2. REVIEW OF LITERATURE

Water pollution is a serious problem in India because the safe drinking water is decreasing at an alarming rate. The major sources of pollution are the rivers and canals flowing nearby villages. Wastes pouring from urban areas into those rivers pollute water sources in rural areas, as may affect the water table (Borchert and Walton, 1971).

At present information and literature available on drinking water quality of several canals, ponds, domestic taps, open wells in India is very less. Therefore before choosing any topic for research, one should invariably look into the past work. The sole contention of the literature review is to know what has been done and what has not been done in the area of research. If done, what were the significant findings? And whether these findings apply to the study area or not? To avoid redundancy only salient studies were included.

An appreciable number of reports are available for limnobiotic studies of water pollution and their abatement. However, no detail report on the quality of water of Andhra Pradesh in relation to urbanization and industrialization is available. Study of different physico-chemical and microbiological parameters of different ground and surface water yield useful data for understanding the nature of water environment throws a flood of light on the changes brought by the intense human interference.

To pollute is to destroy the purity. The word pollution is derived from ‘POLLUTERE’ which means defilement. Any needless degradation of pure
substances leads to pollution. An event that happens to a resource which will make it useless for future use causes pollution. The four types of environmental damages that can occur are:

1. Threats to human health and safety.
2. Damage to economic resources and to material well being.

Hame, (1978) said environmental pollution is a worldwide phenomenon. The problem is accentuated by rapid industrialization, which is fast transforming air, water and soil into big natural reservoirs by dangerous pollutants. Further, rapid industrialization programs, have resulted in the generation of solid, liquid and gaseous wastes in such a huge quantity that a serious threat is likely to be posed to the quality of the life in the years to come. Heavy metals are widespread pollutants of great environmental concern as they are non-degradable, toxic and persistent with serious ecological ramifications on aquatic ecology (Chopra et al., 2009; Jumbe and Nandini, 2009). The urban Aquatic ecosystems are strongly influenced by long-term discharge of untreated domestic and industrial wastewater, storm water runoff and direct solid waste dumping (Sarika et al., 2008). All these released pollutants have a great ecological impact on the water quality.
Abiotic environment of freshwater ecosystem affects the biotic component of the ecosystem. If any change occurs in physico-chemical characteristics of water, it causes a direct impact upon the biotic data. Availability of clean and potable water has become a key issue in several developing countries. Burgeoning population and water scarcity is affecting the quality of life significantly; India is no exception to this (Parashar et al., 2006). The water runoff on the land picks up more soluble species in areas where the weather is still in its earlier stages (Peter Nell, 2004). The greatest risk to the public is water contaminated with community derived waste and sewage (Bhargava, 2006). A number of cities throughout the world, especially in India, are now on the threshold of emerging into metropolitan centres as a result of the rapid industrialization and urbanization. In tropical countries, incidents of water pollution generally occur during the rainy season than compared to other seasons probably because of improper drainage, stagnation of sewage and silage resulting in seepage through the soil, thus polluting the groundwater. Contamination of tap water used for drinking purposes by the sewage when, the pipelines pass through drainage canals through leaks and/or joints in the pipes is a serious problem in the towns and cities in developing countries especially, India (Lalitha, 2008).

One of the serious chemical pollution problems experienced by mankind is mercury pollution in river Minamata of Japan and Wabigoon-English, river of Canada where thousands of people suffered from chronic diseases. The healthy aquatic ecosystem depends on biological diversity and physico-chemical
characteristics (Venkatesharaju et al., 2010). Afzal-Shahzad et al., (2000) made a study of water quality surrounding Hudiara drain, India and Pakistan and found the water unfit for drinking purpose due to the high values of nitrate and selenium.

Ray et al., (2000) made a study on drinking water in Rohtas district of Bihar and observed high iron, magnesium, fluoride and nitrate present in water. Seth et al., (2000) analysed river Ganga at Haridwar. Khwaja et al., (2001) monitored Ganga river water in Kanpur. Similarly, Khanna et al., (2001) studied the water quality of the Ganga canal in Haridwar. Kotaiah and Reddy (2004) studied water quality of canals located at Kurnool district in Andhra Pradesh and observed that the concentration of all the ions in pre-monsoon season were low and exhibited increasing trend to post-monsoon season. Coovam River water was studied by Bhuvaneshwari and Devika (2008).

2.1. Review of literature on physico-chemical and microbiological analysis

Many workers in India made various discoveries and had various studies on water pollution problems in several parts of India in the past several years noticed the hazardous waste released, and reported the episode for the first time in 1986 (Ganges water pollution inquiry report by Civic Affairs, (1969-'70); Sunderesan et al., 1983). When, the river Ganges was set aflame near Monghyr, Bihar State. Discharge of crude oil and other petroleum products along with the refinery effluents into the river and subsequent fire resulted in the suspension of drinking water supply to the town of Monghyr for a few days.
This resulted in serious drinking water problems to the residents of the city. In Madhya Pradesh state, serious environmental pollution hazard hangs over vast tracts of rich forest and agricultural lands, situated along the 32 km long course of river Sankini, which carries huge quantities of fine iron ore dust wash out from the prestigious Bailadila Iron Ore project. The pollution threat has assumed such a serious proportions over the past few years that the entire river has been turned red thus seriously hampering the drinking water needs of the people in villages on the banks of the river.

