Research Article
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Productivity evaluation of lotic and lentic water body in Himachal Pradesh, India

Abstract

The present study discusses the Primary Productivity of lotic and lentic water. The Light and Dark bottle method are used to measure primary production. The primary productivity helps to determine the trophic level of various aquatic systems. The primary productivity of any aquatic ecosystem depends on the planktonic biodiversity. Estimation of primary productivity of a water body helps to assess its carrying capacity for a biological population which sustain in it by the respiration. It is the most important of all biological phenomena on which the entire diverse life depends directly or indirectly. The present study was done to estimate the primary productivity of lotic water and lentic water. The results showed that in Beas River, the NPP, GPP, Respiration and Gross Photosynthesis were 31.25 mgL $m^{-1}h^{-1}$, 125 mgL $m^{-1}h^{-1}$, 112.50 mgL $m^{-1}h^{-1}$, and 0.40 mgL $m^{-1}h^{-1}$, respectively. Whereas, in the Ravi River these were 31.25 mgL $m^{-1}h^{-1}$, 52.08 mgL $m^{-1}h^{-1}$, 25.01 mgL m^{-1} h^{-1}, 0.166 mgL $m^{-1}h^{-1}$, respectively. In case of another two ponds, the NPP, GPP, Respiration and Gross Photosynthesis were 50 mgL $m^{-1}h^{-1}$, 112.50 mgL $m^{-1}h^{-1}$, 75 mgL $m^{-1}h^{-1}$, 0.36 mgL $m^{-1}h^{-1}$ and 62.50 mgL $m^{-1}h^{-1}$, 114.61 mgL $m^{-1}h^{-1}$, 62.51 mgL $m^{-1}h^{-1}$, 0.36 mgL $m^{-1}h^{-1}$, respectively. In the two rivers, it was found that NPP level was in same but GPP and respiration rate were higher in the Beas River water. It shows that the Beas River has the highest rate of photosynthesis as there is the highest number of primary producers. Both the pond has the high value of NPP than river water. However, the highest value of NPP was recorded in lentic water and lowest NPP was recorded in lotic water. The main focus of the study was to estimate the Net Primary Productivity for analyzing the water quality and find the pollution level due to increased anthropogenic activities.

Keywords: beas river, himachal pradesh, lentic, lotic, pond, productivity

Volume 3 Issue 5 - 2018

Pratibha Sharma, Arup Giri
Department of Life Sciences, Arni University, India

Correspondence: Arup Giri, M.Sc., Ph.D, Assistant Professor, Department of Life Sciences, Arni University, Kathgarh, Indora, H.P.–176401, India, Te +91 9646 9193 86, Email arupsatadal@gmail.com

Received: July 28, 2018 | **Published:** September 06, 2018

Introduction

Water is very important for the life of the organism and is most essential for living organism. There is a large number of aquatic organisms such as microscopic planktons and large aquatic animal which lives inside water. Water is present in a large amount on earth but very few are usable, no one can live without water.[1–3] It is also called as the liquid of life and universal solvent because of its importance in the life of all living organism. Now a day, in both lentic and lotic water systems are getting polluted after mixing and contaminated with the discharge of domestic and industrial effluent wastes, leakage from water tanks, marine dumping, radioactive waste and atmospheric deposition.[4–8] A major source of water pollution is like domestic sewage, industrialization, population growth, pesticides and fertilizer, plastic and polythene bags, urbanization and weak management system of governmental authority.[9–11] The researcher found that 75 to 80% of water pollution is due to the domestic sewage.[12] Due to direct discharge of domestic sewage into the river water system, rivers are breaking down with a high load of pollutants like toxicants, solid waste, plastic litters, and bacterial contaminants. All these factors or contaminants caused the deterioration of lotic and lentic water system. Industry caused 25% pollution to the water system because of the high level of toxic metals.[13]

Water scarcity throughout the globe is a current concern. Due to poor water security, 80% population in the world is facing a severe problem for clean water.[14] Deteriorated water is now causing 80% of disease in the earth human population.[15] Unhygienic and poor quality of water occurring deaths about 3.1% and 50% is the child who are most prone to diarrhea.[16] In Himachal Pradesh, river– like Beas, Ravi, Satluj are also affected by the presence of cadmium, lead, siltation, domestic & municipal sewage, industrial sewage and surface run–off that affect the water quality directly or indirectly (Table 1).[17,18]

