1. INTRODUCTION
The shortage of water resources has become a globally serious problem. The sewage after appropriate treatment and the reuse of the recycled water have become the consensus all over the world (Qin et al., 2013). It is very important to recycle the water resource in the designing and planning of the ecological residential quarter due to the critical way to realize the wastewater resource utilization.

Every community produces both liquid and solid wastes. The liquid portion of wastewater is essentially the water supply of the community after it has been fouled by a variety of uses. From the stand point of sources of generation, wastewater may be defined as a
combination of the liquid or water carried wastes removed from residences, institutions and commercial and industrial establishments, together with ground water, surface water and storm water as may be present. Domestic wastewater treatment has become a remarkable aquatic environmental problem all over the world. Due to non availability of cheaper methods and higher cost of treatment plants, municipalities are diverting untreated domestic wastewater in to aquatic bodies like ponds and lakes, where it is causing eutrophication due to higher concentration of nutrients and leads water unhygienic to use (Patel and Kanungo, 2012). If untreated wastewater is allowed to accumulate, the decomposition of the organic materials lead to the production of large quantities of mal odour producing gases. In addition, untreated wastewater usually contains
numerous pathogenic or disease causing microorganisms that dwell in the human intestinal tract or that may be present in certain industrial wastes. Wastewater also contains nutrients, which can stimulate the growth of aquatic plants, and also toxic compounds. Hence, wastewater should be removed from its sources of generation, followed by treatment and disposal. According to the manual of the Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Urban Development, in India the per capita per day water requirement is 100 lpcd (litres per capita per day).

1.1 Sewage characteristics

Municipal wastewater is mainly comprised of liquid (99.9%) together with relatively small
concentrations of suspended and dissolved organic and inorganic solids. Among the organic substances present in sewage are carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their decomposition products, as well as various natural and synthetic organic chemicals from the process industries. In arid and semi-arid countries, water use is often fairly low and sewage tends to be very strong. The major constituents of strong, medium and weak domestic wastewaters are as follows (Metcalf and Eddy, 1995).

Physically, the wastewater is usually characterized by a grey colour, musty odour with about 0.1% of solids content and the remaining 99.9% water content. The solids can be suspended (about 30%) as well as dissolved (about 70%). Dissolved solids can be precipitated by chemical and biological processes. From
a physical point of view the suspended solids can lead to the development of sludge deposits and anaerobic conditions when discharged into the receiving environment.

Chemically, wastewater is composed of organic and inorganic compounds as well as various gases. Organic components may consist of carbohydrates, proteins, fats and greases, surfactants, oils, pesticides, phenols, etc., Inorganic components may consist of heavy metals, nitrogen, phosphorus, sulfur, chlorides, alkalinity, toxic compounds, etc., In domestic wastewater, the organic and inorganic portion is approximately 50% respectively. However, since wastewater contains a high portion of dissolved solids than suspended, about 85 to 90% of the total inorganic component and about 55 to 60% of the total organic
component are available as dissolved. Gases commonly dissolved in wastewater are hydrogen sulfide, methane, ammonia, oxygen, carbon dioxide and nitrogen. The first three gases result from the decomposition of organic matter present in the wastewater.

Table 1: Major constituents of typical domestic wastewater

<table>
<thead>
<tr>
<th>S.N o.</th>
<th>Constituent</th>
<th>Concentration mg/ml</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Strong</td>
</tr>
<tr>
<td>1.</td>
<td>Total solids (mg/l)</td>
<td>1200</td>
</tr>
<tr>
<td>2.</td>
<td>Dissolved solids(TDS) (mg/l)</td>
<td>850</td>
</tr>
<tr>
<td>3.</td>
<td>Suspended solids(mg/l)</td>
<td>350</td>
</tr>
<tr>
<td>4.</td>
<td>Nitrogen (as N) (mg/l)</td>
<td>85</td>
</tr>
<tr>
<td>5.</td>
<td>Phosphorus (as P) (mg/l)</td>
<td>20</td>
</tr>
<tr>
<td>6.</td>
<td>Chlorides (mg/l)</td>
<td>100</td>
</tr>
<tr>
<td>7.</td>
<td>Alkalinity (mg/l)</td>
<td>200</td>
</tr>
<tr>
<td>8.</td>
<td>(as CaCO₃) (mg/l)</td>
<td>200</td>
</tr>
<tr>
<td>9.</td>
<td>Grease (mg/l)</td>
<td>150</td>
</tr>
<tr>
<td>10.</td>
<td>BOD₅ (mg/l)</td>
<td>300</td>
</tr>
</tbody>
</table>

