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Assessment and Design of Bio-Medical Waste Management System for a Medical College Hospital in Tamil Nadu

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Abstract: ***Hospital waste is a mixture of general refuse, biomedical Laboratory and pathological wastes. Totally 75-90% of the waste produced by the health care provides non-risk health care waste. Whereas, the remaining 10- 25% consist of infectious pathological waste and is of great health concern, if not segregated from general hospital waste. This study was initiated to characterize solid and liquid wastes generated in healthcare institutions and to provide a framework for the safe management of these wastes. The project was carried at medical hospital. A waste audit carried out at these sites revealed approximately 10% of solid wastes was hazardous in nature, consisting mainly of infectious, pathological and chemical wastes. The average amount of hazardous wastes per patient per day was found to be 0.080-0.091kg. Hospital effluent not only has aberrant physico-chemical characteristics but also has high loads of multiple drug resistant bacteria and discharging the effluent in a municipal sewage system could be a grave public health hazard. Effluent treatment plant (ETP) with terminal chlorination needs to be added to safeguard the dangers from hospital effluent. However, most of the hospitals believe it to be an unaffordable proposal. The medical hospital is a 1100 bedded tertiary care centre spread over 26 acres of land with huge green belts, requiring 24.44MLD of water per day. The scarcity of water affected the hospital activities and irrigation of green belt. The ETP was setup at and the treated effluent has all the physico-chemical characteristics within the specified limits and is free from viable multiple drug resistant bacteria. The treated effluent water is used for irrigation and sanitary cleaning thus, the ETP has been proved to be eco-friendly cost effective proposal.***

Keywords: Solid Waste Composition, Waste Water Characteristics, Effluent Treatment Plant (ETP)

1. Introduction

Hospital waste is generated during the diagnosis, treatment, or immunization of human beings or animals or in research activities in these fields or in the production or testing of biological. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. These are in the form of disposable syringes, swabs, bandages, body fluids, human excreta, etc. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It has been roughly estimated that of the 4 kg of waste generated in a hospital at least 1 kg would be infectious. Surveys carried out by various agencies show that the health care establishments in India are not giving due attention to their waste management. After the notification of the Bio-medical Waste (Handling and Management) Rules, 1998, hospitals are slowly streamlining the process of waste segregation, collection, treatment, and disposal.

1.1 Impact

Most biomedical waste generated from health care facilities are at present, collected without segregation into infectious and non-infectious categories and are disposed in municipal bins located either inside or outside the facility premises. Sanitary workers pick this waste from here along with MSW and transport and dispose it at municipal dumpsites. Since the infectious waste gets mixed with municipal solid waste, it has potential to make the whole lot infectious in adverse environmental conditions. Moreover, biomedical waste also contains sharp objects (scalpels, needles, broken glasses/ampoules, etc.,) the disposal of which poses a risk of injury and exposure to infection to sanitary workers and rag pickers working at these dumpsites. Since most of these dumpsites are unscientifically managed, the chances of pathogens contained in infectious waste becoming airborne and getting released to nearby water bodies or affecting the local resident population.

1.2 Objective for the Study

1. Objective of the study is to investigate solid waste composition in Medical hospital.
2. To determine waste water characteristics of bio-medical liquid waste.
3. To design the effluent treatment plant design for Medical hospital.

2. Material and Method

A) Solid Waste Composition

Sampling and Analysis: The collection of clinical waste samples and analysis were carried out in 2007. The waste characterization study was carried out in accordance with WHO guidelines (WHO 1999; WHO 2001). All of the wastes generated in the hospitals were segregated and weighed during a period of four month, manually. The environmental health experts as well as members of nosocomial infection control committee of hospitals or managers of waste transportation, collection and sorting, recorded the amount of medical waste on the data form. The wastes from hospitals were collected from storage areas. The quantity and composition of the wastes were determined at each hospital. Parallel to the interviews, the physical compositions of waste in hospitals were determined. Before segregation, the wastes were spread by disinfectant solution (0.5% sodium hypochlorite). Masks and large forceps were used to segregate waste into several types. During segregation, each type of medical waste was discarded into bags. General and medical wastes from outpatient and inpatient services were collected separately. The weighing and analysis of wastes were performed in a special site. The medical wastes were previously sorted into various components such as serum, syringe and needle etc. The weight of each component of the medical waste was recorded on special data forms. Following these procedures, the wastes were transported to a special site for storage and final disposal. This waste composition study was part of a continuing effort to measure and understanding the waste generated in hospitals. The raw survey data was compiled and managed so as to enable the estimation of waste generation quantities and management practices.

