LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS

Abbreviation	Expansion
%	Percentage
º	Degree
′	Minute
″	Second
µ	micron
&	and
3rd	Third
<	Less than
>	Greater than
°c	Degree Celsius
BDL	Below Detection Level
BIS	Bureau of Indian Standards
BNP	Bank Note Press
BOD	Biochemical Oxygen Demand
cm	centimetre
cm^2	Square centimetre
Ca	calcium
$CaCO_3$	Calcium carbonate
COD	Chemical Oxygen Demand
Cl	Chlorine
DO	Dissolved Oxygen
E-coli	Escherichia Coli
eff	Effective
e.g	for example
et al	And others
g	gram
F	Fluorine
FAO	Food and Agriculture Organization
Fe	Iron
Fig	Figure
Flow/hr	Flow per hour
ha	hectare
hr	hour
i.e.	that is
IS	Indian Standard
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kg	Kilo gram
m	Metre
m^2	Square metre
m^3	Cubic metre
MCS	Monte Carlo Simulation
Mg	Miili gram

MIS	Management Information System
ml	Milli litre
mm	Milli metre
m^3/d	Cubic metre per day
mg/L	Miili gram per litre
m/hr	Metre per hour
ml/d	Milli litre per day
m/minute	Metre per minute
m/s	Metre per second
m^3/s	Cubic metre per second
$m^3/m^2/day$	Cubic metre per square metre per day
$m^3/m^2/hr$	Cubic metre per square metre per hour
nm	Nano metre
N	Numbers of filter units
NTU	Nephlometric Turbidity Units
PAI	Population Action International
PCB	Polychlorinated Biphenyls
PET	Polyethelene Terephthalate
ppm	Parts per million
PVC	Poly Vinyl Chloride
Q	Discharge
SiO_2	Silicon dioxide
Sl.No.	Serial Number
TDS	Total Dissolved Solids
UN	United Nation
UNESCO	United Nations Educational Scientific and Cultural Organisation
U.S	United states
UV	Ultra violets
VOC	Volatile Organic Compounds
WTP	Water Treatment Plant
WHO	World Health Organisation

INTRODUCTION

Water is an essential natural resource for sustaining life and environment. The available water resources are under pressure due to increasing demands and the time is not far when water, which we have always thought to be available in abundance and free gift of nature, will become a scarce commodity.

It is well known that 70% of Earth's surface is water of which 97.5% is salt water and only 2.5% is fresh water. Less than 1% of the total freshwater in earth is accessible since the majority is frozen in ice caps or exists as soil moisture. About $1.1X10^{14}$ cubic meters of precipitation fall on the world's continents each year, most of which is absorbed by plants and or evaporated back into the atmosphere, $4.27x10^{13}$ cubic meter of this precipitation flow through river $9x10^{12}$ cubic meter of freshwater are readily accessible for human use another $3.5x10^{12}$ cubic meter are captured and stored in dams and reservoirs. According to the data on water consumption in the world, provided by the United Nations (UN, UNESCO, and FAO), we currently use about 50% of the world's readily available water.

According to a 2007 World Health Organisation (WHO) report, 1.1 billion people lack access to an improved drinking water supply, 88 percent of the 4 billion annual cases of diarrheal disease are attributed to unsafe water and inadequate sanitation and hygiene, and 1.8 million people die from diarrheal diseases each year. The WHO estimates that 94 percent of these diarrheal cases are preventable through modifications to the environment, including access to safe water. Simple techniques for treating water at home, such as chlorination, filtration, and solar disinfection, and storing it in safe containers could save a huge number of lives each year. Reducing deaths from waterborne diseases is a major public health goal in developing countries.

India is blessed with substantial water resources and these resources are regularly replenished by two monsoonal patterns, the South-West and North-East monsoons. In spite of this, India is water stressed and in the near future, it is likely to become a water scarce country as a result of varied reasons. Ground water is depleting at an alarming rate due to over withdrawal. Absolute water scarcity is already being experienced in different parts of the country, in high rainfall areas, low rainfall areas, in hilly terrain and in the plains.

Due to rapid urbanization coupled with population explosion, the state of Kerala is facing water scarcity and is likely to face water famine if proper management strategy of the resource is not adopted. The state receives 2.78 times more rainfall than the national average and five and three times more than Rajasthan and Tamil Nadu respectively. With about 3000 mm rainfall, chains of back water bodies, reservoirs, tanks, ponds, springs and wells, Kerala is considered as land of water. However, the state of Kerala is frequently facing severe droughts followed by acute drinking water scarcity for the last two decades. Rivers hardly contain any water during six months of a year; only few reservoirs get filled up even during the monsoon. In summer, water level goes down to the silted up bottom in many cases. Continued exploitation of ground water resources and utter ignorance on their susceptibility has already caused unimaginable damage and posed a serious threat to the ecological balance. Therefore steps must be taken to maintain hydrological equilibrium between annual replenishable recharge and ground water draft, in order to maintain fresh water balance.

Regional water scarcity is a significant and growing problem, and indicators of water scarcity. In some regions, water use exceeds the amount of water that is naturally replenished every year. About one-third of the world's population lives in countries with moderate-to-high water stress, i.e. countries in which the water consumption exceeds 10 percent of the renewable freshwater resources as defined by the United Nations. By this measure, some 80 countries, constituting 40 percent of the world's population, were suffering from water shortages by the mid-1990s. By 2020, water use is expected to increase by 40 percent, and 17 percent more water will be required for food production to meet the needs of the growing population. According to another estimate from the United Nations, by 2025, 1.8 billion people will be living in regions with absolute water scarcity, and two out of three people in the world could be living under conditions of water stress.

There are currently more than 430 million people living in countries considered to be water stressed. Population Action International (PAI) projects that by 2050, the percentage of the world's population living in water stressed countries will increase by at least threefold of current value. It is estimated that about 250-350 litres per person per day is a rough minimum required for the basic household needs such as drinking, bathing, and cooking. About five to twenty times this quantity is needed to meet the demands of the agricultural, industrial, and energy production sectors. A country with more than approximately 1,700 cubic meters of renewable fresh water per person per year will generally experience only intermittent or localized water shortages. As the amount of available fresh water sinks below this level, countries begin to experience 'water stress'-that is, water supply problems tend to become chronic and widespread. This stress indicator is a caution light, signifying that population growth is reducing the amount of available water per person to troublesome levels. As the renewable water supply falls below 1,000 cubic meters per person, the more serious 'water scarcity' begins to occur.

Decline of ground water table and increase of population has decreased the per capita water availability in India by four times, where as in Kerala, it has decreased by five times. Even though, Kerala receives 2.78 times more rainfall compared to the national average, unit land of Kerala has to support 3.6 times more population. Hence, for self sufficiency, unit land of Kerala has to produce 3.6 times more food and biomass, also the same unit of land has to provide 3.6 times more drinking water and associated water requirements compared to the national average hence it is evident that the state is under water stressed condition.

Water availability statistics are far better as compared to pure water availability as contamination of water sources are growing exponentially with growth of urbanization, Therefore need of water purification is a must. Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. The goal is to produce water fit for a specific purpose. Mainly water is purified for human consumption (drinking purposes), but water purification may also be done for a variety of other purposes, including meeting the requirements of medical, pharmacological, chemical and industrial applications. In general the methods used include physical processes such as filtration, sedimentation and disinfection, biological processes such as slow sand filters or biologically active carbon, chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light. The purification process of water may reduce the concentration of impurities including suspended particles, bacteria, algae, viruses, fungi; and a range of dissolved and suspended impurities derived from the surfaces that water may have made contact with after falling as rain.

The standards for drinking water quality are typically set by governments or by international standards. These standards will typically set minimum and maximum concentrations of contaminants for the particular use of water. It is not possible to tell whether water is of an appropriate quality by visual examination. Simple procedures such as boiling or the use of a household activated carbon filter are not sufficient for treating all the possible contaminants that may be present in water from an unknown source. Even the natural spring water which is considered safe for all practical purposes in the 19th century must now be tested for determining the kind of treatment, if any, it needed. Chemical and microbiological analysis, while expensive, are the only way to obtain the information necessary for deciding on the appropriate method of purification.

The KCAET campus is situated near the banks of the Bharathappuzha river. The daily water requirement of the campus comprises the irrigation requirements of farm and various study plots, and domestic and civic requirements in hostels, residences and offices. As the water requirement is high, frequent pumping is necessary. The pumping station is situated near the river basin, and consequently, the pumped water contains a large amount of sediments. This results in high turbidity, pH, and iron content. The water has a reddish yellow colour with an unpleasant odour. Considering the importance of the availability of good quality drinking water in the campus, an effort is made in this project to develop a simple and efficient water tap filter with indigenous natural filter materials such as sand, coir, charcoal etc. and to assess the quality of the filtered water. This filter can be connected to the water tap as an immediate solution for the available unwholesome water. As a long term solution for this, a complete design and drawing of a water treatment plant for the entire KCAET campus with various treatment units like sedimentation, filtration and disinfection is also attempted in this project work.

The specific objectives of the present study are,

- To assess the quality of water available in the KCAET campus;
- To develop a simple and effective tap water filter with naturally available materials;
- To assess the quality of filtered water from the tap water filter; and
- To propose a detailed design and drawing of a water treatment plant for the KCAET campus.

REVIEW OF LITERATURE

In this chapter a review of the literature on some techniques for water purification, various types of water filters, removal of dissolved minerals and water treatment plant are discussed in detail.

2.1 Water filter

Water is essential for all life and is also a part of the larger ecosystem on which the reproduction of the biodiversity depends. Fresh water scarcity is not limited to the arid climate regions only, but in areas with good supply also, the access of safe water is becoming critical problem. Water filters can be used in such areas to remove impurities from water by means of a fine physical barrier. This cleanses water to various extents for irrigation, drinking purpose etc. Filters occupied with sand, geotextiles and carbon can perform a major role in removing dissolved contaminants, thereby reducing turbidity, and also making pH to the normal range.

Fourie & Addison (1999) studied changes in filtration opening size of woven geotextiles subjected to tensile loads and found a relatively thick woven slit film polypropylene geotextile showed a marked reduction in the filtration opening size of the geotextile as the load was increased. Loads of only 10% of the minimum tensile strength of the geotextile caused a reduction in the filtration opening size of about 28%.

Aydilek & Edil (2002) evaluated the filtration performance of woven geotextiles with sludge from wastewater treatment unit. The laboratory portion of the program included a series of filtration tests with different woven geotextiles. Filtration performance of the sludge-woven geotextile systems was also observed in field test cells. Geotextile samples were exhumed from the cells after exposure and analyzed in the laboratory. The results indicate that the sludge can be filtered using woven geotextiles and the selection of a proper filter can be made on the basis of geotextile pore structure parameters, i.e. percent open area and pore opening size distribution.

