Impact of urbanization on groundwater in central basin of Hyderabad, Telangana State - India

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ABSTRACT

Urbanization likely to impact ground water quality and quantity leading to higher uncertainty and difficulties in management of pollution. Results yielding a good indication but the scenario demands continuous surveillance of waste water disposal from unauthorized discharges from small scale industries in Balanagar, Jeedimeta and Sanathnagar industrial development areas into the Kukatpally nala. It impacts very much on the Hussainsagar lake water. The groundwater flow model has computed groundwater balance for the entire catchment area of Hussainsagar. Significantly the lake water – groundwater interaction in the Hussainsagar was computed from the groundwater flow model. The upstream and down stream channel from Hussainsagar up to Musi river course have also been simulated with river boundary condition in the flow model.

Keywords: Ground water, Inlet channels, Water quality, Flow model

1 INTRODUCTION

Monitoring of groundwater levels and of quality is an essential component of management and protection programmes [1]. This is needed to understand the background situation, to verify risk assessments and to confirm pollution, and to massess the effectiveness of management measures. Some chemical parameters provide good indicators of urban impacts from the processes outlined above [2], Pollution pathways need to be understood [3], and surveillance programmes based on sanitary inspections followed up by engineering interventions developed [4]. Because of the spatial and temporal variation in water quality conditions, a monitoring program which provides a representative and reliable estimation of the quality of surface waters is necessary [5]. Due to spatial and temporal variations in water chemistry a monitoring programme that will provide a representative and reliable estimations is necessary [6]. Recent work by Braud et al. [7] based on relatively long-term observations, confirms that many of the accepted theories regarding urbanization are evident in the changing hydrological regime of a selected peri-urban area, such as reduced baseflow and reduced lag-times resulting in more 'flashy' flood hydrographs from urban areas.

Hussainsagar, the picturesque lake situated in between the twin cities of Hyderabad and Secunderabad which is an ecological and cultural landmark of Hyderabad. Lake was excavated in 1562 mainly to harvest drinking water from Musi River through Balakpur Canal. However with passage of time the lake lost its importance as a source of drinking water supply. The lake in the heart of Hyderabad city receives domestic sewage and industrial effluents through four streams draining the catchment area as shown in Fig. 1

Hyderabad city is growing day by day with the alarming rate. The twin cities of Hyderabad-Secunderabad (herein referred to as “Hyderabad”), is one of the fastest-growing urban agglomerations in India, with an annual population growth rate of more than 5% (UN, 2009). The city population, currently 6.8 million, is expected to exceed 10 million in 2015. At this rate, Hyderabad will rise from its current global rank of 31st to 22nd of the biggest urban agglomerations, overtaking Bangkok, Lima and Hong Kong (UN, 2009).

Figure 1. Location map of Hussainsagar Catchment.

2 STUDY AREA

The catchment area of Hussainsagar is about 287 sq. km, falls into five sub watersheds namely Kukatpally, Dulpally, Bowenpally, Banjarahills and Yusufguda. Hussainsagar Lake has spread over 540 ha and due to encroachments presently the water spread area has shrunk to 450 ha. Its capacity is ~ 1 TMC (Thousand...
Million Cubic Foot) of water drained through 5 inlet streams. Kukatpally nala is the main feeding channel which brings in major bulk of water into the lake. Except rainy season most of the water mass enters into the lake through Kukatpally nala by way of domestic sewage and industrial effluents. As a result the highly coloured and toxic chemical effluents join in watershed, polluting surface water and groundwater.[8,9]

2.1 SOILS, DRAINAGE, GEOLOGY AND GEOMORPHOLOGY

No soil cover visible due to urbanization in most of the area, however the soils underneath are either red loamy or clay loamy with thickness 0.5 to 1.5m in general. Drainage is dendritic to sub-dendritic, flows from N and NW to S and SE following slope. The original drainage is disturbed due to varied LU and concretization.

The Hussainsagar catchment area has a rugged terrain underlain by Granites. They are grey to pink, medium to coarse grained and porphyritic or non-porphyritic and massive in nature. Higher topographic levels forming denudational hillocks sometimes dome shaped mounds (inselbergs) and bouldery outcrops [10, 11, 12]. Totally urbanized Hyderabad city covers 90% of the catchment area. The engineering geological province demarcation indicates granite and gneiss country has low permeability, high bearing capacity (1000–20000kg/cm2) /compressive strength and good foundation characteristics, which are favorable for greater urbanization [13, 14, 15]. The main natural hazard is the depletion of groundwater table due to erratic rainfall heavy runoff (complete urbanization but for few parks, no GW recharge zone) experiences drought situation leading to intense drinking water problem. Precipitation is the main source of the groundwater recharge and takes place during the southwest monsoon. The contaminants enter into subsurface water through fractures and joints. The rate of movement and consequent spread of pollutants depends upon the hydraulic gradient and groundwater velocity.[16].