Data analysis: The quantities of hospital wastes were presented in terms of kg/day for total amount of waste generation. These data were used to determine the quantities of waste generated in hospital.

Waste segregation study: Trash bins with coloring bags were in placed in hospital wards for 24 h in selected wards, surgical units, emergency wards, operation theaters (where not available). The waste was collected after an interval of 12 h as the shift of nursing and paramedical staff switched. Waste Generation Data was calculated based on weighing the waste on a manual scale (Shagufta, 1995; Zafar, 2002).

B) Waste Water Characteristics

Sampling Method: The study was conducted on February 2015. To obtain the data of hospital wastewater characteristics, done taking the data directly and indirectly through library documents, SOP of WWTP, and sampling at the WWTP effluent at hospital at the time of maximum load of wastewater. Parameters measured include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), pH. Sample analysis was done according to the standard methods (APHA, 1998)

Chemical Parameters: pH: The pH was measured by using Pen type pH meter after the calibration. Calibration was done by using the buffer tablets such as pH 4.7 and 9.2

Total solids:
A total solid was determined by using hot air oven.

BOD:
Biological oxygen demand for five days (BOD5) was determined for the waste water sample, using BOD sensor system "FTC 901 Refrigerated" at 20ºC, and then BOD5 in (mg/l) was read.

COD:
Chemical oxygen demand (COD) was determined for waste water sample by COD reactor. The sample was put in the COD reactor for two hours at 150 ºC, titrated it with ferrous ammonium, sulphate, where Ferrous used as an indicator, then COD in (mg/l) was calculated.

C) Treatment Processes Introduction

1) Preliminary Treatment Units: It includes unit operations such as:

A-Screens: The general purpose of screens is to remove large objects such as rags, paper, plastics, metals, and the like. These objects, if not removed may damage the pumping and sludge- removal equipment, hangover wires, and block valves, thus creating serious plant operation and maintenance problems.

B- Aerated Grit champers: It is used remove dust, bone chips, coffee grounds, seeds, eggshells, and other materials in wastewater that are non putrescible and higher than organic matter. By the air, wastewater is freshened, thus reduction in odors and additional BOD_5 R Removal may be achieved.

2) Primary Treatment: It is including primary sedimentation the purpose of this unit is to remove the settle able organic solids. Normally a primary sedimentation will remove 50-70 percent total suspended solids and 30-40 percent BOD_5.

3) Biological Treatment (Secondary Treatment): The purpose of secondary treatment is to remove the soluble organics that escape the primary treatment and to provide further removal of suspended solids. Although secondary treatment may remove than 85 percent of the BOD_5 and suspended solids, it does not remove significant amount of nitrogen, phosphor heavy metals, no degradable organics, bacteria and viruses. These pollutants may require further removal (advanced one).

4) Advanced treatment: It is an additional treatment process, such as filtration, carbon adsorption, and chemical precipitation of phosphorus, to remove those constituents that are not adequately removed in the secondary treatment plant. These include nitrogen, phosphorus, and other soluble organic and inorganic compounds

a) Bar Screen Chamber: The function of the bar screen is to prevent entry of solid particles/ articles above a certain size; such as plastic cups, paper dishes, polythene STP. (If these items are allowed to enter the STP, they clog and damage the STP pumps, and cause stoppage of the plant.) The screening is achieved by placing a screen made out of vertical bars, placed across the sewage flow. **The gaps between the bars may vary between 10 and 25 mm. Larger STPs may have two screens: A coarse bar screen with larger gaps between bars, followed by a fine bar screen with smaller gaps between bars. In smaller STPs, a single fine bar screen may be adequate.** If this unit is left unattended for long periods of time, it will generate a significant amount of odor: it will also result in backing of sewage in the incoming pipelines and chambers.