Aydilek (2002) observed the remediation of high water content geomaterials. In their study the geotextile filter performance remediation of contaminated high water content geomaterials, such as wastewater treatment sludges, harbour dredgings, waste pickle liquor sludges, fly ash slurries, has always been a challenge to the geotechnical community. Among various remediation alternatives, capping and dewatering was increasingly popular. Geotextiles commonly used were expected to prevent erosion of soils in contact with the filter without impeding the flow of seeping water through the soil. Several empirical criteria incorporating varying factors of safety have been proposed for selection of geotextile filters; however, they are not directly applicable to high water content geomaterials. An extensive literature review pertinent to filtration of geomaterials using geotextiles and factors affecting the behaviour of filtration processes were presented. Applicability of a recently developed analytical model to predict the observed filtration behaviour was also investigated.

Yaman et al. (2005) evaluated the geotextile biofilters for wastewater treatment in the pilot plant study using geotextile filters as biofilm attachment media in wastewater treatment. The geotextiles filtered suspended solids and hosted growth of microorganisms to decompose carbonaceous and nitrogenous compounds. The test liquid was primary treatment effluent that treated combined sewage. Their goal was to exceed secondary treatment standards while maintaining a hydraulic loading capacity. The study used 10.16 cm diameter packed columns containing alternating layers of gravel, sand and geotextile filters. It was found that only nonwoven needle punched geotextiles with complex structures and high internal porosity were suitable for their application. The parametric variables included the number of geotextile filter layers, the hydraulic loading rate and pattern, and provision for passive re-aeration.

Lee et al. (2007, 2008) pointed out the disadvantages of the conventional process of combining sedimentation and filtration as the rather long residence time. This is mostly due to the flocculation and sedimentation phases (typically 2 h). The fiber filter developed for the tertiary treatment of biologically treated sewage effluents was used in their study for filtration of drinking water production and was tested. The fiber filter (with in-line coagulation) was used as an alternative to the process of flocculation and sedimentation. In their study, the filtration efficiency of the newly designed filter was estimated using a range of filtration velocities from 60 to 100 m/h and a small dosage of coagulant (1–3 mg/L) injected in-line. Through these experiments, it was shown that the new fiber filter design was very efficient for particle removal at a filtration velocity of 60 m/h (1500 m3/d) and 1 mg/L coagulant dosage, and these were considered as the optimal operating conditions.

Kalinovich et al. (2008) studied the application of geotextile and granular filters for PCB (polychlorinated biphenyls) remediation. The application of a surface, permeable reactive barrier has been implemented at a remote site in the Canadian Arctic for the remediation of soils and water contaminated with PCBs. The initial barrier system was installed in July 2003. Preliminary work in both the field and the laboratory suggested that geotextiles alone may not be adequate for this particular arctic barrier system, owing to issues related to survivability (specifically the effects of high UV and freeze–thaw) and clogging. Subsequent field and laboratory work demonstrated that granular materials trapped the majority of PCB-contaminated soil without impeding hydraulic performance; however, fines were escaping. Extensive column testing in the laboratory has shown that a nonwoven geotextile filter can be applied with success with a granular permeable reactive barrier system.

Guyer (2009) reported the use of geotextiles in pavement and drainage applications. This study indicated that, geotextiles are efficient than normal lining materials because the reduced area of high permeability material concentrates flow and lowers drain efficiency. Wrapping of the pipe may be useful when finer grained filter materials are best suited because of availability and/or grain size requirements. In this case, the geotextile functions as a cover for the pipe perforations preventing backfill infiltration. If the geotextile can be separated a small distance from the pipe surface, the flow through the geotextile into the pipe openings will be much more efficient. Use of plastic corrugated, perforated pipe with openings in the depressed portion of the corrugation is an easy way of doing this.

2.2 Removal of dissolved minerals

Dissolved minerals are the major portion of contaminants especially in ground water. This includes poisonous contaminants such as arsenic, iron etc. The dissolved minerals greatly affect the viability of potable water which includes changes in physical characteristics like pH, colour, turbidity etc. Its removal is a hectic process and thus the dissolved minerals evaluate the filtering efficiency or effectiveness of any filter.

Ogutu & Otieno (1992) conducted a study on assessing the performance of drinking water treatment plant using turbidity as the main parameter. In their study, sampling of water was done at the inlet and outlet of each of the process units of the Moi University drinking water treatment plant (Kenya) regularly for six months and turbidity tests done to asses their performance in terms of turbidity removal. Other physical parameters like pH, residual chlorine and suspended solids were also measured and their relationship with turbidity developed. Results revealed that the optimum coagulant dosage for this plant should be 2 mg/l at pH of 6.8 for optimal turbidity removal; this however, varied from plant to plant. WHO recommendations for turbidity of filtered water to be disinfected with chlorine should be less than 1 Nephlometric Turbidity Units. Higher turbidities measured in the study revealed the presence of cracks and mud balls in the sand media of the filter units causing inefficiencies in filtration as well as lower filtration rates. WHO also recommends turbidities of less than 5 NTU for drinking water and higher turbidities ranging 5-7 NTU measured in this study indicates possibility of faults in the treatment plant and distribution system.

Michalakos et al.(1996) presented the numerous advantages of iron removal by the trickling filter, as (i) rapid oxidation, (ii) no need for an external air supply, (iii) iron oxidation and filtration taking place in the same unit, (iv) reagents are not required for pH correction and flocculation, (v) high removal capacity attained since iron is retained in a very compact form, (vi) high filtration rate due to the robustness of the biological floc and (vii) very economical washing, since the amount of wash water required is small enough compared to the amount of treated water.

Hu et al. (1998) noted that the water from advanced water treatment plants may still have an AOC (assimilable organic carbon) concentration of more than 265 mg/l which is considered high with respect to potable water standards. Treatment processes which increased the amount of organic matter in carbonyl group would likely lead to a product water with poor biological stability.

According to Andersson et al. (2000) iron removal is strongly dependent on the temperature. Ammonia removal capacities ranged from 40 to 90% in pilot filters, at temperatures above 108^0C, while more than

90% ammonia was removed in the full-scale filters for the same temperature range. At moderate temperatures (4–108^{0}C), the first stage pilot filters removed 10–40% of incoming ammonia for both media (opened and closed superstructure).

Mohamed et al. (2003) indicated that a binary mixture of carbons from acid-activated almond and either steam-activated pecan or walnut shells were the most effective in removing metals like iron, mangenese from drinking water of all the systems evaluated. Binary mixtures of acid-activated almond shell-based carbon with either steam-activated pecan shell- or walnut shell-based carbon removed nearly 100% of lead ion, 90–95% of copper ion and 80–90% of zinc ion. Overall performance data on the Envirofilters, suggested that these prototypes require less carbon than commercial filters to achieve the same metal adsorption.

Sadiq et al. (2003) evaluated performance of slow sand filters, To obtain an optimal removal efficiency of about 95 to 100 percent through slow sand filters, the filtration rates and sand bed depths should range from 0.2 to 0.3 m^3/h and 75 to 100 cm, respectively.

Bong-Yeon Cho (2005) conducted a study on Iron removal using an aerated granular filter Laboratory scale experiments concerning iron removal from artificial raw water by an artificial filter using anthracite as filter media were conducted. The major findings were that iron oxidation and removal by an aerated filter is mainly a catalytic chemical reaction rather than a biological reaction. Further, iron removal does not perform effectively without aeration. Iron removal was very effective when the pH was weakly acidity. Iron oxide attached to the surface of the media is identified as ferrihydrite, which catalyzes the oxidation of iron as shown by Mossbauer spectra analysis.

Tekerlekopoulou & Vayenas (2006) studied the ammonia, iron and manganese removal from potable water using trickling filters. The mean size of the gravel and hence, the specific surface area was found to be critical for optimal iron removal. The effect of the operational conditions on the physico-chemical and combined physico-chemical and biological iron oxidation was also studied. Experimental results showed that the combined, as well as the simultaneous removal of the aforementioned pollutants, can be achieved by single-step filtration.

Pratiksha et al. (2006) assessed the quality of drinking water in Chandrapur District. Their study was carried out to have an understanding about the pollution status of Chandrapur district, particularly water quality in vicinity of Industrial area. Environmental studies were carried out on ground and surface water to find out the physico-chemical parameters like pH, BOD, COD, DO, hardness, alkalinity, fluorides, chlorides, TDS and turbidity. Seven samples were collected from different sites to evaluate the drinking water quality in and around Chandrapur district. The analysis of various parameters using standard methods (APHA/NEERI) and their comparison with WHO standard values, suggested that most of the parameters were within permissible limit given by Bureau of Indian standards (BIS). Concentration of parameters beyond the limits in some stations could be reduced and could be an invaluable source for domestic purposes in the region.

Mahvi et al. (2007) evaluated total coliforms and turbidity removal of water in the continuous sand filter. The continuous filter is a kind of sand filter, which will operate without any interruptions for backwashing and also it accepts high-suspended solid levels in feed stream. Fouled sand is continuously removed from the filter bed, washed and recycled back without interruption with filtration process. Various samples of water with certain amounts of turbidity enter through a feed pipe and being distributed to the filter. A central column runs from top to bottom of the filter. The water is led through an outer tube in the column by a set of radial, distributor arms. The polluted water flows up ward through the sand bed. The water emerges; clean, in the top section of the tank, and eventually spills over a weir, and then inters into a discharge pipe. In this research, the continuous sand filter was studied to determine its disinfection efficiency in addition to turbidity removal. The results showed that the filtered water had a high quality and the turbidity reduction was 95.5 %. Inspecting the work of the filter had revealed that the removal rates of coliforms and microbial colonies were 99.67 % and 98.99 % respectively. On the other hand, by the use of direct filtration, turbidity reduction was over 97 %. This continuous sand filter has the advantage of stable operation and more energy saving as compared to the conventional ones.

According to Tekerlekopoulou, and Vayenas(2007) Pilot scale trickling filters were constructed and tested in order to study biological removal of ammonia, iron and manganese from potable water. The effect of the size of the support material on nitrification performance was studied extensively. The mean size of the gravel and hence, the specific surface area was found to be critical for optimal nitrification operation. A steady-state model developed in previous work was used to predict filter's performance. The model was very accurate only for the gravel size for which maximum nitrification rates were observed. The effect of the operational conditions on the physico-chemical and combined physico-chemical and biological iron oxidation was also studied. It was found that the contribution of biological oxidation is significant, increasing filter's efficiency by about 6% and reducing the required filter depth by about 40%. Manganese biologicaremoval was studied using gravel with small mean diameter, thus providing high specific surface area. Feed concentrations up to 4.0 mg/l were treated sufficiently. Finally, experiments were performed to investigate the simultaneous removal of ammonia, iron and manganese. Experimental results showed that the combined, as well asthe simultaneous removal of the aforementioned pollutants, can be achieved by single-step filtration.

