

Effect of Hydraulic Retention Time and Sludge Retention Time on Membrane Bioreactor: Performance in Summer Season

JADHAO R. K. ^{1*} DAWANDE S. D. ²

¹Department of Chemical Engineering, Shri Guru Gobind Singhji Institute of Engineering and Technology, Vishnupuri, Nanded-431606, Maharashtra, India

²Department of Chemical Engineering, Laxminarayan Institute of Technology, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur-440033, Maharashtra India
E-mail: rahulkjadhao@yahoo.co.in

Abstract:

The major reason of this study was to examine the effect of HRT and SRT on parameters such as chemical oxygen demand (COD), soluble COD (Sol.COD), biochemical oxygen demand (BOD), nitrogen (ammonia NH₄, nitrate NO₃) contents and phosphorus contents (Phosphate PO₄), 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. The experiments have been carried out on laboratory-scale hollow fiber submerged membrane bioreactor (MBR) for summer season. The results have shown a high removal efficiency of COD, BOD and ammonia which ranged between 92.51 to 97.95 %, 93.10 to 97.63 % and 97.70 to 98.67 %, respectively. While, for TSS and VSS, the removals were found to reach almost 100 %. Comparatively, the phosphorus removal efficiency (54.50 to 57.95 %) was found inferior than other parameters.

Keywords: *sludge retention time, hydraulic retention time, removal efficiency*

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 [1-3]. It is well recognized that hydraulic retention time and sludge retention time (SRT) are the vital subjects, which can modify the condition of biomass in an activated sludge system [4, 5].

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 [6]. But, it is also expect that biomass properties in a MBR system can be considerably influenced by HRT and SRT [6].

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 of 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 [7]. 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 [8, 9].

Knoblock et al. [10] examined 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. [11] stated the sludge production in the membrane bioreactor to be lower than in a conventional activated sludge process. Chaize and Huyard [12] explored 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 very few reports on submerged membrane bioreactors [13, 14].

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 [15]. Fallah et al (2010) studied 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%. [16]

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 [17]. Therefore, MBR has been widely applied to remove organic pollutants as well as nutrient in wastewater [17]. 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) [17,18]. High sludge concentration can therefore be achieved even in a short HRT. [18]

The major reason 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 summer season.

Material and Methods

Experimental Set Up and Procedure

A Submerged MBR assembly (100 L/day in Capacity) was fabricated to investigate applicability of membrane technology for Indian conditions [1]. The feed substrates for the MBR reactor were municipal sewage collected from the sewer of residential quarters and the hospital wastewater, collected from the drainage of a hospital on regular basis [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, 6].

Analytical methods

All the physico-chemical parameters (TSS, VSS, COD, BOD, NH_4 , NO_3 , and PO_4) were determined according to the procedures outlined in the standard methods (APHA 2005). Temperature, conductivity and DO were measured using thermometer, conductivity meter and DO meter respectively. Flow rate and Trans-membrane Pressure (TMP) were monitored using rota-meter and pressure gauge. [19]

SMP quantification was made on the sludge supernatant that had been obtained by centrifugation at 2000 rpm for 20 min, and on the suspended solid. The SMP from the suspended solid were extracted by addition of 2N NaOH at 4°C for 4 h. The extracted solutions were then centrifuged at 8,000 rpm for 20min and filtrated on a $0.2\mu\text{m}$ membrane. SMP were quantified in influent and permeate samples. Proteins were measured by spectrophotometer methods.

SMP can accumulate on the membranes or penetrate into membrane pores. Accumulation and detachment of membrane flocculants are determined by particle convection towards the membrane

surface and the back transport rate of the deposited particles from membrane surface into the bulk. It is difficult to control the back transport of colloids and solutes only by enhancing aeration intensity due to the small size of these substances. The control of SMP concentration in MBRs is crucial. In general, the control of SMP can be achieved by two approaches: adjustment of operation parameters (i.e., SRT, HRT, DO concentration, temperature, aeration). SMP is a complex mixture of macromolecules including polysaccharides, proteins, nucleic acids, humic acids, etc. In this study, the total SMP is defined as the sum of carbohydrates and proteins because they are the main components of SMP [69]. To analyze the SMP in biomass suspensions, 100 mL of mixed liquor from activated sludge was collected from MBR. The samples were filtered through 0.45-mm PTFE filter to separate the residual biomass, and the filtrates were subjected to SMP analysis. The SMP was calculated as the sum of the following three components:

$$\text{Total SMP} = \text{carbohydrates} + \text{proteins}$$

The phenol-sulfuric acid method [20] and the Lowry method (calorimetrically using Bicinchoninic Micro Acid protein assay)[21] were used for determination of the concentrations of carbohydrates and proteins, respectively. Glucose and bovine serum albumin (BSA) were used as standards for the measurements of carbohydrates and proteins, respectively [22, 24, and 26]. The acetate concentration was measured using a gas chromatograph. The total SMPs were determined from the difference as follows [23, 25, and 27]:

$$\text{Total SMP (as COD)} = \text{Soluble COD} - 1.07 * \text{CH}_3\text{COONa}$$

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 reactor was operated under ambient conditions for which the temperature ranged between 30 to 32°C (Average of 31°C) for the entire operation period. 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 effect of hydraulic retention time (HRT) on various parameters such as COD, Soluble COD, BOD, NO₃, alkalinity, NH₄, PO₄, TSS, VSS, SMP, acetate, proteins and carbohydrates when sludge retention time(SRT) is kept constant is displayed in figure 1 and figure 3 for residential wastewater and hospital wastewater in the summer season. While, the effect of sludge retention time (SRT) on various parameters such as COD, Soluble COD, BOD, NO₃, alkalinity, NH₄, PO₄, TSS, VSS, SMP, acetate, proteins and carbohydrates when hydraulic retention time(HRT) is kept constant is displayed in figure 2 and figure 4 for residential wastewater and hospital wastewater in the summer season.

It is observed 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.