Source: UN Department of Technical Cooperation for Development (1985).
Biologically, wastewater the ones that are of concern are classified as protista, plants and animals. The category of protista includes bacteria, fungi, protozoa and algae. Plants include ferns, mosses, seed plants and liverworts. Invertebrates and vertebrates are included in the animal category. In terms of wastewater treatment, the most important category are the protista, especially the bacteria, algae and protozoa. Also, wastewater contains many pathogenic organisms which generally originate from humans, domesticated and farmed animals that were infected with disease or carriers of a particular disease. Since the identification of pathogenic organisms in water and wastewater is very time consuming and difficult, the coliform group of organisms which are more numerous and more easily
tested for, is used as an indicator of the presence of pathogenic organisms.

Table 2: Possible levels of pathogens in wastewater

<table>
<thead>
<tr>
<th>Type of pathogen</th>
<th>Possible concentration per litre in municipal wastewater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viruses</td>
<td></td>
</tr>
<tr>
<td>Enteroviruses</td>
<td>5000</td>
</tr>
<tr>
<td>Bacteria</td>
<td></td>
</tr>
<tr>
<td>Pathogeneic E.coli</td>
<td></td>
</tr>
<tr>
<td>Salmonella sps.</td>
<td>7000</td>
</tr>
<tr>
<td>Shigella sps.</td>
<td>7000</td>
</tr>
<tr>
<td>Vibrio cholera</td>
<td>1000</td>
</tr>
<tr>
<td>Protozoa</td>
<td></td>
</tr>
<tr>
<td>Entamoeba hystolitica</td>
<td>4500</td>
</tr>
<tr>
<td>Helminths</td>
<td></td>
</tr>
<tr>
<td>Ascaris lumbricoides</td>
<td>600</td>
</tr>
<tr>
<td>Hook worms</td>
<td>32</td>
</tr>
<tr>
<td>Schistosoma mansoni</td>
<td>1</td>
</tr>
<tr>
<td>Taenia saginata</td>
<td>10</td>
</tr>
<tr>
<td>Trichuris trichiura</td>
<td>120</td>
</tr>
</tbody>
</table>

Source: Feachem et al. (1983).

However, this test does not accurately reflect the presence or absence of all pathogens that may be found in the treated effluent, i.e., viruses. Typically, the
concentration of fecal coli forms found in raw wastewater is about several hundred thousand to tens of millions per 100 ml of sample (Ravi et al., 2013).

With growing population, advanced agricultural practices, industrialization, urbanization and multiple use of water has increased the demand for water. Due to daily human activity and also various agricultural and industrial operations, wastewater is produced in enormous quantity. Due to lack of proper management and treatment facilities most of the urban wastewater generated in Indian cities is discharged into natural aquatic systems without treatment. An inadequate treatment facility for sewage has deteriorated the water quality of aquatic resources. The latest study carried out by the Central Pollution Control Board (CPCB) indicates
that about 26,254 million litres per day (MLD) of wastewater is generated in the 921 Class I cities and Class II towns in India (housing more than 70% of urban population). The municipal wastewater treatment capacity developed so far in India is about 7044 MLD accounting for 27% of wastewater generation in these two classes of urban centers (CPCB annual report, 2009).

1.2 Problems of sewage

The risks and dangers from sewage are well documented and sewage treatment is often advocated to mitigate the public health and environmental risks. Sewage disposal affects people’s immediate environments and leads to water related illnesses. Sewage water often contains pathogenic microorganisms
like bacteria, viruses, fungi, algae etc., having the potential capacity to cause diseases that can lead to immense harm to public health. The popular water borne diseases are typhoid, paratyphoid fevers, dysentery, cholera, polio and infectious hepatitis. The responsible organisms occur in the faeces or urine or infected people. Soil contamination and ground water pollution are the major environmental problems of wastewater (Buechler and Gayatri, 2005). The necessity of a multidisciplinary linked approach is also a problem to the wastewater treatment. The process of treatment of wastewater requires the participation of many disciplines including Engineering (Sanitary engineering, chemical engineering, electrical and mechanical engineering, basic principles of physics, chemistry and mathematics), Life sciences (Aquatic biology, microbiology), Earth
Sciences (Geology, hydrology, oceanography) and social and economic sciences (Sociology, law, political science, public relations, economics, administration).