Gidde et al. (2008) conducted a study on the Bentonite clay turbidity removal by herbal coagulant- a rural water treatment technology. Unlike cities whereas fairly large population is using water filters, aqua guards; the rural population is thriving on the contaminated water supply due to lack of financial resources and other pressing essentialities of life. Therefore, it is vital that with increased emphasis on augmenting the source of drinking water, efforts should also be made simultaneously for ensuring its quality. In rural context, both availability of material used in the purification and its acceptability as environmentally safe has to be ensured. This applied research project has shown that turbid water can be treated to the same degree achieved by imported chemicals, by using a natural substance which can be purchased locally from villagers. Moringa oleifera - Alum Blend has been found to be a good substitute to Alum, in addition to its being a natural product with wide availability and cost effectiveness. Advantage observed by introducing the M oleifera seeds as primary coagulant and coagulant aid has potential for its use in coagulation of turbid water with high turbidity removal rate ranging from 89 - 99%. Conjunctive use of Moringa oleifera with Alum showed 40-60% Alum saving.

Al-Rawi (2009) did a study on sand filter capping for turbidity removal for potable water treatment plants of Mosul/Iraq. Sand filter capping had been tried as an alternative for the currently practiced rapid sand filters. A 1000 m^3/day capacity pilot plant constructed along with a full scale water treatment plants was used for this purpose. Four levels of sand material with respect to grain size and thickness were used. This study gave a result of reducing filter numbers or increasing the plant capacity by two folds in the minimum. Economic revenue was gained through reduction of disinfection doses as well as reduction in filter sand material. Runtimes of filters were increased by 2 – 3 folds indicating capability of more furnished water productivity and fewer amounts for backwash need. Above all the water produced was of very good quality that met the most stringent specifications and promoted health. Capping sand filters were proven to suitably operate under varying conditions of influent turbidity and filtration rates.

Toshiya et al. (2010) reported the turbidity removal effect and surface charge shift for electrochemically treated retentate without coagulant addition. In this study comparative testing showed that the electrolytic treatment increased aggregate size and enhanced the turbidity removal effect up to 75% on average with increasing retention time. Even though the Al ion concentration in the retentate was much lower than 0.1 mg/L, along with the large upward shift of surface charge, the turbidity removal effect was enhanced considerably with independently stabilized pH compared with alum as the coagulant. Comparison between the charging behaviors indicated that the electrochemical treatment generates polymeric Al hydroxide species that form adsorption layers with fewer defects, thereby inducing a stronger removal effect.

2.3 Water treatment plant

Water to be supplied for public use must be potable i.e., satisfactory for drinking purposes from the standpoint of its chemical, physical and biological characteristics. Drinking water should, preferably, be obtained from a source free from pollution. The raw water normally available from surface water sources is, however, not directly suitable for drinking purposes. The objective of water treatment is to produce safe and potable drinking water. Some of the common treatment processes used in the past include Plain sedimentation, Slow Sand filtration, Rapid Sand filtration with Coagulation-flocculation units as essential pretreatment units.

Bhunia (1986) examined the Optimal Design and Operation of Wastewater Treatment Plant and developed a dynamic model for the entire wastewater treatment system. Process dynamics were incorporated into cost estimates for the design and operation of the treatment system. An optimization technique was employed to obtain the minimum, total discounted cost . Both fixed and variable costs were considered in a single objective function. The treatment plant model includes primary clarification, aeration, secondary clarification, gravity thickening and anaerobic digestion. The dynamic model of a primary clarifier includes a non-steady state advection-diffusion equation which considers turbulence and deposit resuspension. From this an optimal depth to maximize efficiency was obtained. The activated sludge process model distinguishes between particulate and soluble substrates, and calculates oxygen requirements and sludge production from transient inputs and varying operating strategies.

Katsuyoshi and Mangara (1999) studied the design of water treatment facilities. According to their study, the main factors to be considered for the design of a water treatment plant are; (1) type of water source, (2) finished water quality, (3) skill of facility operators and (4) available size of funds.

Vitaly et al. (2005) studied the removal of *cryptosporidium parvum* oocysts by rapid sand filtration with ballast flocculation-filtration and intermediate downwashes. This study demonstrated that addition of ballast particles consistently reduces the frequency and duration of the ripening sequence based on the assumption that partially positive charged kaolin particles may adsorb onto the surface of *c. parvum* oocysts and neutralize their negative charge.The proposed view was successfully developed into a ballastedflocculation filtration technique used to enhance removal of inorganic particles and *c. parvum* oocysts.

Gupta et al. (2005) assessed water treatment plant by Monte Carlo Simulation(MCS). This paper develops and demonstrates the methodology to assess the reliability of water treatment plant (WTP) using Monte Carlo simulation technique for desired effluent water quality. WTP was designed optimally based on nominal values of input variables and model parameters (i.e., specific gravity of floc, viscosity of water and sedimentation basin). This approach was applied and illustrated for a 50,000 m^3/day conventional WTP treating raw water with suspended solid concentration of 200 mg/litre. The reliability of this plant was found to be 95.24% based on statistics of parameters using 5000 MCS trials and thus failed to achieve the desired water quality standard for 4.76% of time due to uncertainty of variables.

Peter (2006) examined the design aspects of the burgowan water treatment plant. The design of a new 20 ml/d augmentation to wide bay water's burgowan water treatment plant resulted in several innovative features incorporated into the design. Along with conventional design for turbidity and colour removal, the plant incorporated treatment units for the treatment of taste and odour and iron and manganese and with lime/carbon dioxide stabilisation of the treated water.

Goula et al.(2008) determined several specific aspects of the potable water application (low solids mass and volume fraction) to derive a computational tool computationally much more efficient (due to the independent handling of flow field and different particle classes) than the corresponding tools employed to simulate primary and secondary waste water settling tanks. The present code is modified based on data from a real sedimentation tank. Then it is used to assess the significance of extending the feed flow control baffle of this particular sedimentation tank.

Angreni (2009) studied about the optimisation of conventional drinking water treatment plant in Indonesia. Conventional drinking water treatment plant consists of coagulation, flocculation, sedimentation, filtration and disinfection units. Depending on water quality influent, each unit can be optimized to achieve the desired water quality effluent, both in design and operation stages. They presented a review on optimization of conventional drinking water treatment plant that eventually proposing a method to maximize process efficiency with less risks. Overall optimization was carried out by dynamic programming to meet drinking water quality standard.

Boccelli et al. (2010) observed the Drinking water treatment plant design incorporating variability and uncertainty in Office of Research and Development, National Homeland Security Research Center, U.S. This study presented an optimization framework for investigating the effects of five variable influent parameters and three uncertain model parameters on the least-cost treatment plant configuration that reliably satisfies an effluent particulate matter concentration constraint. The inclusion of variability and uncertainty can also produce a shift in the locations of the least-cost configuration regions, which are dependent on the expected influent water quality and the magnitude of variability and uncertainty. The additional information provided by incorporating the variable and uncertain parameters illustrates that parameter distributions related to the primary removal mechanism are critical, and that contact and direct filtration are more sensitive to variability and uncertainty than conventional filtration.

Mamta et al. (2012) examined the Operation and Maintenance of Water Treatment Plant. The study on water treatment plant at Bank Note Press (BNP) campus, Dewas, India revealed that a set pattern of operation and maintenance is being followed due to which it continues to fulfil the requirement of the people. The alum dose ranges from 30-80 mg/l and the dosing equipments were also found satisfactory. Algae growth was not significant in the filters. However, in open filters, frequent cleaning of filter bed walls is required. Use of ozone, potassium permanganate, copper sulphate etc., may be explored through research and development activity for algae problem or any other contamination of water source. Regular training to the plant operators for proper functioning of the system is suggested. Efficient MIS (Management information system) should also be developed to cater to all the activities of the plant.

MATERIALS AND METHODS

During the passage of water from source to storage, the sediment load and contaminant load of water increases, which results in an increase in health hazards. In this project, two strategies for improving the water quality at KCAET campus are proposed. In the first scheme a simple tap water filter is designed and fabricated as an immediate solution to the problem and the quality of filtered water tested for potability. In the first scheme, a simple tap water filter was designed and fabricated as an immediate solution to the unwholesome water and the quality of filtered water tested for potability. A detailed design of a water treatment plant with sedimentation, filtration and disinfection units were also proposed for the campus as a long term solution to the problem.

This chapter deals with different materials used for construction of tap water filter, methodologies adopted for quality analysis of filtered water and the design of water treatment plant.

3.1 Location of the study

Study has been conducted in an existing water tap in the KCAET campus, Tavanur, Malappuram district, situated at 10°52'30" north latitude and 76° east longitude, with an area of 99 acres and pumping stations located near the banks of the Bharatapuzha river. Samples of water for the study were collected from the campus.

3.2 Analysis of water

Water samples were collected from the study area and a complete physical and chemical analysis of the sample were carried out at the Quality control division laboratory of Kerala water authority, Kozhikode. Different tests to be conducted to assess the quality of filtered water were decided based on the results of this analysis.

Plate 1: Collected water sample.

3.2.1 Filter design

The water quality analysis revealed that the water has a low pH and the iron and turbidity content were above the permissible limit. As an immediate solution to the problem, an indigenous tap water filter using commonly available materials is proposed.

3.2.1.1 Filter materials

Commonly available filter materials such as charcoal, sand, coir and tile are used in the filter. Selection of material and the size of filter body is determined based on the type and amount of impurities to be removed.

Charcoal

Carbon filtering is a method of filtering that uses a piece of carbon to remove contaminants and impurities, utilizing chemical adsorption. Carbon is recognized as effective and reliable material in removing impurities. Carbon has excellent adsorptive capacity, an affinity for a wide range of dissolved organics and chlorine and an ability to be custom-tailored specific applications to suit.

Plate 2: Charcoal

Each piece of carbon is designed to provide a large section of surface area, in order to allow contaminants the most possible exposure to the filter media. One pound (450 g) of carbon contains a surface area of approximately 100 acres (40 Hectares). Carbon filtering is commonly used for water purification, as well as in air purifiers.

Carbon filters are most effective in removing chlorine, sediment, and volatile organic compounds (VOCs) from water. They are not effective at removing minerals, salts, and dissolved inorganic compounds. Typical particle sizes that can be removed by carbon filters range from 0.5 to 50 micrometres. The filter media is designated by its particle size. The efficiency of a carbon filter is also based upon the inflow rate. When the water is allowed to flow through the filter at a slower rate, the contaminants are exposed to the filter media for a longer period of time.

Charcoal was obtained from burnt coconut shell for use in tap water filter. The size of particles was below 5 mm. Charcoal was packed uniformly with a thickness of 2 cm.

Coir

Coir is a natural fibre extracted from the husk of coconut and used in products such as floor mats, doormats, brushes, mattresses, etc. Technically, coir is the fibrous material found between the hard, internal shell and the outer coat of a coconut. Other uses of brown coir (made from ripe coconut) are in upholstery padding, sacking and horticulture. White coir, harvested from unripe coconuts, is used for making finer brushes, string, rope and fishing nets.

