STUDY ON SURFACE WATER AND GROUNDWATER INTERACTION IN BIST-DOAB REGION, INDIA

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Abstract: Interactions between river water and groundwater play an important role in water cycle, especially in riparian zone. Understanding and quantifying the exchange processes is very crucial in groundwater studies in region adjoining river and canal systems. Environmental tracers like stable isotopes of oxygen and hydrogen can reveal the interrelationship between surface and groundwater. This study is mainly based on isotopic character of two systems namely surface water (river/ canal) and groundwater in the Bist-Doab region in the state of Punjab, India. The region is undergoing serious groundwater decline despite the presence of two perennial rivers, R. Beas and R. Satluj, and their canal systems. The study is accomplished by collecting water samples from four sections across the rivers, two each from river R. Beas and R. Satluj for around 5-6 km length, one at the upstream and one at downstream of the river. The river water-groundwater interaction at R. Beas stretch is greater when compared with the R. Satluj. The upstream portion of R. Beas shows seepage of river water into groundwater up to a distance of 3km where as at downstream area the interaction decreases to around 2.5km. The surface water- groundwater interaction in the upstream of R. Satluj is almost negligible and is limited to less than few 100m. The region also shows a considerable recharge from Bist-Doab canal. The downstream portion of R. Satluj near the confluence of the rivers shows maximum interaction with river water seeping up to a distance of 3-4 km.

Keywords: *Stable Isotopes of Oxygen & Hydrogen, Riparian zone, R. Beas, R. Satluj, Bist-Doab Canal.*

INTRODUCTION

The interaction between groundwater and surface waters are characterised by a high degree of variability and can therefore be difficult to quantify (Klabus et al., 2006). Water budget remain important aspect in river and lake management studies. But the interaction between groundwater and surface water is important as exchange between the solutes also takes place during the processes (Kidmose, 2010). Interactions between groundwater and surface water basically proceed in two ways: groundwater flows through the streambed into the stream (gaining stream), and stream water infiltrates through the sediments into the groundwater (losing stream). Often, a stream is gaining in some reaches and losing in other reaches (Klabus et al., 2006). The range of available techniques to determine interactions between groundwater and surface water is broad (Klabus et al. 2006).

When ground water mixes with surface water, they impart their characteristics upon one another and unique gradients develop for each parameter. Since ground water and surface water are essentially one resource, there is potential for the surface water quality to affect ground water and vice versa (Naiman *et al*., 1995; Squillace *et al*., 1993; Gardner 1999). Geochemical tracers, such as major chemical parameters (e.g., sodium, nitrate, silica, conductivity) and trace elements (e.g., strontium), are often used to determine the fractions of water flowing along different subsurface flowpaths (Cook and Herczeg, 2000; Klabus *et al*., 2006). Generally, to separate the streamflow components, mixing models (Pinder and Jones, 1969) or diagrams (Christophersen and Hooper, 1992) based on the conservation of mass are applied. The main drawbacks of tracer-based hydrograph separation are that event and pre-event waters are often too similar in their isotope composition and that the composition is often not constant in space or time (Genereux and Hooper, 1998).

On a smaller scale, the differences in concentrations of environmental tracers between groundwater and surface water can be used to identify and delineate zones of groundwater discharge or recharge, provided that the differences are sufficiently large. Stable hydrogen and

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oxygen isotopes are widely used, because groundwater is generally less enriched in deuterium and 18O than surface water (Coplen *et al.*, 2000; Hinkle *et al.*, 2001; Yehdeghoa *et al.*, 1997). Numerous other geochemical and isotopic tracers have been used to study interactions between groundwater and surface water, including alkalinity (Rodgers *et al.*, 2004), electrical conductivity (Harvey *et al.*, 1997), or isotopes of radon (Cook *et al.*, 2003; Wu *et al.*, 2004), chlorofluorocarbons (Cook *et al.*, 2003), strontium (Negrel *et al.*, 2003), and radium (Kraemer, 2005).

The Bist-Doab region is an interfluve region between R. Sutlaj and Beas (Doab: local word for interfluves) occupying northwest region of Punjab. It is experiencing high amount of groundwater depletion despite input from two perennial rivers. Due to increasing agricultural activity, water demand in the region is increasing day by day putting more pressure on groundwater causing groundwater mining and exploitation. At this juncture, it becomes imperative to understand interrelationship between the rivers in the riparian zones and groundwater. The present study aims in identifying regions recharged from rivers and also in understanding surface water (river water) - groundwater interaction region.