For Residential wastewater, the COD removal efficiency decreases from 95.10 % to 94.90 % for 10 days SRT, 96.10 % to 95.85 % for 20 days and from 96.95 to 96.78 % for 30 days SRT, respectively with increase in HRT from 6 to 8 hours. Similarly, the removal efficiency of BOD decreases from 95.25 % to 95.10 % for 10 days SRT, from 96.42 % to 96.20 % for 20 days and from 97.63 to 97.02 % for 30 days SRT respectively with increase in HRT from 6 to 8 hours. The removal efficiency of NH₄ decreases from 98.45 % to 98.10 % for 10 days SRT, from 98.56 % to 98.22 % for 20 days, from 98.67 to 98.12 % for 30 days SRT with increase in HRT from 6 to 8 hours. The removal efficiency of PO₄ decreases from 56 % to 55 % for 10 days SRT, from 56.90 % to 56.20 % for 20 days, from 57.95 to 57.10 % 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 , the COD removal efficiency increase from 95.10 % to 96.95 % for 4 hours HRT, 95.00 % to 96.86 % for 6 hours and from 94.90 to 96.78 % for 8 hours HRT, respectively with increase in SRT from 10 to 30 days. Similarly, the removal efficiency of BOD increase from 95.25 % to 97.63 % for 4 hours HRT, from 95.15 % to 97.23 % for 6 hours and from 95.56 to 97.02 % for 8 hours HRT respectively with increase in SRT from 10 to 30 days. The removal efficiency of NH₄ increase from 98.45 % to 98.67 % for 4 hours HRT, from 98.10 % to 98.44 % for 6 hours, from 97.92 to 98.12 % for 8 hours HRT with increase in SRT from 10 to 30 days. The removal efficiency of PO₄ increase from

56 % to 57.95 % for 4 hours HRT, from 55.5 % to 57.40 % for 6 hours, from 55 to 57.10 % for 8 hours HRT with increase in SRT from 10 to 30 days. Similar trends were observed for TSS and VSS removal efficiency. In both the above cases for Hospital Wastewater, although similar trend is observed, but removal efficiencies were inferior in comparison to wastewater obtained from residential quarter. The variation in COD and BOD removal between both the wastewater is about 3- 5 %. For NH₄, PO₄ and suspended solids these variations are low (0.4 to 0.5 %). The inferior efficiency in this case, could be mainly due to the release of various toxic/ non biodegradable pharmaceutical substances which responded poorly to the bio-agents in the MBR reactor.

Conclusion

A hollow fiber submerged membrane bioreactor was operated at different operating conditions of influent concentration of COD, BOD, ammonia, phosphates, TSS, VSS etc, temperature (30-32°C), HRT (4, 6 and 8 hours) and SRT (10, 20 and 30 days) and its performance was evaluated for treating municipal sewage and hospital wastewater. The results have shown a high removal efficiency of COD, BOD and ammonia which ranged between 92.51 to 97.95 %, 93.10 to 97.63 % and 97.70 to 98.67 %, respectively. While, for TSS and VSS, the removals were found to reach almost 100 %. Comparatively, the phosphorus removal efficiency (54.50 to 57.95 %) was found inferior than other parameters.

The removal efficiencies reduced with increase in HRT, while efficiency increased with increase in SRT. Better results were obtained with residential wastewater as compared to hospital wastewater. The inferior removals may be due to presence of refractory/toxic pharmaceuticals present in the latter case.

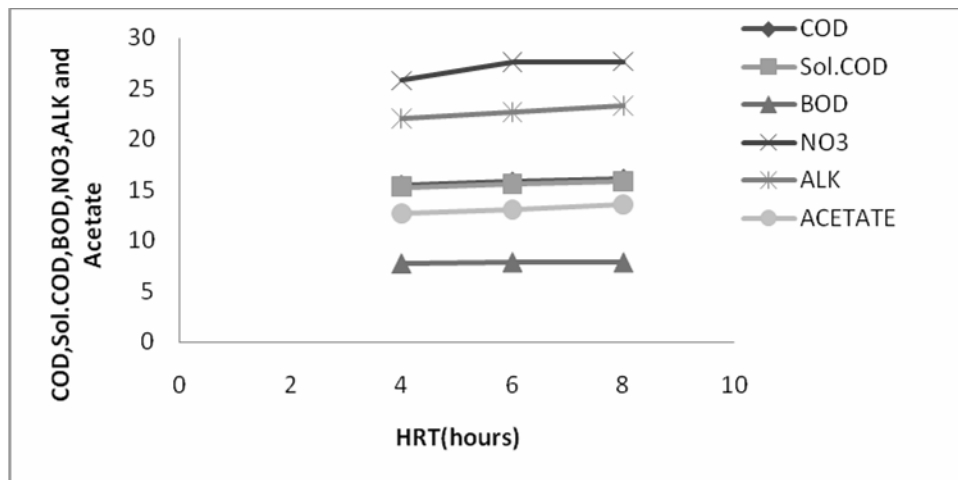
The results of present study have shown that anoxic and aerobic MBR can be an efficient alternative for treating residential quarter wastewater and hospital effluents compared to conventional activated sludge system (Aerobic reactor-Secondary Clarifier) that subjected to a variable concentration of COD, BOD and ammonia.

