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Design of Vaccum Sewerage System

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Abstract - *The West Kochi ABD(Area Based Development) has never had any piped sewerage and centralized treatment system. It is entirely dependent on household level septic tanks and pits. The grey water and sullage from septic tanks are discharged into the road side storm drains ultimately leading to the canals and the sea posing a public health hazard and degradation of the environment. To improve its waste water management and sanitation situation through a scientific sewage collection and treatment system. Under this plan it has been decided to cover the Fort Kochi ABD area comprising wards 1(P), 2, 3, 4 and 5(P) initially , covering an area of 2.7 sq.km. Kochi being a coastal and low-lying area has a high water table and a relatively flat topography. Thus, a conventional gravity based system would lead to deep depths and a higher number of sewage pumping stations which might not be feasible to execute. To overcome these problems a sewage collection system based on a vaccum or suction based technology has been proposed.*

Key Words: **Sewerage, Vaccum sewerage, Sewage treatment plant, Sludge, Grey water**

1. INTRODUCTION

The West Kochi ABD has never had any piped sewerage and centralized treatment system. It is entirely dependent on household level septic tanks and pits. The grey water and sullage from septic tanks are discharged into the road side storm drains ultimately leading to the canals and the sea causing posing a public health hazard and degradation of the environment. Kochi being a coastal and low-lying area has a high water table and a relatively flat topography. Thus, a conventional gravity based system would lead to deep depths and a higher number of sewage pumping stations which might not be feasible to execute. To overcome these problems a sewage collection system based on a vaccum or suction based technology has been proposed. The proposed sewage collection system would cover and estimated 42,000 persons and 10,000 households having a design horizon of 2051. It would comprise a total of 80.56 kms of vaccum sewer lines and additional 46.4 km of gravity riders for connecting the house connections to the vacuum collection chambers/sumps. An STP of 6.5 MLD capacity has been proposed to treat the collected sewage. Due to paucity of space it is planned to construct the STP in a multiple storey utilizing the vertical space. Also, the space above the adjoining canal is planned to be used by construction of a tilted structure. An Advanced Aeration Based Technology of SBR type is proposed for the STP.

1.1 Scope of the work

There is no existing piped sewerage system in the entire West Kochi area including Fort Kochi and Mattancherry. Most of the households have septic tanks or pits in their premise and the overflow from the septic tank is discharged through storm water drains to canals, backwaters, sea etc. This has caused pollution of surface as well as ground water posing a public health hazard. In the entire west Kochi, Sewage is carried through the covered storm water drains, canals and finally gets discharged into the sea. As per the general topography of West Kochi area, the sewage (from septic tanks) as well as sullage is carried through the covered storm water drains and canals. West Kochi area does not have any piped sewerage system or a treatment facility. There are no existing sewerage schemes in Fort Kochi and Mattancherry. Most of the households have septic tanks in their premise and the overflow from the septic tank is conveyed through covered secondary drains.

In the entire west Kochi, Sewage is carried through the covered storm water drains, canals and finally gets discharged into the sea. As per the general topography of West Kochi area, the sewage (from septic tanks) as well as sullage is carried through the covered storm water drains and canals. In the Eastern and Western parts of the ABD the sewage finally get discharged into the sea and in the central area it is discharged into the Kalvathy and Rameshwaram Canal (both are connected and dividing the area into two parts. The water in Kalvathi and Rameswaram canal is highly polluted as it appears blackish most of the time.

It is necessary to plan and implement proper sewerage scheme to the area for reducing ground water pollution, polluting the canals and hence the epidemic vulnerable conditions prevailing in the areas. This project also would be the largest suction / vacuum-based sewer technology in India and one amongst the largest in the world when implemented. This would serve a pilot as well as a model to possibly solve the constraints of a conventional sewer system in areas of high-water table and flat topographies. The successful implementation and operation of this system would pave the way for its emulation in other similar areas of Kerala as well as beyond leading to improved sanitation and a cleaner and safer environment to live in.

1.2 Objectives

(i)Inorder to have an a alternative solution for high water table area for not having any consequences of the coming up of drainage
(ii)Design of vaccum sewerage treatment plant at West Kochi
(iii)Design of sewage treatment plant.

