Effect of Hydraulic Retention Time and Sludge Retention Time on Performance of Membrane Bioreactor for Wet Season

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Abstract:

To understand the effect of HRT and SRT on parameters was the prime motive of the studies. The parameters such as chemical oxygen demand (COD), soluble COD (Sol.COD), biochemical oxygen demand (BOD), nitrogen (ammonia NH_4, nitrate NO_3) contents and phosphorus contents (Phosphate PO_4), total suspended solids (TSS) and volatile suspended solids (VSS), soluble microbial products (SMP), proteins, carbohydrates, acetate and alkalinity (ALK) for hospital wastewater and residential quarter wastewater were considered . The experiments have been performed on laboratory-scale hollow fiber submerged membrane bioreactor (MBR) for wet season i.e. rainy season. The results have discovered a high removal efficiency of COD, BOD and ammonia which ranged between 93.15 to 97.98 %, 94.20 to 98.74 % and 97.21 to 98.74 %, respectively. While, for TSS and VSS, the removals were found to above 99.00 %. The phosphorus removal efficiency (54.55 to 58.00 %) was found to be inadequate compare to other parameters. The removal efficiencies decreased with increase in HRT, while efficiency increased with increase in SRT. Better results were obtained with residential wastewater as compared to hospital wastewater.

Keywords: sludge retention time, hydraulic retention time, removal efficiency, wet season

Introduction:

Submerged Membrane bioreactor (MBR) is consisted of the membrane modules that are situated in a bioreactor. Since this type of membrane bioreactor is more compact and energy saving, it appeared as one of the pioneering and promising solutions for wastewater treatment and reclamation [1-2]. It is well recognized that hydraulic retention time and sludge retention time (SRT) is the one of the vital subjects, which can modify the condition of biomass in an activated sludge system [3-4]. A membrane bioreactor (MBR) system can keep better performance results in term of biomass compared to a conventional activated sludge system through membrane separation technology, which can achieve perfect solid/liquid separation [5]. But, it is also expect that biomass properties in a MBR system can be considerably influenced by HRT and SRT [5].

Compared to conventional biological treatment, many researchers have used MBR systems with longer SRT since they understood that a higher biomass concentration, which was resultant by longer SRT, gave rise to higher treatment efficiency. In order to keep large amounts of biomass, some MBR plants were run with an infinite SRT [6].SRT is a vital characteristic in the elimination of pollutants and in the minimization of the amount of wasted sludge. Long SRT has a commercial advantage and avoid nitrifying bacteria from being washed out of the bioreactor, which improves the nitrification capability of the activated sludge [7,8].

Knoblock et al. [9] studied the relationship between SRT and microorganism specific growth rate in pilot and full-scale membrane bioreactor systems for the treatment of oily wastewater. Trouve et al. [10] statemented the sludge production in the membrane bioreactor to be lower than in a conventional activated sludge process. Chaize and Huyard [11] discovered the treatment performance change at different SRT. However, most of these studies have concentrated on the conventional type, i.e. recirculated type, of membrane bioreactor, in which membrane modules are allocated outside a bioreactor; there are few reports on submerged membrane bioreactors [12, 13].

MBR systems have been employed to treat various types of wastewater with a chemical oxygen demand (COD) concentration ranging from about 100 to more than 40,000 mg/L and a hydraulic retention time (HRT) varying from 4 h to several days [14]. Fallah et al (2010) considered the effect of HRT on SMBR for a synthetic wastewater having a chemical oxygen demand (COD) and styrene concentration of 1500 mg/L and 50 mg/L, respectively. At two hydraulic retention times (HRTs) of 24 h and 18 h, the MBR was operated. It was found out that the removal efficiency of COD and styrene for both HRTs was constantly higher than 99%. [15]

Membrane bioreactor (MBR) system is distinguished by short hydraulic retention time (HRT), small sludge production and perfect nitrification, which are induced from high mixed liquor suspended solids (MLSSs), condition [16]. Therefore, MBR has been widely applied to remove organic pollutants as well as nutrient in wastewater [16]. In some case ,by substituting the settling tank in a conventional activated sludge process with a membrane filtration device, all micro-organisms are retained in the bioreactor and the hydraulic retention time (HRT) becomes completely independent on the sludge retention time (SRT) [16,17]. High sludge concentration can therefore be achieved even in a short HRT. [18]