References

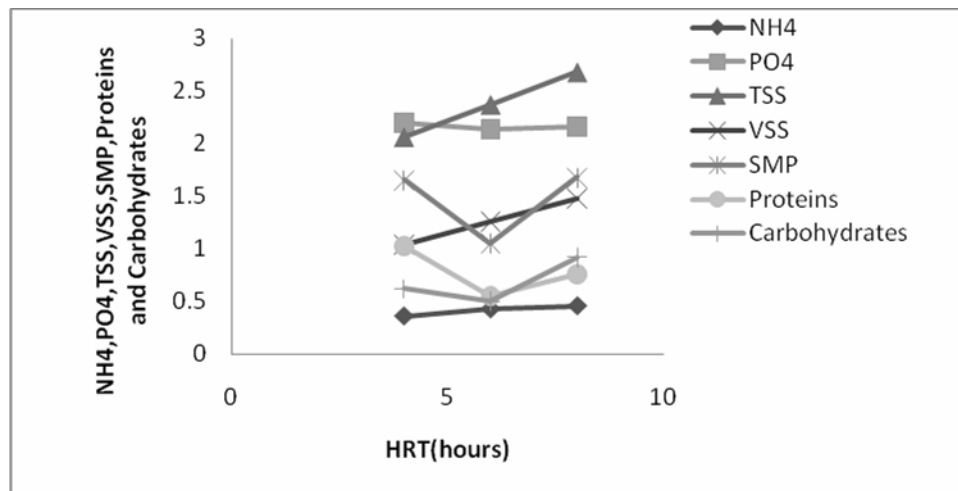
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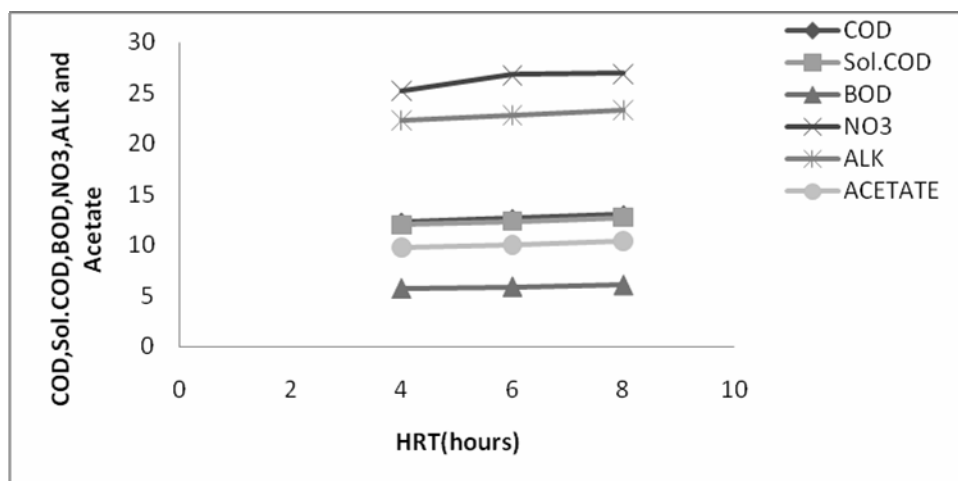
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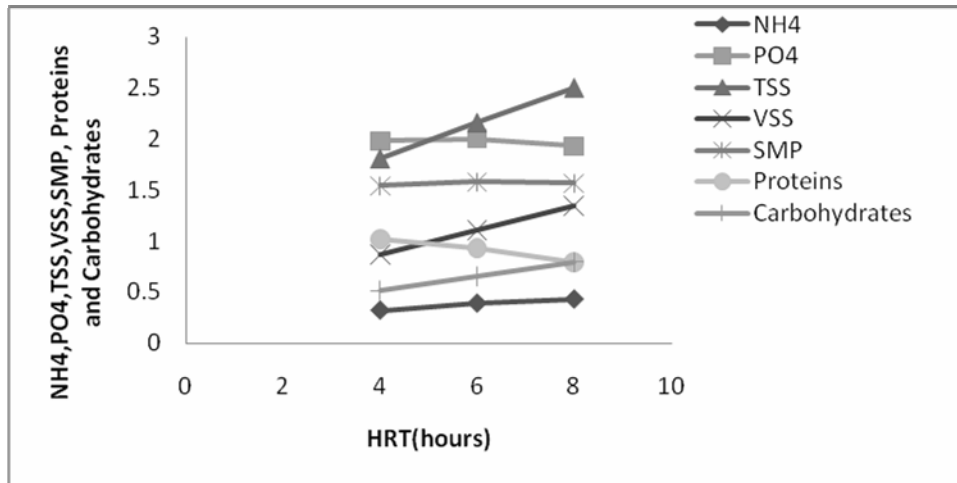
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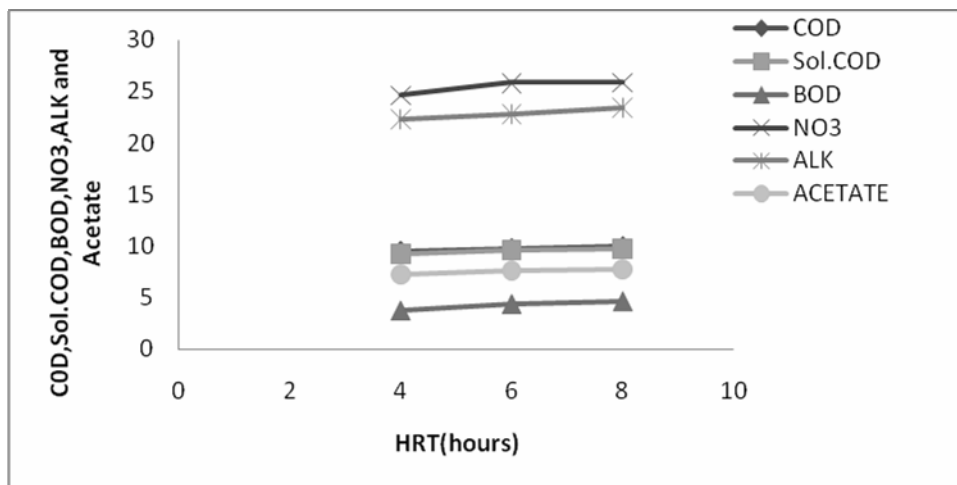
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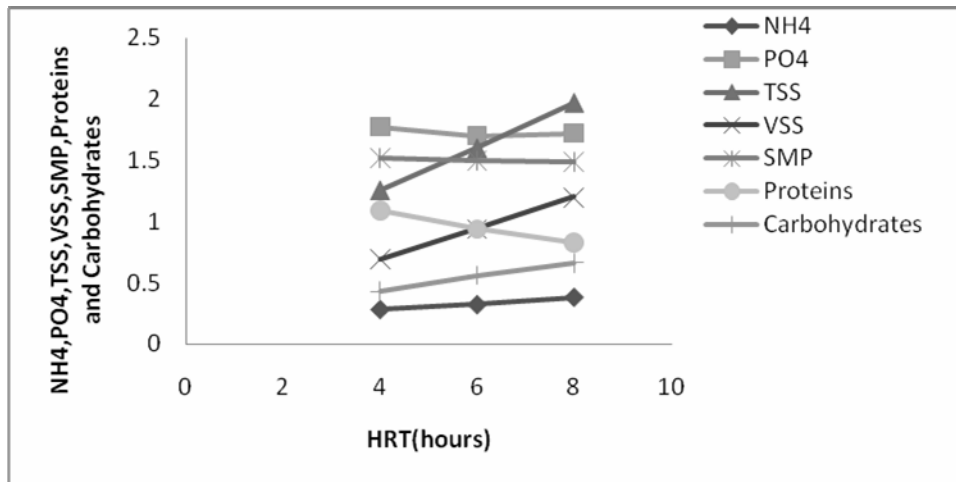
c) SRT = 20 days