2. VACCUM SWERAGE SYSTEM

Vaccum sewerage is a mechanized system of wastewater transport. Unlike gravity flow, vacuum sewers use differential air pressure to move the sewage. A central source of power to operate vacuum pumps is required to maintain vacuum (negative pressure) on the collection system. The system requires a normally closed vacuum/gravity interface valve at each entry point to seal the lines so that vacuum can be maintained. These valves, located in valve pits, open when a predetermined amount of sewage accumulates in collecting sumps. The resulting differential pressure between atmosphere and vacuum becomes the driving force that propels the sewage towards the vacuum station. [2]

The main operating principle of vacuum sewer system is to transport sewage by differential air pressure from the formation place (houses) to the vacuum station. The main components of the vacuum sewer system are vacuum station, vacuum sewer line and vacuum station

When talking about sewer systems most people think of gravity based underground pipe networks which transport wastewater to a wastewater treatment plant via a gradient. For a long time these gravity sewers have been the most common practice especially in densely populated areas to transport wastewater. Often these gravity-based sewer systems also form the drainage infrastructure and are therefore called combined sewers since they convey wastewater and storm water. Nowadays, other concepts are emerging focussing on the separation of waste water and storm water. One interesting option is the vaccum sewer system which is considered an alternative wastewater collection system and can only be applied in separate sewer concepts since the system is not suitable for the drainage of storm water. The term vacuum sewer system has been widely used for simplification reasons and marketing purposes. However, technically 'vacuum' is not the correct term since a vacuum is a void space free of any matter. The presented sewer system operates under negative or suction pressure compared to the atmospheric pressure. A vacuum sewer system works in a similar way as water distribution systems. The only difference is the direction of flow. While water supply uses positive pressure to 'push' the water from the treatment plant to the point of consumption, vacuum sewers use negative pressure to 'draw' the wastewater from the point of generation to the wastewater treatment plant. In contrast to conventional gravity flow or pressured sewer systems vacuum sewers use differential air pressure to transport wastewater which is generated by vacuum pumps located at the vaccum station, a centralized unit and in most designs the only point of electricity consumption. The pumps draw in atmospheric air through specific air inlets located at the wastewater collection points. The air inlets are attached to valve pits which form the point of collection for wastewater from the surrounding buildings. Besides the collection chamber (sump) for wastewater the valve pits contain the control units and the interface valves which form the interface between the negative pressure in the system and the atmospheric pressure in the valve pit. The valve is usually closed and opens after the control unit signals that a predetermined amount of sewage has accumulated in the sump.

The pressure difference between the network and the valve pit causes the water to be sucked into the vacuum main where it is transported to the collection tank located at the central vaccum station. The drawn air expands under the negative pressure conditions and drives the transport mechanism. On the way to the collection tank at the vacuum station the transported wastewater temporarily comes to rest at depressions within the profile of the pipe network due to friction and weight forces. This way the wastewater is transported in frequent intervals until it reaches the collection tank at the vacuum station which contains the pumps and control equipment. From here pumps, usually pressured sewage pumps, forward the wastewater towards the waste water treatment plant.

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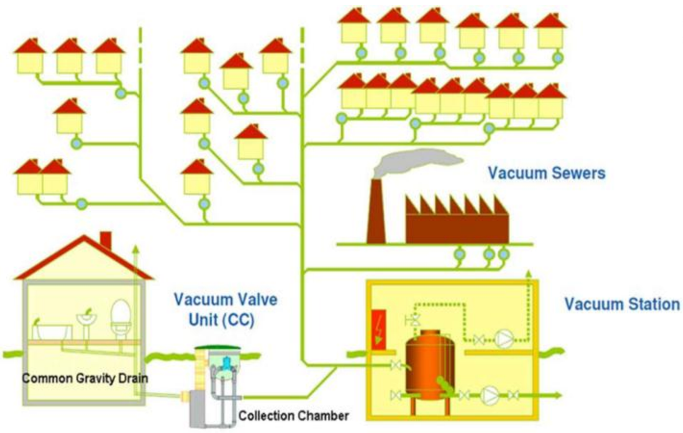

Fig -1: Vaccum Sewerage System [2]

2.1 Study Area

Kochi, the commercial capital of Kerala is also second most important port city on the western coast of India is situated in the Ernakulam District. The District is bounded on the north by Thrissur District, on the east by Idukki District, on the south by Kottayam and Alappuzha Districts and Arabian Sea envelops the city all along the western boundary. Ernakulam district consists of Kochi Corporation, five municipalities (Aluva, Paravur, Angamali, Thripunitara, Kothamangalam, Perumbavur, Muvatupuzza and Kalamassery) and 88 Panchayats.

Kochi has negligible sewerage coverage. About 95% of Kochi's sewage is managed through some form of on-site sanitation facility. The Kochi has two sewage treatment facilities at Elankulum and Marine Drive. Since Sewerage coverage is limited, sewerage management is predominantly through septic tanks and other localised means. Kochi has negligible sewerage coverage, initiative to expand sewerage network face a number of challenges including narrow street width and a high water table. Private agencies provide septage cleaning services and the sector is completely unregulated.