Horned, (1982) analysed the water quality of the Neuse river in terms of variability pollution load and long term trend. Daniel et al., (1982) analysed the water quality of the French river. Foster (1988) investigated the impact of urbanization on the aquifers at various cities of South America. The presence of contaminants like nitrates, toxic metal ions, organic compounds and bacteria in the studied aquifers was attributed to domestic and industrial effluents of the regions.

Jacobson et al (1988) examined water from a large number of wells in Australia for different chemical parameters and found contamination in a majority of the cases, caused by influx of industrial and domestic waste water. Jais et al., (1993) studied drinking water in and around Vijapur.

Kataria and Jain (1995) observed turbidity in groundwater of Bhopal city. Kataria (1996) observed phosphate and sulphate content in bore-well waters of

To evaluate the quality of drinking water in and around Tiruchirapalli City, twenty spots was identified within a radius of about 20 km. All the water samples were found to contain high level of inorganic salts and total hardness with high electrical conductance. Since they are unsuitable for drinking purposes, methods to improve the water quality has been suggested. Abdul Jameel, (2002). The present issues related to groundwater contamination through municipal landfills and leachates in Delhi. An attempt has also been made to evolve abatement measures on ‘Hydro geologic design principles’ and policy guidelines for mitigating the menace of groundwater contamination through landfill sites. Bhowmick, (2002).

Ramanathan, (2002) carried out a study of systematic sampling of groundwater in different seasons from 1997 to 1999 in the entire Perilya district of Tamilnadu. Groundwater is colourless, odourless and is alkaline in nature. The water chemistry shows distinct variation in space and time and shows the influence of the anthropogenic sources. SAR, RSC, Na%, CR, TH etc show that the water is generally good for domestic, agricultural purpose and is not good for long distance transport. Here the Fluoride concentration is generally lower than prescribed limit except few areas where the concentration exceeds 1.5ppm. Groundwater with higher concentration of magnesium causes a laxative effect on human beings and excess fluoride causes severe bone fluorosis (Mishra et al., 2003).
Kotaiah and Reddy, (2004) studied the water quality of Kurnool district near a canals Andhra Pradesh and observed that the concentration of all the ions in pre-monsoon season were low and exhibiting an increasing trend to post monsoon season. The study in canals water samples. The seasonal variations in concentrations of anthropogenic components demonstrate that the Karsts groundwater system is liable to pollution by human activities. Evidence of deterioration of groundwater quality by nitrate contamination has indicated that the nitrate levels routinely exceed the maximum contaminant level of 10 mg/l $\text{NO}_3^-$ in many aquifer systems in Palestine that underline agriculture-dominated watersheds (Almasri, 2004).

From a study on groundwater of Tiruchirapalli, Tamil Nadu, it is found that low calcium content and high alkalinity increases the fluoride level in water whereas the lower the total hardness. The higher is the fluoride ion concentration. It shows that groundwater has been contaminated by the industrial activity and application of large amount of fertilizers around that area (Ramachandramoorthy et al., 2004). Monitoring of Sanganer mole and surrounding tube wells was carried out by Singh, (2005) during the rainy season. The results revealed the discharge of untreated industrial effluents and sewage in to nallah have contributed considerable pollution in the groundwater in its vicinity areas, and is harmful for use in agriculture and drinking purposes. The levels of nitrate and fluoride concentration are higher in well water samples, and need serious attention.
Correlations between various groundwater quality parameters were made with the data of 63 groundwater samples collected from the Jeedimetla Industrial Estate in Hyderabad city by Nageswara Rao, (2005). The correlations were highly significant (>85%) between the parameters pH and alkalinity, pH and cadmium EC and TDS, EC and hardness, EC and copper and hardness and calcium.

All physico-chemical parameters recorded in the study taken up by Sivagurunathan et al., (2005) in Sethiyathope area in Cuddalore district of Tamilnadu state showed higher values in summer season than in winter season, except fluoride content in groundwater.