1.3 Significance of sewage treatment

Global populations are rapidly expanding with urban populations expected to double in the next 40 years (UNFPA, 2009), increasing the demands on food and water resources and already existing inadequate wastewater treatment infrastructure. This is in the light of changing climatic patterns and water availability, weakened ecosystems, inconsistent and poorly integrated management as a whole. The challenges that unmanaged wastewater poses in the urban environment, to food production, industry, human health and the environment are interconnected and are becoming ever more severe. It
is critical that wastewater management has dealt with urgency and should be given very high priority to become an integral part of urban planning, integrated watershed and coastal management. As population increases so does the production of wastewater and the number of people vulnerable to the impacts of severe wastewater pollution. Almost 900 million people currently lack access to safe drinking water, and an estimated 2.6 billion people lack access to basic sanitation throughout the world (WHO/UNICEF, 2010).

Major growth will take place in developing countries, particularly in urban areas that already have adequate wastewater infrastructure. The financial, environmental and social costs are projected to increase dramatically unless wastewater management receives urgent attention. The poor are affected first and foremost
by this global crisis. Diarrheal diseases make up over 4% of the global disease burden, 90% of which is linked to environmental pollution i.e., a lack of access to safe drinking water and sanitation. Comprehensive and sustained wastewater management in combination with sanitation and hygiene are vital phenomena to achieve good health, food security, economic development and jobs.

The quality of water is important for the well-being of the environment, society and the economy. There are however ways to become more efficient and reduce our water footprint. Also, improving water and sanitation services and managing water require investment.
A paradigm shift is required towards new approaches that include wise investments and technological innovation, not a single size fits all, but now ensuring that investments are appropriate to the industries and communities they serve. Such investments can boost economies, increase labour productivity and reduce poverty.

1.4 History of treatment methods

Wastewater treatment and collection has followed paths of both historic and scientific discoveries. From a historic perspective, as communities have grown, so has the need for quality water. The need to supply safe water, remove wastes from water, and to protect public health, have been the endeavors and concern of many generations. Scientifically, as public health issues
and the understanding of what causes outbreaks of disease such as cholera and dysentery have been discovered, the building of infrastructure and development of processes that can be used to end these issues has followed. Crittenden et al. (2005), have described the history of wastewater treatment in chronological order. According to them water treatment methods were recommended in ancient Greek and Sanskrit (India) writings dating back to 2000 B.C. People of ancient times knew that heating water might purify it, and they were also educated in sand and gravel filtration, boiling, and straining. The major motive of water purification was to achieve a better tasting drinking water. Turbidity was the main driving force between the earliest water treatments. Not much was known about microorganisms, or chemical contaminants.
Despite the lack of optimization and the use of trial-and-error construction methods, numerous ancient urban drainage systems can be rated very successful. Eventually, starting from 1914 drinking water standards were implemented for drinking water supplies in public traffic, based on coliform growth. The time lapsed 1940s before drinking water standards were applied to municipal drinking water. In 1972, the Clean Water Act was passed in the United States. In 1974 the Safe Drinking Water Act (SDWA) was formulated. The general principle in the developed world now is that every person has right to safe drinking water.

1.5 Current Urban Drainage Perspectives

Urban drainage in the early parts of the twentieth century was firmly established as a vital public works
system. Engineers continued to improve design concepts and methods. During the second half of the twentieth century regulatory elements were promulgated in the United States, Europe, and other locations addressing urban drainage issues. Extensive monitoring efforts vastly improved the understanding of urban drainage quantity and quality characteristics (e.g. NURP in the United States). Computer modeling tools advanced the methods used to design and analyze urban drainage systems. Regulations, monitoring, computer modeling, and environmental concerns have now altered the perspective of urban drainage from a public health and nuisance flooding concern during the first half of the twentieth century into a public health and nuisance flooding with additional concerns for ecosystem protection and urban sustainability.
Table 3: Government regulations and PCB standards for discharge of sewage

