2. LITERATURE REVIEW

2.1 OVERVIEW

Water withdrawal statistics indicate that annual global water withdrawals have increased by more than six times and the rate of increase in developing countries is 8% [110]. Water is a very basic requirement for the well-being of human kind, vital for economic development and essential for the healthy functioning of all the world’s ecosystems. Reasons for limited availability of resources to use for people include: lack of distribution networks, excessive extraction of groundwater resource and risk from the contamination by the pollutants. Many freshwater resources have become increasingly polluted, resulting in the shrinking of freshwater availability.

In some places groundwater levels continue to fall and the options for increasing supplies have become costly and are often environmentally damaging [79]. Water conflicts are worsening around the world, rivers are drying up and pollution is unabated. The root cause of these problems is poor water governance, which has often been neglected in the past. Rapid urbanization and industrialization has resulted in the squeeze on freshwater supplies for agricultural uses and this necessitates reliable, alternative sources of supply. Consequently, the water crisis situation has engendered new directions for water governance and development and use of urban wastewater as an alternative source of supply.

2.1.1 Fresh Water Availability

Exponential growth of population, rapid industrialization, urbanization, higher cultivation intensities, and poor water management practices over the past century has made freshwater availability a limiting factor in agricultural development [199]. The options for increasing supply have become expensive and often environmentally damaging [79]. “The insufficiency of water is primarily driven by an inefficient supply of services rather than by water shortages. Lack of basic services is often because of mismanagement, corruption, lack of appropriate institutions, bureaucratic inertia and a shortage of new investments in building human capacity, as well as physical infrastructure”[250] water managers and policy makers around the world are compiled to continually look for alternatives to supplement limited and depleting freshwater resources. In such situations, ‘source substitution ’ appears to be the
solution as it allows higher quality water to be reserved for domestic supply and poor quality water may satisfy less critical uses. Urban wastewater (treated) is now considered as a reliable alternative water source without compromising public health and wastewater management is prominent in the water management agenda of many countries [17].

Following are the key points which needs to be considered for water sector [39]

- **Key drivers:** Demand-Supply gaps, Urbanization, Regulations
- **Opportunities:** Efficiency in water supply, reuse of waste water and energy from waste
- **Technical:** Challenges, Lack of raw water, Changing water use patterns, Lack of adequate availability of technical expertise
- **Financial Challenges:** Capital intensive, Tariffs are too low
- **Social Challenges:** Water is a state subject; Water is a highly political issue.

### 2.2 WATER SCENARIO IN STATE UNDERTAKEN FOR STUDY

The share of groundwater in the total supply is projected to decrease in future as large surface water schemes are commissioned, most notably the Sardar Sarovar-based Narmada Main Canal. The shortfall in urban areas is even more critical and requires substantial investment to develop new sources of water and strengthen the water supply distribution network. The demand for drinking water in the six municipal corporations is projected to outstrip the supply 986 mld, calling for an investment of Rs. 8609 million by 2010. Additional investments are also required to rehabilitate the existing distribution network. In Central Gujarat, water availability can be challenging in future, so to meet with water requirement option of reuse has to be explored.

#### 2.2.1 Water Conflicts

Severe water shortages have already led to growing more number of conflicts across the country. 90 per cent of India’s territory is drained by inter-state rivers. The conflict over the Cauvery river water between Karnataka and Tamil Nadu, the Godavari river conflict between Maharashtra and Karnataka and the Narmada water conflict between Madhya Pradesh and Gujarat are all ongoing conflicts. On the international front, India has clearly demarcated water rights with Pakistan through the Indus Waters Treaty [111].
Climate change projections show that India’s water problems are only likely to worsen. With more rain expected to fall in fewer days and the rapid melting of glaciers – especially in the western Himalayas – India will need to gear up to tackle the increasing incidence of both droughts and floods. There is clearly an urgent need for taking action for the observed situation of water. First, India needs a lot more water infrastructure. Compared to other semi-arid countries, India can store relatively small quantities of its fickle rainfall. Whereas, India’s dams can store only 200 cu.m. of water per person, other middle-income countries like China, South Africa, and Mexico can store about 1000 cu.m. per capita.

2.2.2 Wastewater Treatment And Reuse

To ensure sustainable and successful wastewater reuse applications, the following requirements must be fulfilled:

- The potential public health risk associated with reuse of wastewater are evaluated and minimized
- The specific water reuse applications meet the water quality objectives
- In order to meet the requirements, it is necessary to treat the wastewater prior to reuse applications
- Ensure an appropriate level of disinfection to control pathogens

Little work was done before the mid-1990s for the economics of reuse of wastewater in irrigation. [58] Analysis of the optimal treatment of municipal wastewater before its reuse for irrigation purpose was provided. [106] They determined monthly optimal treatment levels and of the mix crops calculated to maximize agricultural incomes, according to farmers’ point of view. Among the literature on IWRM the conceptual approaches to wastewater management with focus on the reuse of wastewater are represented by Harremoes(1997), Huibers and van Lier (2005), Nhapi, Siebel and Gijzen (2005), van Lier and Huibers (2007), Neubert (2009) and Guest et al. (2009).

2.2.3 A Reliable Source Of Water - Urban Wastewater

The agricultural activity is the largest consumer of freshwater resources, currently accounting for about 70% water withdrawals globally and over 90% in the developing world [255]. With increasing population, urbanization, rapid industrial development, the availability of freshwater is likely to be one of the major limits to economic development in the decades to come. It is expected that water now used for agriculture will be diverted to the urban and industrial sectors. So there is a need to
find a reliable new source of supply that can augment the freshwater supplies and reduce the pressure on existing resources. The use of wastewater also helps to close the loop between water supply and wastewater disposal [1]. Wastewater use for non-potable purposes particularly for irrigation is a centuries-old practice. [68]. In many developing countries wastewater (untreated) is a highly important productive resource and is a substantial and sometimes even primary source of income for thousands of small farmers [218]. The reasons for this include: increasing water scarcity, lack of funds for treatment and clear willingness by farmers to use untreated wastewater [68]. Among the different applications of wastewater, it is believed that the agricultural activity/irrigation is the best use of wastewater after treatment [188] and the presence of crop nutrients in wastewater benefits crop production [68]. Urban wastewater reuse experiments around the world have demonstrated the feasibility of water reuse on a large scale and its role in the sustainable management of the world’s total water [14].

2.3 HISTORY OF WASTEWATER REUSE
The ancient practice of applying wastewater containing human excreta to the land has maintained soil fertility in many countries of Eastern Asia and the Western Pacific for over 4,000 years and remains the only agricultural use option in areas without sewerage facilities [258]. Europe has examples of rainwater reuse since the Minoan time, ca. 3,000-1,100 B.C [15]. Reuse of waste water has been practiced since the Ancient Greek and Roman civilizations. Land application of wastewater is an old and common practice, which has gone through different development stages with time, knowledge of the processes, treatment technology and regulations evolution. Wastewater has also been used by the Mediterranean civilizations[15], like in the 14th and 15th centuries in the Milanese Marcites and in the Vlencia huerta and the North European ones, like in Great Britain, Germany, France, and Poland[229]. The systems have been widely employed in the treatment/disposal of municipal wastewater since 1850 (Folsom, 1876). As urban areas began to encroach on sewage farms and the scientific basis of disease became more widely understood, concern about possible health risks associated with the use of wastewater for irrigation increased among public health officials. This led to the establishment of controls on the use of wastewater for agricultural irrigation, which was the first reclaimed water application to be regulated. The first standards adopted by the Californian State Board of Health
in 1918, entitled Regulation Governing Use of Sewage for the Irrigation Practices, prohibited the use of raw sewage for crop irrigation and limited the use of treated effluents to irrigation of nonfood crops and food crops that were cooked before being eaten or did not come in direct contact with the wastewater. [45] California further modified their water reuse legislation seven times up to year 2000. Nightsoil has been used to fertilize the crops and replenish depleted soil nutrients since the ancient times in China and in other areas of Asia. With industrialization and subsequent water carriage sewerage system, interest and effort in wastewater utilization through farming and land application grew.

2.3.1 Key Issues Related To Use Of Wastewater

Wastewater has high potential for reuse in agriculture; an opportunity for increasing food and environmental security, avoiding direct pollution of rivers, canals, surface water; conserving water and nutrients, thereby reducing the need for chemical fertilizer and disposing of municipal wastewater in a low-cost, sanitary way. Wastewater use poses a number of health and environmental risks for the users and communities in prolonged contact with wastewater; for consumers of such produce, neighboring populations due to contamination of groundwater and creation of habitats for mosquitoes and other disease vectors. Important health risks include the transmission of intestinal infections to workers of agricultural activity in wastewater-irrigated fields and to consumers of waste-water irrigated produced due to worms and the transmission of faecal bacterial diseases, like diarrhea, dysentery, typhoid and cholera. The key issues pertaining to the treatment, use, application and impact of wastewater are dovetailed with livelihoods, health, environment and policy concerns. It is important to look at mitigating the negative impacts on the beneficiaries of wastewater use and link up use with sustainable livelihoods outcome.

2.4 FACTORS TO BE ADDRESSED FOR REUSE OF WASTE WATER

Following are the important factors related to implement successful reuse of wastewater.

2.4.1 Water Governance Directions

Water governance is a significant aspect of the international development policy making. The United Nations World Water Development Report-2 [250] recognizes that water crisis is largely a crisis of governance, outlines many of the leading
obstacles to sound and sustainable water management. There is an increasing consensus on the need to improve water governance so as to achieve the Millennium Development Goals [125]. So, good governance which often receives less attention than it merits is an essential aspect of effective water resource management [31]. The situation demands a change or shift in water governance – the process of managing water resources. It [87] describes this shift or change as ‘the changing water paradigm’. Some aspects of theory of governance are that, concerned not only with the State but also with relationships between the State and civil society and its private sectors. It was said that “governance embraces the relationship between a society and its government” [206]. The Dublin Water Principles (1992), through its participation clause, states that water development and management should be based on a participatory approach, involving users, planners, the community, policy-makers at all levels. The same notion is stressed in the Hague Ministerial Declaration (1998), and the Bonn Ministerial Declaration (2001).

2.4.2 Institutional Challenges

Wastewater collection, treatment and effluent use normally encompass a large range of interests at different levels of administration. So the scope and success of any reuse scheme will depend to a large extent on the institutional organization [188]. In any natural resource management regime, coordination complexity results in problems, due to the varying roles and responsibilities and overlapping concerns among the public agencies managing the resources [154]. Previous studies related to wastewater use [17, 18] have identified similar conflicting agendas among water agencies: addressing water rights issues; dealing with opponents to recycling or reuse; modifying existing regulations; acquiring funding, are the institutional challenges facing successful development of this dependable resource.