b) Aerated Grit Chamber: It also known as aerated detritus tank. in this type of grit chamber, the organic solids that would otherwise settle down by gravity is kept in suspension by are injected normally by diffuse aeration system, into wastewater basin to force a spiral or rolling flow. **The raising air bubbles means aeration system provided at the bottom of the tank** or by mean of some type of agitation, the air diffusers are normally located about 50cm above the bottom of tank.

c) Oil and grease trap (skimming tank): oil and grease traps are small size skimming basins provided to remove oil and grease and other floating material such as fats, vegetable debris etc., **normally, they are located ahead of PST to**

protect pumps and downstream treatment components. It also designed that lighter materials like grease and oil content of wastewater rise to the surface of ww and remains on top of liquid until removed. The treated liquid flow out through the outlets provided below the water line.

d) Primary settling tank: It is simple settling tank, normally rectangular or circular in shape, this unit is provided in the domestic ww system**, mainly to remove a large portion of suspended material, which is primarily inorganic in nature, however a small fraction of biodegradable settle able organic matter also gets removed with inorganic fraction**. The conventional sedimentation tank normally removes about 60-70%of suspended solids and 20-30% of associated BOD (organic materials).

e) Secondary Clarifier/ Settling Tank: Biological treatment is achieved by providing activated sludge process. In this treatment soluble BOD is stabilized by oxidation of organic matter by microorganisms. Nutrient and food is supplied to microorganisms for enhancing their growth.Oxygen required is provided by air blower through non-clog type membrane diffusers to achieve higher rate of oxygen transfer efficiency. Mixed liquor overflow from aeration tank is taken into secondary clarification process, for the separation of microorganisms under gravity. Bottom sludge from secondary clarifier is re-circulated back in the aeration tank. Excess biomass is transferred into bio sludge tank. Clear overflow from secondary clarifier is transferred to the tertiary treatment.

f) Sludge Dewatering System: Sludge from primary and secondary clarifiers is collected in primary sludge sump and bio sludge tank respectively. Excess bio sludge is taken to primary sludge sump. From primary sludge sump, sludge is transferred to sludge thickener. Thickened sludge is sent to sludge drying beds for removal of water from sludge. Overflow from thickener is taken into primary clarifier. Leachate collected from sludge dewatering system is collected in Leachate collection tank. That Leachate is then taken into wastewater collection tank for further treatment. Dried sludge from sludge drying beds is removed, packed and disposed to the Transport, Storage and Disposal Facility site at gumdi pondi for secured land filling.

g) **Tertiary Treatment:** Tertiary treatment consists of chemical oxidation, pressure sand filter and activated carbon filter. Effluent from biological treatment is passed through chemical oxidation tanks, where Hydrogen Peroxide dosing is done. Mixing in chemical oxidation tank is provided with air agitation using separate air blowers. Effluent from chemical oxidation tank is collected in intermittent storage tank. From where effluent is further subjected to pressure sand filter and activated carbon filter. Suspended solids get removed in pressure sand filter and activated carbon filter provides treatment for removal of color and COD so that final treated wastewater meets the discharge norms specified by MPCB. Backwashing of both the filters is done daily for cleaning of filter beds. The backwashed water is diverted back into wastewater collection sump for further treatment.

h) Disinfection of Treated Water: The treated water is disinfected to destroy and render harmless disease-causing organisms, such as bacteria, viruses, etc. The most common methods of disinfection include Chlorination, Ozonation and UV radiation. Of these, Chlorine finds widespread application. The primary action of the chemical involves damaging the cell wall, resulting in cell lysis and death. In most STPs, the common form of Chlorine used is Sodium Hypochlorite (Hypo) available commercially at 10-12 % strength, being safe, easy to handle and having a reasonable shelf life.

i) Filter Feed Pumps (FFP): Filter feed pumps are used to take the water from the clarified water sump and pass it through the pressure sand filter and activated carbon filter installed in series.

j) Pressure Sand Filter (PSF): The pressure sand filter (PSF) is used as a tertiary treatment unit to trap the trace amounts of solids which escape the clarifier, and can typically handle up to 50 mg/l of solids in an economical manner. This unit is essentially a pressure vessel that is filled with graded media (sand and gravel). The water filtered with PSF is passed on to the next stage in the STP chain: the Activated Carbon Filter.

k) Activated Carbon Filter (ACF): An activated carbon filter, like the Pressure Sand Filter, is a tertiary treatment unit. It receives the water that is already filtered by the Pressure Sand Filter and improves multiple quality parameters of the water: BOD, COD, clarity (turbidity), color and odor.

l) Clean treated effluent water tank: Holds water before lifting to high-level storage tanks.

