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IMPACT OF REGULATED FLOW ON BIOLOGICAL WATER QUALITY IN UPPER ECOLOGICAL SEGMENT OF RIVER YAMUNA

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ABSTRACT – Flow regulation in upper segment of River Yamuna has affected river water both in terms of quality and quantity. Impact of flow regulation in upper segment of River Yamuna has resulted into moderate (class'C') to heavy pollution (class 'D') at downstream Tajewala barrage to Kalanaur during winter of 2004 whereas at the same location, the water quality improved to class'C' during year 2010. Loss of biological life at Panipat downstream indicated severely pollution in water quality (class 'E') mainly due to discharge from drain no.2. Whereas at Sonepat, severe pollution was due to non-availability of water in River Yamuna. Monsoon affected the biological establishment on river bed substratum thereby changed the clean biological water quality class 'A' to slight pollution of water quality class'B' in himalayan segment and moderate pollution(class 'C') in upper segment of River Yamuna.

Keywords : Flow velocity, Benthic macro-invertebrates,Water quality.

INTRODUCTION

Rivers are the lifeline of majority of population in cities, towns and villages. With increasing population pressure and associated activities, the rivers are affected both in terms of water quality and quantity. After the construction of a barrage or dam or development of irrigation canal network on a river, downstream stretches of river does not get enough water. As a result, the pollutants discharged through several drains, sewage streams and effluents joining the rivers are not diluted. It affects the self purification capacity of rivers and thus river stretches get polluted (Parivesh,1999). River Yamuna is the largest tributary of River Ganga. The main stream of River Yamuna originated from the Yamunotri glacier near Bandar Punch in the Mussorie range of lower Himalayas in the district of Uttarkashi in Uttarakhand. The Tons and Giri rivers are the important tributaries of River Yamuna and principal source of water in mountaineous range. Due to significant variations in hydrological and ecological characterstics, River Yamuna has been divided into five distinct segments (CPCB,2000,2001,2006) such as; himalayan segment, upper segment, Delhi segment, eutrophicated segment and diluted segment. The availability of water in Yamuna river varies with time and space. Most of the water which flows in Yamuna (nearly 80%) flows in monsoon period (July to September) because precipitation is mostly confined to only three months in a year and it fluctuates significantly. The ammount of water which flows in River Yamuna in non-monsoon period (October to June), is extensively used for irrigation and drinking, leaving very little or no water in the river to flow specially in the upper segment. Studies during 1983 to 1988 have indicated that about 70 to 80% of the time downstream flow in upper segment, between Tajewala and Okhla barrage, is less than 3 cusecs. At Tajewala, nearly the entire flow of Yamuna river is diverted for irrigation through Western Yamuna Canal and Eastern Yamuna Canal. A total annual abstraction from Yamuna river at Tajewala has been estimated as 6025 million m^3 which included ,6000million m^3 for irrigation, 10million m^3 for water supply and others included 15 million m^3 (ADSORBS,2006-07). Compared to entire stretch, there was a minimum flow velocity of 0.055 m/s in the upper segment of River Yamuna, from Palla to Wazirabad after monsoon (Mamta *et al,* 2010). Taking the whole of the Ganga basin, on an average in every square kilometer of land surface some one million cubic metres of water is received annually from the atmosphere in the shape of rainfall. But out of this amount, less than half is actually available after deducting the amount of water lost through evapotranspiration (30 percent) and seepage into the ground (20 percent). It has been estimated that some 293.8 billion cubic metres go down into the soils as ground water recharge every year in the Ganga basin (ADSORBS,1982-83). River flow is an important hydrological characteristic which governs the ecological integrity of a river in terms of biological establishment. Biological monitoring provides an effective,

easy to understand, less time consuming and cost – effective method to determine cumulative impact of pollution. With the availability of dilution in water quality of River Yamuna during monsoon, a total of 30 families of benthic macro-invertebrates with the dominance of 76.66% of arthropods, 10% of molluscs, 6.66% of communities each of platyhelminthes and annelids were observed (Mamta et al,2010). The present study deals with the use of benthic macro-invertebrates for bio-monitoring to assess the impact of flow regulation on biological water quality in upper segment of River Yamuna from upstream Tajewala barrage to Palla.