2.4.3 Public Perceptions And Acceptance

For successful implementation of reuse schemes, public acceptance is a very important [17,18]parameter that tendency of people to be motivated by a set of long-term goals, but to act in the short term towards those things that they control, is what affects wastewater reuse projects. Failure to gain public acceptance has led to vocal opposition, at times, has resulted in schemes being stalled. Public concerns about real or perceived risks are weighted against the use of reclaimed water [205]. The following factors influence community’s acceptance of the reuse scheme [189]:
Disgust or ‘yuck’ factor
- The perception of risks associated with using recycled water
- The specific uses, cost of recycled water
- The sources of water to be recycled,
- Issues of choice
- Trust and knowledge
- Attitudes toward environment
- Socio-demographic factors

If wastewater resources are to become an integral component of water and waste management policies, the acceptance of reclaimed water must be comprehensively tackled; this is more critical if the application is for potable uses.

### 2.4.4 Community Participation

Wastewater reuse history is marked with the failure of reuse schemes mainly because of lack of community involvement [189]. “Working with a community that does not have wastewater as a highest priority requires building participation through a combination of discussions about community outcomes, more detailed action steps of technology identification, design work, and management”. [136].

The lack of community participation results in a wide gap between what is desired from wastewater reuse and what is necessary to get there, inability to bridge this gap is the primary reason for failure of locally driven wastewater projects. Since it is public, who will be served by and pay for them, the policies on wastewater use and management must include the human dimension [205]. For a reuse scheme to be sustainable, community involvement and/or participation are very important. Asano[17, 18] suggests that waste water reuse project(s) should be built upon three principles:
- Providing reliable treatment of wastewater to meet strict water quality requirements
- Protecting the public health
- Gaining public acceptance.

### 2.4.5 Market Imbalance

The best application for the use of wastewater after treatment is in agriculture [188] and use of this water for agriculture purposes can relieve a great deal of pressure on fresh water resources. This implies that the largest market for reclaimed water is in
the agriculture sector. Although there is a market for this valuable resource, it is imbalanced, as is explained by [7]: “The market for reusable water is unbalanced and it is due to a growth on the supply side of the market, revealed by increasing number of wastewater treatment plants and stagnancy on the demand side revealed by the substantial proportions of resource being discharged without proper utilization”.

2.4.6 Financial Feasibility And Technicality

Financing a reuse scheme is a challenge because acquiring funds to develop water reuse scheme is an onerous task. “More often than is usually believed, individually rational behavior is compatible with the socially desirable outcomes” [246]. Therefore, public perceptions and acceptance of wastewater, community participation and willingness to pay are all interlinked. Willingness to pay for reclaimed water is also influenced by the tariff structure, which should be such that community being served should perceive it to be appropriate, as well as taking into account the long term viability of the service provider. Sound technicality is another factor to be considered while implementing reuse projects. This is important because the effluent should be treated to a quality acceptable to the end user and matched to particular application.

2.4.7 Economics Of Water Reuse

Reuse projects initiated by the private sector are often driven by need for water or a perceived marketing edge. Projects initiated by the wastewater utility are often driven by a need to meet reuse target and to avoid water based disposal as per Environmental Protection Authority (EPA) guidelines. The client base must be developed by the wastewater utility. This has led to a number of reuse projects where reuse water was priced at a considerably lower level than the potable water. One of the potential outcomes of this type of pricing strategy is the over-use of reuse water. In a first best world, whenever prices are set at less than full cost, efficiency considerations dictate that the rationale for doing this needs to be revealed and a process for returning to full cost pricing needs to be put in its place. [238]

2.4.8 Global Trends Open Up New Investment Opportunities

Adequate water quality supply and insufficient quantities is one of the major challenges facing the modern society. In many countries the available water reserves are now being over exploited to such an extent that the negative consequences can no
longer be ignored. The situation will become even more critical in years ahead. Demand for water is increasing to an extent that it would not be available for basic requirements of individuals. Major investments will therefore be required in the short term to upgrade ageing water mains and sewer systems in particular, higher standards for water quality. Solution also needs to be found out to meet the fresh challenges arising from new micro pollutants that are becoming a problem in industrialized countries. Climate change will cause significant variations in the hydrological regime in many regions, culminating in the water crisis in some areas. These mega trends will intensify the pressure to manage existing water resources far more efficiently in the years ahead. This situation opens up attractive opportunities to all businesses offering products and services for the treatment, supply or use of water. [216]

2.4.9 **Reuse Of Waste Water: Impact On Water Supply Planning**

A procedure for analyzing water reuse alternatives has been prescribed [84] within a framework of regional water supply and waste water disposal planning and management by modeling. He also suggested that planners should address the question of when and in what context waste water should be upgraded for reuse as additional sources of supply. Water from several origins or categories of supply can be allocated to satisfy the demand of various water using sectors or destinations the concepts of water reuse, fits closely the format of the transportation or trans-shipment problem from linear programming as applied by Bishop and Hendricks (1971) to evaluate water reuse potential within the framework of water supply availabilities and water demands of a region and waste water management considerations. A waste treatment plant may be the destination of municipal effluent, while at the same time it becomes an origin for treated waste water available for reuse purpose. Optimal (least cost) solutions can be generated which contain following information:

- Allocation from primary water supply sources to satisfy user demands
- Operating levels for water treatment plants for municipal supplies
- Capacity levels for the use of waste water treatment plants
- Capacity timing reuse of waste water
- Specific reuse made of effluent supplies

2.4.10 **Key Objectives For Water Reuse Concepts**

Scientists working [62] closely on the issues of water reuse are far from having solved all concerns related to the practice. From Decision Support Systems to the simplest
analytical tools, all knowledge is valuable. Detailed studies must be undertaken to identify necessary technologies, schemes, control tools. As public health concerns are normally among the main constraints for reuse any scenario will need to include detailed risk assessments. Once the basic calculations were performed, after that a final decision whether the scheme can be implemented should be based on three phases of risk assessment; analysis, calculation and communication. This will allow fulfilling the key objectives of reuse of waste water: increasing the amount of water resources available, under an acceptable risk with a public full knowledge. Although wastewater reclamation and reuse has gained approval as a necessary tool to be included in sustainable integrated water resources management, there are still several key points to be developed for safe use of the resource. Among the most important items to be developed by adequate research and development (R&D), the risk approach appears to be paramount at present for several reasons

- It could finish the old controversy on restrictive or not so restrictive standards
- It can allow qualifying a reclamation treatment depending on quality of water obtained
- It is a good tool to define the acceptable risk for a given society with its particular conditions

2.4.11 Factors Responsible For Reuse Of Municipal Waste Water

Reuse of municipal wastewater reuse was "inadvertent reuse" or the unplanned addition of the wastewater to water supply. Due to the vastness of knowledge and communications in modern societies, this inadvertent reuse is seldom the case. In modern societies almost all reuse is planned and takes the form of either "indirect reuse" or "direct reuse." Throughout the past two decades the United States and much of the world have witnessed a growing awareness of the concept of water reuse. Baumann and Dworkin (1975) attribute the awareness to four factors which has taken place in the recent history as below:

- The increasing urbanization and industrialization which have resulted in a scarcity of freshwater in many areas
- More and more communities have been forced to turn to polluted sources to meet their need of water supply (i.e., indirect reuse)
- The cost of wastewater disposal has been growing as a result of the desire to limit the amount of pollutants released into our nation's existing water sources
Technological developments in advanced wastewater treatment have lowered the actual costs of treating water.

2.4.12 Environmental Assessment Of Urban Wastewater Reuse: Treatment Alternatives And Applications
The main function of a Wastewater Treatment Plant is to minimize the environmental impact of discharging untreated water into natural water systems. [162]. Wastewater Treatment Plant may get a resource from wastewater carrying out a tertiary treatment on the treated wastewater which can be reused in non-potable applications. Water reuse strategies are intended to address problem of water scarcity without aggravating other environmental problems, thus reflecting the need of their environmental assessment. Comparison of environmental impact was done of producing 1 m$^3$ of water for non-potable uses from reclaimed water, potable water and desalinated water sources. The calculation has used the current operating data from a Wastewater Treatment Plant located in the Mediterranean area, although the results can be applied to any other plant with similar technology. The ozonation and ozonation plus hydrogen peroxide disinfection treatment technologies have similar environmental profiles. Most of the indicators are about 50% higher than the ultraviolet disinfection, except for the acidification (100% higher) and photochemical oxidation (less than 5%). Non-potable uses (both agricultural and urban uses) of reclaimed water have environmental and economic advantages.

2.4.13 Quality Issues Of Wastewater Reuse
Despite a long history of wastewater reuse in many parts of the world, the question of safety of wastewater reuse still remains an enigma mainly because of the quality of reuse water. Public health concern is the major issue in any type of reuse of wastewater, be it for irrigation or non-irrigation utilization, especially long term impact of reuse practices. It is difficult to delineate acceptable health risks and is a matter that is still hotly debated. Adequate treatment schemes must always be designed to eliminate, or at least minimize the potential risks of disease transmission. Consideration of hydro-geologic conditions helps to compare the reuse water quality and the quality of alternative sources intended for the same kind of use.

2.4.13.1 Pathogen Survival
Public health concerns center around pathogenic organisms that are or could be present in wastewater in great variety. Survival of pathogens in wastewater and in environmental conditions other than their host organisms (mainly humans) is
highly variable. Other water quality parameters of concern in wastewater reuse have been toxic metal accumulation and salinity of wastewater. The availability of heavy metals to plants, their uptake and their accumulation depend on a number of soil, plant and other factors. The soil factors include, soil pH, organic matter content, cation exchange capacity, moisture, temperature and evaporation.

Table 2.1 Survival Of Pathogens

<table>
<thead>
<tr>
<th>Type of Pathogen</th>
<th>Survival time in days</th>
<th>In feces and sludge</th>
<th>In sewage and freshwater</th>
<th>In soil</th>
<th>On crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Viruses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enteroviruses</td>
<td>&lt;100 (&lt;20)</td>
<td>&lt;120 (&lt;50)</td>
<td>&lt;100 (&lt;30)</td>
<td>&lt;60 (&lt;15)</td>
<td></td>
</tr>
<tr>
<td>2. Bacteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fecal coliforms</td>
<td>&lt;90 (&lt;50)</td>
<td>&lt;60 (&lt;30)</td>
<td>&lt;70 (&lt;20)</td>
<td>&lt;30 (&lt;15)</td>
<td></td>
</tr>
<tr>
<td>Salmonella spp.</td>
<td>&lt;60 (&lt;30)</td>
<td>&lt;60 (&lt;30)</td>
<td>&lt;70 (&lt;20)</td>
<td>&lt;30 (&lt;15)</td>
<td></td>
</tr>
<tr>
<td>Shigella spp. Vibrio</td>
<td>&lt;30 (&lt;10)</td>
<td>&lt;30 (&lt;10)</td>
<td>&lt;30 (&lt;10)</td>
<td>&lt;10 (&lt;5)</td>
<td></td>
</tr>
<tr>
<td>Cholerae</td>
<td>&lt;30 (&lt;5)</td>
<td>&lt;30 (&lt;10)</td>
<td>&lt;20 (&lt;10)</td>
<td>&lt;5 (&lt;2)</td>
<td></td>
</tr>
<tr>
<td>3. Protozoa</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entamoeba-hystolyticaCysts</td>
<td>&lt;30 (&lt;15)</td>
<td>&lt;30 (&lt;15)</td>
<td>&lt;20 (&lt;10)</td>
<td>&lt;10 (&lt;2)</td>
<td></td>
</tr>
<tr>
<td>4. Helminths</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ascaris-lumbricoides Eggs</td>
<td>many months</td>
<td>many months</td>
<td>many months</td>
<td>&lt;60 (&lt;30)</td>
<td></td>
</tr>
</tbody>
</table>