From a study conducted by Nair et al., (2005) on the assessment of the well water quality of Benghazi, Libya, very high nitrate contents in some of the well waters were recorded which are of concern. Tariq et al., (2006) conducted a study to evaluate the characteristics of various industrial effluents of the Hayatabad Industrial Estate of Peshawar in Pakistan and assess the possible impacts of such effluents on the quality of groundwater from a total of 12 samples. Nair, (2006) studied the quality of groundwater in Northeast Libya and reported higher values for all parameters including Cu and concluded that the well waters were excessively polluted and not fit for drinking purpose. Harish Babu et al., (2006) made a study on groundwater samples during December 2004. The samples were analysed for trace metals, such as iron, lead, cadmium copper, zinc, nickel and barium. Lang et al., (2006) observed that the major anthropogenic components in the surface and groundwater
include K\textsuperscript{+}, Na\textsuperscript{+}, Cl\textsuperscript{-}, SO\textsubscript{4}\textsuperscript{2-} and NO\textsubscript{3} with Cl\textsuperscript{-} and NO\textsubscript{3} being the main contributors to groundwater pollution in Guiyang, China and its adjoining areas. Ram et al., (2006) observed that the high value of TDS, Iron, Total Hardness, Calcium Hardness, Calcium and Magnesium in the ground strata where the aquifer is available or due to leaching of various pollutants through the sides and bottom of unlined drain. Tatawat and Sing Chandel, (2006) studied the groundwater quality of Jaipur city experienced degradation due to rapid urbanization and industrialization. Eleven groundwater samples were collected from Jaipur City, Rajasthan (India) from different hand pumps to study the chemical parameter with the help of standard methods of APHA during pre-monsoon. Groundwater samples were collected from different locations in Churu tehsil, Rajasthan by Sinha, (2007), for their physicochemical studies. On comparing the results against drinking water quality standards laid by Indian Council of Medical Research (ICMR), it is found that most of the water samples are non potable for human beings because of having much higher TDS value.

Ibrahim Bathusha, (2007) collected Groundwater samples from 18 wards of Coimbatore City north zone, among which 2 samples were collected from 2 different locations from each ward, total of 36 samples. Water quality assessment was carried out for various physicochemical parameters. Correlation coefficients were determined to identify the highly correlated and interrelated water quality parameters. Comparison of observed and estimated values of the different parameters reveals that the correlation equations
developed in the study can be very well used for making water quality monitoring. In his study, Sajidu, (2007) collected drinking water samples from boreholes and pipes at 23 sampling sites, mostly villages within the district, for fluoride and other water physicochemical parameters during dry and rainy seasons of 2004 and 2005 respectively. Fluoride endemic areas were identified as those villages around Mtubwi F.P School and Liwonde L.E.A School. This finding was supported by the prevalence of a high proportion of dental fluorosis in standard 3 and 4 pupils in these two schools. Positive correlation was observed between concentrations of fluoride with pH, total dissolved solids and carbonates, while phosphates correlated negatively with the fluorides. No correlation was observed between concentrations of fluoride with nitrates, electro conductivity, total hardness, carbonates and chlorides.

The 26, December 2004 tsunami had a major impact on the quality of groundwater along the south east coast of India, but especially in the tsunami-affected areas of the Nagapatnam district of Tamilnadu. Major pollution resulted primarily from the increase of the salinity in groundwater. Groundwater samples were collected from 11 wells in this area showed significant variations in water quality parameters Ravi Sanker, (2008).

Gadhave, (2008) presented this paper to find the quality of water samples and to find out the magnitude of health problems in industrial area Shrirampur. The natural quality of groundwater tends to be degraded by human activities. The parameters in six sampling locations studied were pH, Total hardness, chlorides, sulphates, calcium and ion concentrations, were
expressed in mg/L. Jakhrani, (2009) stated groundwater quality is deteriorated because of the higher concentration of electrical conductivity, total dissolved solids and hardness as compared to WHO standards. Omofonmwan, (2009) examined the effect of solid waste on the quality of groundwater in Benin metropolis, Nigeria. The analysis of physical, chemical and biological parameters of raw water from eight wells collected around the metropolis close to refuse dumps shows that these wastes produces leachates and gases when they are discomposing and are washed by percolating and infiltration rain water into groundwater. However, most of the water parameters tested fall within WHO recommendations while some are not. Groundwater samples were collected by Gupta, (2009) from different locations in the radius of 25 km. of Kaithal city, Haryana (India), were analyzed for their physicochemical characteristics. On comparing the results against drinking water quality standards laid by ICMR and WHO, it is found that some of the water samples are non-potable for human being due to high concentration of one or the other parameter.

Karunakaran, (2009) collected ten groundwater samples at different locations in and around Namakkal were analyzed for their physicochemical and microbial characteristics. Groundwater suitability for domestic and irrigation purposes was examined by using WHO and BIS standards, which indicate the groundwater in a few areas, are not much suitable for domestic and agriculture purposes. Physicochemical characteristics of groundwater (two open wells, two bore wells) and municipal water in Amalner town were analyzed by Patil,
Total 15 parameters were analyzed and the results were compared with standards prescribed by WHO. It was found that the undergroundwater was contaminated at few sampling sites and Dekhu road showed physicochemical parameters within the water quality standards and the quality of water is good and fits for drinking purpose. Water quality of open wells representing four localities around the Kerala Minerals and Metals Ltd industrial area, Chavara, Quilon district was studied by Shaji, (2009) to assess the suitability of the well waters for domestic purposes. The study revealed that the third and fourth wells are free from heavy metal pollution, but have bacterial contamination, the values of BOD, COD, TDS and phosphate exceeded the maximum permissible limits, the dissolved oxygen was much lower than the desirable limit. Hence all the well water samples are unsuitable for domestic purposes as it is confirmed by water quality index.