The Objectives of this study was to examine the effect of HRT and SRT on parameters such as Chemical Oxygen Demand (COD), Biochemical Oxygen Demand(BOD) , Nitrogen and Phosphorus Contents(Ammonia NH_4,Nitrate NO_3 and Phosphate PO_4), Solid Contents(Total Suspended Solids TSS, Volatile Suspended Solids VSS), Soluble Microbial Products Contents (SMP, Proteins, Carbohydrates and Acetate) and alkalinity(ALK) for wastewater originating from a hospital as well as residential quarter have been carried out by laboratory-scale hollow fiber membrane bioreactor (MBR) for wet season.

Material and Methods:

Experimental Set Up and Procedure

A Submerged MBR assembly (100 L/day in Capacity) was designed to meet Indian standard [1]. The feed substrates were collected from the sewer of residential quarters and the hospital wastewater [2-3].For the reactor assembly,re-denitrification scheme (denitrification tank with a volume of 36 L) had been adopted for nitrogen removal, and a membrane module was immersed in the nitrification tank (volume 49 L). The permeate extraction regime was an alternate relaxation (1 min) followed by a suction phase (9 min). Aeration was carried out at the bottom of filtration module using a coarse diffuser in order to reduce fouling processes by turbulent flow generated along membranes. Mechanical cleaning was achieved by means of air bubble blowing at the bottom of the module. Permeate was withdrawn under suction from the membrane using a piston pump. To avoid the entrainment of air, nitrogen gas was introduced to maintain anoxic condition [4, 5].The analytical methods used in this study were similar to previous publications [1-5].

Operating Conditions

The MBR was operated under various influent wastewater concentrations, for residential quarter wastewater the influent COD and BOD concentrations were found in the range of 310 to 318 mg/l and 156 to 166 mg/l, respectively. While that for ammonia and phosphorus, the initial values found in the range of 20 to 25 mg/l and 4 to 6 mg/l, respectively. The influent concentration of wastewater for TSS and VSS were found in the range of 292 to 328 mg/l and 205 to 240 mg/l, respectively. Whereas for soluble microbial products, proteins, carbohydrates and acetate, the initial concentrations were found in the range of 7.90 to 8.35 mg/l , 4.00 to 5.8 mg/l, 2.40 to 4.25 mg/l and 79.98 to 89.20 mg/l respectively. The concentration of alkalinity was found to be 228 to 239 mg/l.

Similarly for hospital wastewater the influent COD and BOD concentrations were found in the range of 355 to 363 mg/l and 174 to 187 mg/l, respectively. While that for ammonia and phosphorus, the initial values found in the range of 31 to 35 mg/l and 5.2 to 6.8 mg/l, respectively. The influent concentration of wastewater for TSS and VSS were found in the range of 312 to 335 mg/l and 222 to 245 mg/l, respectively. Whereas for soluble microbial products, proteins, carbohydrates and acetate, the initial values found in the range of 8.26 to 8.79 mg/l, 4.05 to 5.9 mg/l, 2.66 to 4.8 mg/l and 92.87 to 101.46 mg/l respectively. The concentration of alkalinity was found to be 222 to 234 mg/l. The hydraulic residence time (HRT) was varied as 4, 6 and 8 h and the SRT in successive tests was set at 10, 20 and 30 days, respectively.

Results and Discussion:

The figure 1 and figure 2 show that the effect of hydraulic retention time (HRT) on various parameters such as COD, Soluble COD, BOD, NO_3, alkalinity, NH_4, PO_4, TSS, VSS, SMP, acetate, proteins and carbohydrates when sludge retention time(SRT) is kept constant for residential wastewater and hospital wastewater in the wet season. While, figure 3 and figure 4 show the effect of sludge retention time (SRT) on various parameters such as COD, Soluble COD, BOD, NO_3, alkalinity, NH_4, PO_4, TSS, VSS, SMP, acetate, proteins and carbohydrates when hydraulic retention time(HRT) is kept constant for residential wastewater and hospital wastewater in the wet season.

It is understood from the results that the results are studied for two different conditions in which either of SRT or HRT was held constant and the other was varied.