The freshwater bodies are divided into three categories i.e. Lentic, Lotic, and Wetland. Lentic or standing water include lakes and ponds. Lotic or running water includes springs, streams, and rivers. Wetland includes marshes and swamps, where water levels frequently rises and fall, seasonally as well as annually.[28] The main source of water in India is river water. In India, there are many rivers which play an important part in the life of Indian people. The river system provides water for irrigation and all other purposes. In Hindu mythology, rivers play an important role and Hindus considered them holy in the country[29]. Indus, Tapti, Brahmaputra, Narmada, Krishna, Godavari and Mahanadi are seven major rivers in India. In Himachal Pradesh, there are main five rivers: The Chenab, The Ravi, The Beas, The Sutlej, and The Yamuna. Himachal provides water to the Indus and Ganges basins (Table 2).[30,31] A pond is standing water body which is smaller than lakes and either natural or artificial. Ponds may be seasonal with the lifespan of few weeks and months, or perennial with age of several hundred years.[28] Ponds contain water with marsh and aquatic plants and animals.[32–34]

Ponds are frequently human– constructed. The ponds mainly consist of three zones:

a. Littoral zone (a belt close to shoreline, light reaching the bottom, supporting rooted plants),

b. Limnetic zone (light intensity is adequate and planktons are the dominant biota) and

c. Profundal zone (light inadequate or absent, only heterotrophs occur).[28]

Table 1 Review of water quality and human health

Sl. no.	Name of the researcher	Effects of polluted water
1.	Juneja et al.[19]	Toxins in industrial waste caused on immune system break down, reproductive problem, cholera, typhoid fever etc.
2.	Nel et al.[20]	Fecal pollution in water caused many waterborne infectious diseases
3.	Ullah[21]	Polluted water fetal for human health as it stimulated respiratory disease, cancer, diarrheal disease, neurological disorder and cardiovascular disease.
4.	Krishnan et al.[22]	Nitrogenous chemicals in the water system are responsible for cancer and blue baby syndrome.
5.	Currie et al.[23]	Pregnant women are most affected by the polluted water which leads to an increased rate of low birth weight.
6.	Khan et al.[24]	Crop production and food chain in the ecosystem got hampered due to the deteriorated type of water quality.
7.	Ahmed et al.[25]	High level of iron in lentic and lotic water system caused the effect on fish population due to defective function of gills.
8.	Salem et al.[26]	High level of toxic metals leads to hair loss, liver cirrhosis, and renal failure.
9.	Chowdhury et al.[27]	Metal contaminated water leads to neural disorder

Table 2 The list of rivers flowing in Himachal Pradesh, India

Name of rivers	Name of origin	Length in H.P.	Tributaries
Chenab	Chandra and Bhaga at Tandi, in Lahaul	122 Km	Chandra, Bhaga, BhutNallah, Maru, Jammu Tawi, DoaraNullah 1&2, HalseNallah, BhimberNullah, PalkhuNullah, and BhudiNullah
Ravi	Bara Banghal, Kangra district	158 Km	The Budhil, TundahanBeljedi, Saho and ChirchindNala
Beas	The PirPanjal range near The Rohtang Pass	256 Km	The Parbati, The Hurla, The Sainj, The Uhl, The Suheti, The Luni, The Banganga and The Chaki.
Satluj	Rakas Lake	320 Km	The Spiti, The Ropa, The Taiti, The Kashang, The Mulgaon, The Yula, The Wanger, The Throng, The Rupi, The Tirung, The Gayathing, The Baspa, The Duling and The Soldang
Yamuna	Yamunotri in Uttarkashi District, Uttarakhand	2320 Km	The Tons, The Giri and The Bata

Source General outline of rivers in Himachal@webindia123

The time is not too far when usable water will be inadequate for the normal living condition of the human population.[28] Management of freshwater bodies should aim to maintain high productivity level of water bodies with provision for a high rate of harvest of plants and animals for human use. Measurement of primary production or photosynthesis is helpful to understand the tropic status and to assess the fish production potential of the aquatic ecosystem. To estimate the bioactivity of a reservoir it is necessary to determine the magnitude of primary production. The fundamental to understand both water quality and fisheries is the study of primary productivity. Increasing the pattern of productivity helps the population to sustain in a healthy circumstances.[35–39] the amount of solar energy trapped by the autotrophic organisms is known as production. The amount of solar energy trapped by the autotrophic organisms in unit time is known as productivity. The amount of plankton present in the water body decides the productivity of that water body.[40,41]