MATERIALS AND METHODS

River Yamuna flows through series of valleys in lower Himalayas and emerges into Indo-gangetic plains. In the upper stretch, it draws water from several major streams. The combined stream flows through the shivalik range of hills of Himachal Pradesh, UttarPradesh and enters into plains of Dak Patthar in Uttarakhand, where the river water is regulated through weir and diverted into canal for power generation. From Dak Patthar it flows through the famous Sikh religious place of Paonta Sahib and reach Hathnikund/Tajewala inYamuna Nagar district of Haryana, where the river water is again diverted into Western Yamuna Canal and Eastern Yamuna Canal for irrigation. Normally,during dry season, no water is allowed to flow in the river downstream to Tajewala barrage. As a result, the river remain dry in some stretches between Tajewala and Delhi. The river regains water because of ground water accrual and contributions of feeding canal through Som nadi(seasonal stream) upstream of Kalanaur. Thereafter, between Panipat to Sonepat, river flows only during monsoon period and enters Delhi near Palla village after traversing a route of about 224km. There was no flow in river at upstream of Panipat. The amount of water which flows in River Yamuna, carries entire waste water discharge from Panipat town through drain no. 2 located around 80 km upstream from Wazirabad barrage opposite to National Fertilizers Limited (NFL) on the National Highway No.2 at Panipat (Haryana). After travelling a distance of few kilometers, river water gets evaporated thus, leaving the river stretch completely dry at Sonepat and upstream of Palla village. Again at Palla, the flow in River water is maintained through discharge from drain no.8 also known as Sonepat drain located around 25 km upstream from Wazirabad barrage at National Highway No.2 near Piao Manihari village (Haryana). Water from Western Yamuna Canal is also diverted through this drain(specially in summer) into River Yamuna. A total of seven sampling locations were selected for assessment of biological water quality on a 224 km stretch in upper segment of River Yamuna from Tajewala to Palla. To observe the impact of flow regulation on biological establishment in upper segment of River Yamuna, three reference stations were selected in himalayan segment, from Kalsi to Dak Patthar. Benthic macro-invertebrates were collected from various locations by using different devices based on substratum composition of river bed(Table 1 &2). Biological water quality assessment was carried out by using BWQC. (Table 3). Hydrological parameters included flow velocity and substratum composition at various sampling locations.

RESULT AND DISCUSSION

Being supported by large snow-fields and glaciers, River Yamuna, the himalayan tributary of the Ganga river, is characterized by well regulated flow throughout the year, though in the cold weather period, the flow is somewhat reduced. Under the high temperature condition prevailing over the Yamuna basin for the greater part of the year, a large amount of water is lost through evaporation. As a result, the total annual evaporation is much more than the total annual rainfall received. The greater amount of rainfall (70 to 85 percent of annual total) occurs in three months (July to September) only in most areas within the basin. It is during this period that the water available from rainfall is usually more than what is lost through evaporation, leaving some surplus water to flow down the river. The weather in the Yamuna basin is characterized by a distinct wet season receiving more than 70% of the total annual rainfall during the period of the southwest monsoon (June to September), a dry spell during the summer (March to May), and a short winter(December to February). Maximum flow in River Yamuna was observed in Himalayan segment at Kalsi (0.58 m/s). There was sudden fall in the flow in upper segment from DakPatthar(0.093 m/s) to almost no flow velocity in river water at Panipat upstream. Flow in River Yamuna terminated at upstream of Panipat and thereafter there was total loss of river water due to gradual evaporation towards downstream. In the absence of river water, no biological life existed in River Yamuna at Panipat downstream mainly due to water quality contribution through drain no. 2 flowing in river with a flow velocity of 0.45 m/s on a sandy substratum of river. This water also get evaporated till it reached Sonepat. Thus at Sonepat, the river stretch was completely dry. The flow in River Yamuna at Palla, is again regulated through drain no.8 providing a flow velocity of 0.43 m/s in order to fulfill the requirement of raw water source for drinking water supply of Delhi (Figure 1). Minimum flow velocity in upper segment of River Yamuna was observed from Dak Patthar to Kalanaur. The total environment of hillstreams