First Condition: HRTs Vary_SRT Constant

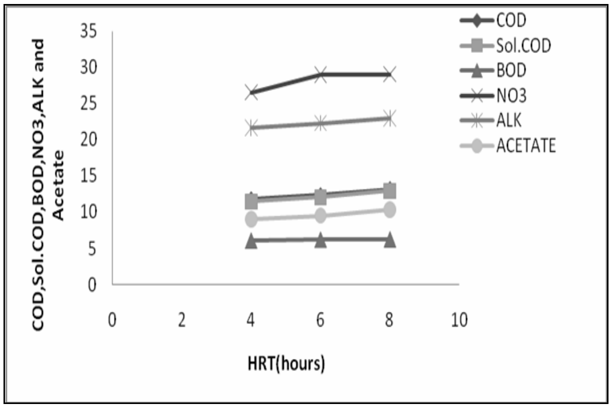
For hospital wastewater, the COD removal efficiency decreases from 93.45 % to 93.15 % for 10 days SRT, 94.52 % to 94.22 % for 20 days and from 95.24 to 95.03 % for 30 days SRT, respectively with increase in HRT from 6 to 8 hours. Similarly, the removal efficiency of BOD decreases from 94.35 % to 94.20 % for 10 days SRT, from 95.52 % to 95.30 % for 20 days and from 96.73 to 96.12 % for 30 days SRT respectively with increase in HRT from 6 to 8 hours. The removal efficiency of NH_4 decreases from 98.02 % to 97.21 % for 10 days SRT, from 98.56 % to 98.06 % for 20 days, from 98.41 to 98.10 % for 30 days SRT with increase in HRT from 6 to 8 hours. The removal efficiency of PO_4 decreases from 55.25 % to 54.55 % for 10 days SRT, from 56.55 % to 55.35 % for 20 days, from 57.35 to 56.80 % for 30 days SRT with increase in HRT from 6 to 8 hours. Similar trends were observed for TSS and VSS removal efficiency. For residential wastewater, although similar trend is observed, but removal efficiencies were better in comparison to wastewater obtained from residential quarter. The deviation in COD and BOD removal between both the wastewater is about 3- 5 %. For NH_4, PO_4 and suspended solids theses variation are low (0.4 to 0.5 %). The better efficiency was found as compare to hospital wastewater.

Second Condition: SRTs Vary_HRT Constant

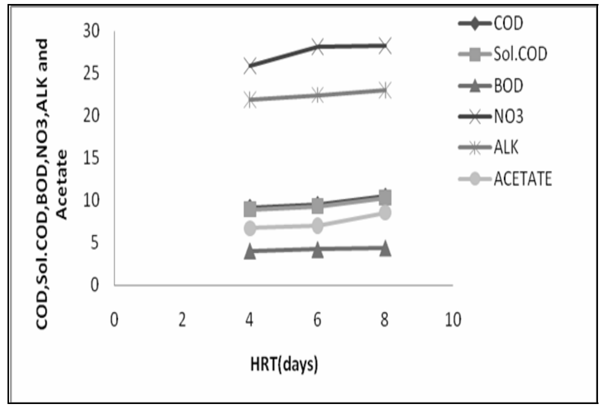
For hospital wastewater, the COD removal efficiency increase from 93.45 % to 95.24 % for 4 hours HRT, 93.36 % to 95.11 % for 6 hours HRT and from 93.15 to 95.03 % for 8 hours HRT, respectively with increase in SRT from 10 to 30 days. Similarly, the removal efficiency of BOD increase from 94.35 % to 96.73 % for 4 hours HRT, from 94.25 % to 96.33 % for 6 hours HRT and from 94.20 to 96.12 % for 8 hours HRT respectively with increase in SRT from 10 to 30 days. The removal efficiency of NH_4 increase from 98.02 % to 98.41 % for 4 hours HRT, from 97.86 % to 98.23 % for 6 hours HRT, from 97.21 to 98.10 % for 8 hours HRT with increase in SRT from 10 to 30 days. The removal efficiency of PO_4 increase from 55.25 % to 57.35 % for 4 hours HRT, from 54.85 % to 57.15 % for 6 hours HRT, from 54.55 to 56.80 % for 8 hours HRT with increase in SRT from 10 to 30 days. Similar trends were observed for TSS and VSS removal efficiency. For residential wastewater, although similar trend is observed, but removal efficiencies were lesser in comparison to wastewater obtained from residential quarter. The deviation in COD and BOD removal between both the wastewater is about 3-5 %. For NH_4, PO_4 and suspended solids theses variation are low (0.4 to 0.5 %). The better efficiency was found as compare to hospital wastewater. Therefore, short HRT coupled with long SRT to achieve high MLSS concentration and membrane performance of PVDF UF membrane for removal of COD, BOD, NH_4 and PO_4.