(Note: Figures in bracket shows the normal survival time)

2.4.13.2 Effluent Quality Standards
Considering the wide-ranging potential for wastewater reuse, it may be difficult to set some common quality standards for all types of reuses. For many countries in Europe, either the guidelines of World Health Organization (WHO) or the US Environmental Protection Agency (USEPA) standards form the basis for any decision or for granting permission to any kind of reuse. Standards or guidelines for other possible reuses such as groundwater recharge, industrial uses etc., are not common, mainly because such types of reuses are not widespread. First water quality criteria for reuse of wastewater in irrigation were set in 1933, by the California State Health Department. These standards are for microbiological parameters that indicate the presence of pathogenic organisms in wastewater.
### Table 2.2 The 1989 WHO Guidelines For The Use Of Treated Wastewater In Agriculture
(Source: Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture)

<table>
<thead>
<tr>
<th>Category</th>
<th>Reuse Conditions</th>
<th>Exposed group</th>
<th>Intestinal nematode (arithmetic mean no. eggs per litre)</th>
<th>Faecal coliforms (geometric mean no. per 100ml)</th>
<th>Wastewater treatment expected to achieve the required microbiological guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Irrigation of crops likely to be eaten uncooked, sports fields, public parks</td>
<td>Workers, Consumers, public</td>
<td>&lt;=1</td>
<td>&lt;= 1000</td>
<td>A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment</td>
</tr>
<tr>
<td>B</td>
<td>Irrigation of cereal crops, industrial crops, fodder crops, pasture and treese</td>
<td>Workers</td>
<td>&lt;=1</td>
<td>No standard recommended</td>
<td>Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal</td>
</tr>
<tr>
<td>C</td>
<td>Localized irrigation of crops in category B if exposure to workers and the public does not occur</td>
<td>None</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Pretreatment as required by irrigation technology, but not less than primary sedimentation</td>
</tr>
</tbody>
</table>

(Note: Arithmetic mean no. of eggs, per 100 ml Geometric mean no. per 100 ml ,In case of fruit trees, irrigation should cease 2 weeks before fruit is picked)

#### 2.4.14 Quality Parameters Of Importance In Agricultural Use Of Wastewater
Following are the quality parameters to be considered for reuse of waste water. [210]

**2.4.14.1 Parameters of health significance**
Organic chemicals usually exist in municipal wastewaters at very low concentrations and ingestion over prolonged periods would be necessary to produce detrimental effects on human health. The principal health hazards associated with the chemical constituents of wastewaters, therefore, arise from the contamination of crops or ground waters. Hillman (1988) has drawn attention to the particular concern attached to the cumulative poisons, principally heavy metals, and carcinogens, mainly organic chemicals. World Health Organization guidelines for drinking water quality (WHO
1984) include limit values for the organic and toxic substances based on acceptable daily intakes (ADI). [226]

Pathogenic organisms give rise to the greatest health concern in agricultural use of wastewaters, yet few epidemiological studies have established definitive adverse health impacts attributable to the practice. Shuval et al. (1985) reported on one of the earliest evidences connecting agricultural wastewater reuse with the occurrence of disease. It would appear that in areas of the world where helminthic diseases caused by Ascaris and Trichuris spp. are endemic in the population and where raw untreated sewage is used to irrigate salad crops and/or vegetables eaten uncooked, transmission of these infections is likely to occur through the consumption of such crops. Indian studies, reported by Shuval et al. (1986), have shown that sewage farm workers exposed to raw wastewater in areas where Ancylostoma (hookworm) and Ascaris (nematode) infections are endemic have significantly excess levels of infection with these two parasites compared with other agricultural workers in similar occupations. In respect of the health impact of use of wastewater in agriculture, Shuval et al. (1986) rank pathogenic agents in the order of priority.

Table 2.3 Relative Health Impact Of Pathogenic Agents
(Source: Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture)

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Pathogenic Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Risk (high incidence of excess infection)</td>
<td>Helminths (Ancylostome, Ascaris, Trichuris and Taenia)</td>
</tr>
<tr>
<td>Medium Risk (low incidence of excess infection)</td>
<td>Enteric Bacteria (Cholera vibrio, Salmonella typhosa, Shigella and possibly others)</td>
</tr>
<tr>
<td>Low Risk (low incidence of excess infection)</td>
<td>Enteric Viruses</td>
</tr>
</tbody>
</table>

2.5 TREATMENTS OF DOMESTIC WASTE WATER

Sewage can be treated close to where it is created by centralized system. A decentralized system like septic tanks, bio filters or aerobic treatment systems can be collected to municipal treatment plant. Sewage collection and treatment is typically subject to local, state and federal regulations and standards. Industrial sources of sewage often require specialized treatment processes (see Industrial wastewater treatment). Sewage treatment generally involves total three stages, called primary, secondary and tertiary treatment [163].

- **Primary treatment** consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter
solids float on the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.

- **Secondary treatment** removes the dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.

- **Tertiary treatment** is sometimes defined as anything more than primary and secondary treatment in order to allow the rejection into a highly sensitive or fragile ecosystem (estuaries, low-flow rivers, coral reefs) Treated water is sometimes disinfected chemically or physically (for example, by lagoons and microfiltration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

### 2.5.1 Disinfection

The purpose of disinfection in the treatment of waste water is to substantially reduce the number of microorganisms in the water to be discharged and back into the environment for the later use of drinking, bathing, irrigation, etc. The effectiveness of disinfection depends on the quality of the water being treated (e.g., cloudiness, pH, etc.), the type of disinfection being used, the disinfectant dosage (concentration and time) and the other environmental variables. Cloudy water will be treated less successfully, since solid matter can shield organisms, especially from ultraviolet light or if contact times are low. Generally, short contact times, low doses and high flows all militate against effective disinfection. Common methods of disinfection include ozone, chlorine, ultraviolet light, sodium hypochlorite. Chloramine, which is used for drinking water and it’s not used in the treatment of waste water, because of its persistence EPA, Washington (2004).

**Chlorination** is the most common method for disinfection. One disadvantage is that the chlorination of residual organic material can generate chlorinated-organic compounds that may be carcinogenic or harmful to the environment. Residual chlorine or chloramines may also be capable of chlorinating organic material in the natural aquatic environment. Because residual chlorine is toxic to aquatic species, the
treated effluent must also be chemically dechlorinated, adding to the complexity and cost of treatment.

**Ultraviolet (UV)** light can be used instead of chlorine, iodine, or other chemicals. Because no chemicals are used, treated water has no adverse effect on organisms that later consume it, as may be the case with other methods. UV radiation causes damage to the genetic structure of bacteria, viruses, and other pathogens, making them incapable of reproduction. The key disadvantages of the UV disinfection are the need for frequent lamp maintenance and replacement and the need for a highly treated effluent to ensure that the target microorganisms are not shielded from the UV radiation (i.e., any solids present in the treated effluent may protect microorganisms from the UV light). In the United Kingdom, UV light is becoming most common means of disinfection because of the concerns about the impacts of chlorine in chlorinating residual organics in the wastewater and in chlorinating organics in the receiving water. Some sewage treatment systems in Canada and the US also use UV light for their effluent water disinfection.

**Ozone (O₃)** is generated by passing oxygen (O₂) through a high voltage potential resulting in a third oxygen atom becoming attached and forming O₃. Ozone is very unstable and reactive and oxidizes most organic material it comes in contact with, thereby destroying many pathogenic microorganisms. Ozone is considered to be safer than chlorine because, unlike chlorine which has to be stored on site (highly poisonous in the event of an accidental release), ozone is generated onsite as needed. Ozonation also produces the fewer disinfection by-products than chlorination. A disadvantage of ozone disinfection is the high cost of the ozone generation equipment and the requirements for special operators.
2.5.2 A Review of Wastewater Treatment By Reverse Osmosis

Figure 2.1 Reverse Osmosis Membrane

Since the development of first practical cellulose acetate membranes in the early 1960's and the subsequent development of thin-film, composite membranes, the uses of reverse osmosis have expanded to include not only the traditional desalination process but also a wide variety of the Wastewater treatment applications. Several advantages of the RO process that make it particularly attractive for dilute aqueous wastewater treatment include: [40]

- RO systems are simple to design and operate, they have low maintenance requirements, and are modular in nature, making expansion of the systems easy
- both inorganic and organic pollutants can be removed simultaneously by the RO membrane processes.

Figure 2.2 Process Of Treatment Inside Membrane
(Source: Hydranautics Design Software version 2012)
• RO systems allow recovery/recycle of waste process streams with no effect on the material being recovered
• RO membrane systems often require less energy, offer lower capital and operating costs than many conventional treatment systems
• RO processes can considerably reduce the volume of waste streams so that these can be treated more efficiently and cost effectively by other processes such as incineration

RO systems can be replaced or used in conjunction with others treatment processes such as oxidation, adsorption, stripping, or biological treatment to produce high quality product water that can be reused or discharged. Applications that have been reported for RO processes include treatment of organic matter containing wastewater, wastewater from electroplating, metal finishing, pulp and paper, mining, petrochemical, textile, food processing industries, radioactive wastewater, municipal wastewater, and contaminated groundwater [28].

Figure 2.3 Layers Of Membrane
(Source: Hydranautics Design Software version 2012)

They [228] have compiled separation and flux data of cellulose acetate membranes for a large number of the organic compounds, including many organic pollutants. They found that organic separation can vary widely (from <0% to 100%) depending on the characteristics of the organic (polarity, size, charge, etc.) and operating conditions (such as feed pH, operating pressure, etc.). It was, [14] reported that some of the factors influencing separation of the several different organics (including acetone, urea, phenol 2, 4-dichlorophenol, nitrobenzene) by cellulose acetate membranes. Rejections varied considerably for the different solutes, and rejections of ionizable organics were greatly dependent on degree of dissociation; non ionized and hydrophobic solutes were found to be strongly sorbed by the membranes and exhibited poor rejection. Duvel and Helfgott (1975) found organic separations varied
with molecular size and branching; they postulated organic separation was also a function of the solute's potential to form hydrogen bonds with the membrane.

2.5.3 Low Fouling Technology

The first technological advancement came in the late part of 1998, with the introduction of the Low Fouling Composite (LFC) membrane. This membrane is characterized with the same or better flux rate of most composite membranes and also with a higher or equivalent salt rejection. This membrane is primarily suited for the treatment of difficult feed waters, municipal wastewater and other unique feed water, which up to now required significant pretreatment prior to subjecting them to any composite RO membrane. When treating surface water or municipal effluents, RO membranes, even with conventional pretreatment, foul very readily. This phenomenon is generally characterized by the formation of a dense layer on the membrane surface, comprising of an excess layer of dissolved organics and suspended organic matter near the membrane surface. The rate of fouling matter converges on it is directly proportional to the permeate flux. The rate of formation of a fouling layer and its bondage to the membrane surface depends, in addition to the flux rate, on the affinity of the membrane surface to the dissolved organic matter. Composite RO membranes, using the aromatic polyamide polymer, are strongly hydrophobic. Therefore, they are prone to high fouling rates and significant reduction in permeate flux, during the treatment of feed waters containing high concentration of organic matter. To significantly reduce fouling tendency, an LFC membrane was developed. The LFC is characterized by a low surface charge and a hydrophilic membrane surface characteristic [122].
The surface charge of the LFC membrane is significantly less negative (more neutral) as compared to the surface charge of conventional composite membranes. This characteristic can be directly translated to the affinity of the LFC membrane to dissolved organic constituents.

