Macroinvertebrates associated with artificial floating islands installed in River Kshipra for water quality improvement
Prashant and Suresh Kumar Billore

ABSTRACT
Artificial floating islands (AFIs) are artificial buoyant superstructures vegetated with riparian plant species, especially reed grass (Phragmites karka) floating on waterscape. These structures are mostly installed in lakes and stagnant systems as a green technology for water quality improvement. In the present study, an AFI was installed in the River Kshipra, Ujjain city at a point where wastewater nullah meets the river. The focus was to study the composition of macroinvertebrates associated with AFIs and to monitor AFIs’ role in river water quality improvement. The inspection indicated that the coir-based AFIs’ substratum supports a variety of macroinvertebrates that are supplementing the role of AFIs for water quality improvement, besides the role of riparian plants. The open river water, far from AFIs, does not support macroinvertebrates in the upper layer of the water column. The installation of AFIs improved the underneath water quality: reducing the pollution load by 46% of total suspended solids (TSS), 51% of turbidity, 37% of total Kjeldahl nitrogen (TKN) and 39% of biochemical oxygen demand (BOD). The AFIs resulted into a development of a floating habitat for diversity of a macroinvertebrates community of predators, filtering collectors, gathering collectors, scrapers and shredders. The AFIs serve a dual purpose: water cleansing green landscape and additional floating niches for aquatic macroinvertebrates.

Key words | artificial floating islands, floating bed, Kshipra River, macroinvertebrates

INTRODUCTION
Wastewater generated from the urban locations and urban storm water runoffs are the potential source of pollution to the downstream waterways and aquatic ecosystems (Suthar et al. 2010). In an urban location, the characteristics and quantity of wastewater vary according to the size of human population, their settlements and industrialization. Ujjain is one of the important and ancient cities in Central India, located on the bank of the mythologically sacred river, the Kshipra. The wastewater with heavy nutrient load of point and non-point origin which meets water bodies are the major cause of apathetic conditions of water bodies at Ujjain (Gupta et al. 2014). The municipal wastewater in Ujjain city is characterized by high concentration of total solids (TS), biochemical oxygen demand (BOD) and total nitrogen (TN), particularly the NH4-N (Billore 1988; Vyas 1990; Dass 1996). At Ujjain, the nutrient rich sewage, agricultural runoff and storm water sewerage directly merges into the River Kshipra without any kind of treatment at several places including the Gaughat area. The nutrient-rich sewage enhances water degradability in almost stagnant River Kshipra ultimately leading to eutrophication, and moderate to high BOD, chemical oxygen demand (COD), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), NH4-N and total phosphorus (TP) at several locations (Sharma 2000). The two elements N and P have been established as the key elements causing aquatic nuisance in the River Kshipra.

The Kshipra River is the very soul of Ujjain. The relation between the two exists from time immemorial. The very shape of Kshipra snugly flanking the city suggests the intimacy. The year-long religious activities of the region, the once-every-12 years great festival of holy bath known as mahakumbh and pilgrimage-tourism are very much dependent on the Kshipra River. During bathing, the river water is also used for drinking (Aachman), irrespective of its water quality (Semwal & Akolkar 2006). From the point of entry near Triveni to the
The eco technological AFIs gradually take their own shape of macroinvertebrates to the AFIs. Additionally, there is lack of research into the association of macroinvertebrates with the AFIs which were installed in the River Kshipra at Ujjain for river water quality improvement. The survey of literature suggested that AFIs have not been studied in relation to the composition of macroinvertebrates.

**Artificial floating islands**

The onsite treatment methods like artificial floating islands (AFIs) are the latest innovations into restoration of degraded water bodies (Bi et al. 2019; Billore & Prashant 2006). The concept of reed beds evolved from constructed wetlands and natural floating islands that are similar to hydroponics (Chen et al. 2016). AFIs are manmade buoyant type superstructures which float above the water scape. These are similar to constructed wetlands where rooted, emergent macrophytes are grown on a fabricated floating mat. AFIs are not a land intensive technique; it is a promising in situ application in stagnant water bodies. AFIs are little affected by submergence stress and fluctuating water levels (Winston et al. 2013).

It is useful in restoring or polishing dilapidated aquatic systems according to ecological principles as floating landscape. The AFIs are designed in a manner so that macrophyte roots penetrate and suspend in the underneath water column for a depth varying between 0.75 and 0.80 m. (Billore et al. 2009). AFIs have been studied for their application as an improvement of environmental quality of water like storm water treatment (Revitt et al. 1997; Kerr-Upal et al. 2000), domestic wastewater (Mietto et al. 2013), poultry processing wastewater (Todd et al. 2003), and artificial nutrient solution (Song et al. 2014). However, there are very few reported applications to date for the water quality improvement of slow flowing/stagnant water bodies like rivers (Billore et al. 2009) and tanks. Additionally, there is lack of research into the association of macroinvertebrates to the AFIs.