Primary productivity is defined as "the rate at which radiant energy is stored by the photosynthetic and chemosynthetic activity of producer."[42] Primary productivity is the most important biological phenomenon in nature on which the entire diverse array of life depends, either directly or indirectly. Primary producers use inorganic nutrients through the process of photosynthesis to built organic matter. Primary producers need essential nutrients to live and grow such as nitrogen, phosphorus, magnesium, calcium, iron, zinc, etc. in sufficient amount. Phytoplankton, Macrophytes, and Periphyton are the main producer in lake and reservoir.[43–45] Primary productivity is also marked as Gross primary productivity. This is the total rate of photosynthesis including the organic matter used in respiration during the measurement period. Net primary productivity (NPP) is the rate of storage of organic matter in plant tissue in excess of the respiratory utilization by plants during the measurement period.[46] Thus, net primary productivity refers to the balance between gross photosynthesis and respiration and other plant losses as death. Primary production in aquatic ecosystems has certain features distinct from that in terrestrial systems.[47,48]

The flow of energy through an ecosystem is a unidirectional process in contrast to nutrients which may be cycled many times. The primary productivity is the root of all food chains and food webs of any ecosystem generating 70% atmospheric oxygen of the world. It is important to note that the study of productivity now receiving so much attention in ecology and the ecologists interested in *ecoenergetics* are primarily concerned with the quality of incident solar energy per unit area of the ecosystem and the efficiency with which energy is converted by organisms into other forms (chemical energy).[49,50] With advances in the concepts of ecology, the more formalized study of

primary production was undertaken first in aquatic systems, then in terrestrial biomes.[51–53] Productivity is considered as an important driver of diversity.[54–56] Knapp et al.,[57] compiled long–term NPP data from 11 Long–Term Ecological Research (LTER) sites to assess the controls of means and temporal variation in NPP in North American terrestrial ecosystems. The main aim of productivity measurement of aquatic systems was to get a better understanding of the food chain relationships and of the functioning of the ecosystem. In an aquatic ecosystem, the main source of energy input is primary productivity. It is directly related to temperature and the available nutrients in the water and soil in relation to other physicochemical factors.[50] Biological production can be used as an index of trophic status, fisheries potential, productivity and biodiversity of water body (Table 3 & 4).[58–60] The object of the present study was to measure the primary productivity of Lotic and Lentic water. Productivity analysis could provide clues for solving water management problems in the study area.

Table 3 Characteristic features in lakes of different trophic categories[80,81]

Tropic level	Primary productivity	Secchi Disk depth	Chl–a	Algal volume	Total–P	Total–N	Dominant fish
Oligotrophic	<30	>5	<2.5	<0.8	<10	<350	Trout, Whitefish
Mesotrophic	25–60	6–Mar	8–Feb	0.5–1.9	25–Aug	300–500	Whitefish, Perch
Eutrophic	40–200	4–Jan	Jun–35	1.2–2.5	20–100	350–600	Perch, Roach
Hypertrophic	130–600	0–2	300–400	2.1–20	>80	>600	Roach, Bream

Table 4 Classification of lakes into trophic classes based on summer surface mean values[82]

Trophic level	Total–P(µg L^{-1})	Total–N (µg L^{-1})	Chl–a (µg L^{-1})	Secchi disk depth (m)
Oligotrophic	<10	<350	<3.5	>4
Mesotrophic	30–Oct	350–650	3.5–9.0	2–Apr
Eutrophic	31–100	651–1200	9.1–25	1
Hypertrophic	>100	>1200	>25	1

Materials and methods

Study Area

India is a developing country, which consists of 29 states and 7 union territories. Himachal Pradesh is the main state of India located in north India. It is situated in the western Himalayas and bordered with Jammu & Kashmir, Punjab, Haryana, Uttarakhand and Uttar Pradesh. It is situated at a high altitude ranging from 450 meters to over 7,026 meters. It is the most beautiful and hilly state having a number of rivers and natural vegetation. It is a sparsely populated state with different topographical and climatic condition. The Geographical Location of Himachal Pradesh is 30' 22' 40" North to 33' 12' 40" North latitude and its longitudinal extent is 75' 45' 55" East to 79' 04' 20" East. Himachal Pradesh occupies an area of 55,673 sq. km. There are five rivers flowing through Himachal Pradesh: The Chenab, The Ravi, The Beas, The Satluj, and The Yamuna. The Beas is the major river system of the Indus basin. After originates in Beas Kund near Rohtang pass, flows in the east–west direction in Himachal Pradesh. Then, it emerges in the plains near Talwara in Hoshiarpur district of Punjab state. The total length of this river is 470 Km and its drainage basin is 20,303 sq. Km.[31] Pond water is collected from Nurpur situated at District Kangra of Himachal Pradesh. Nurpur is located at 32.3°N 75.9°E. It has an average elevation of 643 meters. It was earlier known by the name of Dhameri.