Plate 3: Coir

The purification process of water reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi; and a range of dissolved and particulate material derived from the surfaces. Coir was incorporated to remove debris and other light weight impurities which have less adsorptive properties.

Sand

The sand used in filter should be free from clay, loam, vegetable matter, organic impurities etc. It should also be uniform in nature and size. In the case of filters using sand, the water is allowed to pass slowly through a layer of sand placed above the base material and thus the purification process aims at simultaneously improving the biological, chemical and physical characteristics of water. The sand used in the filter conforms to one used in rapid sand filters.

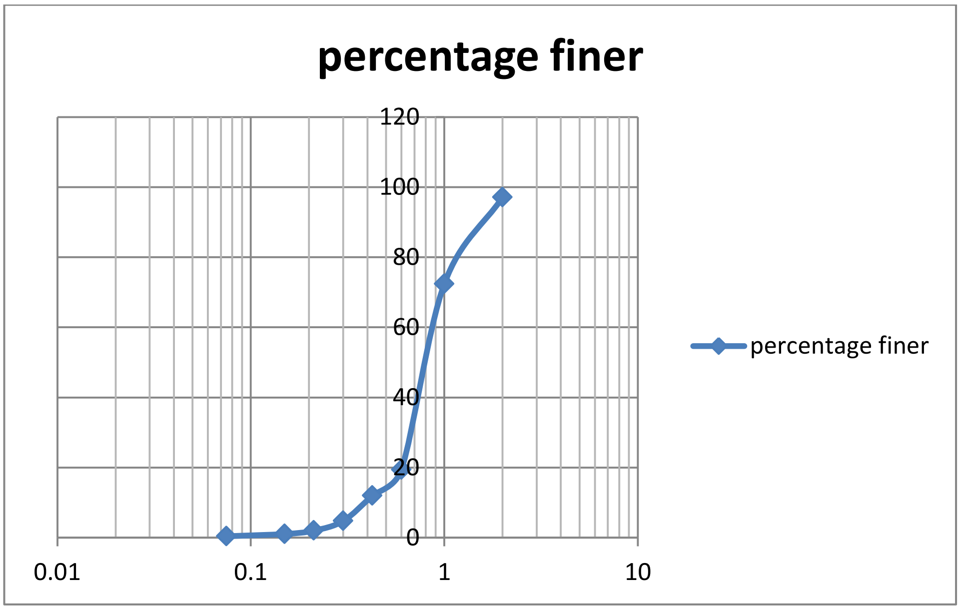


Fig.1: Particle size distribution curve of filter sand

The effective size of sand varies from 0.35 mm to 0.60 mm and the uniformity coefficient of the sand is between 1.20 to 1.70. Since the space of voids between sand particles is more, the rate of filtration will increase.

Plate 4:Coarse sand(eff.Size>1mm) Plate 5:Medium sand(eff.Size 300µ-1mm)

Plate 6: Fine sand (eff. Size <300µ)

Desired quality of sand was obtained through sieve analysis and was divided into three divisions as fine, medium and coarse. Sand for the filtration was graded as coarse sand with effective size > 1 mm, medium sand with effective size in between 300µ and 1 mm and fine sand with particle size < 300µ.

Tiles

Tile pieces possess adsorption property to great extent. It was a common material used as filtering material in wells from ancient times. As roofing tile pieces are made from clay it absorbs odour to some extent.

Plate 7: Mangalore tile pieces

They are broken in to pieces of average size of 3 mm, and fed as an alternative for coir in one trial.

Filter body

Filter body is polyethylene terephthalate (PET) bottle of diameter of 8 cm and height 10 cm, with cylindrical shape. Bottle cap is made of polyvinyl chloride, which possess enough mechanical and tear strength.

3.2.1.2 Fabrication of filter

Cap of the bottle is bored and pipes of 1 inch diameter were connected using hose by means of gas welding. Clamps are provided at the pipe end for firm connection of filter with water tap. Bottle cap can be opened and closed for easy filling and removal of filtering materials.

Plate 8: Filtering unit connected to the tap

Filter bottom was provided with holes of 1mm diameter, in the entire bottom area. Filter materials are filled in the bottle with charcoal at the bottom most part with a thickness of 2 cm, coir layer with thickness of 2 cm, sand of three grades with coarse sand and medium sand of 1.5 cm thickness, and fine sand of 1cm thickness. At the top a layer of coir was provided to avoid disturbance to sand particles. In the second trial, the coir layer at the bottom was replaced with tile pieces with an average size less than 2 mm.

3.2.1.3 Water quality analysis

To evaluate the efficiency of the fabricated filtering unit, a water quality analysis of the filtered water was also carried out. From the initial analysis, the turbidity and iron content were found to be above the desirable limits and the pH was found to be in the acidic range. In order to evaluate the quality of the filtered water, several samples of filtered water were collected and analysed to determine the turbidity, pH and iron content. The procedure for the analysis is discussed below.

Determination of turbidity

Principle

Turbidity in water is caused by the presence of suspended matter, such as clay, silt, finely divided organic and inorganic matter. Turbidity should be clearly understood to be an expression of the optical properly of a sample which causes light to be scattered and absorbed rather than transmitted in straight lines through sample. Attempts to correlate turbidity with weight concentration of suspended matter are impractical as the size shape and refractive index of the particulate materials are of great important optically but bear little direct relationship to the concentration and specific gravity of the suspended matter.

Nephelometric methods employed to measure turbidity. In this method light is allowed to strike a suspension at right angles to the eye of the observer or photoelectric cell of the instrument. The light reflected by the dispersed particles (Tyndall effect) is recorded. This principle is employed in measuring very low turbidities in filtered water. Bacteriologists often use nephelometry in following bacteriological growth rates.

Apparatus

1. Nephelometric Turbidity meter.

Reagents

1. Turbidity free distilled water.
2. Standard Turbid suspension.

Procedure

1. Switch on the instrument and flow 10-15 minutes warm up.
2. Select the appropriate range (for 0-500 NTU range insert the cell riser prior to standardisation. If 0-1000 NTU range is used then cell riser should be removed).
3. Set “standardize” control to maximum.

4. Insert the tube with distilled water in to cell holder and cover with light shield.
5. With “set zero” control adjust the meter to read zero.
6. Remove the tube and replace with the tube containing standard solution. Align the tube as per the markings on cell holder. Cover with light shield.
7. Adjust “standardize” control such that the meter reads the correct value of the standard solution turbidity.
8. The instrument is now calibrated & ready for test samples. Do not disturb ‘Set zero’ and “standardize” control knobs once the instrument is calibrated.
9. Insert the tube containing the test sample whose turbidity is to be measured in the cell holder and cover it with light shield.
10. The reading of the meter gives the turbidity value of the test sample in NTU.

Determination of pH

Principle

pH is the logarithm of the reciprocal of the hydrogen ion concentration more precisely, of the hydrogen ion activity in moles/ litre. pH enters into the calculation of carbonate , bicarbonate and carbon-dioxide, as well as of the corrosion or stability index and in to the control of water treatment processes. The practical pH scale extends from 0, very acidic to 14, very alkaline, with middle value (pH 7) corresponding to exact neutrality at 25ºC. whereas alkalinity and acidity express, the total reserve or buffering capacity of sample, the pH value represents the instantaneous hydrogen ion activity that is the intensity of acidity or alkalinity.

The pH meter makes use of the electrodes for measure pH of a sample. Several types of electrode have been suggested for the electrometric determination of pH. Although the hydrogen gas electrode is recognized as the primary standard, the glass electrode in combination with the reference potential provided by a saturated calomel electrode is most generally used. The glass electrode system is based on the fact that a change of 1 pH unit produces an electrical change of 59.mv at 25ºC.

Apparatus

1. pH meter with electrodes
2. buffer solution
3. thermometer
4. pH paper or pH colour comparator

Procedure

1. Calibrate the instrument with a buffer solution.
2. Dip the electrodes in the given sample and note down the instrument reading.
3. Note the pH of the sample along with its temperature.

Determination of iron

Principle

Iron may be in true solution, in a colloidal state that may be peptised by organic matter , in the inorganic or iron complexes , or in a relatively coarse suspended particles. It may be either ferrous or ferric, suspended or filterable.

Apparatus

1. Nessler tube (calorimetric equipment), 100 ml, tall form
2. Glassware like conical flasks, pipette and glass beads.

Reagents

1. Hydrochloric acid
2. Hydroxylamine solution
3. Ammonium acetate buffer solution

Procedure

1. Pipette 10, 20, 30 and 50 ml standard iron solution in to 100 ml conical flasks.
2. Add 2 ml concentrated Hydrochloric acid and 1ml hydroxylamine solution to each flask.
3. Dilute each about 75 ml with distilled water.
4. Add a few glass beads to each flask & boil the contents until the volume is reduced to15 to 20 ml.
5. Cool the flasks to room temperature & transfer the solutions to 100 ml Nessler tubes.
6. Add 10 ml Ammonium Acetate buffer solutions to 100 ml Nessler tube.
7. Make up the contents of each tube exactly to 100 ml by adding distilled water and let stand for 10 minutes for maximum colour development.
8. Take 50 ml distilled water in another conical flask.
9. Repeat steps 2 to 7 described above.
10. Measure the absorbance of each solution in spectrophotometer at 508 nm, against the reference blank prepared by treating distilled water as described in step 8 & 9. Prepare a calibration graph taking meter reading on y-axis and concentration of iron on x-axis.
11. For visual comparison, keep the Nessler tubes in a stand.
12. Mix the sample thoroughly and measure the 50 ml in to a conical flask.
13. Repeat steps 2 to 7 described above.
14. Measure the absorbance of the solution in a 1 cm. cell in a spectrophotometer at 508 nm.
15. Read off the concentration of iron from the calibration graph for the meter reading.
16. For visual comparison, match the colour of the sample with that of the standard prepared in steps 1 to 7 above.
17. The matching colour standards will give the concentration of iron in the sample.

3.2.2 Design of water treatment plant

Tap water filter that have been designed is aimed for an immediate solution. Design of water treatment plant will be an ultimate solution for the K.C.A.E.T campus. For the design purpose, daily water requirement was computed. The details of population are given table.

Daily water requirement of residential workers were taken as 400 l/day and that of non-residential workers as 100 l/day. The obtained water requirement was projected as 100% increase for a period of 30 yrs.

Table 1: Water requirement of KCAET campus

Sl. No.	Members	Number of members	Water requirement for each members (L/day)	Water requirement (L/day)
1.	Mens hostel inmates	50	400	20000
2.	Ladies hostel inmates	165	400	66000
3.	Quarters inmates	10	400	4000
4.	Gust house inmates	246	400	98400
5.	Teachers	25	100	2500
6.	Administrative staffs	35	100	3500
7.	KVK members	50	100	5000
8.	Farmers	30	100	3000
Total members in KCAET campus		611	Total water requirement	202400 l/day

3.2.2.1 Clarifier

Clarifier is used to remove the sediments. Since the daily water requirement is comparatively low, a rectangular sedimentation tank was proposed.