For the study of different samples of groundwater Kiran Mehata, (2010) collected samples from the locations of Vadgam taluka of Gujarat state in India and analyzed for their physicochemical parameters for concentrations of ions. Its quality was compared with drinking water standards of ICMR and EU (1998). Correlation co-efficient (r) were also calculated for these water quality characteristics and found Fe is positively correlated with many other parameters.

Groundwater samples were taken from 13 different locations of Kotputli town by Ranjan Agrawal, (2010). The quality analysis has been made through different physico-chemical characters. Comparative studies of samples in
different seasons were conducted and were found that there was no appreciable change in the different parameters during rainy season. It was also analyzed that Electrical conductivity and Total Dissolved Solids (TDS) decreased in the rainy season whereas other parameters like Alkalinity, total hardness increased after the rainfall.

The Study of Jothivenkatachalam, (2010) brings an acute awareness among the people about the quality of groundwater by analyzing various physico-chemical characters. A systematic correlation and regression study showed significant linear relationship among different pairs of water quality parameters.

Groundwater samples were collected from eleven stations of Jaipur city during monsoon season by Dinesh Kumar Tank, (2010) and were analyzed for physico-chemical parameters to assess the hydrochemistry of groundwater. The status of groundwater is better for drinking purposes. Results indicate that nitrate concentrations are in an alarming state with respect to the use of groundwater for drinking purposes.

Water samples from 32 bore, 16 open wells and two reservoirs at various locations in GVMC area, Visakhapatnam were collected and analyzed for pH, EC, DO, TH, Calcium, Magnesium, total alkalinity and Nitrate. The chlorine content of water samples near the sea are more than the far away from the sea. From this the author concluded the intrusion of salt water into groundwater
due to the over pumping of the groundwater along the sea coast (Srinivasa Rao, 2010).

Characterization of the physico-chemical parameters of groundwater from fifteen different locations in Ambala, Haryana was carried out by Prem Singh, (2010). To assess the quality of groundwater each parameter was compared with the standard desirable limits prescribed by WHO. Systematic calculation was made to determine the correlation coefficient ‘r’ amongst the parameters. It is concluded that the water quality of water supply systems in different locations of Ambala is of medium quality and can be used for domestic use after suitable treatment.

Various samples of groundwater were collected from different areas in and around the Punnam village of Karur District, India and analyzed for their physicochemical characteristics by Raja, (2002). The results of this analysis were compared with the water quality standards of WHO and CPHEEO. In this analysis most of the physicochemical parameters were found above the prescribed standards.

Alnos Easaand, (2010) collected groundwater samples at the pumping level. Harmful effects of waste water on the chemical compositions of groundwater were detected. In addition to that, toxicity and chemistry of heavy metals also increased in the groundwater.

All the samples were in desirable limit as prescribed for irrigation water standard. Water samples were collected by Ocheri Maxwell, (2010), from 26
rural community boreholes and analyzed for iron concentrations as it affects the quality of water for drinking. The values were compared with WHO drinking water standards for both rainy and dry seasons. Iron concentrations in the boreholes were noted to be higher in the rainy season than in the dry season. The source of iron in groundwater may be attributed to dissolution of iron minerals from rock and soils, corrosion effect of galvanized hand pump components and land use activities.

One of the major sources of groundwater contamination is the surface impoundments used by municipalities and industries, which disposes waste water without any treatment to the receiving bodies or used by farmers for agriculture purpose.

Tayyaba Aftab et al., (2011) studied the physico-chemical properties of irrigation Lahore Branch canal water in Pakistan, and reported higher values of turbidity and, concluded that it does not fit for drinking purpose. Verma, (2012) studied the physico-chemical characteristics of four canals of Allahabad region, and reported that all samples were in desirable limit and further concluded that it can be used for irrigation and drinking purpose.

