Urban development and the Looming water crisis - A case study from Tirupati, South India

JANARDHANA RAJU NANDIMANDALAM[1] & T V KRISHNA REDDY[2]

[1] *Department of Geology; Banaras Hindu University.Varanasi – 221 005, India (e-mail: rajunj7@yahoo.com)*
[2] *Department of Geology; Sri Venkateswara University.Tirupati – 517 502, India (e-mail: tvkreddy2k1@yahoo.co.in)*

Abstract: The town of Tirupati in Andhra Pradesh, South India is home to more than 300,000 people in an area of 110 Km^2. In addition, 40,000 visitors make the pilgrimage to Tirumala in a day. The pace of urban development and the rapid increase in population of Tirupati town, which started in the 1980's, has led to the depletion of surface and groundwater resources. The large numbers of visitors with their additional demands for water has further aggravated the problem of water scarcity in Tirupati town and its environs. The available surface water resource including that provided by the Kalyani Dam is not adequate to cope with the needs of the Tirupati town and groundwater is widely abstracted for public water supply, irrigation and industrial use. Geologically the Tirupati urban and its environs are built up on the Archean granite and also recent thick alluvial deposits. The increase in population and the associated heavy demand for land for residential and commercial development has resulted in 16 surface water bodies (tanks) in and around Tirupati town being filled in and built upon. This loss of surface water storage (in tanks) to urban development has accelerated in recent years; six tanks were filled in between 1975 and 1990 and a further ten during 1990-2004. A hydrograph of an observation well in the Tirupati urban area reveals a rapid decline of water level by around 15 m during the last five years (1999-2004).

The heavy dependence on groundwater has resulted in increasing numbers of wells and boreholes being constructed each year both for domestic use and for agriculture (deep surface bore-wells) in and around the Tirupati urban area and has led to the over-exploitation of groundwater. This serious situation is partly due to severe drought and partly due to rapid urban development, which has led to the filling up of tanks and some river stretches. This has impacted on surface water resources and also reduced infiltration to groundwater. Remedial measures to augment groundwater resources, such as rainwater-harvesting and/ or artificial recharge, are required not only to improve water conservation and management but also to help reduce problems of overdrafts.

Résumé: La ville de Tirupati dans Andhra Pradesh, l'Inde du Sud est à la maison à plus de 300.000 personnes dans une aire de 110 km2. En outre, 40.000 visiteurs font le pélerinage à Tirumala en jour. Le pas du développement urbain et de l'augmentation rapide de la population de la ville de Tirupati qui a commencé dans les années 80, a mené à l'épuisement des ressources de surface et d'eaux souterraines. Un grand nombre de visiteurs avec leurs demandes additionnelles de l'eau a plus loin aggravé le problème de la pénurie de l'eau dans la ville de Tirupati et ses environs. La ressource disponible d'eau de surface comprenant cela fournie par le barrage de Kalyani n'est pas proportionnée pour faire face aux besoins de la ville de Tirupati et des eaux souterraines sont largement soustraites pour l'approvisionnement en eau public, l'irrigation et l'usage industriel. Géologiquement le Tirupati urbain et ses environs sont accumulés sur le granit archéen et également les dépôts alluviaux épais récents. L'augmentation de la population et de la forte demande associée en terre pour le développement résidentiel et commercial a eu comme conséquence 16 corps d'eau de surface (réservoirs) dans et autour de la ville de Tirupati étant complétée et construite au moment. Cette perte de stockage d'eau de surface (dans les réservoirs) au développement urbain a accéléré ces dernières années ; six réservoirs ont été remplis entre 1975 et 1990 et des dix plus encore pendant 1990-2004. Un hydrogramme d'une observation bien dans la région urbaine de Tirupati indique un déclin rapide de niveau d'eau près autour 15 m pendant les cinq dernières années (1999-2004).