Experimental design

Four different sites were selected for the collection of the water sample. Two were Lotic and two were Lentic. Sample collection was done in April month of the year 2018. Water was collected from two ponds, the Ravi River, and Beas River (Figure 1–3). The entire sample has been analyzed by the "Dark and Light Bottle method".

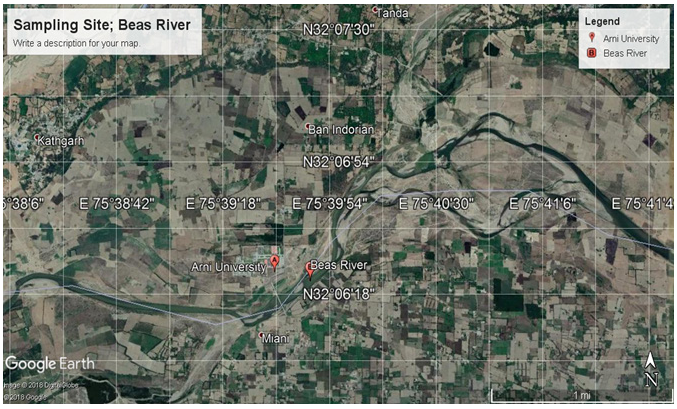

Figure 1 Location of Beas River sampling site in Himachal.

Sample collection

The sample of the water for the measurement and comparison of the primary productivity were collected from Ravi River and Beas River, running from the Himachal Pradesh and Punjab State of India. The water sample is collected at latitude 32.49534°N and longitude 75.81953°E from Ravi River and at latitude 32.10489°N and longitude 75.66057°E from Beas river. Two samples of Pond water were collected from the pond situated near Nurpur. The Sample

Citation: Sharma P, Giri A. Productivity evaluation of lotic and lentic water body in Himachal Pradesh, India. *MOJ Eco Environ Sci.* 2018;3(5):311–317. DOI: 10.15406/mojes.2018.03.00105

one is collected at latitude 32.30186°N, longitude 75.88326°E and sample two at latitude 32.30263°N, longitude 75.91088°E by using BOD bottle of 250 ml (Table 5) (Figure 1–3). The sample of water was collected between 9:00 a.m. to 11:00 a.m. The sample of water containing autotrophs is taken from a given depth of river in three sample bottles. One of the bottles is transparent and permitting photosynthesis to take place (light bottle). The other bottle is darkened to stop photosynthesis. Only respiration occurs in this bottle (Dark bottle). The bottles are then incubated for a certain period. Extreme care was taken to see that no air bubble was left inside.

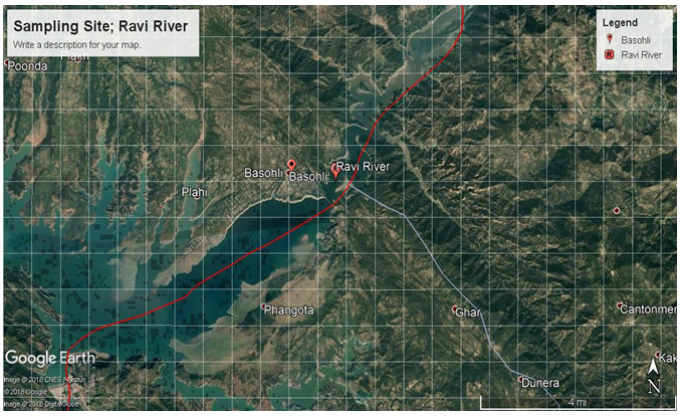

Figure 2 Location of the Ravi River sampling site.

Figure 3 Location of the pond water sampling site.