Design criteria for clarifier

Range of detention time : - 1.5-4 hrs.

No of units : - 2 or more

Depth of water in basin : - 3m to 4.5

Velocity of flow : - 0.3 m/minute

Surface loading : - 1.5 m/hr or 36 m^3/m^2/day

Extra capacity for storage of sludge : - 25%

Flood slope : - 1% for mechanically scraped rectangular tanks.

Length to width ratio for rectangular tanks : - 2 or more

Scraper velocity : - one revolution in 45 to 80 minutes

Velocity of water in outlet conduit : - Not more than 0.4 m/s

Design of the clarifier

Rate of flow = 20.83 m^3/hr

Volume of tank for 4 hr detention time = 83.33 m^3

If 3m is the depth to the tank, then surface area = 83.33/3 =27.78 m^2

Dimension of the tank by considering rectangular in shape = 7m X 4m

Provide an extra depth of 25% of water depth for sludge storage.

Total depth up to weir = 3m+ 25% d+ 0.5 = 4.25m

Surface load = (flow/ hr)/Area of floculator = 20.83 / 27.78

=0.7498 m^3/m^2/h

Which is <1.5 m^3/m^2/hr, Hence the design is safe.

3.2.2.2 Filtration (slow sand filters)

The slow sand filters are used as an alternative to rapid sand filters or in combination with rapid sand filters.

Design of slow sand filter

The design of slow sand filter is governed by many factors, the important among them being:

i) The quality of raw water.
ii) The nature and efficiency of pre-treatment, if provided.
iii) The characteristics of filter media.
iv) The hydraulic loading of filter.
v) The method and interval of cleaning.
vi) The required quality of filtered effluent.

Limitations : The quality of raw water affects the performance of the slow sand filters which are capable of coping with turbidities of 100-200 mg/l for a few days, 50 mg/l is the maximum that should be permitted for longer period. Best purification occurs when the average turbidity is 10 mg/l or less (expressed as SiO_2). Hence, the river water can be treated with slow sand filters only when the raw water turbidity is brought down in the range of 0 mg/l to 10 mg/l by means of flocculation. Sedimentation process, or in addition to this 'roughing' filtration.

The design of a slow sand filter unit includes the following:

i) the size and number of filter unit,
ii) the super-natant water reservoir,
iii) the filter bed,

iv) the filter bottom and under drainage system,

v) the filter box containing (ii), (iii) and (iv) above, and

vi) the filter control system.

In addition, a filter covering structure may be required in certain circumstances.

Sizes and number of filter unit

Rate of filtration normally lies between 0.1 to 0.4 m^3/h per square meter of surface. Let the rate of filtration in the present design by 0.1 $m^3/m^2/h$.

Total area required for 20.83 m^3/hr

$$=20.83/0.1$$

$$=208.3\ m^2$$

The number of filter units is given by the formula:

$$N = \frac{1}{4} \times \sqrt{Q}$$

in which N= the number of filter units which is never less than 2,

$$Q = m^3/\ h$$

There for, $N = \frac{1}{4} \times \sqrt{20.83}$

$$= 1.141, \text{ say } 2$$

Provide one or more unit as standby , there for the total number of beds=3 and

area of each units = 208.3/2

= 104.15 m^2, say 105 m^2

This is in accordance with the range of area prescribed by Huisman. According to him workable size is usually considered to be 100 m^2 while twice this area is to be preferred. A maximum size can be between 2 m^2 and 5000 m^2. The designed filter hence is safe. If the length to width ratio 2:1, then length of each unit is 14.5 m and width 7.25 m.

Depth of water in filter bed

The depth of water is determined according to the maximum resistance anticipated. In practice, the depth varies between 1.0 m and 1.5 m. exceptionally the depth is as high as 2.0 m, but narely more than 2.0 m. Let the depth of water in the present design be 1.25 m.

Filter bed

The most suitable medium for filter bed is sand. Its coefficient of uniformity varies between 3 and 1.5. Let the coefficient of uniformity be 2.

The effective diameter usually lies in the range of 0.15 mm to 0.35 mm. Let the effective diameter in the present case be 0.20 mm.

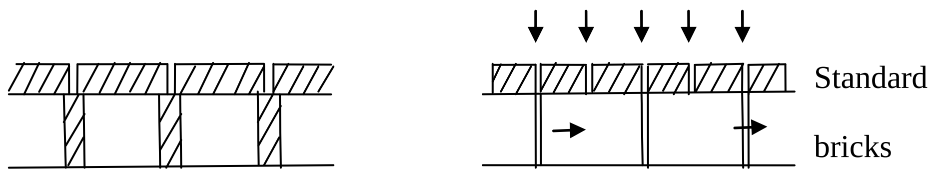
The bed should be composed of hard, durable and preferably rounded sand grain and should be free from clay, loam and organic matter. The sand should not contain more than 2% of calcium and magnesium, calculated as carbonate.

The depth of sand bed varies between 1.2 to 1.4 m. It may be somewhat less if the raw water is reasonably clear and the filter runs are consequently longer than average. Let the depth of sand bed be 1.3 m.

Under-drainage system

It serves two-fold purpose. One, of supporting the filter medium and other of providing an unobstructed passage-way for the treated water to leave the under-side of the filter.

There is tendency to use drainage system other than pipes, these days, except for the smaller filters. One of the simplest arrangements is done by using standard bricks to support the medium and to provide drainage space. Normally, the dimensions of the bricks are 5×11×22 cm. so each channel would drain a strip of 23 cm width (fig.2).



CROSS-SECTION LONGITUDINAL

Fig.2 Under-drainage System using

One of the important criteria about the under-drain system design is that the system should not usually exceed 10% of the resistance of the filter bed when at its lowest (that is, when the sand is clean and the bed is at its minimum thickness, after repeated scrapings) so that the variation over the area of the filter may be kept within the acceptable limit.

A layer of gravel between the under drainage system proper and the filter bed itself helps in two ways. It prevents the filtering medium from entering and chocking the drainage water ways and ensure a uniform abstraction of the filtered water when a limited number of drains are provided.

The supporting gravel system is built up of various layers, ranging from fine at the top to coarse at the bottom. Each layer is composed of carefully graded grains (that is the 10% and 90% passing diameters $\sqrt{2}=1.14$).

The design criteria for the gravel bed are as follows:-

a) The grain of the bottom layer of gravel should have an effective diameter of least twice the size of the openings into the drainage system (e.g., the spacing between open-jointed pipes).
b) Each successive layer should be graded so that its smaller (d_{10}) particle diameters are not more than four times smaller than those of the layer immediately below.
c) The upper –most layer of gravel must be selected with an d_{10} value of the coarsest filtration sand and less than four times greater than the d_{30} value of the finest filtration sand taken from natural deposits which will vary in grain size from one spot to another.

In the present design, let the sand medium have the following values.

d_{15} of sand medium =0.22mm

d_{30} of sand medium =0.30 mm

Upper-most layer of the supporting graved should have a d_{10} value between 0.22×4, approximately 0.90 mm and 0.30×4 =1.2 mm.

The upper-most gravel layer with a d_{10} value of 1.0 mm and a d_{90} value of 1.4 mm ($d_{10} \times \sqrt{2}$) would therefore be suitable. The layer immediately below could have equivalent values of 4.0 mm and 5.6 mm and the 3rd layer 16 mm and 23 mm respectively. Normally, the joints in the under-drainage system are 8 mm or less in width. Hence, these three layers will suffice.

When it is too difficult or expensive to grade the gravel within, the layer to the recommended ratio of 1:√2, the requirement may be relaxed to a factor of 1:2, but in this case the layers should have their d_{10} values restricted to three times that of the layer above. With these criteria, the gravel bed will have following gradation:-

Top-most layer: 1mm to 2.0 mm

Second layer : 3 mm to 6.0 mm

Third layer : 9 mm to 18 mm

Bottom-layer : 27 mm to 54 mm

The normal depth of each layer is 6 cm. the depth may be about 15 cm even. Normally, the total depth of gravel bed is 30 cm. the gravel has high permeability and hence the resistance to downward flow is negligible.

If the first system of gravel layers is adopted, then size of gravel and layer thickness would be as shown in table 2.

Table 2: Details of gravel bed

Position of Gravel layer	Size of gravel	Thickness of layer
Top layer	1 to 1.4 mm	8 cm
Middle layer	4 to 5.6 mm	10 cm
Bottom layer	16 to 23 mm	12 cm

Filter box

Most filter boxes are today built with vertical or near vertical walls of a depth sufficient to accommodate the various parts mentioned earlier. The internal depth of the box would be the sum of the following depths:-

Free board above water level: 0.25 m

Water depth above filter : 1.25 m

Filter medium : 1.30 m

Gravel support : 0.30 m

Brick filter bottom : 0.16 m

Total : 3.26 m

Filter box should be water tight, not merely to prevent loss of treatment water, but to prevent ingress of ground water, which might contaminate the treated effluent. In this regard, additional precaution would be ensure that the floor of the box is above the highest water table.

"short circuiting" or the downward percolation of water along the inner wall face without passing through the filter bed, endangers the purity of the effluent, and structural precautions must be taken against it. One of the following methods can be adopted to prevent the same:

a) Construction of sloping walls, since the sand tends to settle tightly against them.
b) In case of vertical walls, built-in grooves of 6×8 cm along the bottom portion of the internal surface of wall or artificial roughening of the internal surface.
c) A slight outward batter to the internal surface to obtain the advantages of sloping walls.

A precaution once in common use, was to keep the under-drainage some distance from the base of the walls, but this method increases the effective filtering area and is rarely adopted nowadays. Above and below the area of contact with the sand bed all concrete surfaces should be as dense and smooth as possible to reduce fouling by slimes and other aquatic growths.

Problems like thermal expansion and contraction, shrinkage of concrete, uplift of floors and unequal settlement become more difficult as the area of the structure increases. Hence to ensure water tightness, it may be preferable to plan for a larger number of filters of smaller size.

Controls

Controls required in the slow-sand filters are mentioned below: -

- Raw water delivery: When individual pumps are provided for each filter, the quantity of water to be supplied may be controlled at pump outlet.The entrance of raw water in to the supernatant water reservoir has to be so arranged that the sand bed below is not affected by turbulence. One such arrangement is a drainage trough which is constructed under the inlet to absorb the vertical force of the incoming water at the start of filling operations, before a sufficient layer of water has accumulated to protect the filter surface.
- Scum outlet: A trough is preferred for this purpose and scum can be removed simply by increasing the rate of inflow very slightly and allowing the supernatant water to spill over the lip of trough. Valve need not be provided on the trough drain, which is led to waste. The trough also acts as overflow arrangement for supernatant water.