La dépendance lourde à légard des eaux souterraines a eu comme conséquence des nombres croissants de puits et de forages étant construits tous les ans pour l'usage domestique et pour l'agriculture (aléser-puits extérieurs profonds) dans et autour de la région urbaine de Tirupati et a mené à l'au-dessus-exploitation des eaux souterraines. Cette situation sérieuse est partiellement due à la sécheresse grave et partiellement due au développement urbain rapide, qui a mené au remplissage vers le haut des réservoirs et de quelques bouts droits de fleuve. Ceci a effectué sur des ressources d'eau de surface et l'infiltration également réduite aux eaux souterraines. Des mesures réparatrices d'augmenter des ressources d'eaux souterraines, telles que l'eau de pluie-moisson et ou la recharge artificielle, sont exigées non seulement pour améliorer la conservation et la gestion de l'eau mais d'aider également à réduire des problèmes des découverts.

Keywords: Urban geosciences, water resources, environmental impact, surface water, water table, preventive measures.

INTRODUCTION

Drought is a reality in the rural areas and water scarcity is a part of urban life. The rapid rise in the urban population due to migration from rural areas has resulted in increased commercial and housing development. This imposes an extra burden on the water supplies for urban areas. Water table fluctuation is a direct response to the groundwater draft and to recharge in an area. Rainfall is the principal source of groundwater recharge, and the water table normally rises in response to rainfall in a particular period. This relation has been changing because of the reduction in the numbers of water bodies (tanks & ponds) due to rapid urbanization. Further, mismanagement of water resources and the over-exploitation of groundwater has led to the rapid decline of water levels and the drying-up of shallow wells in many parts of urban and rural India. All large tanks within the radius of few kilometres of the city/town have become victims of the rapacious demands of the city dwellers especially those occupying multi-storey mansions. Every multi-storey complex in Bangalore metropolitan city has dozens of deep bore wells pumping water day and night leading to a severe depression in the water table; in consequence, a large number of shallow bore wells catering for the needs of middle class and slum-dwellers are drying-up (Radhakrishna 2004**).** It is paradox that Chirapunji in India with all its distinction of high amount of annual rainfall of 11000 mm experiences water scarcity for nine months in a year.

Many cities, which once had numerous water harvesting structures (tanks), have hardly any left. According to the government's own estimates, depletion of groundwater table has made the State of Rajasthan facing a serious problem of water scarcity, especially in 27 out of 37 districts (Alok & Batra 2000). Given the fact that groundwater levels have declined by 4-10 m in several parts of the Capital of India over the last decades, the Delhi Government is contemplating a law to make it mandatory for all new group housing societies to harvest all that rain falling within their complexes (Anon 2000). Despite generally fairly good rainfall in India, a large fraction is lost through runoff in the absence of sufficient sites for storage and impounding. There is thus an imbalance between recharge and groundwater development in many parts of the country (Raju 1998). Choudhury *et al.* (2000) pointed out that over-abstraction of groundwater has adversely affected the water table resulting in increase in salinity and the possible threat to the civic structures. Yoon *et al.* (2001) estimated the major components of the groundwater balance, which indicated that the groundwater resource of the Seoul area is not endangered quantitatively but that there is a serious problem of quality degradation in the shallow groundwater. This paper attempts to identify the environmental factors responsible for diminishing water bodies and declining water levels in Tirupati and to recommend the remedial measures needed to redress the problem.

CASE STUDY OF TIRUPATI URBAN AREA

Tirupati is located in Chittoor district of the drought-prone Rayalaseema region of Andhra Pradesh, South India (Fig. 1). Geologically, the Tirupati region is covered by granites and dyke rocks of Archean age overlain by recent alluvium deposits typically 10-25 m. thick. Most of the hill streams originating from the Sapthagiri hills to the north of the city exhibit a dendritic and sub-dendritic pattern of drainage; all the streams are ephemeral and flow is observed only for a few hours. Tirupati has a semi-arid climate and groundwater levels in the borewells show a rapid decline due to the overexploitation by an increasing of number of groundwater structures. Tirupati municipality is mainly dependent on imported-surface water (Telugu Ganga Project) in summer to cater for the drinking water needs of the urban people.