Conclusion:

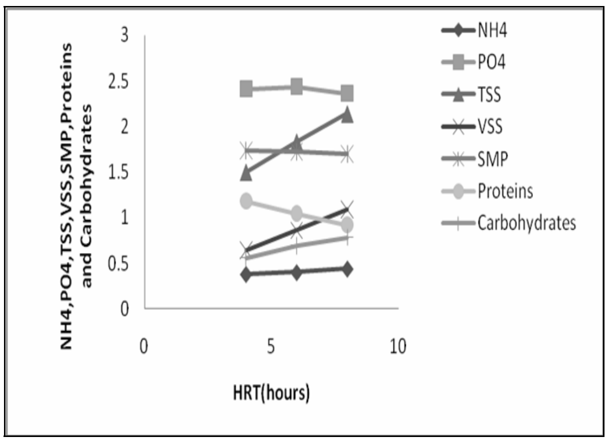
The performance was assessed for treating municipal sewage and hospital wastewater. A hollow fiber submerged membrane bioreactor was operated at different operating conditions. The parameters such as COD, BOD, ammonia, phosphates, TSS, VSS,SMP,protein and carbohydrates etc, temperature (29-32^{O}C), HRT (4,6 and 8 hours) and SRT(10,20 and 30 days) were preferred to investigate the performance of MBR. The results have shown a high removal efficiency of COD, BOD and ammonia which ranged between 93.15 to 97.98 %, 94.20 to 98.74 % and 97.21 to 98.74 %, respectively. While, for TSS and VSS, the removals were found to above 99.00 %. Comparatively, the phosphorus removal efficiency (54.55 to 58.00 %) was found inferior than other parameters. The removal efficiencies reduced with increase in HRT, while efficiency increased with increase in SRT. The better results were obtained with residential wastewater as compared to hospital wastewater. The lower removals may be due to presence of refractory/toxic pharmaceuticals present in the latter case. The results of present study have shown that anoxic and aerobic MBR can be a competent alternative for treating residential quarter wastewater and hospital effluents compared to conventional activated sludge system (Aerobic reactor-Secondary Clarifier) that subjected to a variable concentration of COD, BOD and ammonia.