When subjected to a wide range of surfactants, the LFC retained its flux significantly better than conventional RO membranes. To confirm this observation, the LFC membrane was operated opposite a conventional low pressure composite polyamide membrane. Both membranes were subjected to municipal effluents treated by ultrafiltration capillary membrane technology at Water Factory 21, CA.
The specific flux of the LFC is lower than the specific flux of the low pressure RO membrane; therefore the initial feed pressure was about 90 psi, which is slightly higher than the initial pressure of the low pressure membrane at similar operating conditions. The low pressure membrane permeate flux decreased very rapidly, almost doubling, within the first 2000 hours of operation. The feed pressure had to be increased from approximately 70 psi to more than 160 psi, to maintain a constant permeate flux of 10 gfd. The LFC membrane, on the other hand, operating at an even higher permeate flux rate of 12 gfd remained very stable at a level of 90-100 psi for the duration of the operating period.

2.6 LFC MEMBRANE EXPOSURE TO SURFACTANTS

Conventional membrane results point to the fact that the LFC membrane experienced little to no fouling when operated on municipal effluents, which are generally considered problematic for conventional RO membranes. The LFC membrane was not cleaned, during the 8 month operating period, due to the phenomenal performance stability. After the completion of field test, The LFC’s resistivity to fouling was confirmed by testing the performance of the elements at standard test conditions. The results, depicted in table below, indicate that after 8 months of operation without any cleaning, the average flux decline was only about 10%-20% as compared to the ex-

Figure 2.6 The Operation Of Both Membrane Types With Respect To Feed Pressure And Temperature V/S Time
(Source: New Membrane Research and Development Achievements)
factory test data. After flushing the LFC membrane elements with a high PH cleaning solution, the permeate flux was restored completely, back to the original ex-factory values. The effective restoration of the permeate flux indicates a weak bonding effect between the dissolved organic matter and the membrane surface, a characteristic of hydrophilic surface character.

**Table 2.4 Performance Change Of 4 Inch LFC On UF Treated Municipal Effluent**

<table>
<thead>
<tr>
<th></th>
<th>Flux, gfd</th>
<th>Flux, m3/d</th>
<th>Rejection, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex-Factory</td>
<td>2082</td>
<td>7.88</td>
<td>99.6</td>
</tr>
<tr>
<td>After cleaning operation</td>
<td>1578</td>
<td>5.97</td>
<td>99.6</td>
</tr>
<tr>
<td>After cleaning</td>
<td>1708</td>
<td>6.46</td>
<td>99.2</td>
</tr>
</tbody>
</table>

The following are the extraordinary benefits realized with the use of either technology as compared to conventional pretreatment:

- Significantly better Filtrate Quality — through the use of ultrafiltration membrane technology with respect to membrane chemistry and module design, the quality of the filtrate achieved is significantly better as compared to conventional pretreatment.

- Increased efficiency of RO system design and membrane operation. RO membrane operation is dependent on the quality of the filtrate produced by the pretreatment system. The better the filtrate quality from the pretreatment, the better the RO membranes will operate.

2.6.1 **Sewage Treatment In Developing Countries**

In many developing countries the bulk of domestic and industrial wastewater is discharged without any treatment or after primary treatment only. In Latin America about 15% of collected wastewater passes through treatment plants (with varying levels of actual treatment). In Venezuela, a below average country in South America with respect to wastewater treatment, 97 percent of the country’s sewage is discharged raw directly into the environment. In a relatively developed Middle Eastern country such as Iran, the majority of Tehran's population has totally untreated sewage injected to the city’s groundwater [Haughey, A. (1968)]. The construction of major parts of the sewage system, collection and treatment, in Tehran is almost complete, and under development, due to be fully completed by the end of 2012. In Isfahan, Iran's third largest city, sewage treatment was started more than 100 years ago. In Israel, about 50 percent of agricultural water usage is provided through the reclaimed sewer water [58].
2.7 DEVELOPMENT OF ANALYSIS TOOLS FOR SOCIAL, ECONOMIC AND ECOLOGICAL EFFECTS OF WATER

A decisive factor to achieve a higher percentage of the water reuse is the establishment of effective incentives, which in many instances will be of either an economic or a regulatory nature. The limiting factor for the water reuse can in many circumstances be the quality of the water available linked to the treatment processes (technology) and potential hazards for secondary users. Its economic viability needs a careful cost-benefit analysis for various parties involved to be carried out. However, some water reuse implementation projects have failed because some other key factors, such as social awareness or associated ecological effects, were not accounted [264].

2.7.1 General Modeling Strategy

The formulations of modeling aspects are inspired by work done [205]. In overview, the modeling of any system occurs in five distinct steps (Murthy et al., 1990). Steps are to delineate the system being modeled as a functional specification. A quantitative understanding of the structure and parameters describing the process is required. Five steps for ideal strategy are:

- Functional process specification
- Select the modeling objectives
- Select model type
- Validation of the Model
- Model construction methodology

**Modeling Objectives** - Any given process may have the different ‘appropriate’ models. These prior decisions about the model must be made before the model construction can start. Some of the more relevant objectives concern model purpose, system boundaries, time constraints and accuracy.

- **Model Purpose** - A wide variety of models are possible, each of which may be suitable for a different application. e.g., simple models which may be suitable for model-based control algorithms.

- **Design** - Models allow exploration of the impact of changing system parameters and development of plants to meet the desired process objectives at minimal cost.

- **Research** - Models serve as a tool to develop and test hypotheses and thereby gaining new knowledge about the processes.
### 2.8 WORLD WATER VIEW FOR REUSE OF WASTE WATER

#### Table 2.5 Examples of Waste Water Reuse Experiments Around The World


<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Purpose / Usage</th>
<th>Year</th>
<th>Location</th>
<th>Purpose / Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1912</td>
<td>Golden Gate Park, San Francisco, California, USA</td>
<td>Water lawns and supplying ornamental lakes</td>
<td>1976</td>
<td>Orange Country Water District, California, USA</td>
<td>Ground water recharge by direct injection into the aquifers</td>
</tr>
<tr>
<td>1926</td>
<td>Grand Canyon National Park, Arizona, USA</td>
<td>Toilet flushing, lawn sprinkling, cooling water</td>
<td>1977</td>
<td>Dan Region Project, Tel Aviv, Israel</td>
<td>Ground water recharge and unrestricted crop irrigation</td>
</tr>
<tr>
<td>1929</td>
<td>City of Pomona, California, USA</td>
<td>Irrigation of lawns and gardens</td>
<td>1984</td>
<td>Tokio Metropolitan Government, Japan</td>
<td>Toilet flushing</td>
</tr>
<tr>
<td>1942</td>
<td>City of Baltimore, Maryland, USA</td>
<td>Metals cooling and steel processing at the Bethlehem Steel Company</td>
<td>1985</td>
<td>City of El Paso, Texas, USA</td>
<td>Ground water recharge by direct injection into aquifers and power plant cooling</td>
</tr>
<tr>
<td>1960</td>
<td>City of Colorado Springs, Colorado, USA</td>
<td>Landscape irrigation for golf courses, parks and free ways</td>
<td>1987</td>
<td>Monterey Regional Water Pollution Control Agency, California, USA</td>
<td>Monterey waste water reclamation study for agriculture-irrigation of food crops</td>
</tr>
<tr>
<td>1961</td>
<td>Irvine Range Water District, California, USA</td>
<td>Irrigation, Industrial and domestic uses, toilet flushing</td>
<td>1989</td>
<td>Shoalhaven Heads, Australia</td>
<td>Irrigation of gardens, toilet flushing in private residential dwelling</td>
</tr>
<tr>
<td>1962</td>
<td>La Soukra, Tunisia</td>
<td>Irrigation with reclaimed water for Citrus plants, reduce salt water intrusion into G.W</td>
<td>1989</td>
<td>Consorci de la, Costa, Brava, Girona, Spain, Northern Adelaide Plains, South Australia</td>
<td>Golf course irrigation Class’A’ water used to irrigate horticulture crops</td>
</tr>
<tr>
<td>1968</td>
<td>City of Windhaek, Nambia</td>
<td>Advanced direct waste water reclamation system to augment portable water supplies</td>
<td>1999</td>
<td>Willaunga Basin, Adelaide, South Australia Mawson Lakes Reclaimed Water Scheme</td>
<td>Class’B’ water used to irrigate premium quality grapes A dual water reticulation system, recycled w.w used for toilet flushing, garden watering</td>
</tr>
<tr>
<td>1969</td>
<td>City of Wagga Wagga, Australia</td>
<td>Landscape irrigation of sporting fields, lawns cemeteries</td>
<td>2000</td>
<td>Rouse Hill Recycled Water Scheme</td>
<td>A dual water supply system, with the recycled w.w used for toilet flushing, car washing and garden watering</td>
</tr>
<tr>
<td>1970</td>
<td>Sappi Pulp and Paper Group, Enstra, South Africa</td>
<td>Industrial use for pulp and paper processes</td>
<td>2003</td>
<td>Singapore</td>
<td>The ‘NEWater’ project provides safe, reliable source of high quality drinking water</td>
</tr>
</tbody>
</table>
- **Process control** – Models allow for the development of new control strategies by investigating the system response to a wide range of inputs without endangering the actual plant.

- **Forecasting** – Models are used to predict the future plant performance when exposed to foreseen input changes and provide a framework for testing appropriate counteractions.

- **Performance analysis** – Models allow for the analysis of total plant performance over time when compared with laws and regulations and what the impact of new effluent requirements on plant design and operational costs will be.

- **Education** – Models provide students with a tool to actively explore new ideas and improve the learning process as well as allowing plant operators training facilities and thereby increasing their ability to handle unforeseen situations.

### 2.8.1 Wastewater Reuse In Australia

The scope for Australia to recycle water was first identified during 1977-78 in a report commissioned for the Victorian Government on potential for water recycling (GHD, 1978). This failed to attract the attention of the policy makers and hence had little impact until the 1980s, when issues of environmental health, sustainability, water availability and water quality for consumptive uses emerged as significant political issues [235]. Australia is currently experiencing highest ever amount of pressure on its water resources. It has been stated that “substitution of water used in agriculture and urban irrigation with reclaimed water will free up water and help make appropriate allocations to the environment, thus ensuring good environmental condition for stressed water supplies” [104]. Reclaimed water can definitely become major resource for the agriculture sector, since irrigated agriculture accounts for around 67% of Australia’s total water usage (ABS, 2004). The practice of disposing municipal effluent to land at Melbourne’s Western Treatment Plant, Werribee, has a history of more than 100 years[55].In the City of Wagga-Wagga, where the reclaimed water was being used in 1969, for landscape irrigation of sporting fields, lawns, and cemeteries [17],water recycling received a greater push when the issues of environmental health, sustainability, water availability and water quality for consumptive uses emerged as significant political issues during the 1980s [235]. The Council of Australian Governments (COAG) reforms adopted in 1994 have further accentuated the importance of the water reuse,
and have also resulted in attracting private sector investment in water infrastructure [55]. As a result, by 2001-02, more than 500 wastewater treatment plants were recycling some or all of their treated wastewater [197]. Sustainable practice in water management is being institutionalized within corporations, with government intervention [156].