<table>
<thead>
<tr>
<th>Sl.no.</th>
<th>Parameter</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pH</td>
<td>5.5-9.0</td>
</tr>
<tr>
<td>2</td>
<td>Temperature</td>
<td>Shall not exceed 5°C above the receiving water temperature</td>
</tr>
<tr>
<td>3</td>
<td>Suspended solids</td>
<td>Maximum 100 mg/l</td>
</tr>
<tr>
<td>4</td>
<td>Oil &amp; grease</td>
<td>10 mg/l</td>
</tr>
<tr>
<td>5</td>
<td>Total residual chlorine</td>
<td>1 mg/l</td>
</tr>
<tr>
<td>6</td>
<td>Total kjeldahl nitrogen</td>
<td>100 mg/l</td>
</tr>
<tr>
<td>7</td>
<td>Ammonicl nitrogen (as N)</td>
<td>50 mg/l</td>
</tr>
<tr>
<td>8</td>
<td>Free ammonia (as NH₃)</td>
<td>5 mg/l</td>
</tr>
<tr>
<td>9</td>
<td>BOD</td>
<td>30 mg/l</td>
</tr>
<tr>
<td>10</td>
<td>COD</td>
<td>250 mg/l</td>
</tr>
<tr>
<td>11</td>
<td>Dissolved phosphate</td>
<td>5 mg/l</td>
</tr>
<tr>
<td>12</td>
<td>Sulphide (as S)</td>
<td>2 mg/l</td>
</tr>
</tbody>
</table>

Source: Sewage effluent standards notified by Pollution Control Board of India (CPCB, 2009).
Starting in 1970, public health concerns shifted from water borne illnesses caused by disease causing microorganisms, to anthropogenic water pollution such as pesticide residues and industrial sludge and organic chemicals. Regulation now focused on industrial waste and industrial water contamination, and water treatment plants were adapted. Techniques such as aeration, flocculation, and active carbon adsorption were applied. In the 1980s, membrane development for reverse osmosis was added to the list. Risk assessments were enabled after 1990.

1.6 Indian scenario of sewage treatment

Water is one of the critical inputs for the sustenance of mankind. It is used by both terrestrial and aquatic environments for various activities, balancing the
ecological system of global environment. Water is an important natural source, which is abundant in nature and cover about 2/3ds of earth’s surface. However, only 1% of the water resource is available as fresh water (i.e., surface water - rivers, lakes, streams and ground water) for human consumption and other activities. The major uses of water are for irrigation (30%), thermal power plants (50%), while other uses are domestic (7%) and industrial consumption (~12%) (De, 2002).

The United Nation’s report on “Water for People, Water for Life” (the first ever UN system wide evaluation on global water resources) has put India at 120th position for water quality among the list of 122 nations covered. Only Belgium and Morocco are ranked worse than India. The quality indicator value was based
on quality and quantity of fresh water (especially ground water), wastewater treatment facilities, legalities like application of pollution regulations. Moreover, India’s quality indicator value stood at -3.1 while for based ranked country Finland it was 1.85.

Against the National average target of 135 lpcd of water and 180 lpcd per capita in large cities, the per capita availability is low and ranges from 165 lpcd in a few larger towns to about 50 lpcd in smaller towns. The availability of water in urban slums is about 27 lpcd. Urbanization has given rise to a number of environmental problems such as water supply, wastewater generation and its collection, treatment and disposal in urban areas. In most cases wastewater is let out untreated and it either percolates into the ground and
in turn contaminates the groundwater or is discharged into the natural drainage system adding pollution in downstream areas. According to Central Pollution Control Board, India, the sewage is accounts for more than 75 % of the surface water contamination in India. Due to negligence, ground water is also increasingly getting contaminated. In India less than 50% of the urban population has access to sewage disposal system. Most of the existing collecting systems discharge directly to the receiving water without treatment. Garbage, domestic and otherwise, is directly dumped into water bodies or left on roadside, which are often washed into streams and lakes (CPCB, 2009).

The municipalities dispose off their treated or partly treated or untreated wastewater into natural drains
joining rivers or lakes or used on land for irrigation or fodder cultivation or into sea or combination of these. Toxic chemicals from sewage water transferred to plants enter in the food chain and affect public health. Pathogens occurring in the sewage directly affect the mammals causing severe diseases. About 60% of urban deaths in India are due to lack of safe drinking water facilities. Further deaths due to water borne diseases are second only to malnutrition. It is estimated that around 80% of water consumed by a household is let off to the drains of sewers as wastewater. There is substantial scope for segregated use of the water for further use for gardening, industrial cooling, street cleaning, vehicular washing, fire fighting, irrigation, yard cleaning, fountains, recreational lakes etc., Though methods are available to improve the quality of recycled water to
potable grade, the lack of social acceptance and prohibitive costs may prevent the adoption of these techniques.