Design Period

A sewerage scheme involves the laying of underground sewer pipes and construction of costly treatment units, which cannot be replaced or increased in their capacities easily or conveniently at a later date. In order to avoid such complications, the future expansions of the hospital and consequent increase in the sewage quantity should be forecasted to serve the community satisfactorily for a reasonable year. The future period for which the provision is made in designing the capacities of various components of the sewerage is known as design period. This sewage treatment plant is designed for 30 years. Raw sewage characteristics, tested in Environmental laboratory with Technical division, Tamil Nadu Corporation.

Table 1: the sewage treatment plant is designed based on the raw effluent analysis. The relevant design parameters are tabulated below

S.No	Parameters	Raw Sewage	Effluent (Expected)
1	pH	6.1	5.5-9.0
2	B.O.D	342 mg/l	≤ 20 mg/l
3	C.O.D	961 mg/l	≤ 250mg/l
4	Suspended Solids mg/l	230 mg/l	≤ 30 mg/l
5	Oil and grease	50 mg/l	≤ 5 mg/l
6	Total Solids mg/l	1400 mg/l	
7	Total dissolved Solids mg/l	1700 Solids mg/l	

D) Sewage Treatment Process

General: Sewage contains various types of impurities and disease bacteria. This sewage is disposed of by dilution or on land after its collection and conveyance. If the sewage is directly disposed of, it will be acted upon the natural forces, which will convert it into harmful substances. The natural forces of purification cannot purify any amount of sewage within specified time. If the quantity of sewage is more, then receiving water will become polluted or the land will become sewage sick. Under such circumstances it becomes essential to do some treatment of the sewage, so that it can be accepted by the land or receiving water without any objection. These treatment processes will directly depend on the types of impurities present in the sewage and the standard up to which treatment is required.

Object of Treatment: The main object of treatment units is to reduce the sewage contents (solids) from the sewage and remove all the nuisance causing elements and change the character of the sewage in such a way that it can be safely discharged in natural water course applied on the land. In other words, the objective of sewage treatment is to produce a disposable effluent without causing harm or trouble to the communities and prevent pollution. Practically the treatment of sewage is required in big cities only where the volume of the sewage is more as well as the quantity of various types of solid, industrial sewage etc. is more and porous land or large quantity of water bodies is not available for the proper disposal of sewage.

Degree of Treatment: The degree of treatment will mostly be decided by regulatory agencies and the extent to which the final product of treatment are to be utilized. The regulatory bodies might have laid down standard for the effluent or might specify the condition under which the effluent must be discharged into the natural stream. The method of treatment adopted should not only meet the requirement of the regulatory bodies, but also result in the maximum use of the end product with economy.

Design Period: The treatment plant is normally designed to meet the requirement over a 30 year period after it completion. The time lag between the design and completion should not normally exceed 2-3 years. Care should be taken that the plant is not considerably under loaded in the initial stages, particularly the sedimentation tank. The ultimate design period should be 30 years and to that extent sufficient accommodation should be provided for all the units necessary to cater to the need of ultimate population. Some cases, it may be necessary to combine a number of sewage systems with a common sewage treatment plant.

Location of Treatment Plant

The treatment plant should be located as near to the point of disposal as possible. If the sewage as to be disposed finally in to the river, the plant should be located near the river bank. Care should be taken while locating the site that it should be on the downstream side of the city and sufficiently away from water intake works. If finally the sewage as to be applied on land, the treatment plant should be located near the land at such a place from where the treated sewage can directly flow under gravitational forces toward the disposal point. The plant should not be much far away from the town to reduce the length of the sewer line. On the other hand the site should not be close to the town, that it may cause difficulties in the expansion of town and may pollute the general atmosphere by smell and fly nuisance.