**AFIs and macroinvertebrates**

The eco technological AFIs gradually take their own shape and develop as a floating micro ecosystem above the waterscape. The riparian vegetation complex, floating bed, water, root attached particulate matter (RAPM) is a promising fine habitat for a variety of macroinvertebrate communities. These invertebrates are natural gifts, which may colonize in AFI and work in co-action with riparian species for cleansing and polishing the waterscape. The benthic macroinvertebrates play an important role in an aquatic ecosystem as they are part of the aquatic food chain (Kripa et al. 2015). They serve as an important link between various trophic levels from primary producers to decomposers (Vannucchi et al. 2017).

They have a notable role in the detritus food chain and cycling of nutrients. The role of macroinvertebrates as an indicator of the level of pollution is well documented (Buss et al. 2015). The limited mobility, sensitivity of pollutants, and life span makes macroinvertebrates a potential tool for bio assessment. The present study focuses on the study of composition of macroinvertebrates associated with the AFIs which were installed in the River Kshipra at Ujjain for river water quality improvement. The survey of literature suggested that AFIs have not been studied in relation to the composition of macroinvertebrates.

**MATERIALS AND METHODS**

**Study area**

The experimentation for the evaluation of the association of macroinvertebrates in AFIs was carried out in the River Kshipra at Gaughat sampling station (Figure 1). The selection of site in this section of river was guided primarily by the following attributes: nearby point and non-point sources of pollution, easy access to the site location by road, broad river width, almost stagnant water for maximum months of the year, optimum annual depth of water, visibility of structure and social security of the floating system. The Kshipra River is a slow flowing water body that encircles Ujjain town at three sides covering a length of 11 km from upstream to downstream (23° 12’ N latitude 75° 42’ E longitude, mean sea level 515.45, average annual rainfall 892 mm, mostly occurring during monsoon season, i.e. June to September, annual mean maximum and minimum temperature, 31.4°C and 16.5°C, respectively), in state of Madhya Pradesh in central India. The river attains peak flow during the monsoon (July–August), otherwise remains very slow or almost stagnant for the remaining period of the year. Extreme summers (March–May) are the lean period of
River Kshipra. Certain ecological characteristics of the site are presented in Table 1.

AFIs fabrication

The structure of AFI was indigenously fabricated in a workshop by locally available bamboo. Two layers of tough and buoyant crisscross bamboo structures were made, then coconut coir fiber was sandwiched between them. The role of coconut fiber was as a matrix and to support the root anchor-age of the reed grass. The reed root coconut fiber complex enhanced the micro habitat for aquatic macroinvertebrates for their growth around the roots and in coir bed floating in the water column (Billeore & Prashant 2006). For providing extra support to the AFI, individual units (2 × 1 m) were strategically wrapped in geo-synthetic mesh.
AFI installation in river

The indigenously fabricated small units ($2 \times 1$ m) were brought to the banks of River Kshipra, Ujjain and manually joined together on the water surface to form one mega piece of AFI of 200 m$^2$ ($20 \times 10$ m) (Figure 2). The whole coir-based mega piece was further strengthened on four rails of 6 m heavy-duty circular watertight synthetic pipes (2 mm HDPE gauge, 15 cm diameter) to merge it into a monolithic floating structure. The floating bed structure was tied and fixed with heavy nylon ropes to the river bank in order to keep at single location at the experimental site. Local nursery grown reed grass, *Phragmites karka*, was planted in AFI at the sites at plant density of 8–12 plants per square meter.

### Start-up monitoring

#### Water quality

The reed planted floating islands were towed and stationed at the river side receiving urban sewage from the nearby localities. The mixing of nutrient loaded sewage in the River Kshipra promoted a luxuriant plant growth in the AFIs within three months of its installation (Figure 2). Further, the treatment performance of AFIs were analysed by comparing the quality of water samples (Standard Method APHA) taken from just below (SP2) the AFIs and from the upstream of AFIs (SP1), near the mixing point of urban sewage and the river water.

#### Composition of macroinvertebrates in AFIs

The following steps were executed for collection and identification of macroinvertebrates from the AFIs under the experimentation.

### Collection

The macroinvertebrates were collected from a single unit (2 m$^2$) of AFI.