Water recycling was brought within National Water Reform Framework in 2003. This framework is an inter-governmental agreement aimed to encourage water conservation in cities through better use of storm water and recycled water [120]. series of events in the late 90’s provided powerful incentives for cities and town to consider including water recycling in their water development plans and ultimately converged to accelerate the implementation of water recycling [56]. Australia is today a world leader in the use of treated wastewater. According to ABS (2004) data for 2000-2001, around 27 .8% (511.3 GL) of the total volume of effluent produced (1,837.2 GL) was reclaimed. However, because of differences in definitions, these estimates of reclaimed water use sometimes vary considerably [104]. With around 18% of water being directly reused [197], South Australia stands second after Victoria (45.2%) in the country (ABS, 2004), per capita, has the highest level of wastewater reuse in the country [57].

2.8.2 Feasibility Of Reclamation Of Water From Wastes In The Los Angeles Metropolitan Area

About 40 % of the sewage was wasted to the ocean from the Los Angeles area could have been economically reclaimed for beneficial purposes. The remainder of the sewage is of such poor mineral quality that economic reclamation is not feasible. Planned reclamation of water in Los Angeles Metropolitan Area can be accomplished at costs comparable to, or less than, the costs of present and future supplies imported to the area. The use of water so reclaimed for ground water recharge and certain industrial purposes would conserve high quality local and imported water for domestic supplies and repel sea-water intrusion into the coastal ground water basins would indirectly serve most beneficial uses.

2.8.3 Europe

Compared to other regions of the world, Europe has maximum plentiful water resources. However, droughts experienced in the early 90s and in 2003 changed the situation in Europe, resulting in growing water stress, both in terms of quantity and
quality [113]. To counter water scarcity challenges, European Union and its member states have enacted the Water Framework Directive (WFD1) which highlights an integrated approach to water resources management. The WFD favor municipal wastewater reclamation and reuse to augment water supply and decrease the impact of human activities on environment [28].

2.8.4 Israel

Israel’s national policy aims to gradually increase the fraction of reclaimed wastewater used instead of fresh water for agricultural use. This is reflected by the fact that Israel occupies second place in the overall wastewater reuse after California and has the highest percentage of wastewater reused for agricultural irrigation in the world [8]. It is estimated that by the year 2020, 50% of agricultural water consumption will be provided by treated wastewater. The focus in Israel is directed towards maximizing saving or replacing freshwater for consumptive uses other than drinking.

2.8.5 Wastewater Reuse Criteria In Greece

Parameters that affect the wastewater reuse criteria in Greece are evaluated, concerning among others reuse priorities, available treatment plants and effluent characteristics and recommendations are made for developing future guidelines or regulations for Greece in relation to reuse practices (agricultural, urban, etc). The recommendations are presented in relation to the different types of reuse, with appropriate specific standards and recommended treatment systems wherever applicable. A mathematical model for activated sludge system was constructed based on ASM2. State Point Analysis was used to analyze condition of the Secondary Settling Tanks of the (Yinchuan) wastewater treatment plant [295].

2.8.6 Wastewater Reclamation And Reuse In France

Wastewater reuse is not widely applied in France, because water resources match most of the needs. Only 6 projects were there in operation in 1989. But more than 15 new projects were found to have been set up 7 years later. The enforcement of the recommendations of the Ministry of Health resulted in a slowing down of the development of wastewater reuse and the implementation of wastewater treatments - long residence time lagooning or chlorination and ultra violet radiations - providing water quality higher than required by the standards. France total annual renewable freshwater capacity is estimated equal to 185 Billion (Bn) m$^3$ but decreases to lower
figures during dry periods. In the late 1980’s wastewater reuse was limited to sewage farms of Achères and Reims, relics of the treatment practices of the XIX\textsuperscript{th} century, and recently set up four small projects, three of which are located on islands off the Atlantic and Mediterranean coasts (Rodierand Brissaud, 1989). Despite the poor development of wastewater reuse, the Ministry of Health (MoH) started the elaboration of regulations on irrigation wastewater reuse in 1989. Guidelines issued in 1991 (CSHPF, 1991) are currently used as a provisional regulation [205].

2.8.7 Water Reuse Technology In South Korea

In South Korea, 73.2 percent of supplied water is discharged (16 million m\textsuperscript{3}/day) from municipal wastewater treatment plants. Calculation simply tells that 0.58 billion m\textsuperscript{3}/year can be available if only 10 percent of wastewater could be reused. The effluent of MBR satisfied the medium level water regulation in South Korean except total coliform and residual chlorine. The chlorine disinfection could easily satisfy the others. The residual chlorine in the regulation could limit the various alternated disinfectants. Water quality standards were suggested for the purpose of industrial cooling water generation from the wastewater in South Korea. The results of membrane technology trains with MBR-RO and MBR-NF suggested the NF had great potential for the water reclamation and reuse.

2.8.8 Agricultural Waste Water Reuse In Southern Italy

Within a strategic R&D project, since April 2002, membrane filtration, simplified treatments, storage reservoirs and constructed wetlands technologies are under investigation at field scale to evaluate their effectiveness for treating municipal effluents to be reused in the agriculture [3]. So far, the main results recorded have been the following:

**Simplified treatment** - In order to save the agronomic potential of organic matter and nutrients present in urban wastewater, olive trees were irrigated with effluents produced by skipping biological processes, resulted in a yield increase of 50%;

**Membrane filtration** - The microbial quality of treated effluents was higher than that of benchmark (i.e., local well-water conventionally used for irrigation). Total coliforms were the only microorganisms found on the irrigated crops (tomato, fennel and lettuce). Referring to soil contamination, particularly during summer periods, the irrigation with membrane filtered effluents caused an increase of Na\textsuperscript{+}, Ca\textsuperscript{2+}, EC, SAR and ESP.
Storage reservoirs - After appropriate storage periods: TSS, BOD$_5$, COD and nutrients concentrations achieved in force Italian limits for WW agricultural reuse; Pathogens indicators showed an average decrease of 2–3 log units; Salmonella, from a mean value of 28.2 MPN/100 mL decreased up to 4 MPN/100 mL; Helminth eggs, detected in inflow wastewater with an average value of 4.1/L, were not detected in outflow effluents.

Constructed wetlands - Recorded average efficiencies for TSS, BOD$_5$, COD, TN and TP removal resulted 85%, 65%, 75%, 42% and 32% respectively. Microorganisms indicators showed an average decrease around 2 log units; Helminth eggs, detected with an average value of 12/L, were not detected in the effluent; Salmonella, found in influent with a mean value of 3 MPN/100 mL, was never detected in effluent.

2.8.9 Wastewater Use in Irrigated Agriculture: Management Challenges In Developing Countries

Cities in developing countries are experiencing unparalleled growth, rapidly increasing water supply and sanitation coverage, which will continue to release growing volumes of wastewater. In many developing countries, untreated or partially treated wastewater is used to irrigate the cities’ own food, fodder, and greens paces. Farmers have been using untreated wastewater for centuries, but greater numbers now depend on it for their livelihoods. The diversity of conditions is perhaps matched only by the complexity of managing the risks to human health and environment that are posed by this practice. An integrated stepwise management approach is called for, one that is pragmatic in the short- and medium terms and that recognizes fundamental economic niche and users’ perceptions of the comparative advantages of wastewater irrigation that drive its expansion in urban and peri-urban areas. Comprehensive management approaches in the longer term will need to encompass treatment, regulation and farmer user groups, forward market linkages that ensure food, consumer safety and effective public awareness campaigns.

2.8.10 Waste Water Reuse In India

For ages, the marginalized communities in India have relied on the indirect use of wastewater to grow vegetables, fruits, cereals, flowers, fodder [272]. In recent years, as a result of rapid population growth, massive industrialization and the growing number of cities that dispose of large amounts of sewage into bodies of water, the indirect use of wastewater has increased even further. Most wastewater irrigation, in
the peri-urban and rural areas of India, occurs along the rivers that flow through such rapidly growing cities. The Musi River in Hyderabad is one such river, where around 250 households within the city use wastewater directly from drains or from the river to irrigate their lands [32].

One of the latest crises of modernity is water scarcity. It has been established that this crisis is not a true water scarcity problem but a crisis of governance [206]. More recently, wastewater management and use is considered seriously as an integral part of water management policy in many water-scarce countries. Wastewater from point sources, such as the sewage treatment plants and industries, provides an excellent source of reusable water and is usually available on a reliable basis, has a known quality, and can be accessed at a single point [52]. Urban wastewater use reduces the amount of waste discharged into watercourses and hence improves the environment. It also conserves water resources by lowering demand for freshwater withdrawal. The development of sustainable water reuse schemes often encounter technical, financial, commercial, regulatory, policy, social and institutional impediments [32]. The potential benefits of water recycling, water conservation have been identified as two of the greatest challenges [52]. Most wastewater reuse studies in the past have adopted a scientific and biophysical approach [32] and the dearth of institutional studies using a combination of social, quantitative and qualitative methodologies impedes the formulation of recommendations that could enhance the benefits and ease the concerns of all groups involved with wastewater reuse.

2.8.10.1 Status of wastewater generation and treatment in India

Urban centers in India lack infrastructure for sanitation and the wastewaters generated are not managed appropriately.[267, 268] The Central Pollution Control Board carried out studies to assess the status of wastewater generation and treatment in Class I cities (population > 100,000) and Class II towns (population between 50,000 and 100,000) during 1978-79, 1989-90, 1994-95 and 2003-04. The latest study indicates that about 26 254 million liters per day (ML/d) of wastewater are generated in the 921 Class I cities and Class II towns in India (housing more than 70% of urban population).

There is urgent need to plan strategies and give thrust to policies giving equal weighting to augmentation of water supplied and development of wastewater treatment facilities. The future of urban water supplies for potable uses will grossly depend on the efficient wastewater treatment systems, as the treated wastewater of upstream urban centers will be the source of water for downstream cities [189,191].
In India, as a result of rapid population growth and massive industrialization, the growing number of cities as well as large amounts of sewage is disposed into bodies of water. According to UNDP’s World Water Development Report (2003), 70 percent of industrial wastes in developing countries are dumped into waters without treatment, polluting the usable water supply. Over the past two decades wastewater use in agriculture has increased significantly. With the growing population and increased industrial use of water, use of wastewater for irrigation is going to increase even further. But, these unregulated wastewater irrigation practices reveal a range of associated problems that outweigh the benefits. This highlights the failures of policies and lack of agricultural extension services.

2.8.11 Waste Water Reuse In Major Cities

Waste water reuse is already in consideration. Following are some references for reuse of waste water in India.