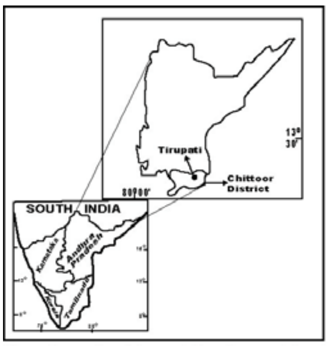

Figure 1. Location Map of the Tirupati Area

RESULTS AND DISCUSSION

Rapid urbanization has taken place in Tirupati town, which is also a pilgrim centre. The Tirupati township with a population of 300,000 has to accommodate up to 40,000 visitors a day who make the pilgrimage to Tirupati. The rapid growth in the population and the expansion of industrial/ commercial activities has been largely due to the migration of the rural population to urban areas seeking improved livelihoods. For more than a decade, Tirupati, which experiences semi-arid climate, has seen it's water sources dry-up, a rapid decline in groundwater levels in the borewells and the virtual cessation of flow in the Swarnamukhi River. The Kalyani dam was constructed to augment the water needs of Tirupati town, which began to experience seasonal scarcity of drinking water from the early 1970s. Whenever the monsoon rains are below normal, the Tirupati region faces a severe water crisis.

Table 1: Population, water bodies and water level particulars of the Tirupati urban area

Year	Population (in thousands)	Number of water bodies	Water Level (m)	Number of wells	Urban development (Km^2)	Description
1977	90,000	>40	4.7	300	8	Shallow dug wells and mainly tank irrigation
1990	170,000	34	6.5	700	28	Shallow dug wells, dug cum borewells and partly tank irrigation
1999	250,000	30	10	1500	--	Dug cum borewells and partly tank irrigation
2004	300,000	<24	25	2500	64	Deep surface bore wells and no tank irrigation

As regards to the city of Tirupati, there were more than 40 irrigation and percolation tanks in and around the town before 1977 (Fig.2). These tanks have played several important roles to trap rainwater, to prevent soil erosion and to recharge the groundwater in the surrounding areas. Some of the tanks, when they dried up for lack of rain, became liable for development, mostly for house construction while others were converted into the government establishments (Table.1). Hydrogeological studies of the Tirupati area indicate that the weathered zone tapped by dug wells is now dry. A piezometer in the Tirupati urban area shows a continuous declining trend of groundwater levels from 10 to 25 m (Fig. 3). The continuous declining of water levels, as evident from the hydrograph, reveals that the discharges from, are more than the recharge to, groundwater. The increase in the number of groundwater structures (wells) from 300 in 1977 to 2500 in 2004 confirms the heavy reliance on groundwater resources for different purposes in Tirupati area. There was a five-fold increase in the numbers of wells within a period of 22 years (1977-1999) and almost a two-fold increase in the last 5 years (1999-2004) within a period marked by rapid urbanization in Tirupati. The observed declining trend in water level over the past 27 years (1977-2004) in the Tirupati urban area is alarming. The decline in the water table (15 m) during the last 5 years period (1999-2004) is so steep that the magnitude of the problem requires serious attention and for remedial measures to be instigated.