STUDY AREA

Bist-Doab, a triangular region with an area of 9060km^2, constitutes Hoshiarpur, Kapurthala, Jalandhar and Nawanshehar districts of Punjab State (Fig. 1). The region is bounded by Siwaliks in the north-east, river Beas in north east-south west and river Satluj in south east-south west. The choe ridden (ravine-ridden) belt in the area bordered by Siwaliks is known as Kandi area. Rainfall in the region is maximum at Siwaliks (1200mm at Dhar Kalan) and minimum at plains. The area is drained by two perennial rivers Satluj and Beas and their tributaries, both the rivers confluves at Harike (Fig. 1). There are two canal networks in the region: (1) Bist-Doab canal (arises from River Satluj) and (2) Kandi canal/Shah Nehar canal (arises from R. Beas). The drainage density is high in the north east strip bordering Siwaliks, but it is moderate to low in rest of the area with sub-parallel and sub-dendritic patterns (Bowen, 1985). Temperature in the region ranges from 40°C during summer to 10°C during winter. Bist-Doab is a densely populated region, accounting for 19.64% of the population of Punjab. Jalandhar has the highest population density in the region while eastern parts of Hoshiarpur and Nawanshehar have a low population density.

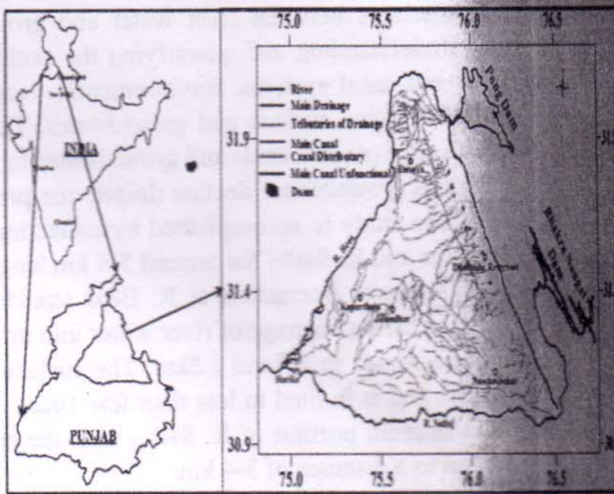

Fig. 1: Study Area

The Quaternary alluvium of considerable thickness is deposited on semi consolidated Tertiary rocks or on the basement of metamorphic/igneous rocks of Pre-Cambrian age. The alluvial plain towards the hills is bordered by piedmont deposits, comprising Kandi region, are made up of boulders, pebbles, gravels, sand and minor layer of clays. It forms the recharge belt of the alluvium. The Quaternary alluvial deposits comprise of fine to medium sands, sandy clays and silty clays and occasional occurrence of gravels and kankars. Older alluvial, consisting pale to reddish brown coloured layers of massive clays, are found in the central part of Bist-Doab (DWSS, 2007). The Bist-Doab region consists of two aquifer groups. The top layer of aquifer group-I comprises of coarse sand beds with thickness ranging from 72 m to 94 m. A regionally extensive clay layer with varying thickness from 16 to 32 m separates this aquifer from underlying aquifer group-II. The aquifer group-II comprises of alternating sequences of thin layers of sand and clay beds. Sediments of this aquifer group are chiefly sand, clay, gravel and occasional kankar (CGWB, 2009).

SAMPLING AND ANALYSIS

The shallow groundwater samples (<30m) from hand pump were collected along four traverses, two from each rivers. The traverses are taken such that the sampling represents both upstream and downstream condition, i.e., one from upstream and another in downstream of rivers. The groundwater from hand pump (shallow aquifer (<30m)) were collected. Each traverse has five to six locations with a distance of upto 6km from the river he isotopic analyses (δ18O and δD) of collected samples were done by standard equilibration od in which water samples are equilibrated with CO_2 H2 (Epstein and Mayeda 1953; Brenninkmeijer and rison 1987). The samples were analysed using a tinuous Flow Isotpe Ratio Mass Spectrometer (CF-S) to measure oxygen (180/160) and Dual Inlet pe Ratio Mass Spectrometer (DI-IRMS) to measure ratio and computed the δ180 and δD using a triple t calibration equation with Vienna standard mean n water (V-SMOW), Greenland ice sheet ipitation (GISP) and Standard light Antarctic ipitation (SLAP) standards. The results were essed by convention as parts per thousand deviations the V-SMOW the calculation is as follows:

sample = (R sample– RV-SMOW/RV-SMOW) x ‰ where, R is the ratio of D/H or 18O/16O in led water (R sample) or in VSAMOW (RSMOW). reproducibility of measurements was better than ‰ for δ180 and better than ±1‰ for δD. Isotopic yses of samples were done at the National Institute ydrology, Roorkee, India.

ULT AND DISCUSSION

The stable isotopes of oxygen and hydrogen are ally considered to be transported conservatively in w aquifer settings (Kim *et al.*, 2003; hothaman *et al.*, 2011). Isotopic composition of R. varies from -5.6 to -7.6‰ for δ180 and -39.1 to ‰ for δD and the R. Satluj varies from -6.6 to ‰ for δ18O and -37.7 to -74.3‰ for δD (Rao *et al.*,). The isotopic composition of groundwater in w aquifer shows much variation with the values ng from -4.13‰ to -8.93‰ and -26.03‰ to -61.11‰ 80 and δD respectively.