2.2. Review of literature on trace metal analysis

Davis and Jacksnow (1975) studied the presence of heavy metals in wastewater in three urban areas. They have reported the occurrence of high concentration of several toxic elements in the domestic and municipal waste. They have also shown that continuous flow of these waste into the canal water may further
enhance the concentration of pollutants, which may be health hazard in those areas. Further the continuous sediment of different rivers was examined with respect to heavy metals. The sediments of Damodar and Hoogly exhibit significant amount of zinc. Moneva and Voinova (1976) described mercury pollution of water. A brief review of studies from different countries indicates that the Hg level in surface and groundwater has increased. The pollution arising from various mining, industrial and agricultural sources poses a definite threat to both human and animals, particularly fish and birds. Thus, control measures are necessary. Fytianos et al., (1986) investigated the distribution of heavy metals in several rivers and lakes of North Greece, samples of surface water were collected once a month from five rivers and five lakes over the period 1983-1984. River Axios has the highest metal concentration of Cd, Cu and Pb, Nestos river was comparatively less polluted than the others. The main pollutant, which flows into the Axios 1985 to January, 1986.

Israel, (1991) studied the occurrence of heavy metals in Ganga river water and sediments in various districts of Uttar Pradesh. He suggested that pollution in Saharanpur, Meerut, was caused due to the heavy inflow of untreated or inadequately treated municipal and industrial effluents due to increase in population and industrial development. The analytical results showed the presence of relatively high concentration of heavy metals in water and in sediment samples of these places. The heavy metal concentration was reported higher in sediments as compared to water. Sahota et al., (1996) found
mercury contamination of drinking water at Bathinda and Patiala. Kumar et al., (1997) observed drinking water of the central part of Jharia coalfield and observed high concentration of Cd, Pb, Fe, As and Se in drinking water. Singh et al., (1997) studied river Beas in Himachal Pradesh and found that manganese and iron fairly exceeding permissible limits of drinking standards. Nikumbh et al., (1998) assessed surface and groundwater samples of Pune area and observed high concentration of Pb, Hg. Cd and Ni in water. Rao et al., (1998) observed incidence of iron in groundwater in Delang block in coastal Orissa. Adelekani and Abegunde (2011) determined the concentrations of heavy metals, in soil and groundwater at automobile mechanic villages located in Ibadan. Soil and groundwater samples from 7 automobile mechanic villages and a control site in Ibadan, analysed for selected heavy metals namely: Cd, Cu, Pb, Cr and Ni. Soil samples were obtained in triplicates and at depths while water samples were obtained from dug wells at the sites. Compared to the limits set by WHO for drinking water, values measured in the groundwater samples were lower than those limits and the exception of Cu where all the values were higher than the limits. Cougar et al., (2011) studied heavy metal concentrations in ground water and the spatial difference between sampling stations can be attributed to the existence of faults and dioclases in the geologic structure of Miduk region which causes the groundwater sampling sites to be impressed by different contamination sources (toe seepage and upper seepage water originated from different zones of tailings dump).
Liu et al., (2011) assessed the impact of long-term electroplating industrial activities on heavy metal contamination in agricultural soils and potential health risks to local residents. Results Hazardous levels of Cu, Cr, and Ni were observed in water and paddy soils at sites near the plant. Water, paddy soil, and rice from the studied area have been contaminated by Cu, Cr, and Ni. Cu and also Ni are the key components contributing to the potential health risks. Wang et al., (2011) investigated in order to understand current metal contamination due to industrialization and urbanization in Xiamen, China. The data suggested that copper-rich suspended solids contributed substantially to copper accumulation by *M. iridescence* and played a critical role in the pathway of copper into the food chain. The conclusions of this investigation are likely to be applicable to other relevant scenarios. Chib et al., (2011) studied the spatial and temporal occurrence of heavy metals (Al, Cd, Pb, Zn, Cr, Co, Cu, Fe, Mn and Ni) in water and sediment samples was investigated in a sub-basin in the southeast of Brazil (São Carlos, SP). All samples were analysed using the USEPA adapted metal method and processed in an atomic absorption spectrophotometer. The source of contamination was probably diffuse, due to products such as batteries and fluorescent lamps, whose dump discharge can contaminate the bodies of water in the region during the rainy season. Akoteyon et al., (2011) examined groundwater contamination around municipal landfill site in Alimosho Local Government Area of Lagos State, Nigeria. The result showed that the mean concentrations of all measured parameters except Cr and Mn conform to the maximum permissible limits of
WHO standards for drinking water quality. We also suggest that there should be adequate maintenance and adherence to the world standard of landfill operation in order to safeguard the health of the populace. Dermats et al., (2012) investigated the potential contribution of geogenic chromium (Cr) to a contaminated aquifer of a heavily industrialized area in Greece. Many cases resulted in serious soil and groundwater contamination incidents. Preliminary results indicate that the Cr(VI) plume in the study area is likely caused by a combination of geogenic and anthropogenic sources. Ying et al., (2012) analysed, and ecological risks were evaluated according to the sediment quality guidelines. The results showed that the average concentrations of heavy metals in surface water were ranked as: As>Zn> Cu>Cr>Pb>Ni>Cd>Hg. The analysis of ecological risk assessment based on sediment quality guidelines suggested that heavy metals in most sediment from the Honghu Lake had moderate toxicity, with Cr being the highest priority pollutant. He et al., (2012) developed a DNA-based luminescence methodology for the rapid and sensitive detection of mercury (II) ions in real water samples. The results showed that the system could function effectively in real water samples under conditions of low turbidity and low metal ion concentrations. However, high turbidity and high metal ion concentrations increased the background signal and reduced the performance of this assay. Maxwell and Jonathan (2012) examined the concentration of lead, a toxic element in rural groundwater of Benue state. Lead concentrations in the boreholes were noted to be higher in the wet season when compared to that of the dry season. The possible cause of lead
concentrations in the study may be attributed to the increased use of chemical fertilizers on farms that find their way into groundwater sources being a rural environment. Okoro et al., (2012) analysed to assess the suitability of the water for human consumption and domestication purposes. The measured heavy metals concentrations exceeded the World Health Organization (WHO) standard guideline for potable water usage. The result reflects probable pollution from the industrial effluent which are often released into storm water runways without further treatment. Pearson correlation analysis was used to describe the data. Kataria, (1996) investigated total coliform count in the drinking water sources of Bhopal, Madhya Pradesh. Maximum probable number (MPN) in the study area exceeded the WHO limits at different sampling stations, as these were located in low lying areas. Higher values in summer and monsoon indicated a high degree of pollution. Studies by Norton and Lechevallier (1999) showed characteristic changes in bacterial population through potable water treatment and distribution. Therefore, it appears to be necessary to ensure that water treatment and distribution do not cause any shift in the composition of the bacterial population that would favour opportunistic pathogens. Human faecal material is considered to be a greater risk to human health as it is more likely to contain human enteric pathogens.