Table 5 The latitude and longitude of various sampling locations

S. no.	Sampling location	Latitude	Longitude
1	Beas river	32.10489°N	75.66057°E
2	Ravi river	32.49534°N	75.81953°E
3	Pond–1	32.30186°N	75.88326°E
4	Pond–2	32.30263°N	75.91088°E
S. no.	Sampling location	Latitude	Longitude
1	Beas river	32.10489°N	75.66057°E
2	Ravi river	32.49534°N	75.81953°E
3	Pond–1	32.30186°N	75.88326°E
4	Pond–2	32.30263°N	75.91088°E

Method

The primary organic production of the river water was determined by 'light and dark bottle method'.[61] Gaarder and Gran in 1927 first proposed the technique of using light and dark bottles and Winkler's titration to measure the production and consumption of Oxygen. It is the most common method for measuring production and productivity in the aquatic medium. It measures the amount of dissolved (or free) oxygen present in water or wastewater. Dissolved oxygen concentration is defined as the number of millilitres of dissolved gas (oxygen) per litre of water.[28] In this method, by estimating dissolved oxygen content productivity is measured.

Water productivity calculation

Gross Primary productivity (GPP), the Net Primary Productivity (NPP) and Respiration were calculated in the following manner:

$$Gross\ Primary\ Productivity = \frac{LB - DB}{T} \times \frac{0.375}{PQ} \times 1000\ mg / L / h$$

$$Net\ Primary\ Productivity = \frac{LB - IB}{T} \times \frac{0.375}{PQ} \times 1000\ mg / L / h$$

$$Respiration = \frac{IB - DB}{T} \times \frac{0.375}{PQ} \times 1000\ mg / L / h$$

Where:

LB = Light bottle,

DB = Dark bottle,

IB = Initial bottle,

T = Time of incubation,

PQ = Photosynthesis Quotient = 1.25,

RQ = Respiratory Quotient =1 and

The value 0.375 represents a constant to convert Oxygen value to Carbon Value.[62]

Results and discussion

In the present study, primary productivity of lotic and lentic water have been studied. For the study of lentic water two ponds were selected from Nurpur region and for Lotic water two rivers were selected which flows through Himachal and Punjab. Measurement of Primary production and Photosynthesis is helpful to understand the water quality and trophic status of the aquatic ecosystem. The level of NPP, GPP, and respiration of Beas River, Ravi River, Pond–1, and Pond–2 is given in Table 6. The results showed that in Beas River, the NPP, GPP, Respiration and Gross Photosynthesis were 31.25 mgL $m^{-1}h^{-1}$, 125 mgL $m^{-1}h^{-1}$, 112.50 mgL $m^{-1}h^{-1}$, 0.40 mgL $m^{-1}h^{-1}$, respectively. Whereas, in the Ravi River these were 31.25 mgL $m^{-1}h^{-1}$, 52.08 mgL $m^{-1}h^{-1}$, 25.01 mgL $m^{-1}h^{-1}$, 0.166 mgL $m^{-1}h^{-1}$, respectively. In the case of another two ponds, the NPP, GPP, Respiration and Gross Photosynthesis were 50 mgL $m^{-1}h^{-1}$, 112.50 mgL $m^{-1}h^{-1}$, 75.00 mgL $m^{-1}h^{-1}$, 0.36 mgL $m^{-1}h^{-1}$ and 62.50 mgL $m^{-1}h^{-1}$, 114.61 mgL $m^{-1}h^{-1}$, 62.51 mgL $m^{-1}h^{-1}$, 0.36 mgL $m^{-1}h^{-1}$, respectively. In the two rivers, it was found that NPP level was in same but GPP and respiration rate were higher in the Beas River water. It shows that Beas River has the highest rate of photosynthesis as there is the highest number of primary producers. Both the pond has a high value of NPP than river water. However, the highest value of NPP was recorded in lentic water

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and lowest NPP was recorded in lotic water. There is variation in NPP of water sample at different locations.

Table 6 Values of NPP, GPP, and Respiration of Rivers (Beas and Ravi) and Ponds (1 & 2)

Parameters	Units	Beas river	Ravi river	Pond–1	Pond–2
NPP	mgL/m³/h	31.25	31.25	50	62.5
GPP	mgL/m³/h	125	52.08	112.5	114.61
Respiration	mgL/m³/h	112.5	25.01	75	62.51
Gross photosynthesis	mgL/m³/h	0.4	0.166	0.36	0.36