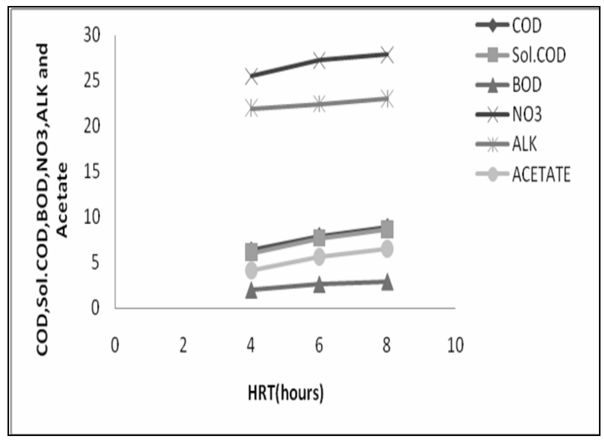
a) SRT = 30 days



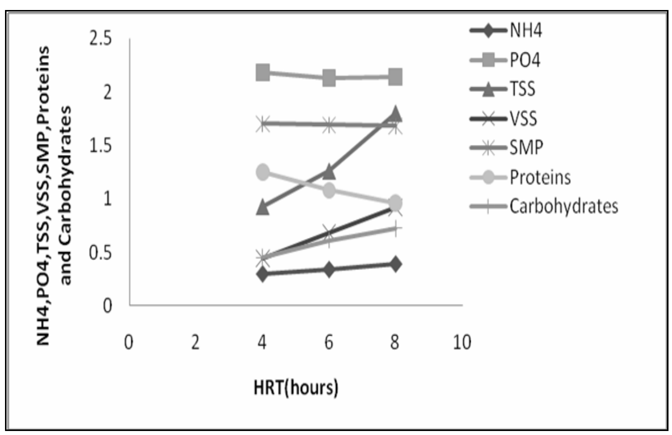
b) SRT = 20 days



c) SRT = 20 days

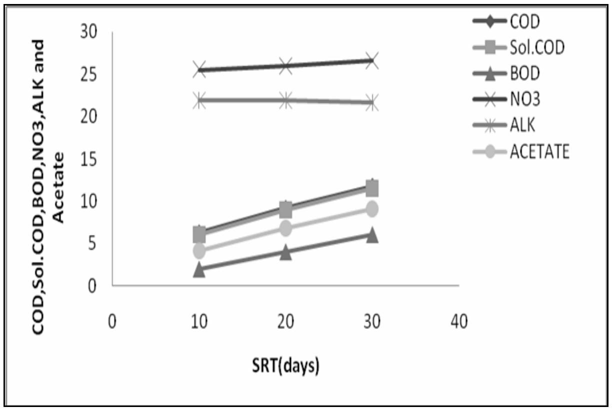


d) SRT = 10 days

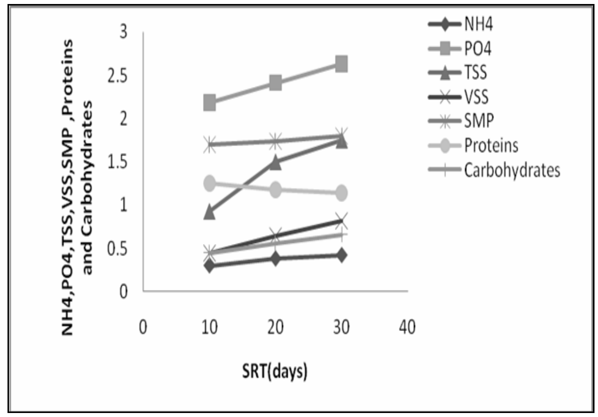


e) SRT = 10 days

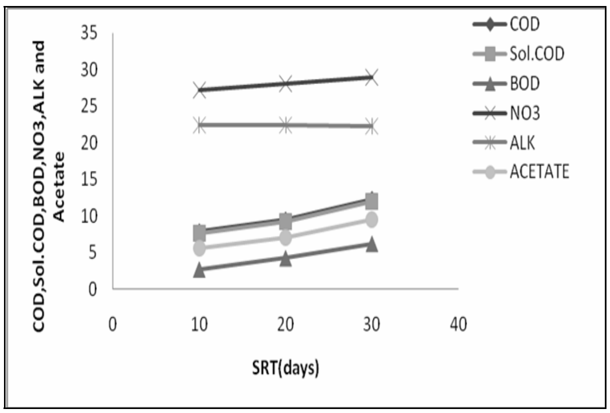
Figure 1: Variation in various parameters with Constant SRT and different HRTs _ Residential Quarter