The importance of reuse and recycling of treated sewage and industrial effluents has been realized on account of two distinct advantages viz., reduction of pollution in the receiving water bodies and reduction in the requirement of fresh water for various uses. Reuse of municipal wastewater after necessary treatment to meet industrial water requirement is being practiced in India. Thus, wastewater can be considered as both a resource and a problem.

In India, in class I cities, activated sludge process (ASP) is the most commonly employed technology, covering 59.5% of total installed capacity followed by
up flow anaerobic sludge blanket (UASB) technology, covering 26% of total installed capacity. These two technologies are mostly used as the main treatment unit of a scheme including other primary or tertiary treatment units. A break up of various treatment schemes involving ASP or UASB as one of the units is also given in the tables. Series of waste stabilization ponds (WSP) technology is also important as it is employed in 28% of the plants even though its combined capacity is only 5.6%. In class II towns, series of waste stabilization ponds (WSP) technology is the most commonly employed technologies, covering 71.9% of total installed capacity and 72.4% of STPs, followed by up flow anaerobic sludge blanket (UASB) technology, covering 10.6% of total installed capacity and 10.3% of STPs. UASB technology is mostly used as the main treatment
unit of a scheme including other primary and tertiary polishing units (CPCB publications – Status of sewage treatment in India, 2009).

Sewage treatment plants in India are mostly based on conventional processes (activated sludge process (ASP) followed in a few cases by biofilters and extended aeration modification). Conventional treatment processes are effective but are often chemically, energetically and operationally intensive, focused on large systems and require considerable infusion of capital, engineering expertise and infrastructure. When making the technology or process more energy efficient and there is global pressure on India to reduce carbon emission in view of climate change scenario, a paradigm shift from conventional to biological treatment of wastewater is an urgent need.
To improve effluent quality, the UASB process is mostly followed by post-treatment processes like extended aeration lagoon, stabilization pond, biological activated sludge and physical sand filtration to remove macronutrients, pathogens and organic materials, which is a limitation of the UASB process. The conventional treatment offers an advantage in terms of efficient treatment but looking into the economy, energy consumption, land requirement and ease of handling, a set of treatments is proposed in the Indian context for wastewater reuse.

1.7 Treatment of wastewater

The objective of the sewage treatment is to produce a disposable effluent without causing harm to the surrounding environment and also prevent pollution
In the past, the disposal of wastewater in most municipalities and communities was carried out by the easiest method possible, without much regard to unpleasant conditions produced at the place of disposal. With increased industrial and urban development, effluent disposal and its effects on the environment now require special consideration. Currently, surface water discharge remains the most common method of wastewater disposal. After proper irrigation of wastewater in the sewers it is treated in various methods including secondary treatment.

The process of removing contaminants from municipal wastewater is called sewage treatment. Sewage treatment generally involves three stages, called primary, secondary and tertiary treatment. The treatment of wastewater is accomplished by four basic methods or
techniques i.e. physical, mechanical, biological and chemical. Most wastewater is treated in industrial scale wastewater treatment plants (WWTPs) which may include physical, chemical and biological treatment processes (Narmada and Mary selvam kavitha, 2012).

According to Ramalho (1977), the conventional classification of wastewater treatment methods are classified in to pre-treatment (screening, grit removal and fat and grease separation), primary treatment (screening, sedimentation and flotation), secondary treatment (activated sludge process, extended aeration process - tapered, step and complete mix aeration, contact stabilization, aerated lagoons, wastewater stabilization ponds, trickling filters and anaerobic treatment), and tertiary treatment (micro screening,
precipitation and coagulation, adsorption, ion exchange, reverse osmosis, nutrient removal process). Although modern technology has made a large number of sophisticated processes available capable of solving many wastewater problems, most have some disadvantage. Rectification or sorption techniques are prohibitively expensive. Incineration often causes air pollution problems and many chemical precipitation processes produce large amounts of sludge the disposal of which can pollute potable water sources.