2.2 OBJECTIVES OF THE STUDY

The objective is to study Urban Hydrology, Groundwater Quality, Pollution Management and Quantification of Groundwater Resources (with special reference to dynamic resources) of Hussainsagar catchment area (in and around twin cities of Hyderabad and Secunderabad) falls under Musi Sub-basin, Krishna river basin, Greater Hyderabad city, Telangana.

The main purpose of the study is to assess the present status of groundwater pollution due to urbanization as well as industrial emissions and quantification of groundwater resources (with special reference to dynamic resources) in Hussainsagar Catchment.

3. METHODOLOGY

At present the issue of urban environmental sustainability is becoming a critical issue because of urbanization and its associated environmental impacts that are happening at an unprecedented rate. The life style of urban populace demands a large amount of materials and energy to sustain their metabolism. Anthropogenic flows exceed natural flows. Due to the large growth rate of the exploration of essential materials, manmade flows are approaching and even surpassing natural flows of many substances. As a consequence, the flows, stocks and concentrations of certain substances such as heavy metals and nutrients are rising [17, 18, 19]. New solutions are needed to overcome the problems of water scarcity, deteriorating water quality, lack of sufficient water supply systems, inappropriate handling of wastewater and inadequate storm water management flood risk etc.

There is a need to study the urban hydrology with reference to all the parameters mentioned in above paragraph. An attempt has made in the present study to assess the hydrological condition in respect of quantity and quality by considering the following themes in the catchment.

- Groundwater Quality
- Groundwater Flow Model

4. DISCUSSION ON FINDINGS

Groundwater samples collected in pre-monsoon and post monsoon during study period were analyzed for major ions in the Water Quality Level II+ lab of the Groundwater Department. Groundwater samples collected for pre-monsoon and post monsoon during study period were analyzed for major ions in Groundwater level II+ lab. The average values of the chemical parameters are tabulated in Table 1 (fig 2).

Table 1 Average Values (mg/l except pH) of the chemical parameters during 2011-2013.
The process of groundwater flow is generally assumed to be governed by the relations expressed in Darcy’s law and the conservation of mass. The purpose of Mass transport model in groundwater is to compute the concentration of a dissolved chemical species in an aquifer at any specified time and place. Changes in chemical concentration occur within a dynamic groundwater system primarily due to four distinct processes i.e. advective transport, Hydrodynamic dispersion, Fluid sources, Reactions Using the computed velocity field from the groundwater flow model, a mass transport simulation was carried out using MT3D software.

The source loading from the Jeedimetla, Balanagar and Sanathnagar industrial effluent discharges through Kukatpally nala in the upstream of have been assigned TDS concentrations of 1500 mg/l to the stream nodes passing through Sanathnagar and Balanagar areas. TDS concentration of about 1800 mg/l to the stream nodes passing through the Jeedimetla and after joining with Kukatpally nala up to the Hussainsagar lake and in downstream stream of Hussainsagar up to Musi river at the groundwater table during 50 years of mass transport simulation (Fig. 4). The longitudinal dispersivity was assumed as 20 m and longitudinal to horizontal and longitudinal to vertical was assumed as 0.1 and 0.01 respectively in the Mass Transport in 3 Dimensions (MT3D) model. The effective porosity in the granitic weathered and fractured medium was assumed as 0.1. Initial average background TDS concentration of groundwater has been assumed as 700 mg/l for the catchment area.

**Figure 3. Average Values of Chemical Parameters during Study Period**

Elevated TDS concentration > 1000 mg/l could be clearly seen in the Kukatpally watershed during the study period. This may be due to leaching of solid waste in the industrial area and also disposal of effluent and its interaction with groundwater. In 2012, TDS in Post-monsoon is less than the Pre-monsoon due to good rainfall. The analysis from most of the Data Sets is -TDS is highly correlated with Cl, So4 and Mg.

**Figure 4. TDS (mg/l) loading nalas & Hussainsagar Lake since 1980 – Mass Transport Model**

Chloride concentration > 250 mg/l was also reported in Kukatpally, Yusufguda and near Rasoolpura adjacent to old airport areas. Sulphate (SO4) concentration was reported elevated and confined to industrial areas of Sanathnagar & Balanagar during the study period. The Nitrate as Nitrogen was exceeding 10 mg/l indicates impact of urban solid waste disposal practices; also indicate maturity of urbanization in the respective areas and its non-scientific sewerage disposal practices. Fluoride concentrations are found to be within limits except at a few locations. In general wherever slightly lower concentrations of all constituents reported may be attributed to the improved pipe water supply system in the catchment area during study period.