Layout of Treatment Plant

The following point should be kept in mind while giving layout of any sewage treatment plant:

- All the plant should be located in the order of sequence, so that sewage from one process should directly go to other process.
- If possible all the plant should be located at such elevation that sewage can flow from one plant into next under its force of gravity only.
- All the treatment units should be arranged in such a way that minimum area is required it will also ensure economy in its cost.
- Sufficient area should be occupied for future extension.
- Staff quarter and office also should be provided near the treatment plant, so that operators can watch the plant easily.
- The site of treatment plant should be very neat and give very good appearance.
- Bypass and overflow weir should be provided to cut out of operation any unit when required.

All channels, conduits should be laid in such a way as to obtain flexibility, convenience and economy in the operation.

Point Considered in Design

Following points are considered during the design of sewage treatment unit:

- The design period should be taken between 25 to 30 years.
- The design should not be done on the hourly sewage flow basis, but the average domestic flow plus the maximum industrial flow on the yearly record basis.
- Instead of providing one big unit for each treatment more than two numbers small units should provided, which will provide in operation as well as no stoppage during maintenance and repair of the plant.
- Overflow weirs and the bypasses should be provided to cut the particular operation if desired.
- Self cleaning velocity should develop at every place and stage.
- The design of the treatment units should be economical; easy in maintenance should offer flexibility in operation

3. Results and Discussion

A) **Composition Of Bio-Medical Solid Waste:** Theaverage results composition of biomedical solid waste is presented for August 27th 2014 from Fig. 1, September 27th 2014 from Fig. 2, October 27th 2014 from Fig.3, November 27th 2014 from Fig.4

Table 2: Total Amounts of Solid Waste Generated in each month (Kgms)

Color bags	Total amount of waste generated in each month (kgms)				Total amount of waste generat ed in (kgms)
	Aug 27th 2014	Sep 27th 2014	Oct 27th 2014	Nov 27th 2014	
RED (BIG) Infectious waste	23.8	25.3	18.6	17.9	48.35
RED (SMALL) Infectious waste dipped in fluid	10.65	20.7	13.5	23.4	63.5
BLUE Sharp waste	11.1	17.5	17.5	18.2	55
YELLOW Anatomic waste	2.8	0.5	0.3	0.7	60.2