2.8.11.1 Ahmedabad

Ahmedabad is a seventh largest city in India registering a population of 4519278 (census 2001). Population growth is result of natural increase in population, net migration and merging of adjacent areas to the municipal limits. The city lies in region of North Gujarat, which is dry and sandy. The sea is 80.65 km far, at the Gulf of Cambay. Sabarmati, one of the longest rivers of Gujarat, bifurcates the city into eastern and western parts. Though the river is perennial, it practically dries up in summer; leaving very little water. Major expansion in the textile industry boosted its development – once known as the “Manchester of India”. The major strain was on water supply. There are a number of commercial establishments and private residences/societies with their own bore wells. Public water is supplied by the Ahmedabad Municipal Corporation (AMC), the Ahmedabad Urban Development Authority (AUDA). AUDA supplies only to those areas that fall within its town planning scheme. Although the supply of water has increased from 20.24 MGD in 1951 to 104.83 MGD in 2001,35 the per capita consumption has decreased. It is estimated that almost 80 percent of the water supplied for domestic use passes out as wastewater.

2.8.11.2 Kolkata

The city limits expanded after Kolkata Municipal Corporation Act, 1983, was passed. River Hooghly flows past the western part of Kolkata. The demographic density
during 1981 was 22,260 people per sq km; during 1991, this increased to 23,670 persons per sq. km in Kolkata. The residents get their water supply from the three main sources: The KMC, supplying treated water through an underground pipeline network. Roadside public bore wells dug by KMC. Innumerable private bore wells dug by the residents. The municipal corporation supplies about 750-800 MLD from its surface water sources and 136 MLD from groundwater [39]. Additionally, it also supplies 300 MLD of unfiltered but chlorinated water.

2.8.11.3 Tamil Nadu
Waste stabilization ponds (WSP) have been used extensively all over Tamil Nadu over the last few years for the treatment of municipal and industrial wastewaters. Anaerobic WSP are single stage, continuous-flow, anaerobic reactors operating at ambient temperatures and low volumetric organic loading as a pretreatment method. On a wastewater management scheme, involving reuse for agriculture, the zero-energy demand of a waste stabilization pond series for effective removal of organic and microbiological loading under existing legislation and guidelines will remain a valuable tool for sustainable development.

2.8.11.4 Wastewater Irrigation In Vadodara
Wastewater is gaining the popularity as a source of irrigation water in different countries around the world. Its economic benefits and its importance as a coping strategy for the poor have had little recognition. An interesting case study is presented for the rural areas downstream of Vadodara in Gujarat, India, where wastewater supports annual agricultural production worth Rs. 266 million. Both food crops and cash crops are irrigated by domestic wastewater and industrial effluent. In this area one of the most lucrative income-generating activities for lower social strata is the sale of wastewater (and renting pumps to lift it). The lack of alternative sources of water has generated viable markets for wastewater. Increased disposable incomes have resulted from the catalytic use of wastewater that was formerly not socially acceptable, i.e. the farmers considered it unhealthy and unclean. The use of the wastewater to grow food crops poses uncertain risks to the health of both consumers and those who actually handle the wastewater. [271]

2.8.12 Case Studies For Reuse Of Waste Water
Following are some reference studies, in which reuse of waste water is followed for different uses.
2.8.12.1 Assessment Of Reclaimed Municipal Wastewater Application On Rice Cultivation

[77]The research was carried to assess the effects of application of reclaimed municipal wastewater on rice cultivation in Thessaloniki, Greece during a 2-year period (1999–2000). Effects on production cost, soil composition, and health risk were examined. A randomized complete block design was used for the paddy field with three treatments and four replicates. The treatments were (1) River irrigation water with N–P fertilization, (2) Reclaimed wastewater irrigation with surface N fertilization (3) irrigation with reclaimed wastewater irrigation without fertilization. The results showed that total production cost decreased 8.8% and 11.9% by applying the second and third treatments, respectively, compared to the first treatment, without significant differences in the agronomic and rice quality traits.

2.8.12.2 Agricultural Waste Water Desalination By Reverse Osmosis

[90]In investigations made by the San Joaquin District of the California Department of Water Resources (DWR) on desalination of subsurface tile drainage water between 1976 and 1979. Throughout 1977, the RO plant was operated to supply product and brine waters for other activities at the WWTEF, and product water recovery was as high as 90 percent. Between May 1977 and August 1978, a silica solubility study and flow-reversal tests were run at the RO plant. Between August and November 1978, the 500-tube plant was reequipped with the new membranes, and from February to August 1979, a system optimization study was conducted at the plant in cooperation with UCLA. DWR personnel operated the equipment, collected the data, forwarded their findings to UCLA for analysis. Data obtained from the studies were used to develop a computer program that provided an optimization model of the 500-tube RO plant. The RO plant developed unstable operating conditions at recovery levels of about 95 percent because of low brine flow rates and extremely high brine concentrations. The flow-reversal procedure should be investigated as a means for reducing instability condition caused by the low brine flow and high brine concentration at very high recovery operation. The bench-scale IX tests indicated that RO brine TDS content ranging from 50000 to 60000 milligrams per liter was most suitable for regeneration of IX resins. Also, the effectiveness of calcium (Ca) removal from the feed water by ion-exchange was reduced considerably because of large amount of magnesium (Mg) present in the feed water. The regeneration with RO
process brine was shown to be technically feasible, offering an acceptable alternative to the conventional method of resin regeneration.

2.9 WATER SCENARIO IN INDIA

India is the 2nd country in the world having the highest amount of precipitation. In our country 85% of water is used for farming, 10% for industry and 5% for domestic use. The competition between these is increasing day by day. Due to increasing population and pollution due to human activity, the supply of water is reducing. As per the World Water Institute, India will be a highly water stressed country from year 2020 onwards. The meaning of water stress is that less than **1000 cubic meter of water will be available per person per annum** (water scenario in India proceedings of Trombay symposium on desalination and water reuse, 2007). On an average the rainfall received in our country is 1200 mm, with maximum of 1100 mm in Cherrapunji and the minimum average rainfall in West Rajasthan of @ 250-300 mm.

The urban water supply and sanitation sector in the country is suffering from inadequate levels of service, an increasing demand-supply gap, poor sanitary conditions, deteriorating financial and technical performance. According to Central Public Health Engineering Organization (CPHEEO) estimates, as on 31st March, 2000, 88 per cent of urban population has access to a potable water supply. But this supply is highly erratic and unreliable.

2.9.1 Indian Water Technology Systems

In most of the cities, centralized water supply systems depend on surface water sources like rivers and lakes. Chennai, for instance, has to bring in water from a distance of 200 km whereas Bangalore gets its water from the Cauvery River, which is only 95 km away. Where surface water sources fail to meet the rising demand, groundwater reserves are being tapped, often to unsustainable levels. Delhi: The nation’s capital is perpetually in the grip of a water crisis; more so during the dry season, when the situation gets particularly worse. As demand-supply gap widens, more groundwater is being exploited. Of the water supplied by the municipality, approximately 11 per cent comes from the groundwater reserves and remaining from the Yamuna River. It is, however, difficult to establish the total quantity of groundwater extracted because of a large number of tubewells (owned by individuals, industries and bottled water companies) remain unregistered. Chennai: The main
sources of public water supply in the city are the three reservoirs – Poondi, Redhills and Cholavaram – with an aggregate storage capacity of 175 MCM. Even when the reservoirs are not full, they get inflows from intermittent rains. On the other hand, losses due to the process of evaporation from the reservoirs result in the effective availability being lower than the storage.

2.9.2 Bangalore

With a population of 5,686,000, Bangalore is India’s fifth largest city. As per estimates of the Bangalore Water Supply and Sewerage Board (BWSSB), the total demand of water is 840 million liters per day (MLD) (assuming a population of 6 million and a supply rate of 140 liters per capita per day [lpcd]). The demand works out to be 1200 MLD, at standard rate of 200 lpcd set by the Bureau of Indian Standards (BIS) for water.

According to the latest census, India’s population is about 1020 million, which is projected to go up to 1333 million by AD 2025 and further to 1640 million by AD 2050. It is projected that per capita water availability in India may reduce to about 1200 m³/year by 2047.

2.9.3 Steps To Meet Water Requirements

Following are the steps to meet water requirement.

- Educate to change consumption and lifestyles
- Invent new water conservation technologies
- Recycle the wastewater
- Improve irrigation and agricultural practices
- Appropriately price the water
- Develop energy efficient desalination plants
- Improve water catchment and harvesting
- Look to community-based governance and partnerships
- Develop and enact better policies and regulations
- Holistically manage ecosystems
- Improve distribution infrastructure
- Shrink corporate water footprints
- Build international frameworks and institutional cooperation
- Address pollution
- Public common resources / equitable access
2.9.4 Application Of A Combined UF/RO System For The Reuse Of Filter Backwash Water From Treated Swimming Pool Water

Results are studied from the full-scale application of a combined ultrafiltration (UF) and reverse osmosis (RO) treatment process for reuse of spent filter backwash water (SFBW) from treated swimming pool water[75]. Ultrafiltration treatment showed a significant reduction of particulate matter. Turbidity decreased from values between 5 and 25 FNU in the feed (SFBW) to values below 0.02 FNU. At plant investigated in this study, filtration periods up to 90 min were achieved. With this configuration, efficiencies of more than 97% for the UF plant were obtained. In order to avoid an increasing concentration of salts and dissolved compounds, up to one-third of the UF filtrate was directed to the RO plant. As a result, there is no deterioration of the swimming pool water quality especially the concentration of disinfection by-products did not increase. The results of this study indicated an almost complete removal of particulate matter due to UF treatment. As a consequence of the accumulation of TSS, COD in the concentrate of the UF plant, respective threshold values of the German federal receiving wastewater utility regulation cannot be met, and either the discharge of concentrate into the sewer will be extra-charged or alternative disposal options must be considered.

2.9.5 A Mini-Review Of Modeling Studies On Membrane Bioreactor (MBR) Treatment For Municipal Wastewaters

[10]Membrane bioreactor (MBR) technology is a promising method for water and wastewater treatment because of its ability to produce high-quality effluent that meets water quality regulations. A mini-review of modeling studies on the application of MBR for the treatment of the municipal wastewaters was conducted to assess current MBR, modeling efforts. Models describing biomass kinetics in an MBR include the ASM model family, SMP model, ASM1-SMP hybrid model. The ASMs were developed to model the activated sludge process and their ability to accurately describe the MBR process that has not been verified by in-depth experiments. Research suggests that SMPs are important components in describing biomass kinetics due to the high SRTs in MBR systems. Accordingly, the SMP model demonstrated the capability of characterizing the biomass with a reasonable to high degree of accuracy. The modified version of ASM1 that incorporates SMPs
demonstrated fairly reasonable accuracy in quantifying COD and soluble nitrogen concentrations but underestimated MLSS concentrations.

The empirical hydrodynamic model is too simple to describe the membrane fouling phenomenon, and the sectional resistance model lacks accuracy. Both the fractal permeation model and resistance-in-series model by Lee et al provide good scientific insight, but specific experimental verification is necessary for general use of models. The resistance-in-series model developed by Winitgens et al. shows the most promise, as it is fairly accurate, accounts for cleaning cycles, and can predict permeability changes over time. Further tests are needed to determine whether the model requires calibration or if the model parameters are applicable to other MBR systems.