**Mass Transport Model**

The computation of migration of TDS concentration plume from the Kukatpally nala, Hussainsagar Lake and along the stream in the downstream of Hussainsagar was made for next 50 years in the mass transport model. The respective migration pattern during different years of simulation was presented in Figure 5 & 6. All the computed contaminant migration patterns during the periods represent a business as usual scenario without any remediation intervention by either government or public. The width of the TDS concentration plume along Kukatpally nala would be about 400 m. The maximum

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|                | Pre | Monsoon 2010 | Post | Monsoon 2011 | Post | Monsoon 2012 | Post | Monsoon 2013 |
|----------------|-----|--------------|------|--------------|------|--------------|------|--------------|
| **Parameter**  |     |              |      |              |      |              |      |              |
| **pH**         | 7.8 | 7.5          | 7.5  | 7.4          | 7.2  | 7.2          | 7.1  | 7.1          |
| **TDS**        | 71.8| 765.6        | 673.9| 715.3        | 695.1| 655.9        | 654.7| 645.7        |
| **Na**         | 106.1| 113.2       | 98.9 | 96.3         | 109.3| 100          | 90.2 | 90           |
| **K**          | 6.3 | 6.6          | 6.47 | 6.8          | 6.71 | 3            | 4.67 |             |
| **Ca**         | 59.4| 72.8         | 70.6 | 85.6         | 79   | 66.2         | 65.7 |             |
| **Mg**         | 37.0| 45.1         | 32.4 | 32.25        | 32.2 | 31.86        | 35.65|             |
| **Cl**         | 121.7 | 146.6      | 126.6| 106.3        | 126.1| 126.6        | 127.3|             |
| **SO4**        | 69.6 | 78.6        | 71   | 70           | 64.2 | 76.7         | 70   |             |
| **HCO3**       | 251.7 | 241.4      | 221.3| 257.7        | 231.7| 187.9        | 192.8|             |
| **NO3**        | 12.6 | 16           | 37.7 | 17.3         | 14.38| 10.53        | 11.64|             |
| **F**          | 1.076 | 0.9        | 1.028| 1.013        | 1.052| 0.884        | 0.898|             |

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groundwater velocity computed from the groundwater flow model was 15 m/year and average groundwater velocity could be even lower. The movement of TDS plume from the lake would be spreading to Indira Park and Ashoknagar areas in the downstream of the lake.

Figure 5. Computed TDS (mg/l) during 1980 – 2030 in First Layer (Scenario 1)
Figure 6. Computed TDS (mg/l) during 1980 – 2030 in Second Layer (Scenario 1)

Already HMDA with JICA assistance has started restoration of Hussainsagar lake contamination. In the context, modernization of sewer lines and diversion of sewage bypassing the Hussainsagar Lake has been implemented. If all things go as per the master plan, it may take another couple of years to completely restore the lake water in Hussainsagar. As groundwater velocity is very low it may take few more years to contain the groundwater contamination.

A second scenario was carried out to assess the impact of the restoration measures from the year 2011 in Mass transport model with reduced TDS loading as a result of restoration measures along Kukatpally nala as well as from the Hussainsagar Lake. The predicted TDS concentration plume up to 2040 indicated slight reduction of plume width with lower concentrations as compared with business as usual scenario (Fig. 7).

Figure 7. computed TDS (mg/l) during 2011 – 2040 in first layer (Scenario 2)

The groundwater flow model has been further used to compute the groundwater balance for the entire catchment area of Hussainsagar. Different zones were assigned in the catchment and zone budget was computed. The significant feature was the computation of lake water – groundwater interaction in the Hussainsagar and also from different stream channels passing in different zones. The zone budget indicated that the seepage from the lake bed will be about 10 MLD in addition to the surface water evaporation from the lake @ 6mm/day over 450 ha surface area. The planned withdrawal for horticulture from the lake was about 10 MLD. Thus the Hussainsagar lake would require inflows of ~ 50 MLD for maintaining FTL. The HMDA has already made renovation of the existing tertiary treatment plant of HMWS&SB of 20 MLD and initiated construction of two STPs (Tertiary Treatment Plants) one on Kukatpally nala and another one on Picket nala with a combined capacity of 30 MLD.

5. Conclusion & Recommendations
Increasing industrialization / urbanization is posing a threat to the lake maintenance. Even if an intense rainfall of 60-80 mm/day received in the catchment may assume dangerous situation of flooding in the downstream.

Further utilities suggested below may also be considered for implementation immediately.

a. Sewerage facilities: Construction and up gradation of sewerage treatment plants to meet the inflow capacity, capacity enhancement of interception and diversion works, and construction of sewer lines
b. Recycled water (treated wastewater) supply facilities: Construction of reservoirs, pumping stations and pipelines
c. Lake Environment improvement: Desilting/dredging and disposal of sediments, shoreline improvement, surplus weir repair, drainage improvement, etc.
d. Slum development: Construction of solid waste management facilities, public toilets and sewerage networks

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