d) SRT = 20 days

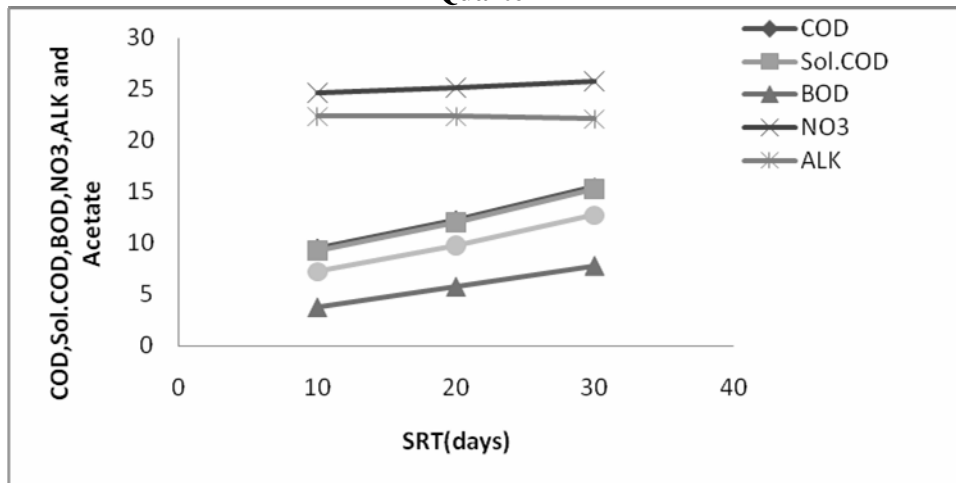


e) SRT = 10 days

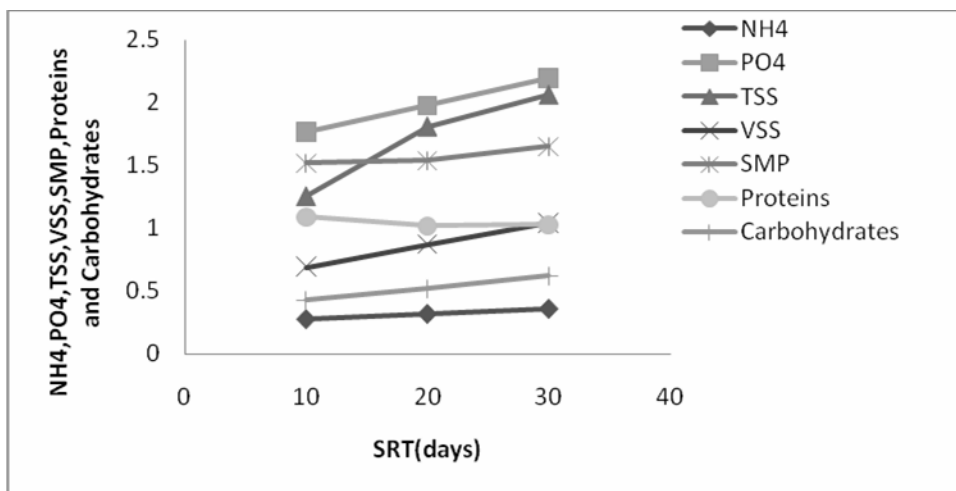


f) SRT = 10 days

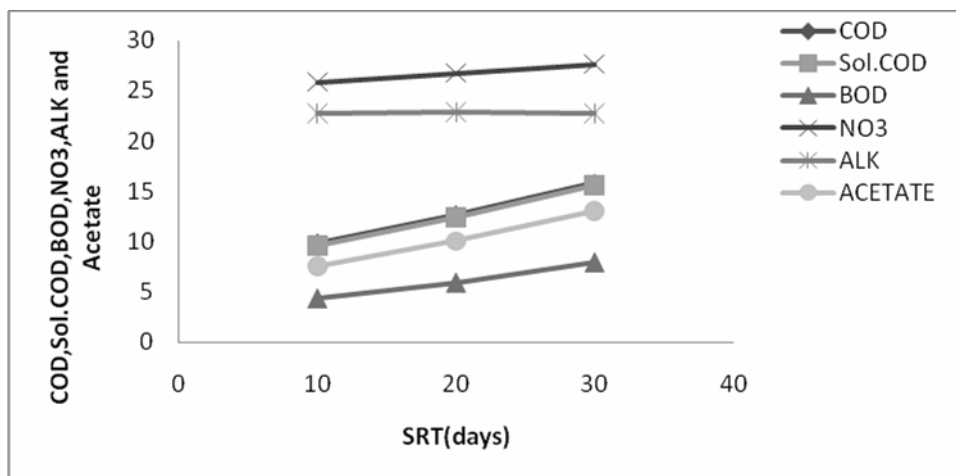
Figure 1: Variation in various parameters with Constant SRT and different HRTs _Residential Quarter



