Assessment of river Yamuna and groundwater interaction using isotopes in agras and mathura area of Uttar Pradesh, India

Abstract

Yamuna river water quality has been deteriorated from Delhi onwards mainly in Agra and Mathura areas of Uttar Pradesh due to discharge of large quantities of untreated or partially treated wastewater into the river. Groundwater is also saline in these areas. Thus, the resultant poor water quality could worsen the problems of portable water supply to rapidly growing population of these areas. Groundwater and river water respectively is the main drinking water source in Mathura and Agra. Therefore, there is need to investigate the quality of bankside groundwater and surface water in Mathura and Agra as potential source of drinking water and also to assess the interaction between Yamuna river and groundwater. Keeping in view the above points, present study was carried out to assess river Yamuna and ground-water interaction using isotopes in the Agra and Mathura area of Uttar Pradesh, India. Samples of river and groundwater were collected from hand pumps/bore wells along the periphery of the Yamuna River. Analyses of the electrical conductivity (EC), temperature and isotopic composition (δD) demonstrated that the groundwater is highly influenced by the river Yamuna. Groundwater containing seepage component is indicated by low temperature, low EC and depleted isotopic (δD) composition. The influence of river on groundwater is found to decrease with the increasing distance from the river. The contribution of river water to the groundwater is more in Mathura as compared to Agra.

Keywords: Isotopes, Groundwater, Yamuna, Agra, Mathura

Introduction

With an increase in demand of water in domestic, agricultural and industrial sectors due to ever increasing population, the discharge of various wastes in receiving water have also increased. Groundwater is the largest fresh water resource and considered to be the safe for drinking purposes among all water resources. For many communities groundwater may be the only economically viable option for drinking. However, this resource has also been polluted due to a variety of land and water-based human activities. Yamuna River is a major source of irrigation to the rural and semi-urban areas of Agra and Mathura. Several researchers reported that large quantities of impartially to partially treated domestic and industrial wastewater are discharged into the Yamuna River between Delhi to Agra city deteriorating the river water quality.1–3 It is need of an hour to investigate the quality of bankside groundwater and surface water in Mathura and Agra as potential source of drinking water and also to assess the interaction between Yamuna river and groundwater. Usually, management of surface water or groundwater resources has focused on considering them to be separate entities while with the development of land and water resources, notable changes were observed in quantity and quality of these resources. Generally, it is seen that all surface water features (rivers, lakes, reservoirs, wetlands, and estuaries) interact with groundwater in many forms. In several situations, the surface water body is a source of groundwater recharge or vice versa as pumpage of groundwater can deplete water in streams, lakes, or wetlands4–6 and contaminated surface water can cause degradation of groundwater quality. Thus, effective land and water management requires a clear understanding of the linkages between groundwater and surface water as it applies to any given hydrologic setting. Isotopic tracers can provide information on hydrograph separation on the fraction of surface water in groundwater or vice versa due to different isotope composition of both the sources.6 Generally, to separate the stream flow components, mixing models7 are applied however, numerous applications under different hydrological settings using various tracers have been documented8–12 and differences in concentrations of environmental tracers help in quantify groundwater recharge as stable hydrogen and oxygen isotopes of groundwater are generally less enriched than surface water.13–15 The interactions between groundwater and surface water, can be found using geochemical such as alkalinity,16 electrical conductivity17 and isotopic tracers such as isotopes of radon,1 chlorofluorocarbons,10,11 strontium,18 and radium.19 In the present study to assess the interaction of Yamuna River and groundwater of Agra and Mathura, the technique of stable hydrogen isotope was used.

Study area

The study area forms part of Yamuna River Basin. Yamuna River has a 580km long stretch between Wazirabad Barrage in Delhi and its confluence with Chambal River near village Panchnada wherein river water is highly polluted. Agra and Mathura are two prominent cities situated on the Right Bank of Yamuna River within this stretch. The drinking water supply for both of these cities is in a critical condition for quantitatively it is insufficient and qualitatively unsuitable. On one hand Yamuna River water is affected by physical, chemical and microbiological pollution and on the other hand groundwater has very high Total Dissolved Solids (TDS). The objective of the present
study is to observe the surface water contribution to groundwater quantitatively and qualitatively, on pumping the groundwater through the groundwater structures located closer to the bank beyond the Highest Flood Level (HFL) and accordingly the study area has been specified. The study area includes three cross-sections across Yamuna-Right-Bank (YBR), one cross-section YBR each at Agra and Mathura and groundwater sampling points safely off the Yamuna River course where River-Water and groundwater mixing is not expected. These sections and sample locations are shown in Figure 1 and their details are given in Table 1. Agra and Mathura both have semi-arid climatic conditions. The normal annual rainfall, at Agra, is 679 mm, spread over 37 rainy days. The normal annual rainfall at Mathura is less than Agra which is 544 mm and spread over 32 rainy days. The area around the selected sections and sample collection points exhibits plain topography with a gentle slope towards Yamuna River which shows effluent conditions except during the monsoon period. Geologically the area is represented by alluvium of Holocene and recent age. The alluvium is deposited on the rocks of Super Vindhyan Group of Proterozoic age. The alluvium as exposed at Agra and Mathura is fine grained and greyish white in color. It is porous and permeable and hence forms good aquifers.