To understand the river water-groundwater ction river water samples and groundwater samples been collected along four traverses, two at river and two at river Beas. At river Satluj: (1) in am from River Satluj to Aur, (2) in downstream River Satluj to River Beas including Yusufpur and ana, the distance between of each traverse was about m across the river Satluj. At River Beas: (1) in am from River Beas to Mushaibpur, (2) River Beas ttudinga and the distance from river Beas to last on of the traverse is 4.5 and 5km respectively. To ut the distance of river water seepage/mixing with dwater the isotopic composition of river and dwater at farther stretch was considered as end member and two component model was applied. The equation used for calculating river water seepage is:

Percentage of river water interaction = $\{[\delta D_{(mix)} - \delta D_{(groundwater)}] / [\delta D_{(riverwater)} - \delta D_{(groundwater)}]\} * 100$

Where, $\delta D_{(mix)}$ is isoptic composition of groundwater between two end members i.e. two extreme locations, δD (riverwater) isotopic composition of river water (-58‰ for Beas and -74‰ for Satluj) and δD (groundwater) groundwater composition at farthest location (which varies between -30 to -40‰).

The study shows that river water groundwater interaction at R. Beas is prominent at upstream with the river seeping into adjoining areas upto around 3km. The location Naushera Pattan which is approximately 1-1.5km from the River Beas shows river water interaction upto 70% and the locations Leachpur and Harsha shows upto 40% river water (Fig. 2a). The River Beas at downstream shows relatively lesser seepage in comparison with River Beas at upstream. The location Amritpur which is around 2km from River Beas shows around 40% river water (Fig. 2b).

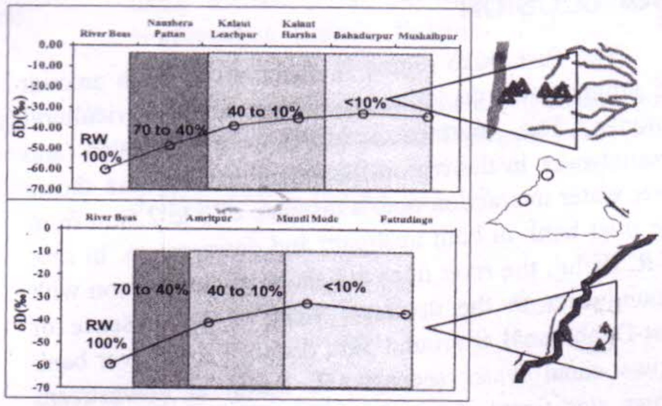

Fig. 2: River water-groundwater interaction at R. Beas Stretch (a) Upstream, (b) Downstream

River Satluj shows almost no interaction with groundwater in the upstream of the study area with less than 10% at location Bhurj Thaldas which is around 1km from the river bank (Fig. 3a). But the presence of Bist-Doab canal, which is at a distance of around 5km from river, at location chakdana shows canal water seepage (70% canal water). In case of downstream of the River Satluj, the river shows relatively high amount of interaction (upto 60%) with groundwater with river water seeping into groundwater upto around 3km (Fig. 3c). The presence of R. Beas at the other stretch does not show any influence on the groundwater at this part of the study area.

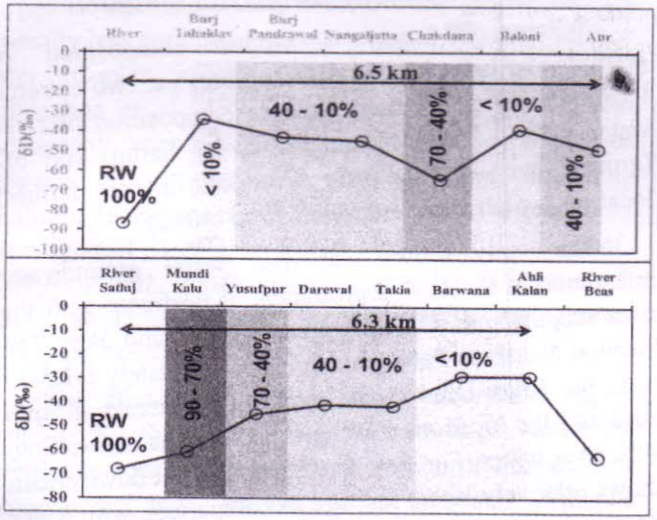

Fig. 3: River water- groundwater interaction at R. Satluj Stretch (a) Upstream, (b) Downstream

CONCLUSION

The Bist-Doab region is experiencing high amount of groundwater depletion due to increasing agricultural activity. The interaction between river water and groundwater in the region illustrates that R. Beas shows river water interaction upto a distance of 3 to 2.5km from the river bank in both upstream and downstream. In case of R. Satluj, the river does not show any interaction with groundwater in the upstream whereas the presence of Bist-Doab canal at around 5km distance from river bank shows canal water seepage. R. Satluj at downstream shows significant interaction with groundwater up to a distance of 2-3 km from river bank.

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