- Supernatant water drain: In order to expose the sand surface for cleaning, it is necessary to remove the supernatant once in one too three months. A separate drain and emptying trough is therefore provided through the supernatant water may be discharged to waste or discharged to raw water pumps. Provision for adjustable sill along the part of the trough is length is useful to match the lip of the trough to the new level of sand bed after each cleaning.
- Bed drainage: This is necessary to lower the level of water within the bed by a further 10 cm or more so that the top layer is relatively dry and easy to handle.
- Effluent control valve: this is the most important valve in the filter operation. The valve has to be adjusted as the bed resistance increases throughout the length of the filter run to control the rate of filtration.

3.2.2.3 Design of chlorinator

It is the instrument used to fulfil the following criteria:

- To regulate flow of gas from chlorine container.
- To regulate desired rate of flow within the range of the machine.
- To provide proper mixing of chlorine to water.

No. of cylinders:

Let the dosage rate of chlorine be 2 ppm.

Chlorine requirement per day = 20.83 x 10^3 x 2 x10-6 x 24 = 1 kg.

Hence a 50 kg cylinder can be adopted for a period of approximately 2 months.

Collecting channel design

Let velocity of flow in the channel be 0.1 m/s.

Flow rate through the channel = 0.00578 m^3/s.

Area of channel = Q/v = 0.00578 / 0.1 = 0.0578 m^2

Let width of collecting channel be 0.3 m.

Therefore, depth of water in the channel = 0.0578 / 0.3 = 0.2 m.

Mechanical scraper: - It will be driven by an electric motor. Scraper revolution will be one in one hour.

3.2.2.4 Design of ground storage tank

The reservoir was designed for a storage capacity of 20.83 m^3, with rectangular cross-section.

Depth of tank was assumed to be 3 m.

Therefore area of tank = $\frac{\text{volume}}{\text{depth}} = \frac{20.83}{3}$

$=6.94m^2$

Therefore,

Length of the tank = 3.5m

Width of the tank = 2 m

RESULTS AND DISCUSSION

Results obtained from the study "Design and development of water treatment methods for improving water quality of KCAET campus" are presented and discussed in this chapter after analyzing the observations taken during the course of work.

4.1 Complete physical and chemical analysis.

Table 3: Results of physical and chemical analysis

Sl. No.	Substance or characteristics	Unit	Desirable limits	Permissible limit in the absence of alternate	Actual contents
			I S 10500 :1991		
1	Turbidity	NTU	5	10	127
2	pH		6.5-8.5	6.5-8.5	5.2
3	Electrical	µ mhos/cm			104

	conductivity				
4	Acidity	mg/litre			11
5	Alkalinity	mg/litre	200	600	28
6	Total dissolved solids	mg/litre	500	2000	44
7	Total Hardness	mg/litre	300	600	22
8	Calcium	mg/litre	75	200	5.6
9	Magnesium	mg/litre	30		1.9
10	Chloride	mg/litre	250	1000	24
11	Flouride	mg/litre	1	1.5	BDL
12	Iron	mg/litre	0.3	1.0	1.2
13	Nitrate	mg/litre	45	100	5
14	Sulphate	mg/litre	200	400	180
15	Phosphate	mg/litre			BDL

Remarks:- Low pH . Iron and Turbidity content above the permissible limit.

Complete physical and chemical analysis of water sample from the K.C.A.E.T campus was done at Kerala water authority, Kozhikode and the results obtained is shown here. The result shows a notable difference from permissible values of turbidity, pH and iron content. So the quality analysis of filtered sample was decided to be done in accordance with these parameters.

4.2 Tap water filter

The filter was constructed with two combinations of filter media. Materials are filled as specified and samples were filtered. Graphical representation of filter with two different medium are given in figure 3 and figure 4.

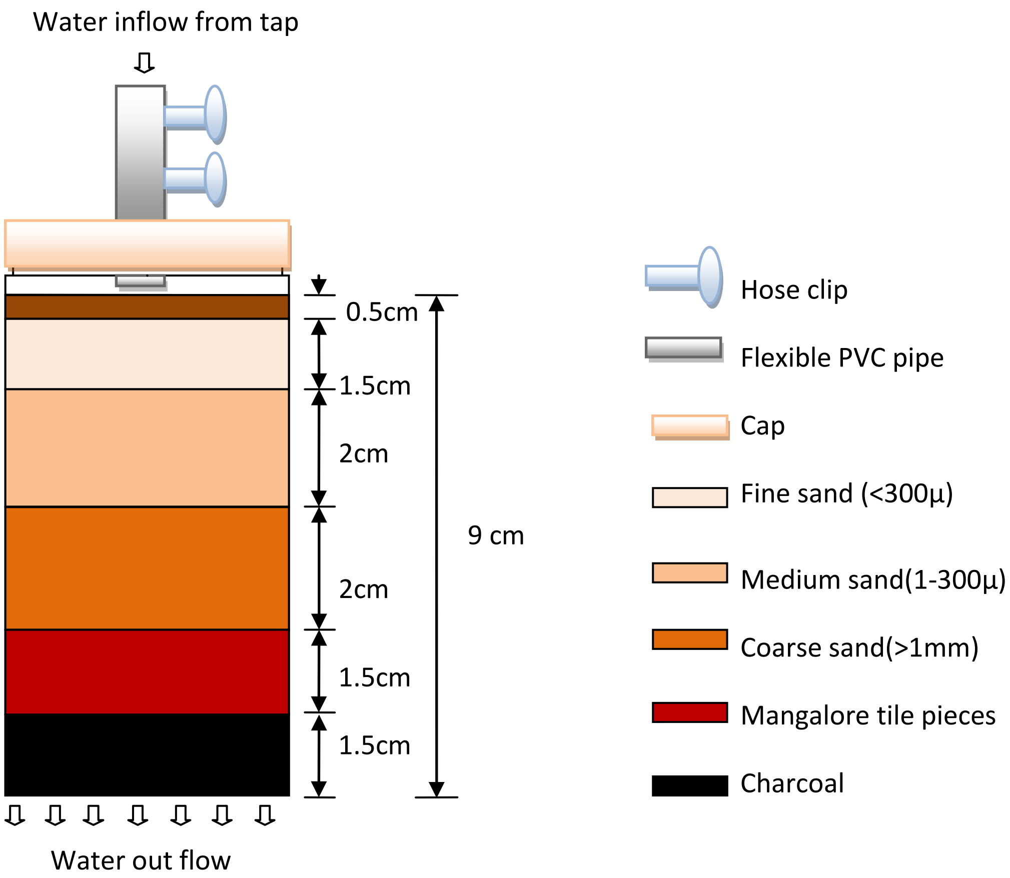


Fig.3 Filter unit with Mangalore tile pieces.

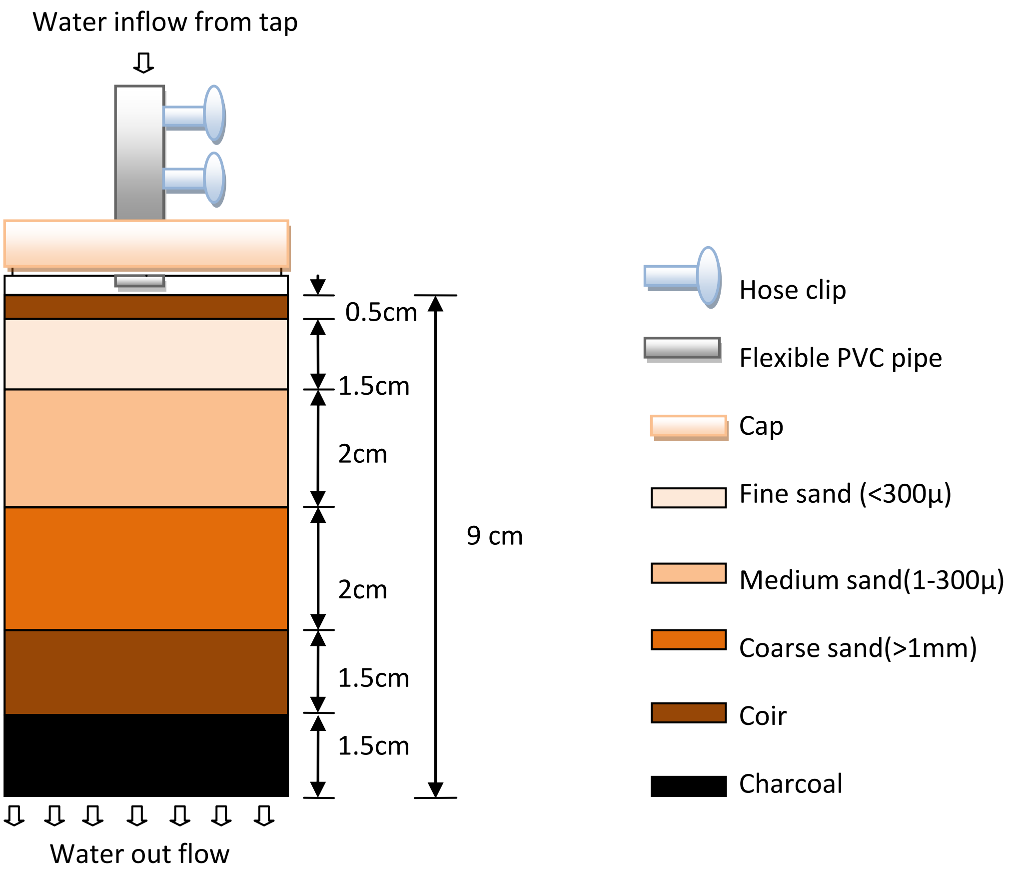


Fig 4: Filter unit with coir fibres

Constructed tap water filter was connected to a tap situated in the campus. Water samples were collected before and after the filtration. Quality analysis has been conducted and the data were given below.

4.2.1 Turbidity

Turbidity was the major problem in the collected water samples. The desirable limit of turbidity in water is 5 NTU- 10 NTU. But in the case of water from the campus, turbidity content was 127 NTU, which was far higher than the desired limit.