2.9.6 Baffled Membrane Bioreactor (BMBR) For Efficient Nutrient Removal From Municipal Wastewater

The feasibility of treating municipal wastewater [142] was examined by a baffled membrane bioreactor (BMBR), particularly in terms of nitrogen removal. Submerged membrane bioreactors (MBRs) are now widely used for various types of wastewater treatment. One drawback of submerged MBRs is the difficulty in removing nitrogen because intensive aeration is usually carried out in the tank and the MBRs must therefore be operated under aerobic conditions.

To examine the applicability of BMBR, pilot-scale experiments were carried out using real municipal wastewater. Although neither external carbon addition nor mixed liquor circulation was carried out in the operation of the BMBR, average removal rates of total organic carbon (TOC), total phosphorus (T-P) and total nitrogen (T-N) reached 85%, 97% and 77%, respectively, with the hydraulic retention time (HRT) of 4.7 h. It was found that denitrification was limiting step in removal of nitrogen in the BMBR in this study. Various types of monitoring carried out in the BMBR also demonstrated the possibility of further improvements in its performance. Nutrient removal by the BMBR was more efficient than that by other MBRs previously reported, despite the fact that the feed water in this study was “weak” wastewater with a low concentration of organic carbon, which is considered to be disadvantageous for the denitrification process. Without adding the external carbon, concentrations of T-N and T-P in the treated water could be continuously lowered to
0.5 and 0.1 mg/L within a HRT of 4.7 h, respectively. Even when the BMBR was operated under relatively low temperatures (10–15°C), the reactor continuously showed good performance, which indicates the reliability of the reactor.

2.9.7 Integrated Water Resource Management Model For Process Industry In Lithuania

A structured “integrated water resources management” (IWRM) model [135], for the water management is a useful tool for research into complex water using production systems in industries.

The comparative analysis of water usage in industry has revealed that Lithuanian enterprises use 3 x 10⁵ (in some cases 10) times more water per unit of production compared to best examples from other parts of the world. This is especially true in the textile, pulp and paper, metal processing, chemistry and food industries. The IWRM model is useful to assess and systematically evaluate ways of reducing freshwater usage and opportunities for wastewater reuse. By applying this model to the enterprise there are possibilities to create various scenarios for the optimal management of water resources within single production processes or within the entire multi-process system of the entire company.

IWRM helps in water savings of 52% per ton of product. In the case of a small textile enterprise, water savings of 62% were calculated. By applying the IWRM model under free market conditions, the industrial company gains by: a) optimization of freshwater usage in technological processes; b) improving the choice of optimal production modes; and c) forecasting freshwater rates and wastewater quantities.

2.9.8 Comparison Of Tertiary Treatment By Nano filtration And Reverse Osmosis For Water Reuse In Denim Textile Industry

The wastewaters resulting from different baths of a dyeing factory specialized in denim fabric are collected and treated by an activated sludge plant. This study investigated coupling of activated sludge treatment with either nanofiltration (NF) or reverse osmosis (RO) to recycle water and reuse it in the process. NF experiments were first conducted with a HL membrane in different configurations: dead end and cross flow for flat sheets and also in spiral wound form. Results on water permeation and salt rejection show that performances are configuration dependent.
For the study of the NF/RO textile waste water treatment, experiments were conducted with spiral wound membranes in order to be closest to the industrial configuration. After analyzing the removal efficiencies of suspended solids and chemical oxygen demand (COD) of treatment plant, experiments were conducted using an HL2514TF spiral wound membrane preceded by ultrafiltration (UF) treatment, RO membrane (AG2514TF) to compare performances in water yield and quality for the same pumping costs.

The results show that NF allows higher yield, while respecting the Tunisian standard of water reuse (COD< 90mg L$^{-1}$). Above 9 bar, the TDS rejection reaches 60% and the hardness is lower than the factory constraint (100mgL$^{-1}$ CaCO3), allowing reuse of the water in the process. The tests with the Sepa CF cell allow one to achieve higher performances in terms of water permeation and salt rejection. The NF experiments conducted with the HL 2514 membrane showed that 11 bar is a suitable operating pressure. It allows a yield of 9% and a COD reduction and TDS rejection of 62%, values in conformity with the Tunisian water reuse standards.

2.9.9 Removing Of Urea And Ammonia From Petrochemical Industries With The Objective Of Reuse, In A Pilot Scale

Seyed Ahmad et.al., 2010 designed a pilot plant was based on five stages: two aerobic, two anaerobic and sedimentation. When the pilot was installed the connections for loading and circulation were made. After installation of the pilot the recycling operation of sediment sludge from the bottom of the settler to the aerobic vessel was started. Since this sludge contains active microorganisms, it could enhance the efficiency of purification process in comparison with those without active sludge. Sampling from vessels was done every two days, and tests were made for measurement of total alkalinity, ammonia, ammonium ion, suspended solids, COD, nitrogen dioxide and acidity, in which after 30 days from the first circulation, the samples were found to be without ammonia or its derivatives. The trend of ammonia changes throughout the different stages is like the TA changes. Hence, wastewater ultimately will be free of ammonia contamination as a result of the complete ammonia changes (100%) in the second aerobic sampling vessel. The removal and purification of the system is highly dependent on the $\text{pH}$ changes. $\text{pH}$ parameter changes along with TA and ammonia parameters change and will increase to less than 8.3 after the removal process.
2.10 WASTEWATER RECYCLE, REUSE, AND RECLAMATION OF DOMESTIC WASTEWATER

The summary of reuse of waste water in the world is presented over here in different countries.

2.10.1 USA

The city of Altamonte Springs, near Orlando in Florida, USA has a long established sewage reuse scheme for non-potable residential and other uses, through dual reticulation systems [209]. The incentives to build reuse scheme came from concerns about maintaining the quality of the lake which received the treated wastewater of the city, and from the need to limit withdrawals of potable water from the Central Florida groundwater aquifer. Wastewater for the reclamation is withdrawn from the isolated sewer lines collecting wastewater predominantly from residential sites. It is low in salinity. The treatment train includes:

- Primary sedimentation tanks
- Secondary biological treatment which includes nitrification systems
- Chemical coagulation, filtration, reaeration and high-level disinfection
- Polishing for dechlorination and pH control
- Trenchless technology was used to retrofit the city with small-diameter pipes for delivery of reclaimed water

This scheme serves a population of some 45,000 people, and the reclaimed water is used for the irrigation of lawns in industrial, commercial and public buildings (including the grounds of a public hospital), as well as open space irrigation. Some of the reclaimed water is being supplied to office and apartment buildings for toilet flushing, once through cooling in industries. The water is also used for water level control in the lake, automobile washing, public fountains and water falls. About 30–40% of the total water use is provided by the dual reticulation system, which produces about 45 MI per day of reclaimed water. Extensive public consultation combined with a mixture of forceful advocacy on the part of city’s water supply authority has resulted in a general public acceptance. The city ordinance was amended to enforce compulsory connection to reclaimed water distribution network. Initial apprehensions about public health risks proved to be misplaced, as no public health impact had been detected in the first six years of operation from 1989 to 1995.
2.10.2 Japan

Japan has a long history of planned wastewater reclamation and reuse, the first of which dates back to 1951, when secondary treated effluent of the Mikawashima wastewater treatment plant in Tokyo was experimentally used for paper manufacturing in a paper mill nearby. Today, Japan has well developed policies and programs for wastewater recycle and reuse, to promote water pollution control, environmental protection, and amenities for urban environment. Treated wastewater has also been used for washing passenger trains, and as plant water in solid waste incineration plants. The water reuse projects are favored as they stimulate private sector investment in such works as installing drainage and flush-toilet facilities, thereby creating economic side benefits.

2.10.3 Tokyo

The water demand for this newly developed business district has been largely coped-up with the supply of reclaimed wastewater through a dual reticulation system. Secondary treated wastewater forms the influent to the water recycling system. The recycling system is made up of rapid sand filters, pumping facilities, force mains, recycling center that house distribution reservoir and distribution pump, distribution network. The Shinjuku water distribution center is located in the basement of a hotel. Because of its location, noise, odor and other nuisances are strictly controlled. The system supplies reclaimed water to the 19 high-rise buildings that house commercial and office premises, up to a daily maximum of 8000 KL, since 1991. The Tokyo Metropolitan Government, in an effort to promote water conservation, and wastewater reclamation, introduced increasing block rate structure of water and waste charges. All new buildings were requested to provide dual system, for the use of reclaimed water. By setting up 20% lower water charge for the reclaimed water; its use has been encouraged. The Fukuoka city comprises a population of over 1.3 million, and covers an area of about 340 sq.km. Due to the non-availability of stable water source either through large rivers or groundwater, for domestic and industrial water supply, the Fukuoka City Council started vigorously promoting a water conservation plan since 1979, which included wastewater reclamation and reuse. The city reclaimed water supply amounting to 4500 KL per day in 1995, is planning to achieve the rate of 8000 KL/day by the end of the century.
2.10.4 **Australia**

Recycling reclaimed water and storm water for residential non-potable uses has been estimated to have potential to reduce residential water demands by an average of 40—50% in most Australian cities. There are many pilot scale dual reticulation schemes in Australia. Social surveys conducted in Melbourne indicated that people support recycling of bathroom and laundry wastewater. In Western Australia, domestic gray water reuse has been an accepted option for future urban expansions. Commercial scale systems have been installed in Rouse Hill, a suburban area near Sydney, and New Haven in South Australia. The Rouse Hill scheme is Australia’s first full-scale application the domestic non-potable reuse through a dual reticulation system.

2.11 **HYDRANUTICS DESIGN SOFTWARE**

Since its founding in 1975, Hydranautics has been committed to the highest standards of technology research, product excellence, customer satisfaction. Hydranautics entered the reverse osmosis (RO) water treatment field in 1970, and is now one of the most respected and experienced firms in the membrane separations industry. Hydranautics became part of the Nitto Denko Corporation when it was acquired in 1987[120].

Hydranautics software is continuously involved in research and technology, result of which is ongoing development of a range of specialized membrane products. Hydranautics' products are currently in use for diverse applications as potable water, boiler feed water, industrial process water, wastewater treatment, surface water treatment, seawater desalination, electronic rinse water, agricultural irrigation and pharmaceuticals.

Hydranautics is first membrane manufacturer to meet the highest quality standards with ISO 9001 Quality System Certification.

Hydranautics, membrane separation technology, provides two software programs:

- **IMSDesign** - a comprehensive software design program that allows the user to design a membrane system using Hydranautics' membranes.

Hydranautics, offers latest comprehensive system design software package. The realistic expectation of the performance over time and under a variety of conditions is clearly demonstrated. Parameters such as salt passage increase and flux decline due to fouling are easily accessible to the user - not obscured within
the framework of the program. IMS Design gives users complete control over the information used in the membrane selection process. This control assures user full confidence in the projected performance of any Hydranautics membrane.

- **RO Data** - an easy to use the normalization program that tracks the performance of any RO system to assure optimum performance.