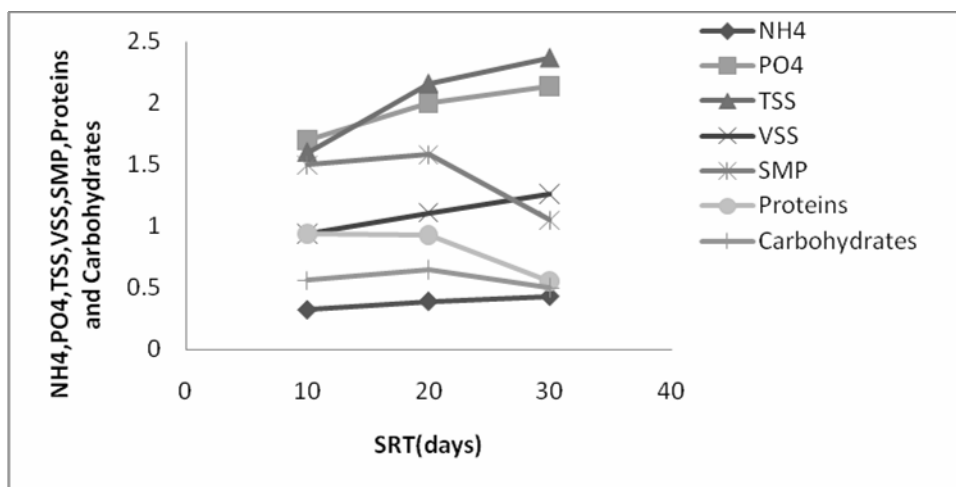
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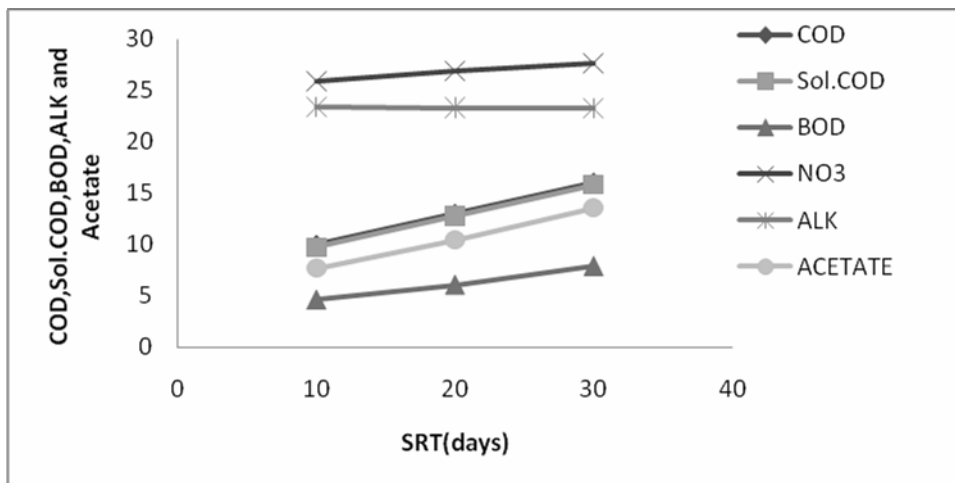
b) HRT = 4 hours



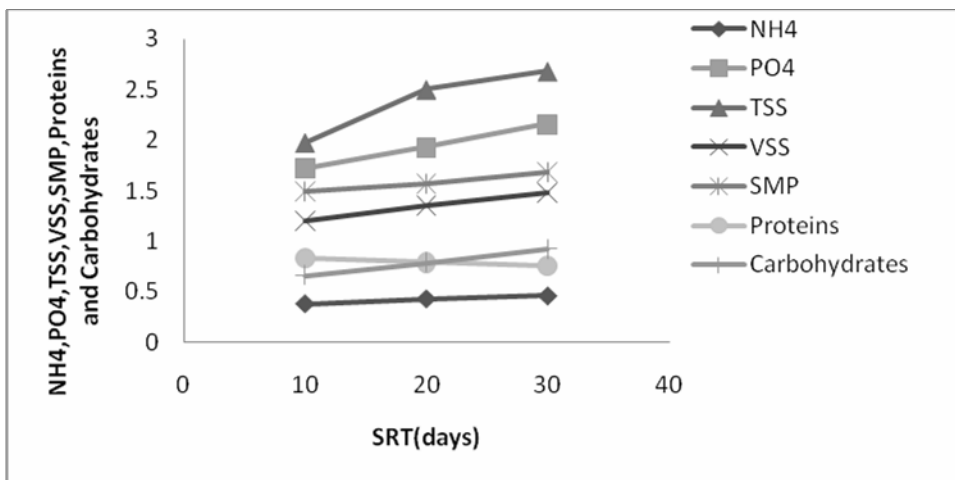
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d) HRT = 6 hours