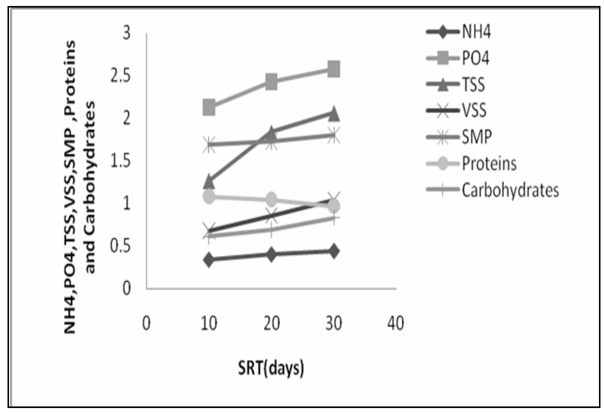
a) HRT = 4 hours



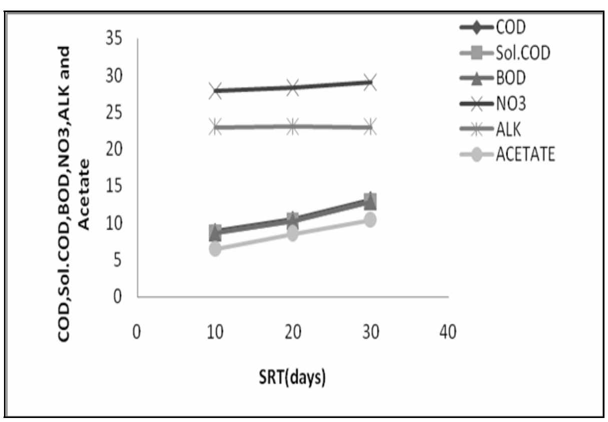
b) HRT = 4 hours



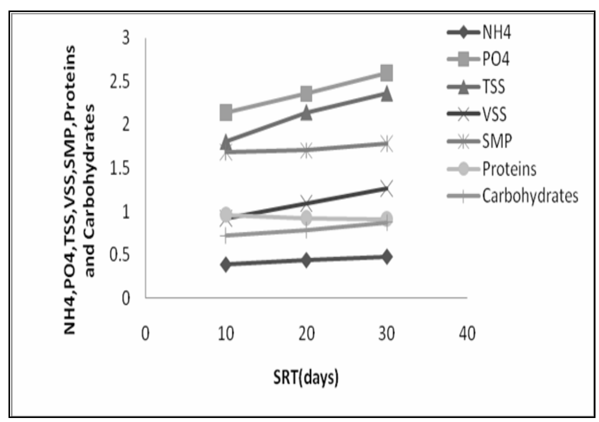
c) HRT = 6 hours



d) HRT = 6 hours

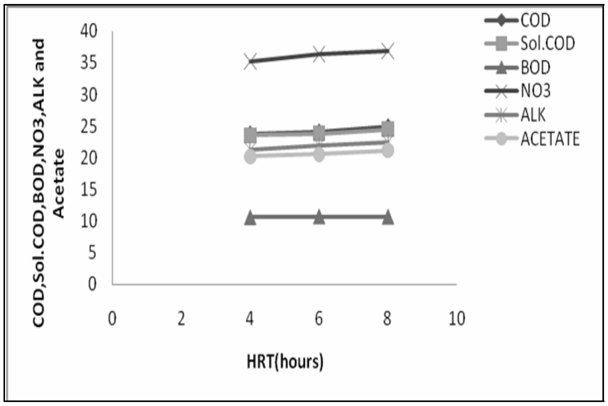


e) HRT = 8 hours

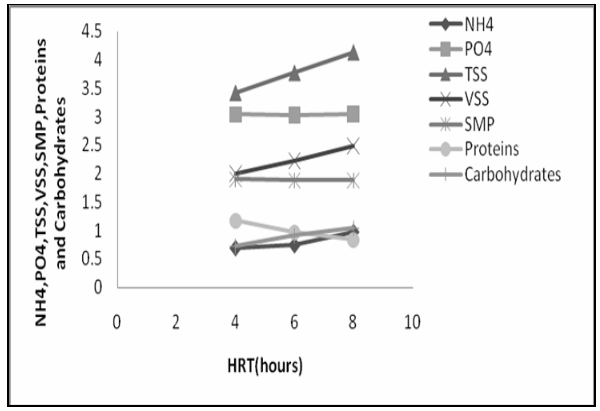


f) HRT = 8 hours

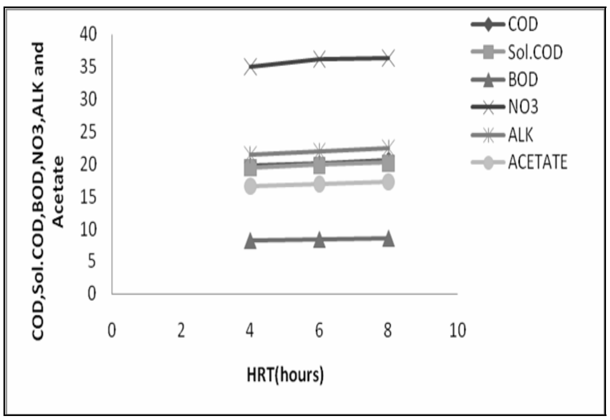
Figure 2: Variation in various parameters with Constant HRT and different SRTs Residential Quarter