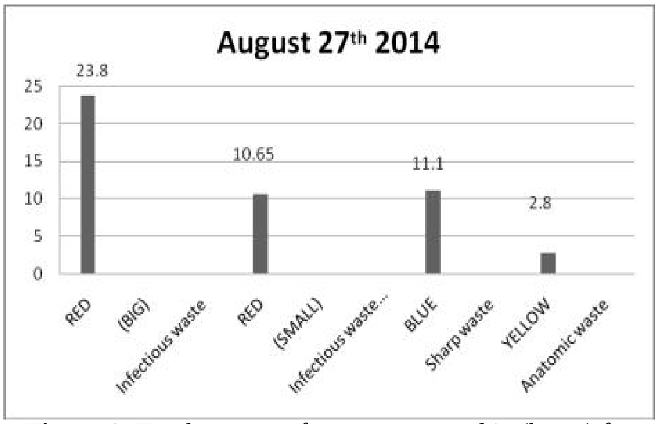

Figure 1: Total amount of waste generated in (kgms) for August 27th 2014

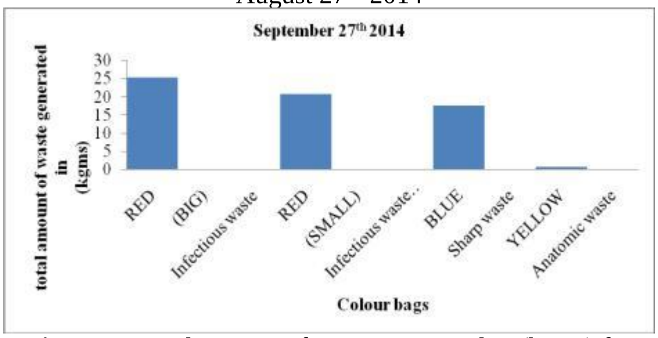

Figure 2: Total amount of waste generated in (kgms) for September 27th 2014

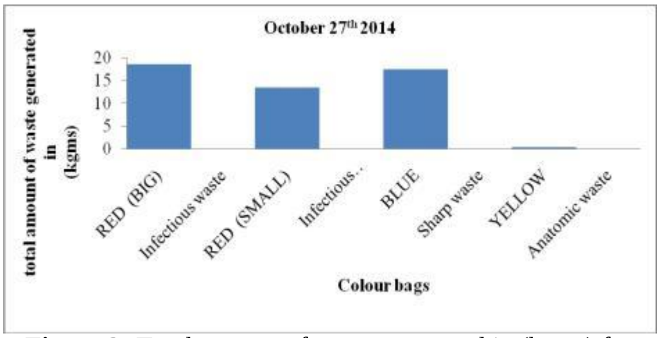

Figure 3: Total amount of waste generated in (kgms) for October 27th 2014

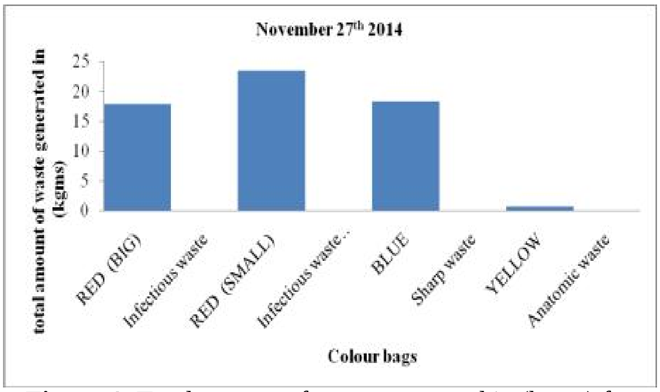

Figure 4: Total amount of waste generated in (kgms) for November 27th 2014

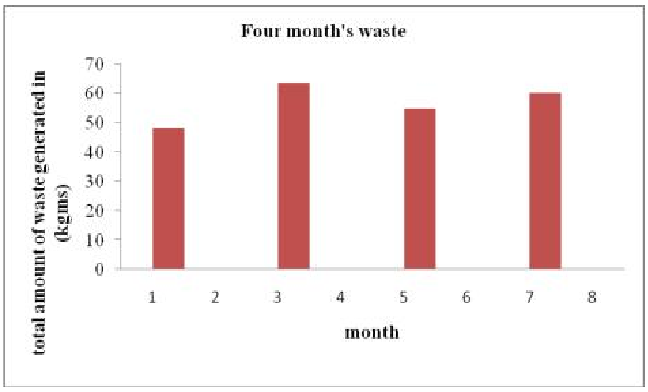

Figure 5: Total amount of waste generated in (kgms)

From the Fig 1 to 4.2it is clear that the composition of wastes disposed in each month for four month such as, red big bag contain infectious waste 85.6kgms, red small bag contain infectious waste that dipped in the fluid HCL then we put weight 68.25kgms, blue bag contain sharp waste 64.3kgms, yellow bag contain anatomic waste 4.3kgms.

In this four month the ward and bed for patients not constant. Each and every day increase and decrease. The bed for four months 27th day August 27th 2014 [1798],September 27th 2014 [1048],October 27th 2014 [985] November 27th 2014 [1092]

B) Effluent Treatment Plant:

Flow chart of effluent treatment plant

Units	*Size*	*Design Details*	*Quantity*
Flow Collection tank	0.849 cumec 6 m X 3m X3m+ 0.5 (fb)	Design flow=0.849cu Mec Detention time = 60 sec	1
Screen Chamber	2.0m X 0.60m X 0.70m	1.18m/s flow velocity. Provide bars Of 10mm*50mm with clear opening of 25mm.n=16bars	2
Grit Chamber	7.87m X 4.5m X 3m	Peak flow42.5m3/m In	2
Oil and	11m X 6.5m X	detention time	1