2.2 Sequencing Batch Reactor

Sequencing batch reactors (SBR) or sequential batch reactors are a type of activated sludge process for the treatment of wastewater. SBR reactors treat wastewater such as sewage or output from anaerobic digesters or mechanical biological treatment facilities in batches. Oxygen is bubbled through the mixture of wastewater and activated sludge to reduce the organic matter (measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD)). The treated effluent may be suitable for discharge to surface waters or possibly for use on land.

While there are several configurations of SBRs, the basic process is similar. The installation consists of one or more tanks that can be operated as plug flow or completely mixed reactors. The tanks have a "flow through" system, with raw wastewater (influent) coming in at one end and treated water (effluent) flowing out the other. In systems with multiple tanks, while one tank is in settle/decant mode the other is aerating and filling. In some systems, tanks contain a section known as the bio-selector, which consists of a series of walls or baffles which direct the flow either from side to side of the tank or under and over consecutive baffles. This helps to mix the incoming Influent and the returned activated sludge (RAS), beginning the biological digestion process before the liquor enters the main part of the tank

There are five stages in the treatment process: Fill,React, Settle,Decant,Idle

The inlet valve opens and the tank is being filled in, while mixing is provided by mechanical means (no air). This stage is also called the anoxic stage. Aeration of the mixed liquor is performed during the second stage by the use of fixed or floating mechanical pumps or by transferring air into fine bubble diffusers fixed to the floor of the tank. No aeration or mixing is provided in the third stage and the settling of suspended solids starts. During the fourth stage the outlet valve opens and the "clean" supernatant liquor exits the tank. Aeration times vary according to the plant size and the composition/quantity of the incoming liquor, but are typically 60 to 90 minutes. The addition of oxygen to the liquor encourages the multiplication of aerobic bacteria and they consume the nutrients. This process encourages the conversion of nitrogen from its reduced ammonia form to oxidized nitrite and nitrate forms, a process known as nitrification. To remove phosphorus compounds from the liquor, aluminium sulfate (alum) is often added during this period. It reacts to form non-soluble compounds, which settle into the sludge in the next stage.

The settling stage is usually the same length in time as the aeration. During this stage the sludge formed by the bacteria is allowed to settle to the bottom of the tank. The aerobic bacteria continue to multiply until the dissolved oxygen is all but used up. Conditions in the tank, especially near the bottom are now more suitable for the anaerobic bacteria to flourish. Many of these, and some of the bacteria which would prefer an oxygen environment, now start to use oxidized nitrogen instead of oxygen gas (as an alternate terminal electron acceptor) and convert the nitrogen to a gaseous state, as nitrogen oxides or, ideally, molecular nitrogen (dinitrogen, N_2) gas. This is known as denitrification. Anoxic SBR can be used for anaerobic processes, such as the removal of ammonia via Anammox, or the study of slow-growing microorganisms. In this case, the reactors are purged of oxygen by flushing with inert gas and there is no aeration. As the bacteria multiply and die, the sludge within the tank increases over time and a waste activated sludge (WAS) pump removes some of the sludge during the settle stage to a digester for further treatment. The quantity or "age" of sludge within the tank is closely monitored, as this can have a marked effect on the treatment process. The sludge is allowed to settle until clear water is on the top 20 to 30 percent of the tank contents. The decanting stage most commonly involves the slow lowering of a scoop or "trough" into the basin. This has a piped connection to a lagoon where the final effluent is stored for disposal to a wetland, tree growing lot, ocean outfall, or to be further treated for use on parks, golf courses etc. In some situations in which a traditional treatment plant cannot fulfill required treatment (due to higher loading rates, stringent treatment requirements, etc.) the owner might opt to convert their traditional system into a multi-SBR plant. Conversion to SBR will create a longer sludge age, minimizing sludge handling requirements downstream of the SBR. The reverse can also be done where in SBR Systems would be convertedinto extended aeration (EA) systems. SBR treatment systems that could not cope up with a sudden constant increase of influent would easily be converted into EA plants. Extended aeration plants are more flexible in flow rate, eliminating restrictions presented by pumps located throughout the SBR systems. Clarifiers can be retrofitted in the equalization tanks of the SBR. [5]