It tracks RO system performance and specifically designed to be a user-friendly interface for RO system operators. RO Data for Windows is a powerful RO normalization program. The program allows users to input, edit, display, print reference, operational and normalized data tables. Graphs of operational and normalized parameters can be displayed and printed from these tables or the data can be exported to MS EXCEL spreadsheets for developing custom graphs. To assure the highest standards of data integrity, normalization program is in compliance with ASTM Standard D 4516-85, "Standard Practice for Standardizing Reverse Osmosis Performance Data."

### 2.12 ENERGY CONSERVATION IN WASTEWATER TREATMENT FOR AGRICULTURAL REUSE, RESOURCES AND CONSERVATION

A study was conducted [22] which prepares the ground for energy savings at the treatment plants themselves. The study consisted of two parts: a survey of different types of the treatment plants and a more detailed analysis of an activated-sludge and an aerated-lagoons plant. Results show that energy utilization ranges from 140 to 800 W h/m$^3$ and a properly managed activated-sludge plant can spend less energy than an aerated-lagoon plant.

A possible reduction of 20% in plant energy utilization may bring about up to 8% reduction in the effluent cost and promote its agricultural application. A total of 100 million m$^3$/y of wastewater is now being treated in Israel consuming 20 million kW/h of electricity per year. By the end of this decade 300 million m$^3$/y will be undergoing treatment demanding 80-100 kW h/y. Due to problem of water scarcity in Israel, most of the effluents will be recycled for agriculture use. Results show that energy utilization in plants falls in the ranges of 40-800 W h/m$^3$ and 0.53-2.8 kW h/kg BOD removed. Aerated lagoons generally utilize 350-400 W h/m$^3$ while for activated sludge the range is 600-800 W h/m$^3$. 
Facultative recirculation ponds and trickling filters plant investigated utilized only 160-170 W h/m³. Economic calculations show that the energy cost of recycled effluents for irrigation is about 30-40% of the total; the above 20% reduction means a 6--8% reduction in water cost, which will result in significant savings for the farmer.

2.12.1 Management And Reuse Of Local Water Resources In Residential Developments In Adelaide

Water sensitive urban design (WSUD) typifies an approach to the planning and design of urban development which seeks to integrate the urban water systems with natural systems associated with the hydrological cycle; (Annette B. Barton, 2005) it aims to replace wasteful and environmentally harmful conventional water management practices with methods which are more sustainable and ecologically compatible. WSUD has two broad divisions: Storm water management which focuses on flood control, pollution control and water harvesting (or reuse); wastewater management - which focuses on "on-site" (or local) treatment and reuse. In the area of residential development, some effort has been made to apply WSUD principles, particularly in the area of storm water quantity and quality management, but reuse of storm water and wastewater has not been so actively pursued. In 1997 the Brisbane City Council commissioned the case study into water sensitive urban design, which had as its key objective: a comparison of lot yield, construction cost, maintenance cost and environmental implications of a 'conventional' and 'water sensitive' design layout for a parcel of land of approximately 3.3 hectares in area. (McAlister, 2000) The study, undertaken by WBM Oceanics Australia, has been reported in McAlister (1997a) and McAlister (1997b). It involved application of WSUD principles to a site, adjacent Bulimba Creek, for which a conventional design had already been undertaken and partly completed. WSUD Best Planning Practices and Best Management Practices were reviewed and shortlisted, by multi-disciplinary study team, and a site layout developed. Features of the WSUD design included: 40 allotments with an average size of approximately 590 m²; rooftop runoff disposal using on-site rainwater tanks overflowing to on-site infiltration trenches which overflow to the street; 'Mini' roadside detention basins, leaky wells; a larger 'bottom of the catchment' detention basin overflowing to the creek.
2.12.2 Status of Surface and Ground Water Resources in Gujarat

Gujarat’s total water resource potential is 50,000 MCM (Million Cubic Meters) of which the surface water is about 38,000 MCM (76 percent) and groundwater is about 12,000 MCM (24 percent). The groundwater resources of Gujarat are hardly one fourth of the total water resources. The over exploitation of groundwater, in terms of both magnitude and intensity, not only depletes the water tables and increases per unit cost of water supply, but also leads to deterioration of the water quality. This is occurring mostly in the alluvial areas of North and Central Gujarat. There has been a decline in the total utilizable groundwater, from 17365.40 MCM in 1984 to 12848.27 MCM in 1977.

The polluted water reduces net utilizable safe water and aggravates the problem of water scarcity in Gujarat. The Gujarat Ecological Commission (2005) report observes: “The six corporation cities of the state release about 933 million liter per day (MLD) of waste water into rivers, while other towns release about 1400 MLD. The core principle of its water policy is “user pays, polluter pays.” And this policy works well in South Africa. Mexico dared raise water rates (water fees) and as a result, now it generates revenue more than US $ 1 billion (Rs. 47,000 crore) annually. This has enabled the Mexican water institutions to invest in managing and upgrading their water infrastructure.’ [92, 93]In Gujarat, as in India, water charge for canal irrigation is not based on the volume of water used by the farmers, but charged at flat rate. In the absence of volumetric water charge, farmers have little incentive to value and use water efficiently. Also, the subsidized electricity charges tempt the farmers to exploit and overuse water. This also leads to the problem of water logging and shift in the nature of crops to water based ones, which sometimes do not suit the geo-climatic conditions of the land. Also, this not only depletes the water tables, but also compels to use the depleted water, which exerts a heavy burden both on the exchequer and the power sector of Gujarat.
2.13 GUJARAT’S WATER SECTOR

While south Gujarat has abundant water resources, north Gujarat, Saurashtra, Kutch are water-deficient areas. The share of groundwater in the total supply is projected to decrease in the future as large surface water schemes are commissioned, most notably the Sardar Sarovar-based Narmada Main Canal. Even after accounting for the availability of ground and surface water, a significant shortfall in water supply is expected which it is possible to meet by water conservation and recycling activities. The shortfall in urban areas is even more critical, requires substantial investment to develop new sources of water and strengthen the water supply distribution network. The demand for drinking water in the six municipal corporations is projected to outstrip supply by 986 mld, calling for investment of Rs 8609 million by 2010. Additional investments are also required to rehabilitate the existing distribution network [78, 79].

2.14 FUTURE DIRECTIONS FOR WATER REUSE

In many parts of the world, agricultural irrigation using reclaimed water has been practiced for many centuries. Landscape irrigation such as irrigation of golf courses, parks, playgrounds has been successfully implemented in many urban areas for over 30 years. Salt management in irrigated croplands may require special attention in many arid and semi-arid regions. Beyond irrigation and non-potable urban reuse, indirect or direct potable reuse needs careful evaluation, close public scrutiny. It is obvious from public health and acceptance standpoints that non-potable water reuse
options must be exhaustively explored prior to any notion of indirect or direct potable reuse.

Groundwater recharge with reclaimed water and direct potable water reuse share many of the public health concerns encountered in drinking water withdrawn from polluted rivers and surface water reservoirs. Three classes of constituents are of special concern where reclaimed water is used in such applications:

- enteric viruses and other emerging pathogens
- organic constituents including industrial, pharmaceutical chemicals, residual home cleaning and personal care products and other persistent pollutants
- salts and heavy metals

The ramifications of many of these constituents in trace quantities are not well understood with respect to long-term health effects. For example, there are concerns about exposure to chemicals that may function as the endocrine disruptors; also the potential for development of antibiotic resistance is of concern. As a result, regulatory agencies are proceeding with extreme caution in permitting water reuse applications that affect potable water supplies. Figure below shows typology of waste water usage for all purposes [14].

Figure 2.8 Typology Of Wastewater Usage For All Purposes
(Source: Anderson (2003), Salgot and Tapies (2004) and Van der Hock (2004))
2.15 IDENTIFYING THE GAP BETWEEN WORK DONE AND THE RESEARCH WORK

The provision of safe and adequate drinking water to all in an equitable manner is a complex issue. “In the past 75 years, 26 years were declared as drought years in Gujarat. The State government spends about 125 to 150 crore rupees annually on making the emergency arrangements for drinking water to overcome the scarcity.

“The People spend about Rs. 700 to 800 crore, on water and the social cost of paucity of water is estimated to be Rs. 2000 crore per annum.” [92, 93] 75 percent of the water needs are met through the groundwater. “The Gujarat Water Supply and Sewerage Board (GWSSB) has declared more than 75 percent villages in State as ‘No Source Villages’ implying villages with no dependable or sustainable source of water” [111]. As per the Urban Progress Phase III, Ahmedabad drew about 432 million liters per day (MLD) in 2002 for citizens.

The water was supplied at a rate of 135 lpcd and 76 percent of city’s households were provided with individual taps. This depleted the groundwater table at an annual rate of 2 to 3 meters. This provision has now increased to 160 lpcd with water withdrawal of 650 MLD.[9] The slum dwellers and urban poor, who do not have water tap connections, have to be satisfied with inferior quality of water at a relatively higher price. [282] The measures like transfer of water from water surplus areas by Sardar Sarovar Project, interlinking of State’s rivers and the Water Supply Grid for Gujarat, Sujalam Sufalam Yojana, check dams and rainwater harvesting schemes and the Regional Water Supply Schemes for rural-urban areas, are not adequate to reach some parts of Saurashtra and Kutch and to assure safe and adequate drinking water for all in an equitable manner [93, 94, 95, 96, 97].

There is a considerable gap between the supply and demand for water in the State. The supply of water was estimated at about 800 MCM/year in 2025 against the demand of water at around 1462.2 MCM/year. The water deficit would be about 662.2 MCM/year (TAHAL Committee report of the Government of Gujarat).

A literature review shows the following research gaps:

➢ To identify opportunities and constraints to reuse of waste water
Providing flexibility for individual industries to vary the requirements to suit local circumstances of affordability and risk

Need for a uniform approach to assess the feasibility of reuse

Test commercial feasibility for the wastewater treatment and recycling

Lack of decision support tools to efficiently allocate water and wastewater resources among different sectors

With issues of climate change, increases in urban population and increased demand for water from competing sectors, wastewater reuse is becoming an important strategy to complement existing water resources for both developing and developed countries and there are lessons, experiences, data and technology that can be shared for mutual benefit. With the aim to avoid water scarcity condition in central Gujarat region, the present study is undertaken. Here mainly two treatment plants are observed closely to identify possibilities of reuse of waste water which can prove techno economical solution for the nearby area. The testing is done at small scale to recommend it on a larger scale and proved a promising solution to meet with the current requirements of water usage [159].

One model is stated here which explains the process of ongoing development of waste water reuse.

**Figure 2.9  Options For Industrial & Municipal Wastewater Reuse**
(Source: Crook J 2005. The ongoing evolution of water reuse criteria. James Crook)[45, 31]
This model shows the path for exploring options for reuse of industrial and municipal waste water for which study has been carried out.

In the first case study, three treatment options are tried and one is suggested as techno economical solution which can save freshwater quantity. CETP waste water shows results in desirable limit that meet with standards for reuse, after treatment of reverse osmosis. If these proposed plants are constructed, then it will prove a solution for industries or farmers to get water. It will save considerable amount of freshwater quantity which may be utilized for potable purposes.