Table 3 Technical Details of ETP Units

grease trap	1.5m	t =5.0 min.	
Primary sedimentation Tank	21.24mX5.31m X3.1+ 0.6(fb)	detention time 2.07hr, Overflow rate at average flow= 36m^3/m^2.d	1* (6basin)
Aeration tank	22mX10.88mX 4.5+0.8(fb)	Detention time = 8.37hr	1* (8basin)
Secondary clarifier	19.15m.diaX3. 5+0.5m(fb)	Detention time under average design flow plus recirculation = 5.63hr	1* (8basin)
Chlorination contact Tank	18m X 9.6 m X 3.4m	Provide 3 no. of chlorination [2working +1stand by] each of 60kg/d capacity	1
Filter Feed Tank	32 m X 16m X 3m	Detention time = 1.5hrs	1
Pressure sand filter	20 m.dia X 1.5 – 1.8m	Loading rate on filter 12 m^3/m^2 /Hr.Depth of sand layer0.6– 0.75 m	1
Activated carbon filter	22 m.dia X 1.5 – 1.8m	Loading rate on filter = 10 m^3/m^2 / hr. Depth of sand layer ayer 0.6 –0.75 m	1
Primary sedimentation sludge	11.5m.dia X 3m	Amount of Solids produced per basin per day at a removal rate of 63 percent =588.41 kg/d	1
Sludge thickener	5.5m.dia X 3m	drying ratio = 5 percent, Thickener =141 m^3/d	6
Sludge drying beds	30 m X 3m X0.25m	Volume of sludge =157.103m3/day	**7 beds**

4. Conclusion

A) Solid Waste Composition

The result obtain during present investigation rival that waste generation from august to November 27th 2014 Red big bag waste that means (infectious waste) gradually decrease each month Aug 23.800kgms, Sep 25.300kgms, Oct 18.600kgms, Nov 17.900kgms. Red small waste that means (infectious waste) gradually increase each month Aug 10.650kgms, Sep 20.700kgms, Oct 13.500kgms, Nov 23.400kgms. Blue bag (Sharp waste) Aug 11.100kgms, Sep 17.500kgms, Oct 22.600kgms, Nov 18.200kgms. yellow waste (anatomic waste) Aug 2.800kgms, Sep 0.500gms, Oct 0.800gms, Nov 0.700kgms. So proper segregation is important otherwise it become hazardous one.

Proper management of Bio medical waste is a concern that has been recognized by both government agencies and the Non government organizations. Several hazards and toxic materials containing should be disposed off with proper take and care. Inadequate and inefficient segregation and transportation system may cause severe problem to the society hence implementing of protective measures, written policies all of these factors contribute to increased risk of exposure of staff, patients and the community to biomedical hazards. Safe and effective management of bio medical waste is not only a legal necessity but also a social responsibility. Lack of concern in persons working in that area, less motivation, awareness and cost factor are some of the problems faced in the proper hospital waste management clearly there is a need for education as to the hazards associated with improper waste disposal.With respect to the above scenario, steps are being taken to improve the present system of BMW management in the state. The Common Bio-Medical Waste Treatment and Disposal Facilities (CBMWTDF) are operating at Thanjavur(Sengipatti)

Both the facilities manoeuvred by Private Operators, provide service for collection, transportation, treatment and disposal of BMW in lieu of a service cost. These facilities are now covering large number of health care units situated in different districts. An affirmative step is also taken in part from Medicare Incin Pvt. Ltd to set up a CBMWTDF in Thanjavur(Sengipatti), This resolves the problem of waste generated by the rural health care units, which could not be accessed on a day-to-day basis because of these units being situated in remote areas and operating in small capacities

B) Effluent Treatment Plant (ETP):

The technical project involves integration of various fields. This report has combined all the aspects of environmental, chemical, biological and civil engineering. The plant is designed to meet future expansion for the next 30 (2050) years, population of 2, 26,276.2.This project consist the design of the complete components of a wastewater treatment plant from receiving chamber, screening chamber, grit chamber, fine screen, primary sedimentation tank, secondary sedimentation tank, activated sludge tank, sludge drying beds, chlorination tank, Filter feed tank, pressure sand filter, activated carbon filter, treated effluent tank and sewers systems with civil estimation. The construction of Wastewater treatment plant will prevent the direct disposal of wastewater from municipality sewer system of hospital into nearby River and the usage of treated water will reduce the surface and ground water contamination

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