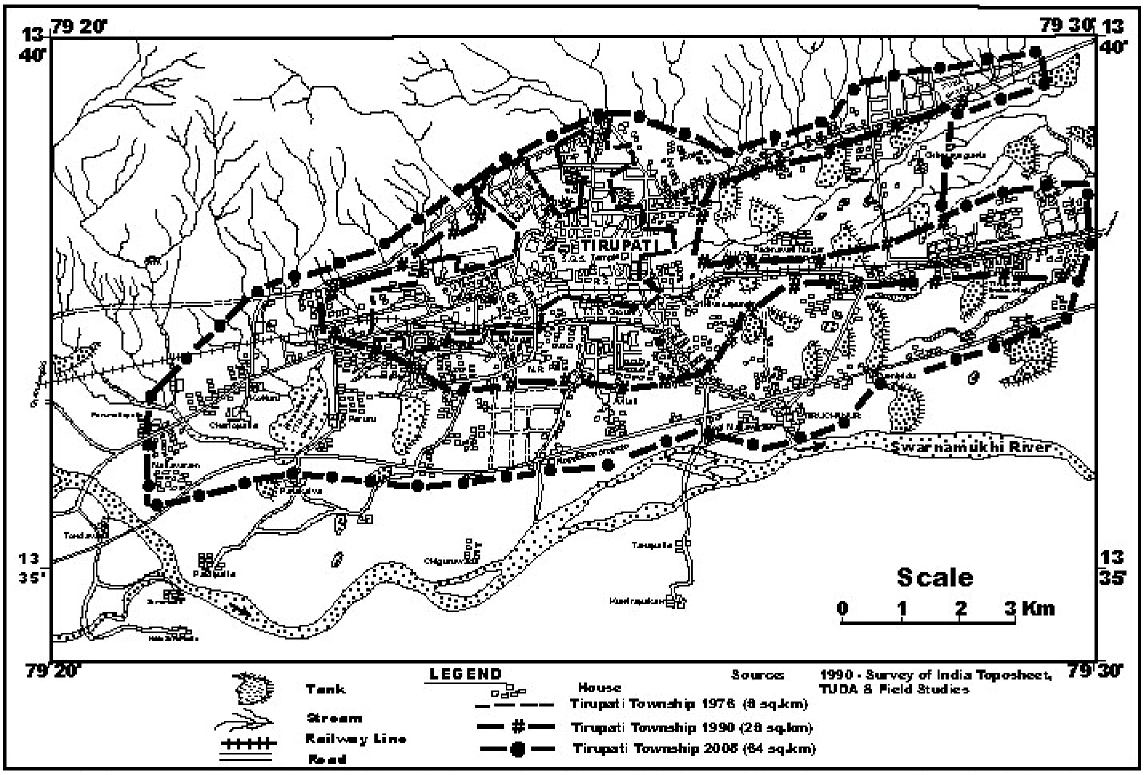

Figure 2. Urban Development and their effect on Water Resources

The reasons for this situation are clear and include severe drought periods, the rapid urbanization and the encroachment upon the tanks and supply channels, the heavy dependence on groundwater for domestic and agricultural purposes in the absence of surface water and the consequent overexploitation of groundwater. The groundwater potential is reduced not merely due to urbanization resulting in overexploitation but also because of the absolute dependence of agriculture on the deep borewells in, and around, urban areas. This declining trend in water resources, which has already set in motion the deterioration in the quality of urban life, has served as an eye-opener for initiating measures for the alternate rainwater harvesting structures and better water management.

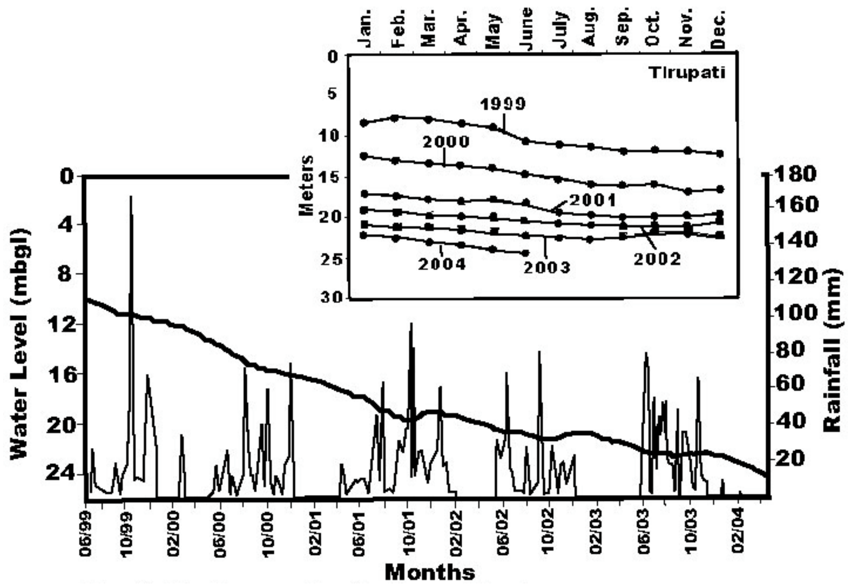

Figure 3. Hydrograph of Tirupati urban area
(Source: A.P. State Groundwater Department, Chittoor district)