Table 4: Turbidity in different samples

Sample	Turbidity before filtration (NTU)	Turbidity after filtration (NTU)	
		Coir	Tile
1	115	28	22
2	115	27	22
3	116	28	22

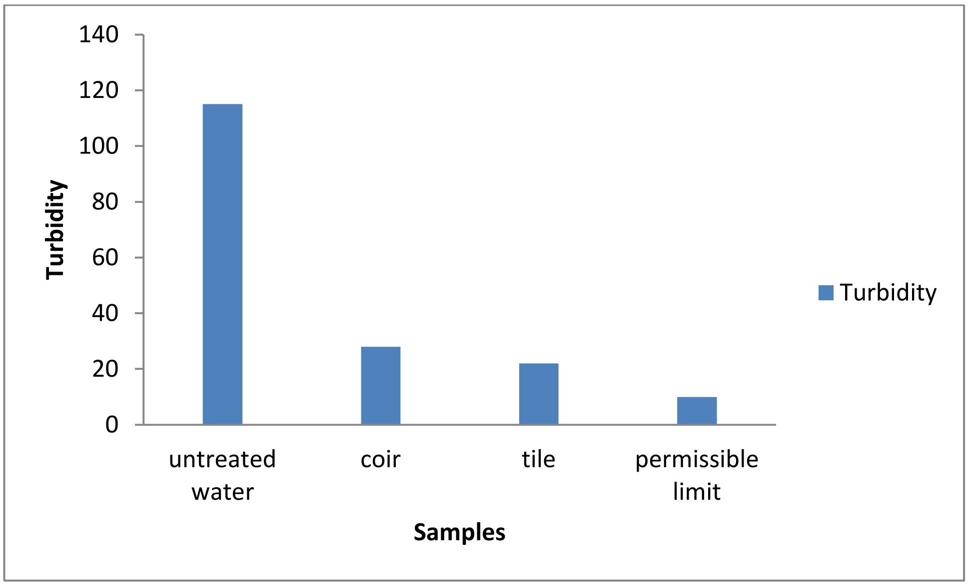


Fig. 5: Variation in turbidity for different samples.

The result shows a considerable variation in turbidity of filtered sample from the unfiltered sample. The quality of the filter is shown by the consistently high percentage removal of turbidity. The turbidity removal of the filter with tile layer is found to be more than that with the coir layer as expected.

4.2.2 pH

The desirable limit of pH lies between 6.5 - 8.5. The untreated samples were moderately acidic in nature.

Table 5: pH in different samples

Sample	pH before filtration	pH after filtration	
		Coir	Tile
1	5.4	6.2	6.7
2	5.4	6.2	6.7
3	5.4	6.2	6.7

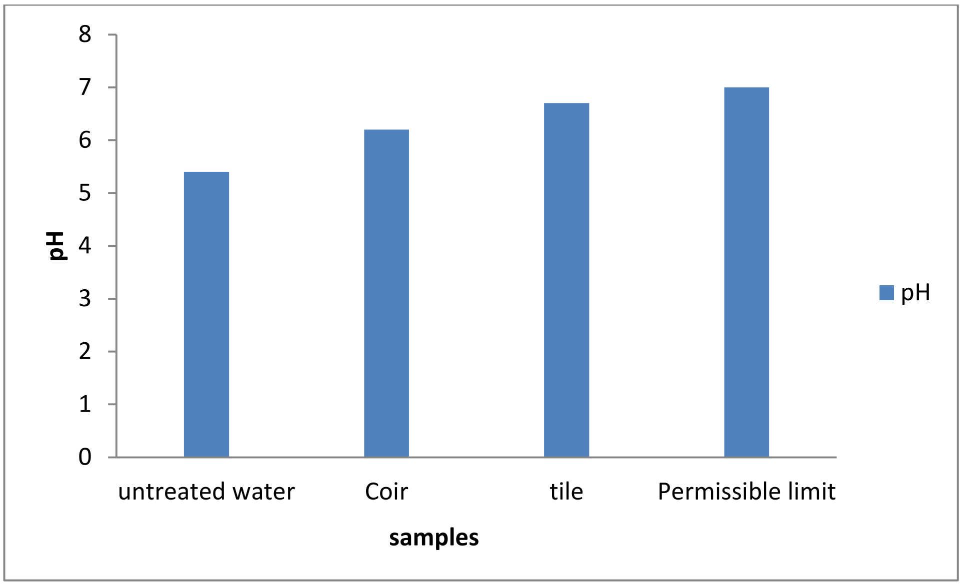


Fig 6: Variation in pH for different samples.

The treatment resulted in comparable variation in pH. For filtered sample with tile, the pH range falls in between the desired levels. This shows the effective adsorptive power of tile in filtration unit. And for coir, due to the less adsorption, the range pH was slightly less than that from tile and does not fall in between the desired limit.

4.2.3 Iron content

Table 6: Iron content for different samples

Sample	Iron content before filtration	Iron content after filtration	
		Coir	Tile
1	1.2	0.3	0.2
2	1.2	0.3	0.2
3	1.2	0.3	0.2

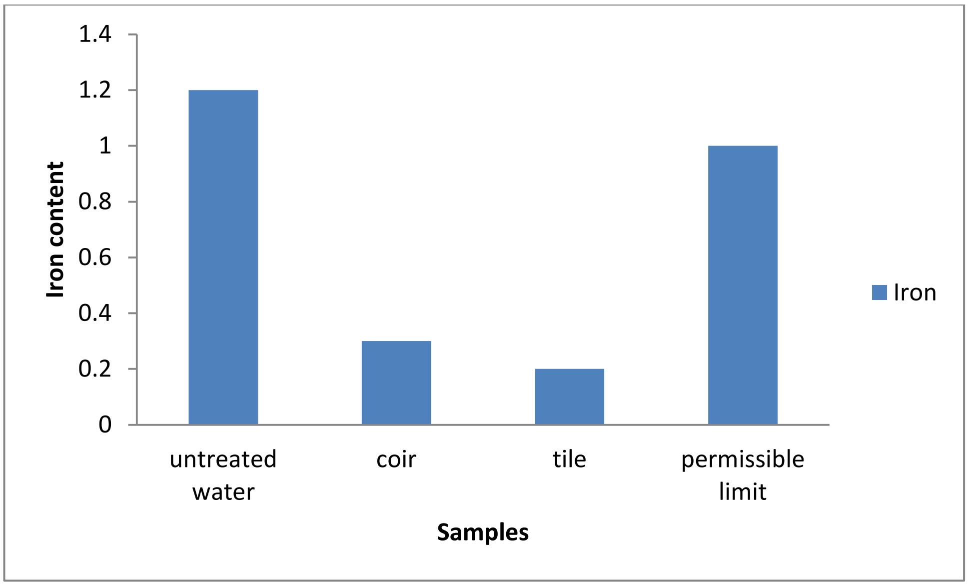


Fig 7: Variation in iron content for different samples.

Iron traces can be visually identified by to the presence of colour. The desirable limit is 0.3 mg/litre and permissible limit in the absence of alternate source is 1 mg/litre. But in actual condition, the amount of iron was 1.2 mg/litre. This was one of the important tasks to the filter unit, i.e., to remove the iron content. The results show that this was done effectively by filter unit in both the cases.

After assessing the water quality for both trials of filter media, considerable variation in physical and chemical parameters were found in sample from tile filter media than coir media.

Plate 9: Water samples from the tile filtered unit and unfiltered sample

Plate 10: Water samples from the coir filtered unit and unfiltered sample

4.3 Design of water treatment plant

The design was proposed for the expected water requirement of 400 m^3/day. The major parts of the treatment plant are clarifier, slow sand filter unit and ground storage tank. Major dimensions of the plant are given below: -

4.3.1 Clarifier

Detention time	: 4 hrs
No of units	: 2
Dimension of the tank by considering rectangular in shape	: 7m X 4m
Total depth up to weir	: 4.25m

4.3.2 Slow sand filter

Total number of beds including one as standby	: 3
Dimension of each unit	: 14.5 m X 7.25 m.
Depth of water	: 1.25 m.
The coefficient of uniformity of filter sand	: 2.
The effective diameter of filter sand	: 0.20 mm.
Depth of sand bed	: 1.3 m

Gravel bed gradation:-

Top-most layer: 1mm to 2.0 mm

Second layer : 3 mm to 6.0 mm

Third layer : 9 mm to 18 mm

Bottom- layer: 27 mm to 54 mm

Proper controls should be provided.

Collecting channel

Velocity of flow in the channel	:0.1 m/s.
Width of collecting channel	:0.3 m.
Depth of collecting channel	:0.4 m.

4.3.3 Chlorinator

Dosage rate of chlorine	: 2 ppm
Chlorine requirement per day	: 1 kg

4.3.4 Ground storage tank

The reservoir was designed with rectangular cross-section

Depth of tank	: 3 m.
Length of the tank	: 3.5m
Width of the tank	: 2 m

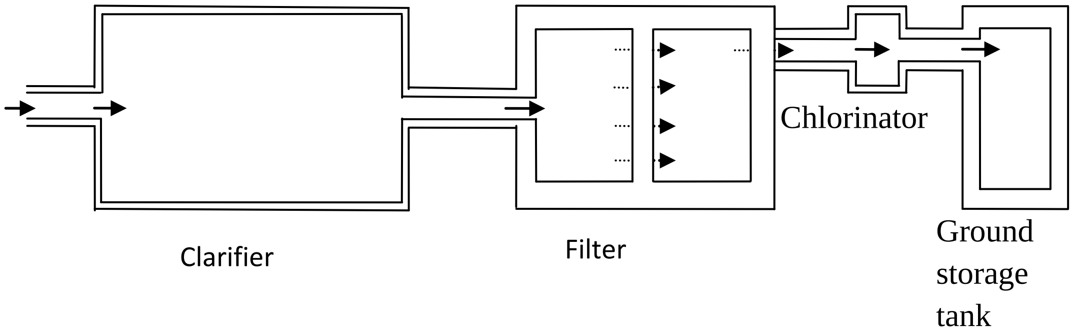


Fig. 8: General layout of water treatment plant

SUMMARY AND CONCLUSION

Quality of water is a prime aspect of human concern. It is desirable that the water supplied by a public supply system be treated by conventional processes to yield potable water meeting the drinking water standards. The KCAET water supply system had problems complying with drinking water quality requirements regarding turbidity and iron content. The reason for this is the proximity of the pumping station to the Bharathapuzha river basin. As a solution to this problem, a tap water filter designed, fabricated and tested, and complete design of a water treatment plant was also proposed. The fabrication of the potable economic tap water filter, with indigenous filter materials and the design of a water treatment plant for KCAET campus lead us to the following conclusions.

After assessing the quality of water from the KCAET campus, it was found that the water for daily use is inferior in many quality aspects. Water from the supply system was found to be turbid along with presence of iron content, clearly indicating the presence of suspended particles with brownish yellow colour even with visual observation. The range of turbidity exceeded about ten folds above the desired limit. Iron content was also above the desired limit, with an acidic character, which cause health hazards to the consumers.

Water quality assessed after filtration showed a remarkable decrease in contaminant load. Turbidity fell down from a value of above 100 to a range within BIS standards, iron content and pH also fell to a range of desired limits.

Tap water filter was constructed with two combinations of filter media. After analysing the water samples from both trials of filter media showed a markable difference in water quality. Medium with tile pieces showed better results than medium with coir in quality aspects as well as in aesthetic appearance, because of increased absorption property of filter media.

Since filter media was made of easily available low cost natural materials, complexity of construction reduced and cost of fabrication as well as operation was found to be low.