From the microbial counts like TC, FC and FS, it was evaluated that the Rivers and canals in Cuttack are grossly polluted, which carried high potency of microbes and reached the concentration levels to extremes during the summer season, making the water unsuitable even for bathing (Das, 2000).
A total of 143 groundwater samples was collected in five important hydrologic systems in the United States were analysed for microbiological indicators and found that land use was found to have the most significant effect on concentrations of bacterial indicators in stream water. Presence of septic systems near the sampling site and well depth were found to be related to detection of coil forms in groundwater, although these relationships were not statistically significant; Donna. S. Francy, (2004).

Afzal Shahzad et al., (2000) made analysis on groundwater surrounding Hudiara drain, India and Pakistan and observed high concentration of faecal count. Garg (2003) studied the water quality of well and bore well of 10 selected locations of Chitrakoot region and found high microbial count due to contamination and subsurface seepage of septic tanks. Obiri-Danso et al., (2003) showed that none of the microbial indicators of faecal contamination (TC and FC) were detected in bottled water.

The percentage of samples for testing positive for indicating bacteria may decrease after collection from highly contaminated sources because of die-off, as bacteria compete for limited oxygen and nutrients in the water (Momba and Notshe, 2003).

Some organisms, such as the coli phages, appear to be specific indicators for sewage because they are consistently isolated in large, but variable numbers from sewage. Frequent studies conducted; show the relations between
the presence of enteric viruses with the presence of coli phage or the fecal-indicator bacteria in groundwater supplies (Francy et al., 2004).

The flow independent nature of faecal indicator bacteria and *Escherichia coli* pages is consistent with the idea that these contaminants are ubiquitously present on the surface of the urban landscape and rapidly percolates into the surface water as the landscape is wetted by rainfall Surbeck, 2006.

From an experimental study it is revealed that poor quality of water may be attributed to the seepage of sewage carrying a lot of pathogens into the groundwater. By setting a treatment plant either at domestic level or on a large scale by municipality may control the presence of bacteria in the drinking water Ramani Vimala et al., 2006.

The investigation conducted by Senthil Kumar et al., (2006) on groundwater quality in Thanjavur city explained that the MPN index showed positive correlation with the nutrients. The drainage of domestic sewage in the well surround, stagnation of waste water around tube wells, broken & cracked platforms are accountable for high faecal contamination of groundwater.

Kassenga (2007) found 4.6% and 3.6% of total and faecal coliform bacteria in bottled water respectively.

Tyagi et al., (2006) stated that worldwide coliform bacteria are used as indicators of faecal contamination and hence the possible presence of disease causing organisms, therefore, it is important to understand the potential and limitations of these indicator organisms before realistically implementing the
guidelines and regulations to safeguard our water resources, public health and reveal the total spectrum of waterborne pathogens.

All wells near to Lake Erie were positive for both total coli form and *Escherichia coli*. Seven wells tested positive for *Enterococci* and *Arcobacter* (an emerging bacterial pathogen) and F+ specific coli phage was present in four wells (Linda, 2007).

Groundwater is contaminated in Kampala's peri-urban areas with high organic, thermo tolerant coli forms (median values as high as 126E3 cfu/100ml) and faecal Streptococci (154E3 cfu/100 ml). These include animal rearing, solid waste dumping, pit latrine construction and grey water or storm water disposal in unlined channels leading to increased localized microbial (faecal) and organic contamination during the rains (Kulabako *et al.*, 2007).