1.8 Minor treatment systems

With the increasing urban population, there is a tremendous stress on basic amenities like water and sanitation. Sustainable wastewater management calls for
a system where wastewater is regarded as a resource which can be recycled and reused. Both communities and watersheds require an integrated approach which is affordable, adaptable and responsive to local needs. In centralized system conventional gravity sewers are present for treatment and surface water discharge. Sewage from each source is collected in large, deeply buried pipes that are laid at a specified grade to prevent solids from settling. The sewer must have regularly spaced manholes and as many lift stations as necessary to move the sewage to a single treatment plant that discharges treated effluent to a receiving stream.

The advantages include universally understood technologies, well-suited for dense urban populations and the disadvantages are costly, capital and labor
intensive, with additional monitoring costs. The decentralized system contains onsite, cluster and mixed systems. Decentralized solutions treat and disperse wastewater as close as possible to its source, use the soil in preference to surface water discharge and maximize reuse opportunities. They employ low cost and low maintenance infrastructure (e.g. onsite and cluster systems), require appropriate management and disperse smaller volumes of treated sewage to the environment at multiple locations. The characteristics of decentralized system include, the area divided into sections by problems, drainage basins, and other common features, each area is evaluated and prioritized by relative risk to health and environment and solutions to those problems and mixed solutions can include on-sites, clusters, and centralized zones under a single management
authority. The advantages of decentralized system include low cost (less expensive than centralized system), less disruption during construction & simpler monitoring and the disadvantage is discouragement of regulatory and financing rules.

Because of the size, small communities are facing a variety of problems for wastewater disposal. They includes 1. Stringent discharge or disposal standards. 2. High per capita cost. 3. Limited finance and 4. Limited operational and maintenance. Now-a-days, to construct apartments, shopping malls and gated communities, it is essential to take no objection certificate (NOC) from local pollution control body for wastewater discharge. Other problems of small scale wastewater systems include design, contracting, inadequate construction, inadequate construction
supervision, project management, operations and maintenance. The general flow rate for small scale wastewater systems ranges between 190-1900 L/day. Till date with the advancement of technologies, the small scale wastewater systems include contact stabilization, sequencing batch reactor, rotating biological contractor (RBC) and finally physical and chemical treatments. With these systems also, the wastewater treatment is limited.

There is an urgent need to plan strategies and give thrust to policies with equal importance for the development of wastewater treatment facilities and reuse. Water can be reused for various purposes like recreation, cleaning, toilet flushing and other uses where meeting the drinking water criterion is not mandatory.
Reuse of treated water needs infrastructure, space at the treatment site and treatment technology to meet the intended criteria.

1.9 Alternatives

Use of domestic wastewater for irrigation include benefits of safe and low cost treatment of wastewater, conservation and recharge of ground water reserves after phyto-remediation by plants and use of nutrients in wastewater for productive purposes. Systematic studies on wastewater characteristics are needed for deciding on application of wastewater at rates, which ensure a balance between nutrient input and plant uptake. It promotes plant growth and limiting pollution risk. Samples of domestic wastewater are recommended for
fertigation of timber plantation and raising plants for energy generation from biomass.

1.10 Biofilms

The ultimate goal of natural and biologically controlled purification is to transform any pollution material into anoxicous components. To achieve this end it is sometimes necessary to develop specialized populations or to provide unusual environments. Such specialized populations (seeds) have been described for the treatment of a variety of naturally occurring and synthetic materials. This development is frequently termed “acclimatization,” but more properly should be considered selective growth and adaptation of organisms resident in the environment (Paul et al., 1960).
A biofilm is an assemblage of surface-associated microbial cells that is enclosed in an extracellular polymeric substance matrix. As early as 1973, Characklis studied microbial slimes in industrial water systems and showed that they were not only very tenacious but also highly resistant to disinfectants such as chlorine. A biofilm is an assemblage of microbial cells that is irreversible associated (not removed by gentle rinsing) with a surface and enclosed in a matrix of primarily polysaccharide material. Non cellular materials such as mineral crystals, corrosion particles, clay or silt particles, or blood components, depending on the environment in which the biofilm has developed, may also be found in the biofilm matrix. Biofilm associated organisms also differ from their counterparts (freely suspended) with respect to the genes that are transcribed.
Biofilms may form on a wide variety of surfaces, including living tissues, in dwelling medical devices, industrial or potable water system piping or natural aquatic systems. The water system biofilm is highly complex, containing corrosion products, clay material, fresh water diatoms, and filamentous bacteria. Biofilms are composed primarily of microbial cells and extra cellular polysaccharides (EPS). EPS may account for 50% to 90% of the total organic carbon of biofilms (Flemming et al., 2000) and can be considered the primary matrix material of the biofilm.