The daily water consumption was estimated to be 400 m^3 /day for the estimated population after 30 years. Design of water treatment plant was based on the estimated daily water requirement. Water treatment plant comprises of a clarifier, slow sand filter, chlorinator and a ground storage tank. Since water requirement is comparatively low, a small size treatment plant is required. A scrapper equipped clarifier will be a good alternative for a large aerator- mixer-flocculator-clarifier combination.

As the water flow rate is low, slow sand filter will be the apt choice of construction with chlorinator attachments. The area requirement and cost of operation for slow sand filter is low compared to rapid sand filter, which needs regular back washing. Various controls should be provided for effective working.

Scope of future expansion

- Filter body can be divided into different compartments which restricts the inter mixing of filter materials in the filter media.
- Filter media can be confined to a single unit, which facilitates easy filling and removal of filter media, for commercial purpose.
- Relative study of filtration efficiency the fabricated filter with other commercially available tap water filters.
- Variation in filtration efficiency of the fabricated filter with time.

REFERENCES

Abhishek, S., Ajeshkumar, V., Deepak, P. H., Harisankar, C. and Vishnu, M. M. 2010. Improved design and installation of an economic roof top rainwater harvesting system. B.tech (Ag. Engng.) Project, Kerala Agricultural University, Thrichur.

Ahmedna, M., Marshall, W. E. and Rao, R. M. 2000. Production of granular activated carbons from select agricultural by products and evaluation of their physical, chemical and adsorption properties. *Bioresource Technol*. (71): 113–223.

Amarnani S. R. and Rao, R. P. 1999. *Indian J. Environ. Hlth*. 41(4): 300-411.

Baker, D. L and Duke, W. F. 2006. *Intermittent slow sand filters for household use—a field study in Haiti*. IWA Publishing, London. 278–282.

Bansal, R. C., Donnet, J. B. and Stoeckli, F. 1988. Active carbon.

Berrin, T. and Frank , V. 2005. Enhancement of media filter performance with coagulant use for treatment of diesel oil contaminated surface water. *Desalination.*173:69-76.Available:http://www.elsevier.Com/locate /desal. [12 August 2004].

Dimitrakos, M. G., Nieva, M. J., Vayenas, D.V. and Lyberatos, G. 1997. Removal of iron from potable water using a trickling filter, *J. Wat. Res*. 31: 991–996.

Feldman, P., Rosenboom, J. W., Mao, S., Chea, S., Peng, N., and Iddings, S. 2007. Assessment of the chemical quality of drinking water in Cambodia. *J. Wat. Hlth.* 5(1): 101-116.

Frank, D. 2000. Activated carbon filtration. *Water quality products magazine*

George, N. and Shaukat, F. 2003. Simultaneous nitrification– denitrification in slow sand filters. *J. Hazardous Matr.* B96: 291–303. Available: http://www.elsevier.com/locate/jhazmat. [29 July 2002].

Hilmoe, D. J., Dimitracopoulos C. J. and Diaz-Bossio,L. M. 1984. Effective Filtration Methods for Small Water Supplies. *US. EPA.* 600(12): 84-88.

Khanna, P. and Kaul, S. N. 1995. Appropriate waste management technologies for developing countries. III international Conference.

Kubare, M., Haarhoff, J. 2010. Rational design of domestic biosand filters. *J. Wat. Supply Res. Technol. AQUA.* 59: 1–15.

Lee, J. J., Cha, J. H., Ben, Aim. R., Han, R. C. and Kim. R. 2008. Fiber filter as an alternative to the process of flocculation–sedimentation for water treatment. *Biochem. Engng*. J. 231: 323-331. Available: http: //www. elsevier.com/locate/beg. [1 november 2007].

Luby, S., Agboatwalla, M., Raza, A., Sobel, J., Mintz, E., Baier, K., Rahbar, M., Qureshi, S., Hassan, R., Ghouri, F., Hoekstra, R. M., and Gangarosa, E. 2001. A low-cost intervention for cleaner drinking water in Karachi, Pakistan. *Int. J. Infectious Di.* 5: 144-150.

Mansoor, A. M. and Komal, D. 2010. Performance evaluation of biosand filter modified with iron oxide-coated sand for household treatment of drinking water. *Desalination* 276: 287–293. Available : http:// www. elsevier. com/locate/desal. [6 May 2011].

Martin, J. A., Ronald, W. B., Ray, C., Steve, E. H. and Pierre, P. 2008. *Turbidity and microbial risk in drinking water*.

Mohamed, A., Wayne, E. M., Abdo, A. H., Ramu, M. R. and Ipek, G. 2004. The use of nutshell carbons in drinking water filters for removal of trace metals. *Wat. Res. J.* 38: 1062-1068. Available: http:// www. elsevier. com/locate/waters . [29 October 2003].

Mouchet, P. 1992. From conventional to biological removal of iron and manganese in France. *J. Am. Wat. Works Ass*. 84: 158–166.

Nadim, R. K., Brady, V. P. and James, L. K. 2009. *Arsenic removal from drinking water: A handbook for Communities.*

Pratiksha, T., Pravin, M., Batra, R. J. and Weginwar, R. G. 2012. Quality assessment of drinking water: A case study of Chandrapur. *J. chem. Pharmaceutical Res.* 4(5): 2564-2570. Available: http://www.jocpr.com.

Punmaya, B.C. 2001. *Soil mechanics and foundation*. Laxmi Publications pvt ltd. New Delhi. 125-129.

Rangwala, S.C. 2003. *Water supply and sanitary engineering.* Charotor publishing house, Anand. 115-160, 595-600.

Sharma, S.K., Kappelhof, J., Groenendijk, M. and Schippers, J.C. 2001. Comparison of physicochemical iron removal mechanisms in filters. *J. Wat. Supply Res. Technol*. 50: 187–198.

Tamara, S., Marinko, M., Natasa, R., Felicita, B., Laszlo, S. 2005. Removal of ammonia, iron and manganese from groundwater of northern Croatia pilot plantstudies. *Biochem. j*. 40: 327-335. Available: http://www. elsevier.com/locate/beg. [3 january 2004].

Tekerlekopoulou, A.G., Vasiliadou, I.A. and Vayenas, D.V. 2006. Physico-chemical and biological iron removal from potable water. *Biochem. Engng. J.* 31: 74–83. Available : http://www.elsevier.com/locate/beg. [28 May 2006].

Tekerlekopoulou, A.G, and Vayenas, D.V. 2007. Ammonia, iron and manganese removal from potable water using trickling filters. *Biochem. Engng. J.*

210: 225–235. Available : http://www.elsevier.com/locate/beg. [11 May 2007].

Timpe, R.C., Mann, M.D., Pavlish , J.H. and Louie, P.K.K. 2001. Organic sulfur and hap removal from coal using hydrothermal treatment. *Fuel Proc.Technol*.73:127–141.Available: http://www.elsevier.comrlocaterfuproc. [30 April 2001].

Trivedi, R.K. and Goel, P.K. 1984. Chemical and biological methods for water pollution studies.

Tobin, R. and Armstrong, V.C. 1980. Assessing the effectiveness of small filtration systems for point-of-use disinfection of drinking water supplies.

Vitaly., Gitis., Viatcheslav, F.R., Haugth, C. and Robert, M. C. 2005. Removal of cryptosporidium parvum oocysts by rapid sand filtration with ballasted flocculation-filtration and intermediate downwashes. 33: 355- 364.

APPENDIX 1

Indian standard specifications for drinking water IS - 10500

S.NO.	Parameter	Requirement desirable Limit	Remarks
1.	Colour	5	May be extended up to 50 if toxic substances are suspected
2.	Turbidity	10	May be relaxed up to 25 in the absence of alternate
3.	pH	6.5 to 8.5	May be relaxed up to 9.2 in the absence
4.	Total Hardness	300	May be extended up to 600
5.	Calcium as Ca	75	May be extended up to 200
6.	Magnesium as Mg	30	May be extended up to 100
7.	Copper as Cu	0.05	May be relaxed up to 1.5
8.	Iron	0.3	May be extended up to 1
9.	Manganese	0.1	May be extended up to 0.5
10.	Chlorides	250	May be extended up to 1000
11.	Sulphates	150	May be extended up to 400
12.	Nitrates	45	No relaxation
13.	Fluoride	0.6 to 1.2	If the limit is below 0.6 water should be rejected, Max. Limit is extended to 1.5
14.	Phenols	0.001	May be relaxed up to 0.002
15.	Mercury	0.001	No relaxation
16.	Cadmium	0.01	No relaxation
17.	Selenium	0.01	No relaxation
18.	Arsenic	0.05	No relaxation
19.	Cyanide	0.05	No relaxation
20.	Lead	0.1	No relaxation
21.	Zinc	5.0	May be extended up to 10.0
22.	Anionic detergents (MBAS)	0.2	May be relaxed up to 1

APPENDIX 2

Drinking water specification: IS: 10500, 1992

(Reaffirmed 1993)

S.No	Parameter	IS: 10500 Requirement (Desirable limit)	Undesirable effect outside the desirable limit	IS: 10500 Permissible limit in the absence of alternate source
Essential Characteristics				
1.	pH	6.5 – 8.5	Beyond this range the water will effect the mucous membrane and / or water supply system	No relaxation
2.	Colour (Hazen Units), Maximum	5	Above 5, consumer acceptance decreases	25
3.	Odour	Unobjectionable	--	--
4.	Taste	Agreeable	--	--
5.	Turbidity, NTU, Max	5	Above 5, consumer acceptance decreases	10
Following Results are expressed in mg/l :				
6.	Total hardness as $CaCO_3$, Max	300	Encrustation in water supply structure and adverse effects on domestic use	600
7.	Iron as Fe, Max	0.30	Beyond this limit taste/appearance are affected, has adverse effect on domestic uses and water supply structures, and promotes iron bacteria.	1.0
8.	Chlorides as Cl, Max	250	Beyond this limit tast, corrosion and palatability are effected	1000
9.	Residual, Free Chlorine, Min	0.20	--	--

ABSTRACT

Maintaining the quality of drinking water in the KCAET campus has been a challenging task from the inception of the college. The main objective of this work is to improve the quality of drinking water in the KCAET campus. In this work, a simple tap water filter was designed and fabricated as an immediate solution to improve the drinking water quality. Locally available materials like charcoal, sand, coir fibres and tile pieces were used inside the tap water filter used for filtering the water. A quality analysis of the filtered water was also done. Experiments were done for different combinations of filtering materials. The result of the study reveals that the filtering unit with charcoal, tile pieces and sand combination is found to be most effective in removing colour, iron content and turbidity and maintaining the pH value.

As a long term solution to the water quality problems, a design of a water treatment plant complete with sedimentation, filtration and disinfection units were also proposed in this work. The water treatment plant was designed for the future requirement after thirty years. A ground level storage reservoir for temporary storage of treated water was also designed.