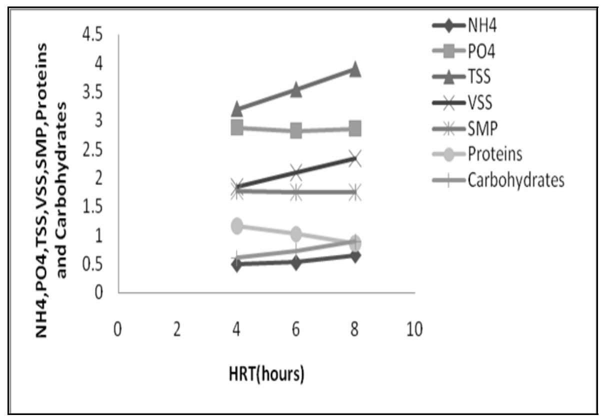
a) SRT = 30 days



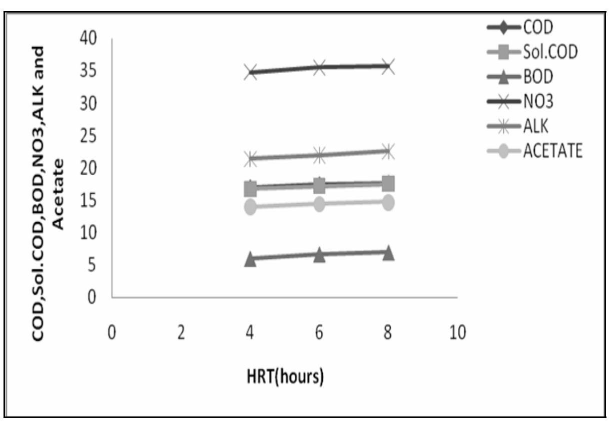
b) SRT = 30 days



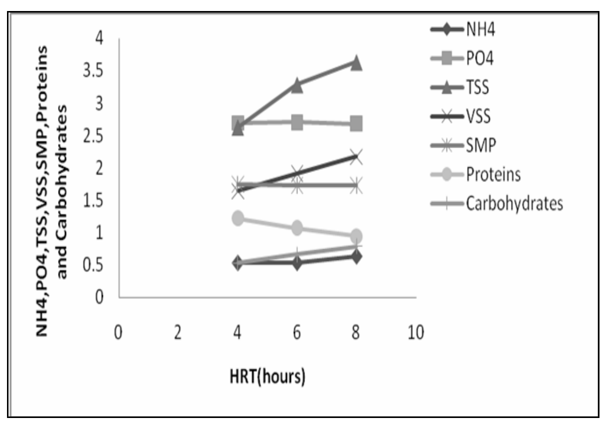
c) SRT = 20 days



d) SRT = 20 days

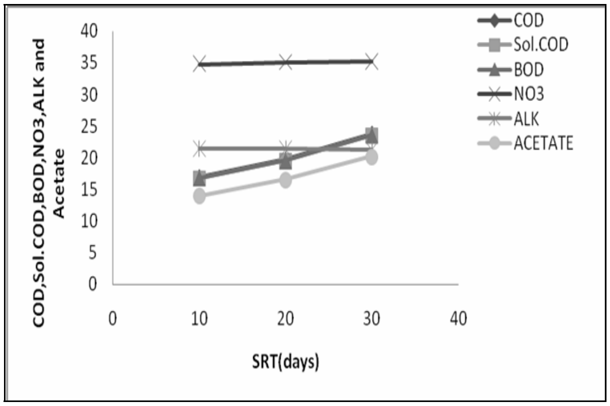


e) SRT = 10 days

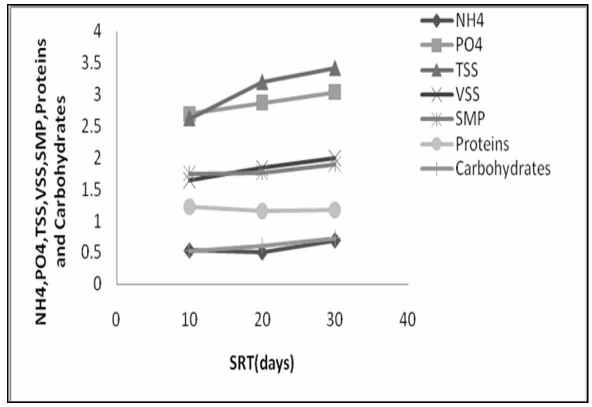


f) SRT = 10 days

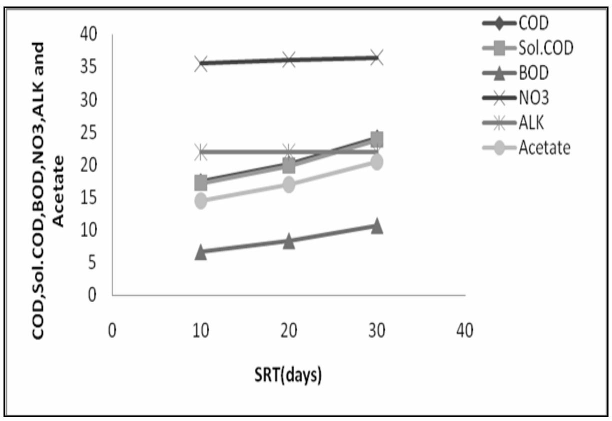
Figure 3: Variation in various parameters with Constant SRT and different HRTs_Hospital