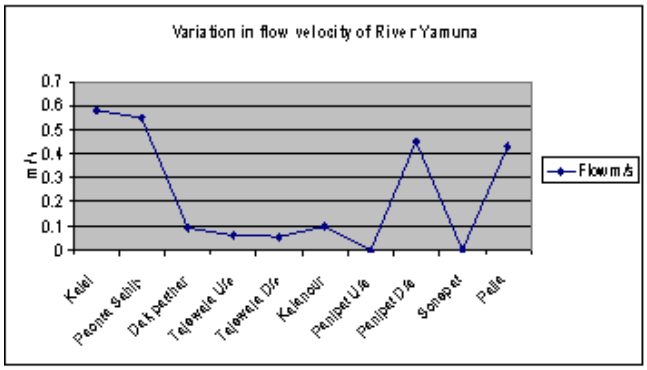
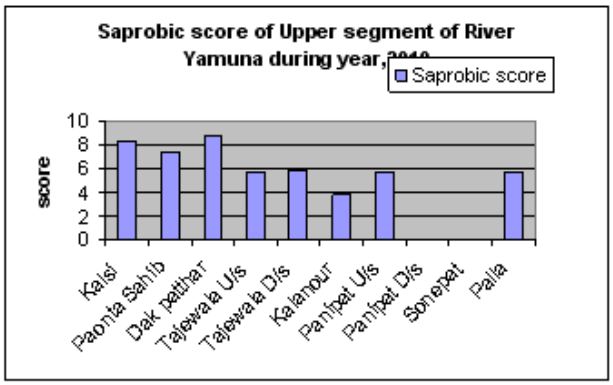


Figure 1



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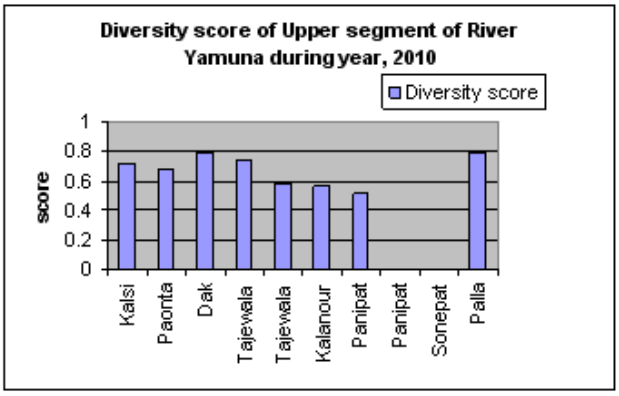

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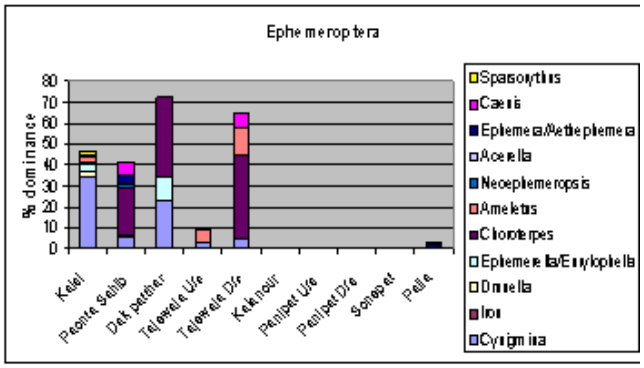
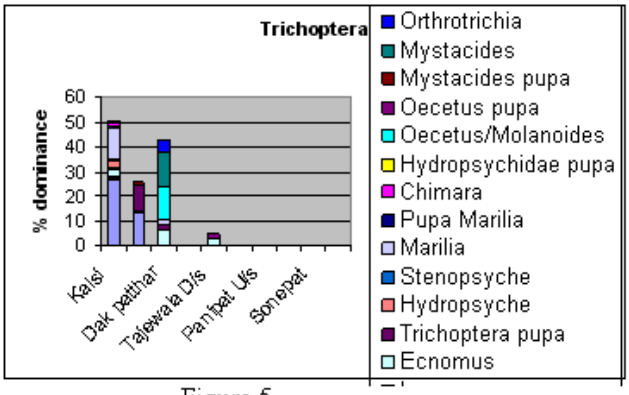


Figure 4

Table 1 : Substratum composition in the Upper ecological segment of River Yamuna.