Rainwater harvesting

Rainwater harvesting is simply the capturing and storing the rainwater, when and where it falls, by different methods for infiltration and percolation into underground to augment the groundwater reservoir. Rainwater harvesting is not just about saving rainwater; in fact, in urban areas, rainwater harvesting is the only long-term solution to chronic water shortages. This is necessary because of the high fraction of the water budget that runs off due to flash floods events especially during low rainfall years. Good management of natural resources can help regenerate the local economy and reduce rural-urban migration (Anil Agarwal 2001). Several methods of rainwater harvesting for artificial recharge are in vogue, the choice being dictated by local hydro-geological and soil conditions (Todd 1980). In urban areas, recharge of groundwater through storm runoff and roof top water collection, and the diversion and collection of runoff into dry tanks from playgrounds, pavements, parks and other vacant places can be implemented by both government and non-government establishments. Recycling and reusing of water is yet another important activity of water harvesting, and needs to be adopted by urban households. In the rural areas, different techniques of rainwater harvesting need to be employed for increasing the contact area and residence time of surface water with the soil layers to augment the groundwater recharge.

CONCLUSIONS

The heavy dependence on groundwater ensures that the numbers of wells and boreholes, for both domestic and agricultural purposes (including deep bore-wells), in and around the Tirupati urban area increases annually and has led to the over-exploitation of groundwater. The urbanization process increases the fraction of the catchment that is impermeable and has also drastically reduced the permeable soil surface area; hence the rapid decline in the natural recharge to the groundwater. The urbanization process and the increase in population will eventually lead to the disappearance of tanks/ percolation ponds. This is a phenomenon observed in many parts of the Tirupati urban area and the problem of depletion of water levels in this region will definitely become aggravated. Continuous declines in water levels of around 15 m, at a rate of 1.7 to 4.4 m/year, are observed in the Tirupati urban area during the last five years. To reverse this situation, it is necessary to implement mandatory rainwater harvesting and artificial recharge schemes in areas where groundwater discharge has surpassed the annual replenishment. This will require the involvement of the householders and others in the local community.

Since the water levels are continuously declining and the rapid urbanization process continues in the Tirupati area, rainwater harvesting schemes to augment groundwater resources are urgently needed. Roof top rainwater harvesting (RTRH) in the Tirupati town should be strictly implemented. Legislation should be enforced to prevent new boreholes and wells being constructed in and around the Tirupati urban area. Existing water bodies in the Tirupati region should be well maintained and protected from encroachment by urban development. A large number of wells that have become dry as consequence of overexploitation within the Tirupati urban area could be converted into recharge wells by diverting the rooftop and flood runoff into the wells. The deterioration of groundwater quality in the Tirupati area might be checked through restrictions being imposed on the increased groundwater usage of the deeper aquifer.

Corresponding author: Dr Janardhana Raju Nandimandalam, Department of Geology, Banaras Hindu University, Varanasi – 221 005, India. Tel: +91-9839877919. Email: rajunj7@yahoo.com.

REFERENCES

ANIL AGARWAL. 2001. Drought? Try capturing the rain. Briefing paper for members of Parliament and State Legislatures. *Centre for Science and Environment*, New Delhi, **16 p.**

ALOK KUMAR & P.K. BATRA. 2000. Declining groundwater resources and need for its management in Rajasthan. *Proceedings of the National Seminar on Groundwater Management Strategies in Arid and Semi-arid Regions*, June 23-24, Jaipur, Groundwater Department, Rajasthan.

RADHAKRISHNA, B.P. 2004. Man-made drought and the looming water crisis. *Journal of the Geological Society of India,* **63**, 477-481

ANON. 2000. Depleting water table is now a capital woe, *The Hindustan Times,* New Delhi, April, 29.

RAJU, K.C.B, 1998. Importance of recharging depleted aquifers: State of the art of artificial recharge in India. *Journal of the Geological Society of India*, **51,** 429-454.

CHOUDHURY, K., SAHA, D.K.& GHOSH, D.C, 2000. Urban Geophysical studies on the groundwater environment in parts of Gangetic delta. *Journal of the Geological Society of India*, **55,** 257-267.

TODD, D.K. 1980. Groundwater Hydrology. *John Wiley and Sons,* New York, **535p.**

YOON-YOUNG KIM, KANG-KUN LEE & IG HWAN SUNG. 2001. Urbanization and the groundwater budget metropolitan Seoul area, Korea. *Hydrogeology Journal*, **9**, 401-412.