Table 1 Sampling details

| S. No. | Location/ID | Depth | Distance from river (m) | Latitude | Longitude |
|--------|-------------|-------|-------------------------|----------|-----------|
| 1      | Water-Works (WW), Jiwani Mandi-A*/WW-Agra | 20/ Ground water | 140 | 27.20327 | 78.03197 |
| 2      | Water-Works, Jiwani Mandi-A*/R-Agra | 15/River | 200 | 27.20392 | 78.03162 |
| 3      | River-Water Works, Jiwani Mandi-A*/HP-1-Agra | +/- River | - | 27.20298 | 78.03335 |
| 4      | River-Gokul Barrage-M*/R2-Mathura | +/- River | - | 27.44361 | 77.7139 |
| 5      | Gokul Barrage itself-M*/HP-2-Mathura | 25/Ground water | 30 | 27.4434 | 77.71367 |
| 6      | Water-Works-M*/HP-3-Mathura | 25/Ground water | 615 | 27.44742 | 77.70939 |
| 7      | Nagar Palika Parishad-M*/HP-4-Mathura | 25/ Ground water | 7544 | 27.50253 | 77.6652 |

A*, Agra; M*, Mathura.

Methodology

To assess the surface water-groundwater interactions, samples from river water and groundwater from different depths were collected. To ensure representative sampling from the aquifer, the groundwater was flushed adequately or till constant pH and EC was achieved. Then the water samples (500ml) were collected in air/water tight polypropylene (plastic) bottles after rinsing the bottles by the groundwater that is to be sampled. The sample bottles were stored in refrigerated conditions to check fractionation of samples due to evaporation. Stable isotopes (δD) are analysed on DI-IRMS (Dual inlet isotope ration mass spectrometer) with the minimum error limit within±1‰. The isotopic analyses (δD) of collected water samples are done by standard equilibration method in which water samples are equilibrated with H2.

Results and discussion

Groundwater containing seepage component is indicated by low temperature, low EC and depleted isotopic (δD) composition (Table 2). Due to the conservative nature of stable isotopic compositions in water and hardly any affect by water-rock mineralization under normal conditions, the isotopic variations may occur in the periphery of river as a consequence of concentration variations in the input such as rainfall and river water. The δD values of the river water and groundwater samples collected in September 2015 shown in Table 2 giving accurate information on the input signal. These samples are well distributed illustrating that surface and groundwater from the shallow Quaternary aquifer most probably originate from present-day precipitation. The δD values enriched from -53.81‰ to-47.51 ‰ in Yamuna water from Mathura to Agra due to evaporation effect (Table 2). These show that the heavier isotopes were enriched in river water in the upstream, which resulted mostly from evaporation where these samples were collected (Figure 1). Isotopic composition of river water was mostly negative. It could be due to precipitation with lighter isotopes. Signatures of both of the groundwater samples at Agra (WW and HP-1) indicate that the sample HP-1 (-57.21‰) was depleted as compared to WW (-50.54‰), possibly indicating that the riverbank-aquifer water may originate from a mixing of original groundwater and river water with more depleted isotope values and HP-1 is located at more distance (200m) than the WW (140m). The transitional wells of Water Works Agra (WW) and Water Works Mathura (HP-3) both each at a distance of 140 and 615m, respectively from the river, seemed to be closely connected to the nearest river water as the groundwater had similar trends of stable isotope signatures with the river. That is because of the recharge from river water via bank infiltration relatively depleted δD signatures. The isotopic value of the groundwater sample of HP-4 is more enriched and higher EC values indicating the anthropogenic effects with almost no signatures.
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Table 2: Isotopic and physico-chemical characteristics of water samples

| S. No. | Sample code/id  | Source          | ph | ECuS/cm | Water temp. (°C) | δD(0) |
|--------|----------------|-----------------|----|---------|------------------|-------|
| 1      | WW-Agra        | GW*(140m)**     | 6.99 | 1432    | 29.5             | -50.54 |
| 2      | R1Agra         | RIVER           | 9.45 | 1152    | 35               | -47.51 |
| 3      | HP-1 Agra      | GW(200 m)       | 6.87 | 1755    | 27.8             | -57.21 |
| 4      | R2Mathura      | RIVER           | 8.95 | 1435    | 37.4             | -53.81 |
| 5      | HP-2 Mathura   | GW(30 m)        | 7.1  | 1423    | 29.2             | -62.45 |
| 6      | HP-3 Mathura   | GW(615 m)       | 7.22 | 1506    | 28.8             | -53.93 |
| 7      | HP-4 Mathura   | GW(7544 m)      | 6.79 | 2890    | 28.8             | -47.27 |

*GW, Ground water; **Distance from river

Conclusion

Groundwater containing seepage component is indicated by low temperature, low EC and depleted isotopic (δD) composition. The influence of river on groundwater is found to decrease with the increasing distance from the river. The contribution of river water to the groundwater is more in Mathura as compared to Agra. This study result could be useful in planning and management of the water resources of the study area by developing potential river bank filtration sites.

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Conflict of interest

None.

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