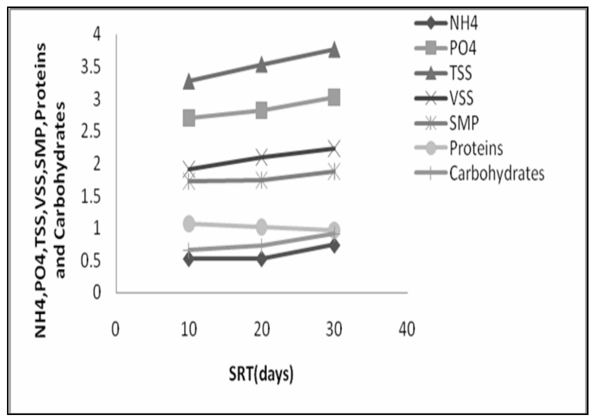
a) HRT = 4 hours



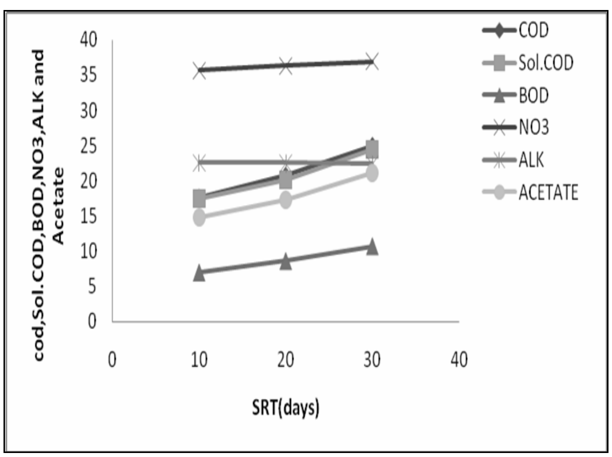
b) HRT = 4 hours



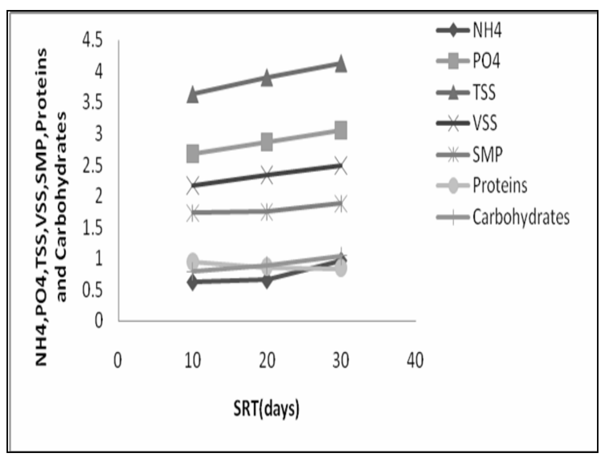
c) HRT = 6 hours



d) HRT = 6 hours



e) HRT = 8 hours



f) HRT = 8 hours

Figure 4: Variation in various parameters with Constant HRT and different SRTs_Hospital

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