Ecological segment	Sampling location	Dominance sequence of substratum type
Himalayan	Kalsi	Cobbles>boulders>pebbles>sand>gravel>silt=clay
segment	Dak Patthar	Cobbles>pebbles >sand>silt>gravel>boulders
(Reference station)	PaontaSahib	Cobbles=sand>pebles=silt
Upper segment	Upstream Tajewala barrage	Cobbles>pebbles=sand
	Downstream Tajewala barrage	Cobbles>Pebbles=sand>gravel>boulders
	Yamuna Nagar, kalanaur	Sand>silt>clay>detritus
	Upstream Panipat, Mavi bridge	Sand>silt>pebbles>clay>macrophytic vegetation
	DownstreamPanipat,Khojkipur	Silt>clay
	Sonepat	Sand
	Palla	Sand>detritus>macrophytic vegetation

is the result of interaction among a number of factors some of which are considered more important Many factors such as the current speed, temperature, substratum, vegetation, dissolved substances, liability to drought and floods, food, competition between species, shade, and zoogeography regulate the occurrence and distribution of stream invertebrates(Kumar *et al*. 1999; Menon et al. 2000, Hynes,1970). Many of these factors are interrelated-current, for example, very largely controls the substratum; water temperature affects dissolved oxygen, and both current speed and turbidity also influence the amount of dissolved oxygen, which in turn governs the biological productivity. The



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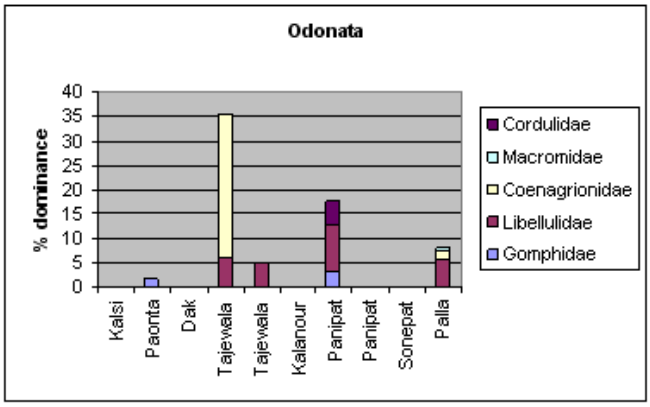

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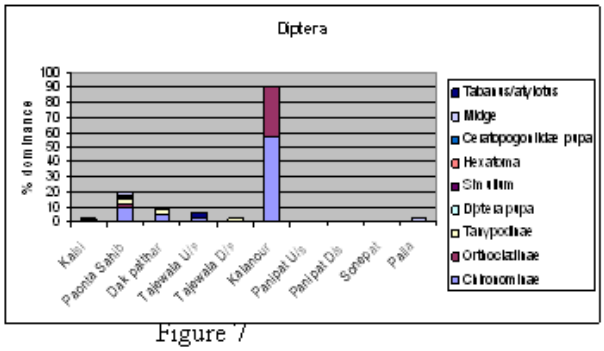

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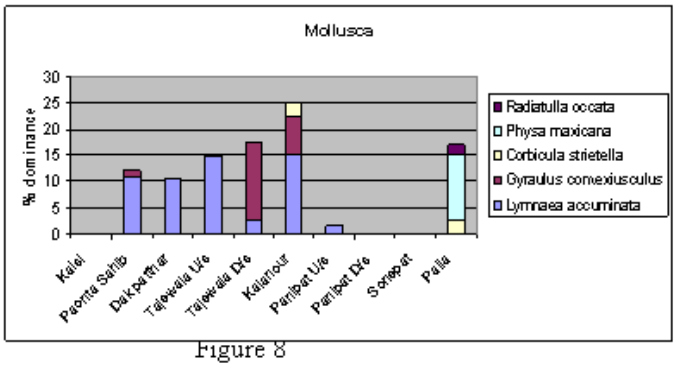

Figure 8

Table 2 : Sampling methods for benthic macro-invertebrates.

