity of flooded River Alaknanda. Representative water samples were collected from eight different sites selected along the river stretch and relevant physico-chemical parameters along with biological indicators (coliform and periphyton) were analysed to get effective results. The results indicated that all the studied parameters were under the permissible limits prescribed by World Health Organization (WHO) and Bureau of Indian Standards (BIS) except the coliform count, which ranged between 65 and 270/100 ml. The biochemical tests and staining tests marked the species of *Lactobacillus, Bacillus, Clostridium, Streptococcus, Staphylococcus, Escherichia coli, Shigellas, Salmonella* and *Pseudomonas* in the studied stretch of the Alaknanda. A high range of dissolved oxygen (DO, 8–9.8 mg/l) and a low range of biochemical oxygen demand (BOD, 1.2–2.8 mg/l) for the studied river stretch showed its good purification potential. Moreover, algae like *Oscillatoria, Euglena, Chlamydomonas, Navicula, Nitzschia, Fragillaria, Amphora* and *Synedra* which are considered as good self-purification agents of water bodies, were dominant in organically polluted sites. The periphyton density was recorded as a maximum of $19.9 \times 10^{10}/m^2$ in the month of February at the S4 site and the periphyton biofilm thickness was recorded as a maximum of 3.8 mm at the S4 site in April. Mostly, the sites having high BOD, that is, S4 and S6, harboured a high level of bacterial and algal species representing them as a good indicator of organic pollution. The study suggests that the water of the studied stretch of the River Alaknanda is not compatible for drinking purposes without treatment as the presence of various pathogenic agents has been observed that may enhance the chances of various diseases and infections to local people of the region.

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1. Introduction

Aquatic ecosystems are destabilized worldwide mostly by pollution that resulted due to land-use change, industrial waste water, sewage, agricultural runoff and other point and non-point sources (Berndtsson and Bengtsson 2006, Devi *et al.* 2008, Mayes *et al.* 2007, Banerjee and Srivastava 2010, Singh *et al.* 2012). Such ecosystems, especially rivers, are the basic source of drinking water supply and therefore monitoring their quality regularly is the prime concern of today's research. Out of the major rivers of northern India, one that demands urgent attention is the Alaknanda, a Himalayan river originating in the state of Uttarakhand, India. It is one of the mainstreams of the Ganges, the holy river of Hindus. It has been reported that the Alaknanda river has been mostly contaminated with sewage and domestic waste released from the various densely populated towns situated on the banks of this river, namely Srinagar, Rudrapyrag, Devpyrag, etc. (Badola and Singh 1981, Semwal and Akolkar 2006). The dumping of waste from hospitals, hostels, colleges, shops, etc. has started affecting the health of the River Alaknanda. The self-purification capacity of the River Alaknanda has been weakened by the substantial anthropogenic activities of the nearby population (Sood *et al.* 2010). The sustainability of the river depends on it self-purification capacity, which is a set of complex interconnected biological, physical and chemical processes, performed naturally by the system for the maintenance of its water quality (Heindenwag *et al.* 2001, Wei *et al.* 2009). This process includes the biodegradation of waste through nitrification, denitrification, mineralization, flowing, dilution, deposition and adsorption which are favoured by biotic and abiotic components (Drinan and Spellman 2001, Fisenko 2006). Thus, the health of rivers can be judged by the self-purification capacity. The self-purification potential of the rivers is basically assessed by monitoring the abiotic factors (i.e. physicochemical) or biotic factors (Ali *et al.* 2000, Ayoade *et al.* 2009, Banerjee and Srivastava 2009, Kumar *et al.* 2010, Ishaq *et al.* 2013), that is, diatoms (Schoeman 1979), macroinvertibrates (Sharma and Rawat 2009, Lee *et al.* 2015), bacteria (Okpokwasili and Akujobi 1996, Sood *et al.* 2008), algae (Cattaneo *et al.* 1995) separately.

Physical parameters such as temperature, turbidity, total solids, colour, etc. and chemical parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD), phosphorous, nitrogen, heavy metals, total organic matter, etc. are some of the parameters effectively used in assessing the water quality (Chauhan and Rai 2010, Singh *et al.* 2015). Biological parameters in the aquatic system include biological indicators like bacteria, algae fish, etc. (Cuffney *et al.* 2000, Nor Zaiha *et al.* 2015). Among the bacteria, *Escherichia coli*, because of their wide distribution and diversity, are used as an effective indicator for estimation of the water contamination level (Skraber *et al.* 2002, Sati *et al.* 2011). *E. coli*

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