The higher value of NPP and GPP is due to penetration of more light intensity which facilitates the higher rate of photosynthesis and ultimately the productivity. The amount of gross production available to the consumer is evaluated by the ratio of the net and gross primary production.[63–65] Table 7 represents the ratio between the different productivity parameters of lotic and lentic water bodies. The NPP: CR >1 could be attributed to the clarity of water as well as suitable temperature which favors abundance of phytoplankton and more photosynthetic activities. It accounts for more penetration of light into the water body. The ratio <1 could be on account of less penetration of light into the water due to increased suspended particles resulting in lesser photosynthetic activity and thereby decrease in productivity. Higher production is not governed by a single factor as stated by Singh at al.[63] There are many other factors on which the production of the aquatic ecosystem depends. The rate of production in an aquatic ecosystem is controlled by physicochemical and biological factors. The NPP value for lotic water is <50 mgL $m^{-1}h^{-1}$, so the nature of lotic water is ultraoligotrophic and NPP value for lentic is 50–300 mgL $m^{-1}h^{-1}$, so the nature of lentic water is oligotrophic.[66] The highest primary productivity is found at lentic water as compared to lotic water. This indicates that the planktonic activity is greater in lentic water. The NPP value for lotic water is <50, so the nature of lotic water is ultraoligotrophic and NPP value for lentic is 50–300 mgL $m^{-1}h^{-1}$, so the nature of lentic water is oligotrophic. The low productivity could attribute to the low nutrient levels. Due to the addition of various products in river water the physiochemical parameters of water changes. Many anthropogenic activities lead to the addition of waste into river water. This decreases the primary productivity of the rivers and directly or indirectly affects many aquatic plants and animals. The density or number of aquatic plants and animals decreases. So, it is necessary to treat the water to maintain the primary productivity so that the aquatic plants and the animal can survive in it.

Table 7 Ratio between different productivity parameters of lotic and lentic water bodies

Rivers	NPP:GPP	NPP:CR
Beas	0.25	0.277
Ravi	0.592	1.24
Pond–1	0.44	0.66
Pond–2	0.54	0.99

Dissolved oxygen (DO) in water affects the oxidation–reduction state of many of the chemical compounds such as nitrate and ammonia, sulfate and sulfite, and ferrous and ferric ions. It is extremely useful in self–purification of water bodies. The reduction in DO level causes the anaerobic condition in water and adversely affects the aquatic biota.[67] Much of the DO in water comes from the atmosphere due to wind action. Algae and rooted aquatic plants also give out oxygen into water through photosynthesis.[68] The oxygen content in natural water varies with temperature, salinity, turbulence, the photosynthetic activity of algae and higher plants and the atmospheric pressure.[69] Variations in the amount of DO occur over a day. This is due to photosynthetic and respiratory processes of algae and higher plants.[70] The waste and domestic sewage affects the overall condition of the water bodies which is depicted by a decrease in DO, increase in BOD, high ammonia, nitrite and low values of water quality indices (WQI).[71] The high amount of organic matter undergoing biological degradation is the reason for the depletion of DO in water.[72,73] The lowering of DO concentration in the water is because of greater input of waste from the different type of anthropogenic activities. Low nutrient levels and high turbidity seems to be due to low productivity.[74] The decrease of oxygen in the dark bottles helps in determination of respiration rate which is given as their carbon equivalents.[75–77] Water quality water is affected by the wastes from the homes, agricultural runoff and the drains carrying municipal sewage of the cities. According to the Central Pollution Control Board, untreated sewage is responsible for 70% of the pollution in rivers which results in low DO and high BOD.[67,73,78,79] According to the present study, ponds seem to have the highest Net primary productivity than the rivers. Low Net Primary Productivity at rivers may be due to the addition of a high amount of wastes. Moreover, domestic waste is added to a high amount to Beas and Ravi Rivers as these are situated near the rural area.

Conclusion

The highest primary productivity is found at lentic water as compared to lotic water. This indicates that the planktonic activity is greater in lentic water. The NPP value for lotic water is <50 mgL $m^{-1}h^{-1}$, so the nature of lotic water is ultraoligotrophic and NPP value for lentic is 50–300 mgL $m^{-1}h^{-1}$, so the nature of lentic water is oligotrophic. The low productivity could attribute to the low nutrient levels. Due to the addition of various products in river water the physiochemical parameters of water changes. Many anthropogenic activities lead to the addition of waste into river water. This decreases the primary productivity of the rivers and directly or indirectly affects many aquatic plants and animals. The density or number of aquatic plants and animals decreases. So, it is necessary to treat the water to maintain the primary productivity so that the aquatic plants and an animal can survive in it.

Acknowledgements

The Authors are thankful to Dr Rajesh Kumar, Head of the Division and Indu Kumari, Research Associate, Life Science Department, Arni University for providing the lab facility.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Citation: Sharma P, Giri A. Productivity evaluation of lotic and lentic water body in Himachal Pradesh, India. *MOJ Eco Environ Sci.* 2018;3(5):311–317.
DOI: 10.15406/mojes.2018.03.00105