In order to avoid the macroinvertebrates population from the margins of the floating island due to the border effect, the centrally located single unit was selected for the purpose of collecting macroinvertebrates sampling. The AFIs were towed to the banks and a single unit was taken out carefully. The single unit of AFI was placed on a

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**Table 1**

<table>
<thead>
<tr>
<th>River sections (ghats)</th>
<th>Distance from U/S (km)</th>
<th>Depth (m)</th>
<th>Bed charter and dominant macrophytes</th>
<th>Activities around</th>
<th>Some features around</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reti ghat</td>
<td>3.22</td>
<td>7.90</td>
<td>Coarse sand and boulders/ <em>Hydrilla &amp; Potamogoton</em></td>
<td>Irrigation, cloth washing, bathing, sand mining and fishing</td>
<td>Merging of small nullah, intensive agriculture in flood plains</td>
</tr>
<tr>
<td>Gaughat</td>
<td>3.62</td>
<td>7.00</td>
<td>Coarse sand, ballistic rock &amp; boulders/ <em>Hydrilla, Potamogoton &amp; Vallisneria</em></td>
<td>Drinking, irrigation, bathing and fishing</td>
<td>Merging of small nullah, drinking water plant intake well, eastern flood-plain is intensively used for agriculture (annually three crops and vegetables)</td>
</tr>
<tr>
<td>Ramghat</td>
<td>6.00</td>
<td>3.05</td>
<td>Coarse sand and boulders/ <em>Potamogoton, Ceratophyllum, Vallisneria &amp; Azolla</em></td>
<td>Pilgrim bathing, post funeral rites and cloth washing</td>
<td>Crowds of millions take holy-bath during Kumbh and several festivals</td>
</tr>
</tbody>
</table>

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**Figure 2** | Reed planted AFI installed in River Kshipra, Ujjain, India.
pre-erected stand at the river bank for collecting the macroinvertebrates. The unit was shattered mechanically with the help of a tough bamboo stick, for intercepting the dropping organisms in the underlying net. Bolting silk cloth, brush, forceps, polyethylene collection bags, magnifying glass, plastic buckets, and nekton net, etc. were used for the collection of the macroinvertebrates. The coir bed was also supporting growth of macroinvertebrates, so a proportionate amount of coir was pulled out from the AFIs and washed properly in a bucket full of clear water. The macrozoobenthic sample was then collected by passing the bucket water through nekton net. A proportionate amount of RAPM was also taken out and thoroughly washed in 20 L of water and sieved through the bolting silk mesh for the collection of attached macroinvertebrates from the single unit of AFI.

**Preservation and identification**

The collected samples were sealed, labelled and preserved in 10% formaldehyde solution. Then the collected samples were brought back to the laboratory. The preserved macroinvertebrates samples were sorted manually and were identified with the help of keys and manuals (Edmondson 1959; Needham & Needham 1974; Tonapi 1980; Subramanian & Sivaramakrishnan 2005).

**RESULTS AND DISCUSSION**

**Water quality**

The laboratory analysis of water samples reflected that the AFIs caused a reduction by 51% in turbidity, 37% in TKN, 46% in TSS and 39% reduction in BOD. The installation of AFIs into River Kshipra brought a positive improvement into the river water quality (Table 2).

**Macroinvertebrates associated with AFIs**

AFIs provided a floating substratum the solid liquid interface for growth and development of benthic macroinvertebrates at the water surface however the adjoining open waters were devoid of macroinvertebrates.

The current study recorded 19 taxa falling in 14 families belonging to seven orders of macrozoobenthic organisms associated with the AFIs installed in the River Kshipra (Table 3). Three families of molluscan group and seven families of arthropod were reported. Among these, the molluscan family of Thiaridae was found to be dominant. Among the seven orders of aquatic macroinvertebrates reported in the