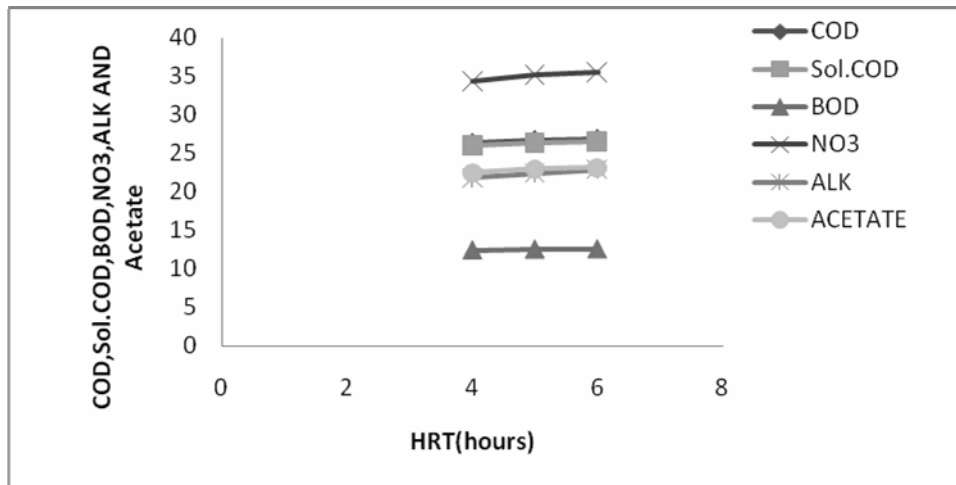


e) HRT = 8 hours

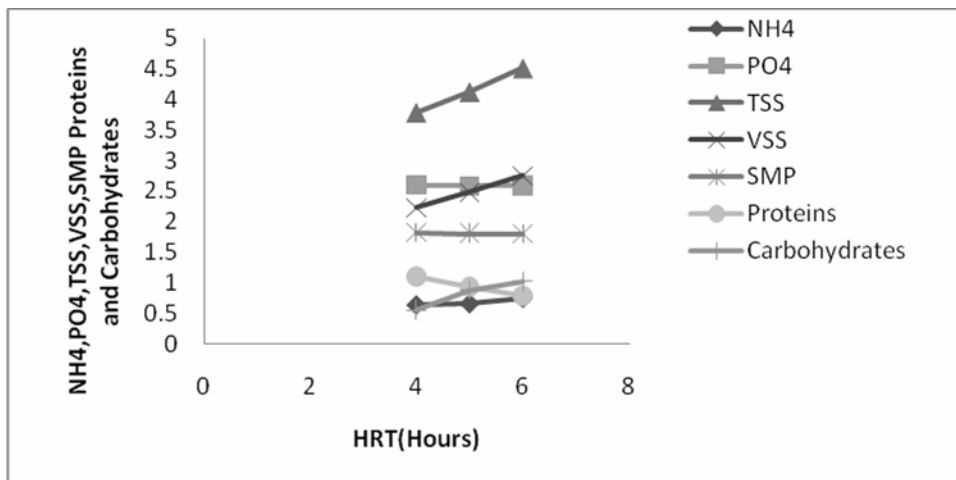


f) HRT = 8 hours

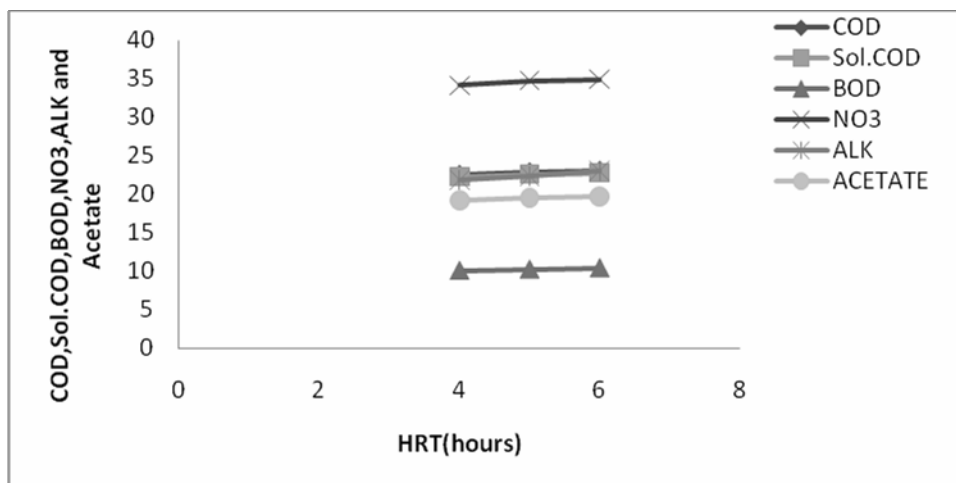
Figure 2: Variation in various parameters with Constant HRT and different SRTs _Residential Quarter