Shallow groundwater down to a depth of 16.2m at an average contained more biomass and cultivable microorganisms than deep groundwater. Biomass and sulphide concentration at 300m depth, suggest that anaerobic methane oxidation may be a significant process in depth in Olkiluoto (Karsten *et al.*, 2008).

Syed Hafizur (2009) considering the hypothesis “shallow tube-well water might be contaminated by microorganisms from a nearby open pit latrine”, litho-stratigraphy, physico-chemical properties along with microbial contamination level of shallow tube well water and socio-economic aspects related to sanitation of a rural village Gakulnagar in Bangladesh were
investigated. Values of all parameters were found within the tolerable limits, except coli form, in very few samples, where pit latrines were adjacent to the tube-well. Values of total coli form bacteria showed an inverse relationship with the distance between the tube-well and the pit latrine.

Drinking water quality of 359 deep and semi-deep wells have tested for microbial quality in Saqqez rural area, Iran and found there was no *E. coli* contamination in 88 per cent of drinking water. (Ghaderpoori, Mohammad Hadi Dehghani, 2009).

Elizabeth Ramirez (2010) from his observations concluded that water samples of well having coli form values were lower than the maximum permissible limit indicated in the Mexican Ecological Criteria of Water Quality. The concentrations of dissolved solids are increased in wells with lower altitudes. Here, the water is considered very hard; because of both carbonate and non-carbonate hardness was detected. The average values of physicochemical parameters were below the maximum permissible limits indicated in the Mexican official norm.

To assess the Quality of the island, groundwater samples were collected by Chin Yik Lin (2010) from five representative wells at the low lying area of Pulau Tiga in order to study the physico-chemical parameters. In general, groundwater in Pulau Tiga is moderate in conductivity and bacteriological analysis showed that the groundwater quality was poor, with faecal coli form counts exceeding the WHO permissible limits for drinking water. Coli form in
groundwater might be originated from sanitation facilities located too close to the wells.

Obasohan (2010) highlighted the historical perspective of the relationship between microbes and humans regarding the “ranging war” between them, arising from the reckless exploitation of the biosphere by humans and the resulting “revolt” by microbes in the form of various pathogenic diseases that now plague mankind.

An assessment was done on the microbiological quality of water in dug wells in urban communities in Kumasi, Ghana by Oyedeji (2010). A total of 256 water samples was taken from eight wells and examined for faecal coil forms, enterococci and helminths. High contamination levels were recorded in the wells, during the wet season. This study showed a stronger influence of poor sanitation and improper placement of wells on water quality compared to improvements made from lining and protection of wells.

According to the study of Muhammad Saeed Anwar, (2010) a total of 530 well water samples have collected from different localities of whole of the Lahore city, representing areas with different socio-economic conditions (SEC). Among 530 water samples, 197 samples (37.2%) were positive for bacterial contamination. It was observed that bacterial contamination was maximum in areas with low SEC (43.6%), followed by intermediate SEC (36.5%) and high SEC (22.9%). He concluded that bacterial contamination is severe in Lahore.
Various studies have been done to find out physico-chemical, biological and microbial parameters and the inter relationship to various water bodies in various parts of our country.


2.3. Review of literature on water quality index (WQI)

Groundwater quality in two well-developed cities of Haryana, viz. Hisar and Panipat was assessed for drinking purpose based on water quality parameters, with respect to different land-use areas viz., residential, industrial, commercial and agricultural areas. Water quality index based on 9 parameters showed that at Panipat, groundwater in all the land-use zones was fit for consumption (WQI < 50), whereas at Hisar, water in agricultural areas was good in quality, but that in other areas varied in magnitude of pollution (WQI > 50 to 100). (Kaushik, 2002).
Murali, (2005) concluded that the groundwater quality of different wards of Coimbatore east zone after examining various physico-chemical parameters. The water quality index (WQI), calculated for five parameters of these samples, ranged between 75 and 100. The results show that the water is suitable for domestic purposes.

Physico-chemical characteristics of boreholes of industrial areas of Visakhapatnam were monitored by Ramakrishna Rao, (2004). Water Quality Index calculated from ten physicochemical parameters taken together varied from 50.0 - 97.41. The water was not confirming to drinking standards and hence it is suggested to take all the necessary precautions before the waters are sent into public distribution system.

Yogendra, (2007) calculated Water Quality Index (WQI) of an urban water body, Gopishettykere, in Shimoga town Karnataka in order to ascertain the quality of water for public consumption. In this study, Water Quality Index was determined on the basis of various Physico–Chemical parameters and was categorized based on water quality rating scale, good to very poor.