In single species biofilms, the biofilm associated bacteria alter gene expression to maximize survival in their particular microenvironment (Haung et al., 1998; Xu et al., 1998). In mixed biofilms, which are more representative of biofilms occurring in nature, bacteria
distribute themselves according to who can survive best in the particular micro-environment and also based on symbiotic relationships between the groups of bacteria (Moller et al., 1996; Moller et al., 1998; Okabe et al., 1999). Thus, the bacteria in a multi-species biofilm are not randomly distributed but rather organized to best meet the needs of each.

1.11 Biofilters

Biofiltration is a pollution control technique using living microorganisms for bioremediation process of pollution. Generally uses of biofiltration process include processing wastewater, degradation of hazardous chemicals from surface runoff and microbial oxidation of contamination in air. Microorganisms including bacteria and fungi are immobilized in biofilter and
degrade the pollutant. Ottengraf (1983), is the pioneer in the investigation of the behaviors of biofilters. According to him, the biofilter can be classified into three phases viz., a gas phase (the air stream), a liquid biolayer (waster and biomass) and a solid phase (the particle). Ottengraf (1983), assumed the kinetics of the biodegradability which takes place was zero order. Various kinds of natural and synthetic packing materials are used in biofilters. They include wood chips, peat, vegetable mulch, plastic balls, tubes etc.,

Adsorption processes are widely applied for separation and purification because of the high reliability, energy efficiency, design flexibility, technological maturity and the ability to regenerate the exhausted adsorbent. One method of important
extending the adsorption treatment processes is biofiltration (Alder, 2001). The biological filter relies on the activities of the community of microorganisms that become attached onto the filter media. Microbes oxidize organic matters in water to produce energy and therefore available nutrients sources in feed water are essential for their development.

Biofiltration can effectively remove organic matter that is not able to be removed from water and biologically treated sewage effluent in conventional sewage treatment. The microbial attachment process, the factors that influence biological filtration, the kinetics of microbial growth and details of the microbial community in the biofilter. With stringent water pollution control, biofiltration provides greater environmental
sustainability than traditional aquaculture in managing waste production and also a possibility to integrate it with various purposes.

1.12 Aims and Objectives

1) In the present study, an attempt was made to utilize various kinds of low cost, economically viable and readily available filter media. A novel and holistic approach was manifested for pollutants removal and efficiency of various filter materials were determined in the direction of pollutant removal using a specific consortium of microbes.
2) The aim of the study is to achieve high removal efficiency of pollutants and to maintain an optimal performance in long term run. Novel filter materials were selected which were not present in the list of literature survey to know the applicability for biofiltration system.

3) In view of above, an attempt was made for sewage treatment by biofilter method. A consortium of microorganisms was selected and evaluated their efficiency by periodical testing procedures.

4) Later, various filter materials were selected viz., natural unprocessed material (granite chips), natural processed materials (clay balls, sintered
glass cylinders), natural biogeneic materials (corn cobs, wood chips) and synthetic processed materials (nylon threads, plastic balls) and analyzed for their efficiency to work as filter materials.

5) Various physico-chemical parameters were analyzed for each organism and filter material. In the present work, 7 packing materials used as support media in biofiltration are analyzed and compared to evaluate their suitability according to physical characteristics.

6) The nature of the packing material in biofilters is an important factor for the success in their construction and operation. The materials studied
were chosen in a novel approach, which were not present in previous studies in the field of biofiltration including both organic and inorganic (or synthetic) materials.

7) A set of fifteen different parameters were selected to cope with well established factors, such as a material specific surface area, volume, hydraulic retention time and time period. The economic importance of filter material was highly considered and material selection was done based on purchase cost, availability and durability.

8) One ranking of packing materials was established for each parameter studied in order to define a
relative suitability degree. Since biofiltration success generally depends on a combination of the ranked parameters, a procedure was defined to compare packing materials suitability under common situations in biofiltration. The selected scenarios, such as biofiltration of intermittent loads of pollutants and biofiltration of waste water were investigated.

9) Raw sewage, treated sewage, biofilm formed during the process of treatment and consortium were studied further, using electron microscopy, electrophoresis of proteins and LC MS analysis.