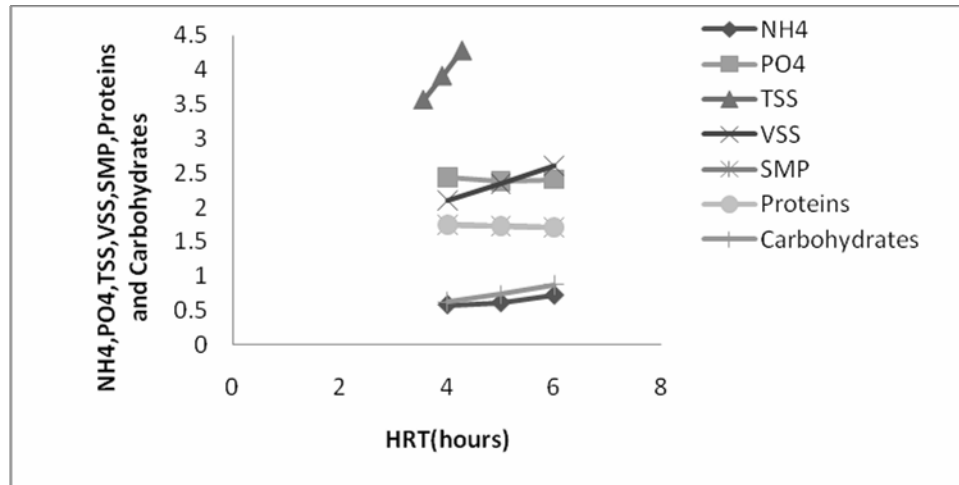
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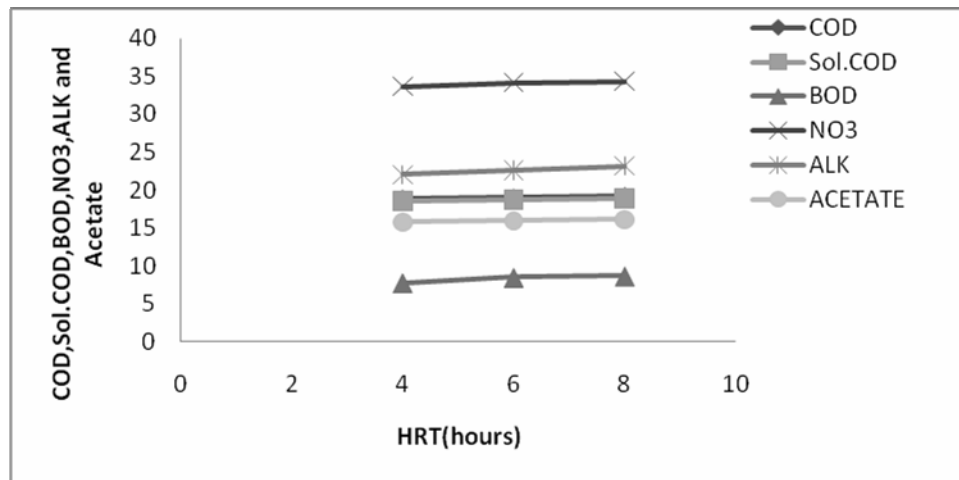
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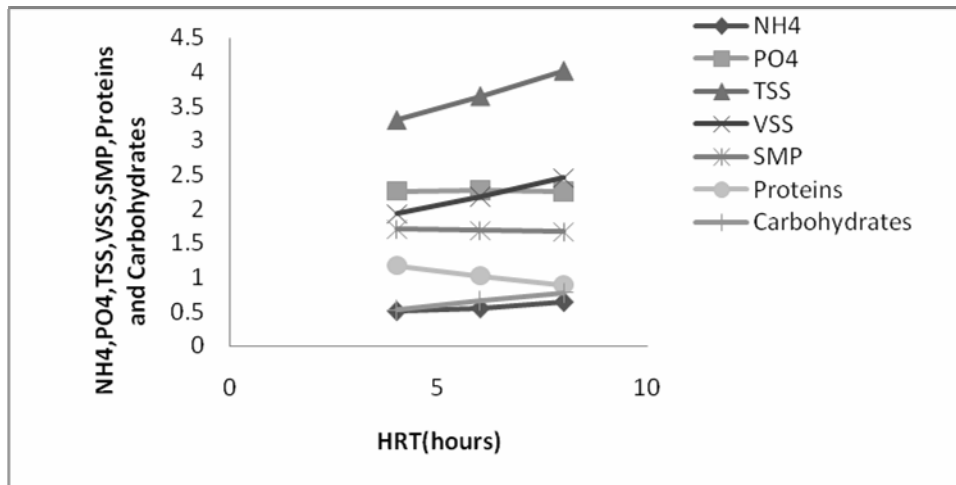
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d) SRT = 20 days