This work is aimed to assessing the Water Quality Index (WQI) for the groundwater of K.R Puram industrial area in Bangalore and analyzed 30 groundwater samples in and around the industrial area. The WQI for these 30 samples ranges from 20.20 to 309.75 with an average value of 104.67. The high value of WQI at these stations has been found to be mainly from the
higher values of iron, nitrate, TDS, total hardness and fluorides in the groundwater Sankar (2008).

Bishnoi and Malik (2008) studied physico-chemical analysis of the groundwater at 41 different locations in Panipat city (Haryana), India to find suitability for domestic purposes.

The work Ramakrishnaiah, (2009) was aimed at assessing the Water Quality Index (WQI) for the groundwater of Tumkur taluk. For calculating the WQI, 12 parameters have been considered. The WQI for these samples ranges from 89.21 to 660.56. The high value of WQI has been found to be mainly from the higher values of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate and manganese in the groundwater. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption.

Rajankar, (2009) calculated Water Quality Index (WQI) for different groundwater sources i.e. dug wells bore wells and tube wells at Khaperkheda region, Maharashtra (India). Twenty two different sites were selected in post monsoon, winter and summer season. The calculated WQI showed a fair water quality rating in the post monsoon season which then changed to medium in summer and winter seasons for dug wells, but the bore wells and hand pumps showed medium water quality rating in all seasons where the quality was slightly differs in summer and winter season than post monsoon season.

Rizwan Reza (2010) assessed the water quality index (WQI) for the River water of Angul district of Orissa. The samples (n=12) were collected from
various locations of river Brahmani and its tributaries. The highest value of WQI of the samples was 89 in monsoon season while the lowest value was 50 in summer season. The lower value of WQI has been found mainly due to the higher values of BOD, Coliform and slightly lower value of DO in the river water during summer.

Anita Pius and Charmaine Jerome, (2010) concluded that Groundwater is an essential and vital component of our life support system. Groundwater samples from selected bore wells were analysed for important physico-chemical attributes and from the data obtained, the water quality index (WQI) was calculated. The WQI values ranged from 49.2 to 409.94. The Pearson correlation was performed to find the relationship between WQI and quality of life. It was observed that the correlation coefficient ‘r’ was -0.499(p<0.001).

The Water Quality Index (WQI) was calculated by Gunvant, (2010) for the assessment of groundwater quality near to the dye user industry. Various physicochemical parameters have been calculated in all the samples. In some of the parameters the concentration observed were found to be above the permissible limits of WHO. Drinking water was found to be severely contaminated at all the sites of study.

Sundar Kumar (2010) has estimated the groundwater quality of Rajam Mandal which is located on the east coast of Srikakulam District of Andhra Pradesh, India. More than 170 samples of the groundwater are collected
manually from the bore wells which were approximately equally distributed all over 31 villages of Rajam Mandal. The data base obtained from water quality testing is used as an attribute data base for preparation of thematic maps showing distribution of various water quality parameters and Water Quality Index. The spatio-temporal variation in water of Sabarmati River and Kharikat canal at Ahmadabad was studied by Rita Kumar, (2010). An assessment of various physico-chemical characteristics of water was carried for a period of 12 months. Statistical analysis among various physicochemical parameters and WQI has been carried out. Spatial and temporal variations were observed in river with increasing value of various parameters from upstream to downstream and relatively high pollution load at two sites of Kharicut canal. Physico–chemical analysis of open well and bore water samples was carried out from eight sampling sites of Guntur rural area for the month of February 2010 by Subba Rao, (1997). The analysis of different parameters was carried out as per standard methods. Water Quality index (WQI) in order to assess the suitability of water for drinking purposes. The results obtained on WQI from different sampling stations were found to be varied from 38.3 to 42.6.

Ashok Kumar Yadav (2010) assessed the hardness of groundwater in Todaraisingh tehsil of Tonk district of Rajasthan state. The study has been carried out to examine its suitability for drinking, irrigation and industrial purpose. The presence of problematic salts contained in groundwater due to local pollutants and affected the groundwater quality adversely. It was found that drinking water is severely polluted with hardness causing salts.
Rajendran (2011) collected water samples from 10 wells of selected places in and around Pulivalam, an area located about 35km away from the Rockford city, Tiruchirappalli has been assessed using the Heber Water Quality Index-1 (HWOI-I), a novel and indigenous statistical analysis. The total HWQI –I values, for all the samples were in the range of 40.5 to 53.5. These values suggest that almost all the water samples are bad in quality and unfit for drinking and domestic uses.

One hundred sachet water samples were randomly collected by Flora and Michael (2012). The pH was observed very high. The residual chlorine was not detected and according to them the faecal coliforms and *Escherichia coli* had the highest incidence.

From the above literature reviewed so far, no in depth study was encountered which can holistically addresses the water quality status from different sources in Bhimavaram. Hence, choosing of the problem as my doctoral topic on a crucial and life saving resource of Bhimavaram that too during the international decade for action ‘water for life’ is amply justified.