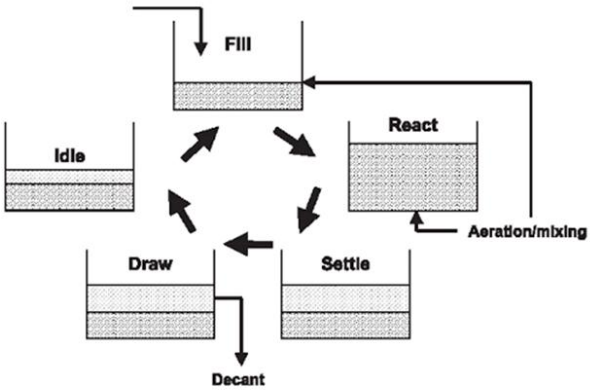

Fig :2 Schematic diagram of SBR [5]

3. DESIGN STEPS

LPCD =135

Return Factor = 80%

Peakflow = 2.25

Amount of sewage produced = 0.8×135

= 108 LPCD

Total Households = 10,000

Total Population = 42000
Flow per persons = 108 × 2.25 = 243

Total Sewearge Flow =7059.656LPM

Table -1: Initial characteristics of waste water collected from the project area

Parameter	General Standards for Discharge of Environmental Pollutats as per CPCB			Value
	Inland surface water	Public sewers	Land for irrigation	
Ph	5.5-9.0			
TDS(mg/l)	2100	2100	2100	886
BOD (mg/l)	30	100	100	357
COD (mg/l)	250	-	250	749.56
Temperature (^{0}C)	SHALL NOT EXCEED 5^{0}C ABOVE RECEIVING WATER TEMPERATURE			31.6
Oil & grease (mgl)	10	10	20	26
TKN as N (mg/l)	100	-	100	35.04
Nitrate nitrogen as N (mg/l)	10	-	20	0.76
Dissolved oxygen (mg/l)	-	-	-	4.91

Design flow Q_p max = 4843.7 l/min

Daily sewage flow = 2790 m^3/min

Vaccum tank = 65 kpa

Selected pump maximum available vaccum = 87.205 kpa

Vaccum pump capacity = 1509m^3/hour

Running peak hour =Q_p max × 0.06 (1 + T_{max}) / ∑n×s

= 36 min/hour

Vaccum unit load Q_p max = 5617 l/min

Reserve capacity Q_{RES} = 773 l/min

Energy consumption per day = Q_{day} × (1 + T_{max}) n×s
= 0.09 kwh/m^3

4. CONCLUSIONS

West Kochi being a coastal and low-lying area has a high water table and a relatively flat topography .Thus, a conventional gravity based system would lead to deep depths and a higher number of sewage pumping stations which might not be feasible to execute. To overcome these problems a sewage collection system based on a vacuum or suction based technology has been proposed.

This project when implemented successfully has the potential to significantly improve the quality of life and living standards in the West Kochi ABD. A sewerage system with all houses connected to it would improve the surface as well as ground water quality in the area.

This project when completely executed would be able to completely free the road side storm water drains of sewage and sullage. These drains would be carrying only rainwater flows and remain dry/empty during the non-rainy seasons. This would not only improve the aesthetics of the area but also lead to a cleaner and safer environment.

In terms of surface water rejuvenation, this project holds significant potential to revive Kalvathy canal to a significantly cleaner form. This is because this canal has its starting point as well as its catchment within the ABD. However, since the canal it is tidal in nature and the surrounding areas don't have any sewerage system, the sewage discharged from the surrounding areas into the sea would find its way back in during high tides although in a much more diluted form.

REFERENCES

[1] Borkar R.P, Gulhane M.L, and Kotangale A.J (2013) "Moving Bed Biofilm Reactor – A New Perspective in Wastewater Treatment", IOSR Journal Of Environmental Science, Toxicology And Food Technology .Volume 6, Issue 6

[2] Abdelsalam Elawwad, Mostafa Ragab, Hisham Abdel-Halim (2014) " Vacuum Sewerage System in Developing Regions and the Impact on Environmental Management". Proceedings of the 4th International Conference on Environmental Pollution and Remediation. Paper no :82

[3] Mr. Shashikant Gopal Kamble1, Prof. M. B. Kumthekar ,Mr. Deepak H. Koli (2015) "Vacuum Sewer System" IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 03, 2015

[4] Katarzyna Miszta-Kruk [2015]. "Reliability and failure rate analysis of pressure, vacuum and gravity sewer systems based on operating data" IJSRD - International Journal for Scientific Research & Development.

[5] M.K Jungles (2014) "SBR Operation for treating waste water with aerobic granular sludge", International Journal of Engg & sciences & (IJES), chem.engg vol.31.

[6]Cental Public Health and Environmemtal Engineering Organisation (CPHEEO) Manual