Substraum Type/size	**Method of sampling**
Boulders (>256mm)	Large stones from side, middle of fast flowing shallow stream were picked up and organisms were removed by brush or soft forcep pins directly in to sampling bottle containing field water. Hand net was placed firmly on to the river bed, against the flow and the mouth of the net was placed adjacent to large stone or rock. Large stones or rocks lying under water were brushed off for collecting animals.
Cobbles (255-64mm)	Large stones were picked up quickly from side, middle of fast flowing shallow stream and the organisms were removed by brush or soft forcep pins directly in to sampling bottle(Tarson) containing field water.
Pebbles (63-16mm)	The hand net was firmly placed on to the stream bed against the flow and the stream bed was disturbed by kicking up. Detached organisms from substratum were collected into the net animals by overturning and showering the net on a white tray. The same exercise is repeated at different places on sampling site for collection of sufficient diversity.
Gravel (15-2mm)	Loosely attached gravels were collected by showel and throughly seived in river water. The live animals were pickedup by forcep pins and collected in sampling bottles.
Sand, Silt &, Clay (<2mm)	The river bed was scraped by sieve or at least 5 grab sample were collected by showel, from one site. The sample was washed in the sieve by rotating left and right in water to remove sand. Benthos were separated by forcep pins into bottles containing field water.
Macrophytic vegetation, Detritus	By uprooting submerged, floating water plants by Shovel, Hand net, benthic macro-invertebrates were collected by forcep pins. Detritus was sieved through shovel and animals were picked up.

flow velocity and substratum composition on seven locations in upper segment of River Yamuna was compared with three locations in himalayan segment (Table 1). Cobbles dominated the river bed substratum in the himalayan segment and at Tajewala in upper segment of River Yamuna. In the downstream stretch, the river bed has been trasformed mostly into sandy substratum and quite often covered by silt and clay (Table 1). Consequently, maximum saprobic score was obtained in himalayan segment of River Yamuna from Kalsi to Dak Patthar and minimum at Kalanaur(Figure 2). Saprobic score was low during winter of year 2004 compared to year 2010, thus indicating improvement in water

Table 3 : Biological Water Quality Criteria (BWQC).

Sl. No	Taxonomic Groups	Range of saprobic score (BMWP)	Range of Diversity Score	Water quality characteristic	Water quality class
1	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Diptera	7 and more	0.2 - 1	Clean	A
2	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Planaria, Odonata, Diptera	6 – 7	0.5 - 1	Slight Pollution	B
3	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Crustacea, Mollusca, Polychaeta, Diptera Hirudinea, Oligochaeta	3 – 6	0.3 - 0.9	Moderate Pollution	C
4	Mollusca, Hemiptera, Coleoptera, Diptera, Oligochaeta	2 – 5	0.4 & Less	Heavy Pollution	D
5	Diptera, Oligochaeta No animals	0 – 2	0 - 0.2	Severe Pollution	E

Table 4 : Trend in biological water quality in Upper ecological segment of River Yamuna

Sampling location	Biological water quality class December, 2004	Biological water quality class February, 2010
Upstream Tajewala barrage	C	C
Downstream Tajewala barrage	C-D	C
Yamuna Nagar, Kalanaur	D	C
Upstream Panipat	C	C
Downstream Panipat	-	E
Sonepat	C	E
Palla	C	C

quality over the years(Table 3). Existance of aquatic life expressed in terms of saprobic score at all the seven locations indicated availability of an uninturrupted flow of river in the entire upper stretch of River Yamuna during year 2004. Whereas, no saprobic values could be obtained due to no flow of water between Panipat and Sonepat during year 2010 (figure 2). Thus, At Sonepat, 0.0 saprobic score was mainly due to non availability of water in the stretch upto Palla. Similar to saprobic score, diversity score was higher during year,2010 and maximum diversity was observed at upstream Palla. There was no biological diversity observed at Sonepat during winter of 2010(Figure 3). The results indicated maximum diversity score at DakPatthar and Palla and minimum at Panipat upstream. Thus, aquatic life in upper segment of River Yamuna is affected both in terms of quality and quantity of water during non-monsoon period. Most of the genera of texa ephemeroptera were dominant in himalayan segment from Kalsi to DakPatthar. *Sparsorythus* was among the rare ephemeroptera, indicated water quality of himalayan segment at Kalsi. A total of 11 genera were identified in upper segment of River Yamuna where few genera of ephemeroptera were observed in a limited stretch from upstream to downstream Tajewala barrage. *Cynigmina* of heptageniidae family was dominant in himalayan segment and was observed up to stretch of Tajewala in upper segment. *Choroterpes* of leptophlebidae family was dominant at Paonta Sahib, DakPatthar and Tajewala downstream. *Ephemera*/*Aethephemera* appeared at Palla indicating the sandy substratum and impact of diversion of Western Yamuna Canal water from Tajewala to drain number 8 joining at Palla (Figure 4). Maximum number of trichoptera indicated maximum flow velocity of river in Himalayan segment at Kalsi. A total of 14 number of genera of trichoptera were collected from River Yamuna in himalayan segment whereas only 2 genera were observed in upper segment at downstream of Tajewala (Figure 5). Presence of trichoptera in river indicated clean and flowing condition and dominance of cobbles in river bed substratum in himalayan segment and to certain extent at upper segment in Tajewala downstream. Absence of trichoptera at upstream Tajewala indicated impact of flow regulation due to barrage. Odonates were the indicators of flow regulation in upper segment. Presence of odonates in river indicated impact of humen influence on water quality as well as decrease in flow velocity of River Yamuna at Paonta Sahib and Panipat upstream. A total of five families of odonates were identified in upper segment of River Yamuna. Coenagrionidae was having maximum dominance at Tajewala barrage where the river water was almost blocked and diverted to western and eastern Yamuna canal. Libellulidae was also most common in upper segment(Figure 6). River Yamuna has been acclaimed as a holy river in Indian mythology. Pilgrimmage centres such as Yamunotri (Uttarakhand), Paonta Sahib (Himachal Pradesh) and large urban centers such as

