Introduction

Water is a prerequisite for life, to the extent that extra-terrestrial life is sought to be detected by identifying whether a planet or heavenly body has water atleast in traces. In case of human beings, around 57% of the body weight is constituted by water (Guyton, 1991). Water becomes essential for human survival in various forms: direct consumption, pre-digestion (cooking) of food, agriculture, livestock farming, manufacturing and industrial processes. The National Water Policy (2002) (of India) states that water is a prime natural resource, basic human need, and a precious national asset. The United Nations General Assembly declared the period from 2005 to 2015 as the International Decade for Action, “Water for Life”: most recently, in July-2011, the UN General Assembly declared safe and clean drinking-water and sanitation a human right essential to the full enjoyment of life and all other human rights (WHO, 2011). Unlike many materials, there is no substitute for water in many of its uses (Sylverster, 2003).

Of all the constituents of the earth, water has many special and exclusive characteristics: pure water being colorless, odourless, and with a capacity to dissolve within itself many other materials. As in the case of almost all materials, water is invariably never pure, inspite of which its utility remains unassailed with each end-use tolerating various impurities to certain extents. The impurities in water are natural and / or man-made. Manmade impurification is always detrimental to its usage for the assigned purpose.

The location of human settlements and their general prosperity are dictated by the availability of abundant and reasonably pure water. This is true for pre-historic times as well as the present. In modern society, as in the case of many human
activities and requirements, sourcing and distribution of water is a co-operative effort, especially in the form of municipal water supply schemes, rural water supply schemes and the like. Such organised sourcing and supply of water is meeting most of the requirements of the urban populations. The quality of water in such organised supplies varies widely but is generally within the acceptable limits of impurity. It is important to note that even such organised supplies have to depend on either riverine or groundwater sources.

With the ever-increasing demand for water, the population is forced to tap all available sources, while the quality of water, irrespective of the source, has come down due to pollution. Rapid growth of urban settlements and the not so fast widening of municipal water supply systems is forcing some of the population to depend on unregulated sourcing of groundwater either for domestic or industrial purposes. The quality of such water is suspect and it is therefore essential to identify the major impurities and the extent of pollution in such water, so that remedial measures can be taken towards better human health and efficient industrial processes. Taking into account the limited band of pollution acceptable for human consumption, surface water and groundwater are the primary sources for human consumption, farming and certain industries, while sea water is restricted to certain industries, that too as a cooling medium and for certain types of aquaculture. Water uses with the highest demands for quantity often have the lowest demands for quality, whereas drinking water needs to be of the highest quality, but in relatively small quantities (Meybeck et al, 1996). Even these small quantities aggregate to very high volumes, when factored with our burgeoning population.

In many regions, water scarcity and water pollution became an issue (Falkenmark, 1990; Arnell, 1999; Bouwer, 2000). Nearly half of the Earth's population does not have enough water to drink; and demand is doubling every 21 years (Vidal, 1995). Even though the general levels of public health have improved during the last few decades, impure water is being identified now as a primary causative agent for certain diseases. It is therefore very important to monitor the purity of available water, identify the pollutants, their source and device methods to make the water safe for consumption.
The impurity of water can be categorised as: i) Physical; ii) Chemical; iii) Biological & iv) Radioactive. Since groundwaters constitute an important source of water, it is essential to study their pollution levels. This gains importance in highly populated urban as well as rural areas. There are many areas in India where more than 90% of the population depends on groundwater for drinking and other purposes (Ramachandraiah, 2004), while the subsurface has come to serve as the receptor for much rural, urban and industrial wastewater and for solid waste disposal. There are increasingly widespread indications of degradation in the quality and quantity of groundwater, serious or incipient, caused by excessive exploitation and / or inadequate pollution control. The scale and degree of degradation varies significantly with the susceptibility of local aquifers to exploitation-related deterioration and their vulnerability to pollution (World Bank, 1998).

A number of factors influence the quality of water. Gibbs (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of water. The influence of geology on chemical water quality is widely recognized (Gibbs, 1970; Lester & Birkett, 1999). The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998). The water chemistry of the surface and groundwater also depends on inorganic chemicals and suspended solids from urban run-offs (McGregor et al, 2000), whereas the microbial content is dictated by the environmental conditions.

Morris et al (2003) theorise that unlike rivers or lakes whose contamination is generally highly visible and rapidly occurring, groundwater is out of sight and undergoes change over potentially long time scales, so that it can be years or decades before contaminants leached from the land surface will adversely affect a groundwater supply. The major sources of pollution of groundwater include industrial effluents, domestic solid and liquid wastes, surplus pesticides and fertilisers (Burchi, 1999) used in agriculture, apart from pollution from contact with mineralogical soil and rock formations. Many of the urban and rural areas share the causative agents of groundwater pollution, while certain industrial and mining processes and farming practices give rise to specific issues in certain cases. In the case of thickly populated urban areas, the primary contributor is unhygienic disposal of sewage and debris.
Urbanisation and industrialisation have a profound effect on urban groundwater resources, which are inextricably linked with land use and effluent and waste disposal practices in a complex fashion (World Bank, 1998). Rapid urbanisation and the resultant stress on already inadequate water supply and sanitation are identified as challenges facing us (Ashbolt, 2004). Urbanisation affects both the quantity and the quality of underlying groundwater systems, urbanised areas being the clearest example of the powerful and usually unbalanced effect of human-induced factors on a geological environment, which very often disturbs hydrogeological safety of the area (IMWA, 2011). The necessity and scope to study various aspects of groundwater pollution is wide and demanding, especially in view of the increasing threats of pollution combined with rapidly increasing population.

Visakhapatnam is a typical urban community where natural features, industries and pressure of fast increasing population all contribute to pollution of groundwater, and is notorious for having figured as one of the twelve areas in India that were identified in 2010 as problematic (APPCB, 2010).

A number of factors that have a bearing on the quality of groundwater are very prominent in Visakhapatnam: increasing population, industrialisation, insufficient sewage and solid waste handling and disposal systems, over-extraction of groundwater and, very importantly, amelioration measures not keeping pace with the requirements. Monitoring the effects of these factors on groundwater is necessary on a continuing basis, since these factors are interdependent and subject to change across time, often aggravated or mitigated by climatic conditions and anthropogenic activities.

Earlier investigations during the past few decades on groundwater quality in and around Visakhapatnam are found to be largely concerned with the physico-chemical aspects, and, to a lesser extent, heavy metal contamination, with bacteriological assessments not being given adequate importance. Further, the studies were focussed mainly on the areas in the vicinity of industries. Hence, there is a need to simultaneously study the above aspects, across other thickly populated areas of Visakhapatnam, assess their inter-relationships and increase our knowledge-base towards equipping planners to address the problems of groundwater pollution.
The quality of groundwater in a particular geographic setting can vary substantially within spans of a few kilometers, especially in urban and industrialised areas. It is therefore necessary to carry out investigations based on carefully selected sampling locations, grouping them based on the natural and built environments.

The present study is made with the following objectives:

a) To assess the affect of urbanisation, industrialisation and other anthropogenic factors on groundwater quality in terms of physicochemical properties, heavy metal content and bacteriological contamination;

b) To compare the quality parameters across various urban zones;

c) To identify the problematic parameters and sources of groundwater pollution, especially with a thrust on bacteriological contamination.