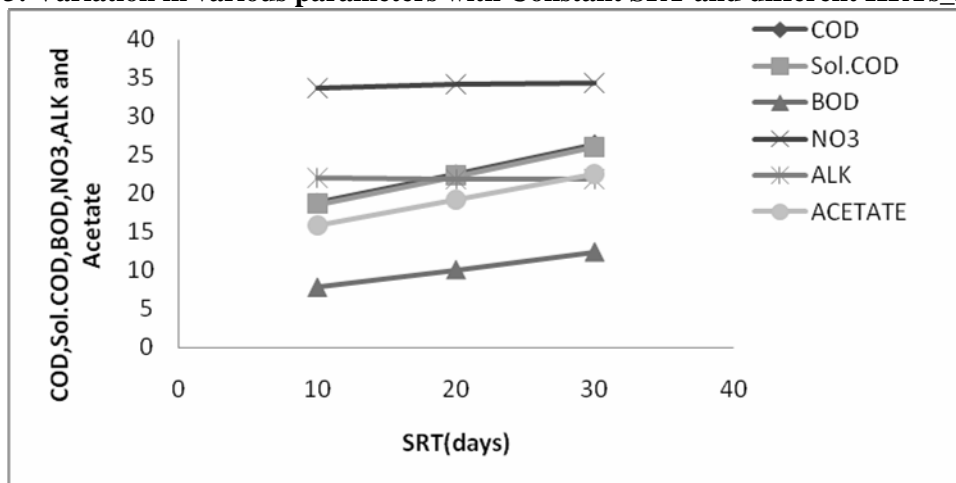


a) SRT = 10 days

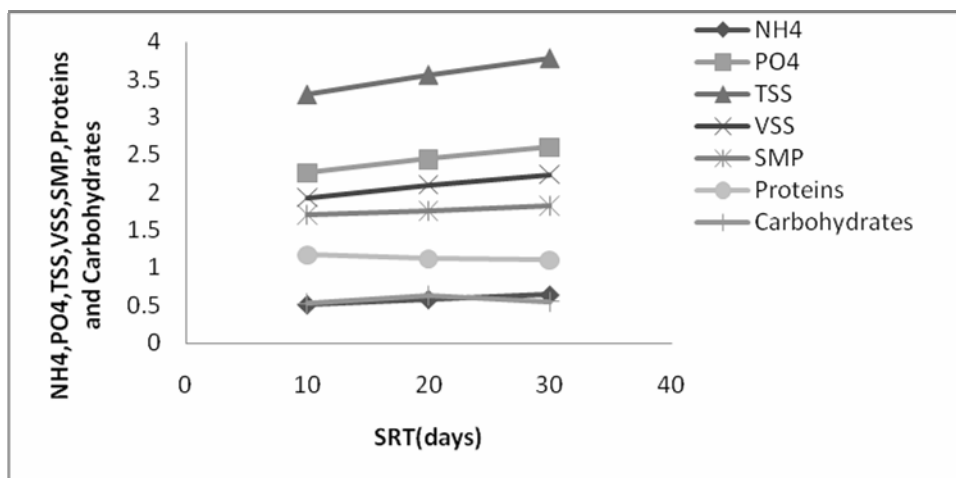


b) SRT = 10 days

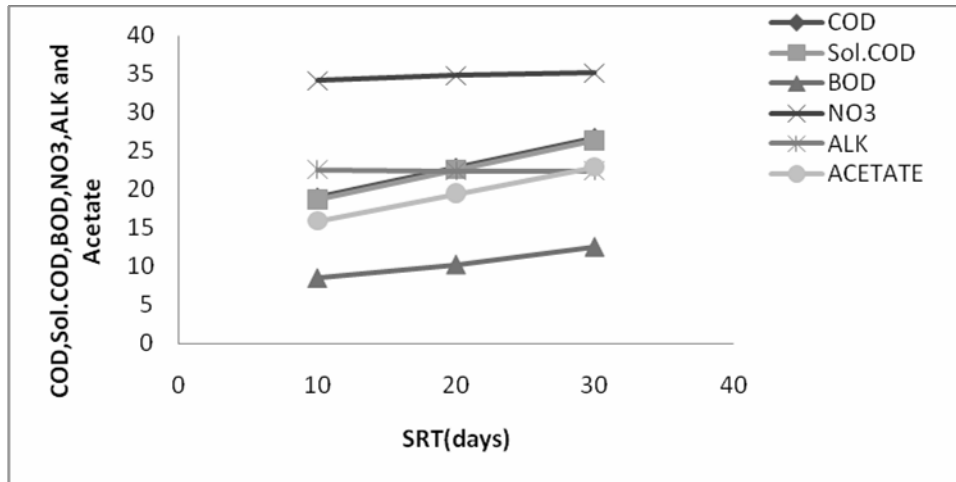
Figure 3: Variation in various parameters with Constant SRT and different HRTs_Hospital



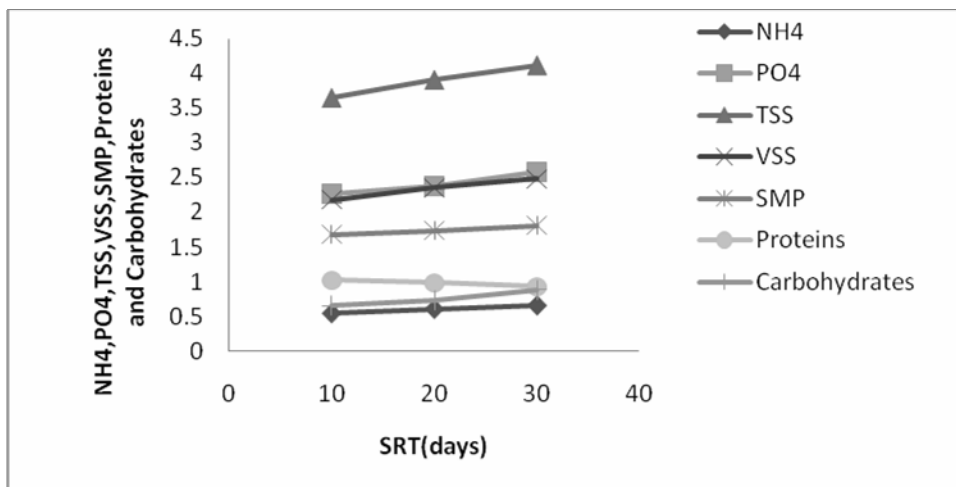
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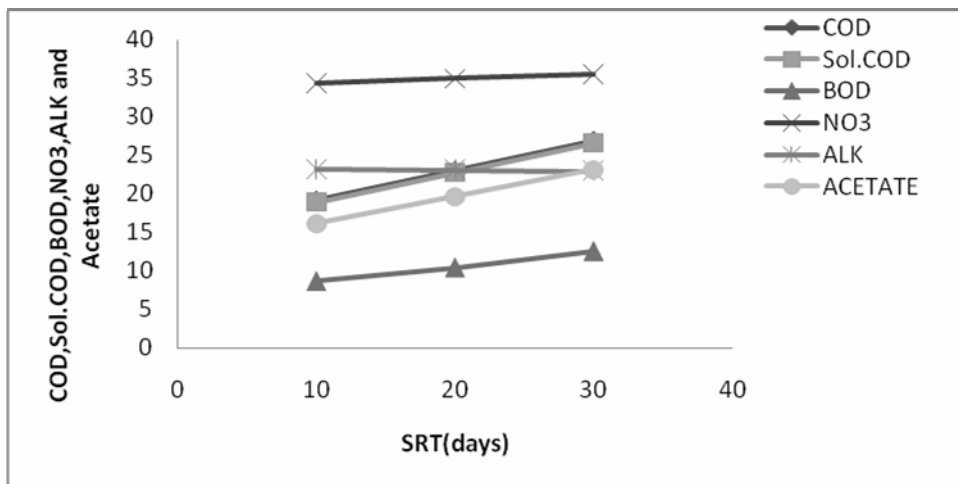
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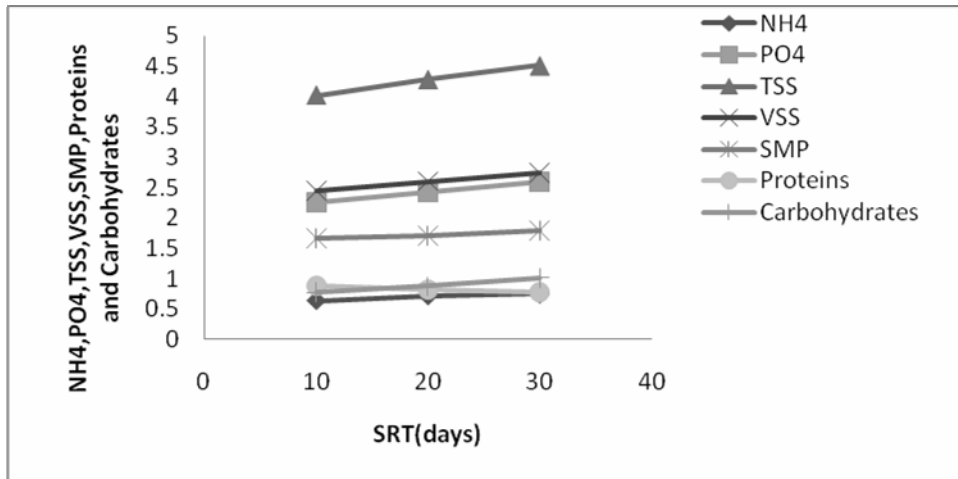
c) HRT = 6 hours



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