Yamuna Nagar, Panipat and Sonepat are located at the banks of Himalayan and upper segments of this river. As a result, upper segment of River Yamuna is also affected due to domestic waste water discharge from thsese towns. This is evident from the presence of various genera of sub family of chironomidae such as Tanypodinae, Orthocladinae and Chironominae in entire stretch with maximum dominance at Kalanour (Figure 7). *Corixa* was having a common occurrence in upper segment of River Yamuna. Psephenoidinae preferred clean natural substratum to attach itself on cobbles and therefore rarely observed at Kalsi. Dominance of dytiscidae larva at Panipat upstream indicated gradual deterioration in water quality of River Yamuna from Kalsi to Kalanour. Presence of *Hydruous indicus* at Tajewala upstream and its dominance at Palla also indicated similar water quality after diversion of river water through Western Yamuna Canal via drain no. 8 to River Yamuna at Palla. Paleamon were most dominant crustacean and site specific of Palla in upper segment. Molluscs generally indicate lowering in flow velocity and impact of human influence on water quality among them *Lymnaea accuminata* was commonly observed in the stretch from Paonta Sahib to Panipat upstream. *Gyraulus convexiusculus* were dominant at Tajewala downstream to Kalanour. *Physa maxicana* and *Radiatulla occata indicated* occurrence of macrophytic vegetation and were specific at Palla village (Figure 8). A comparision in biological water quality of River Yamuna showed moderate (class'C') to heavy pollution(class 'D') at downstream Tajewala barrage to Kalanaur during winter of 2004 whereas at the same location, the water quality improved to class'C'. On the other hand, water quality was severely polluted (class 'E') at Panipat downstream due to discharge from drain no.2. At Sonepat, severe pollution was mainly due to non-availability of water(Table 3). Studies have revealed that monsoon affected the biological establishment on river bed substratum thereby changed the clean biological water quality(class 'A') to slight pollution(class'B') in himalayan segment and moderate pollution(class 'C') in upper segment of River Yamuna(Mamta et.al., 2010).

CONCLUSON

A river is one which flows uninterruptedly from upstream to downstream. Regulation of flow in upper ecological segment of River Yamuna on account of construction of dams and barrages and thereby diversion of water to irrigation canals for various beneficial purposes, has affected the minimum flow requirement of river in downstream stretches. After the construction of a barrage or dam or development of irrigation canal network on river, downstream stretches of river does not get enough water required for sustainable development of aquatic life. As a result, pollutants discharged through drains carrying sewage streams and effluents joining the river at downstream barrage are not diluted. It affected the self purification capacity of river and thus entire river stretch downstream at Panipat to upstream Pallla was devoid of biological life in upper segment of River Yamuna. A total of 11 genera of ephemeroptera, 2 genera of trichoptera, and a total of five genera of families of odonata were identified in upper segment. Presence of communities of diptera family chironomidae was having a common occurrence in upper segment thus indicated impact of sewage discharge in River Yamuna.. Molluscs generally preferred sandy river bed substratum and low flow velocity of River Yamuna at Palla.

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