<table>
<thead>
<tr>
<th>Family</th>
<th>Genus /species</th>
<th>Functional feeding groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Order Odonata</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Libellulidae</td>
<td>Crocothemis servilia</td>
<td>Predators</td>
</tr>
<tr>
<td>2. Gomphidae</td>
<td>Ictinogomphus rapax</td>
<td>Predators</td>
</tr>
<tr>
<td>B. Order Hemiptera</td>
<td></td>
<td></td>
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<tr>
<td>3. Belostomatidae</td>
<td>Diplonychus sp.</td>
<td>Predators</td>
</tr>
<tr>
<td>4. Lithocerus sp.</td>
<td></td>
<td></td>
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<tr>
<td>5. Nepidae</td>
<td>Ranatra spp.</td>
<td>Predators</td>
</tr>
<tr>
<td>6. Notonectidae</td>
<td>Notonecta sp.</td>
<td>Predators</td>
</tr>
<tr>
<td>7. Corixidae</td>
<td>Sigara sp.</td>
<td>Predators</td>
</tr>
<tr>
<td>8. Gerridae</td>
<td>Limnometra sp.</td>
<td>Predators</td>
</tr>
<tr>
<td>C. Order Coleoptera</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Sphaeridae</td>
<td>Hydrophilus sp.</td>
<td>Scrapper</td>
</tr>
<tr>
<td>10. Hydropsychidae</td>
<td>Hydropsyche sp.</td>
<td>Filtering collectors</td>
</tr>
<tr>
<td>D. Order Archoidea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Chironomidae</td>
<td>Chironomus sp.</td>
<td>Gathering collectors</td>
</tr>
<tr>
<td>12. Thiaridae</td>
<td>Thiara lineata</td>
<td>Scrapers</td>
</tr>
<tr>
<td>13. Thiara tuberculata</td>
<td></td>
<td></td>
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<td>14. Thiara scabra</td>
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<td></td>
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<tr>
<td>E. Order Arcoida</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Bithyniidae</td>
<td>Gabbia articulata</td>
<td>Scrapers</td>
</tr>
<tr>
<td>16. Planorbidae</td>
<td>Gyraulus labiatus</td>
<td>Scrapers</td>
</tr>
<tr>
<td>17. Gyraulus rotula</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Unionidae</td>
<td>Lamellidens sp.</td>
<td>Scrapers</td>
</tr>
<tr>
<td>Total number of species = 19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
present study, the dominant order was Hemiptera (33%), followed by Mesogastropoda (17%) and Basommatophora (17%), Coleoptera (11%) and Odonata (11%), Arcoida (6%), and Diptera (6%), respectively (Figure 5). Of them, the distribution of families was flat, most of the families were incorporating single species, but the dominant family was Thiaridae of the order Mesogastropoda. The noteworthy contributions on aquatic macroinvertebrates studies accomplished in India have worked on distribution and composition of benthic macroinvertebrates (Sharma & Rai 1991; Sivaramakrishnan et al. 2000; Subramanian & Sivaramakrishnan 2005; Dinakaran & Anbalagan 2007). At the same time, aquatic fauna of Madhya Pradesh has been investigated by Ramakrishna et al. (2007), Chandra (2011) and Jaiswal et al. (2014), but no studies have been made on macrozoobenthic organisms associated with the AFIs.

During the present study it was observed that the AFIs serve as a beautiful micro-habitat for aquatic macroinvertebrates communities. The AFIs of the River Kshipra gave shelter to a variety of macroinvertebrates characterized as predators, scrapers, filter collectors, gathering collectors and shredders. While cleansing the underneath waters, the reed root coir matrix of AFIs arrest the particulate matters present in the water column and retain them as RAPM (Figure 4). The RAPM serve as a source of food to the associated macroinvertebrates. Many experts have reported that source of food and suitable shelter/habitat are important factors governing the distribution of macroinvertebrates (Subramanian & Sivaramakrishnan 2005; Dinakaran & Anbalagan 2007). Based on the Functional Feeding Group, the reported macroinvertebrates are distributed as scrapers (47%), predators (41%), filtering collectors (6%) and gathering collectors (6%) (Figure 3).

Scrappers, being the dominant functional feeding group, feed upon the algae/diatoms and fine organic particles (Ramírez & Gutiérrez-Fonseca 2014). Predators, the second largest dominant functional feeding group in the study, feed upon the smaller collectors and shredders. So, there indicates availability of shredders and collectors in their habitat. The gathering collectors are considered to play a role in improving the transparency of aquatic systems because of their ability to feed upon fine/ultrafine particulate matters (inorganic/organic) present in the beds and substrates of streams (Graca 2001; Vannucchi et al. 2015). It has been reported that macroinvertebrates breakdown organic matter and supplement the cycling of materials in the aquatic systems (Palmer 1997). However, it is globally reported that there is a loss into the stream biodiversity.
that has resulted because of urban growth, agriculture and other human disturbances (Docile et al. 2016). In this relevance, AFIs provide a nice substratum for the growth and maintenance of invertebrates, thus conserving the diversity of the river streams through a floating landscape approach.

The results clearly indicate that the cost-effective, zero emission, zero energy, zero chemical and eco-friendly AFIs system will develop into a green floating garden for in situ cleansing of the stagnant aquatic bodies (Billore et al. 2009).

CONCLUSION

AFIs are the recent innovation in the field of water pollution control and restoration of dilapidated water bodies. Stagnant water bodies are always at risk of point and non-point source pollution due to their nature. AFIs provide a good habitat for the growth of macroinvertebrates. Around 20 species of macroinvertebrates were identified in the AFIs installed in the River Kshipra. These organisms include shredders, gathering collectors, filtering collectors, filter feeders and grazers. These are natural gifts, which colonize in AFI and work in co-action with Phragmites karka for cleansing and polishing waterscape. These AFIs are black box bioreactors of numerous active physical–chemical and biological processes, which ultimately result in online reduction of pollution load.

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REFERENCES


Chandra, K. 2011 Fauna of Madhya Pradesh (including Chhattisgarh) Series 15 (3). Published by the Director, Zoological Survey of India, Kolkata, India.


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