INVESTIGATION OF THE POLYELECTROLYTES' EFFICIENCY IN THE TREATMENT OF LAUNDRY GREYWATER DURING THE COAGULATION-FLOCCULATION PROCESS

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Abstract
The global pursuit of a continuous and stable water source is essential in the face of climate change and mismanagement of water resources, which has exacerbated water scarcity. This research aimed to investigate the efficiency of polyelectrolyte as the main coagulant in the coagulation-flocculation treatment process to determine their suitability in producing an alternative water source.

Introduction
In this study, I will be using synthetic laundry greywater (LDGW) as a model water which is considered the most contaminated among other greywater fractions such as bath and even mixed greywater (laundry, bathing and kitchen wastewater all together) and we will be focusing on the coagulation-flocculation process in which we will determine the efficiency of a cationic type polymer agent (ACEFLOC 80902) on LDGW that has been always used as a coagulant aid after metal salts as main coagulants in this process.
The efficiency of the polyelectrolyte will be monitored by measuring the physical and chemical characteristics of greywater before and after treatment and under different flocculation speed and time.
A further investigation of the polyelectrolyte's efficiency response to pH change will be performed. The methods were selected mainly because of their proven efficiency and wide use in the wastewater treatment sector. The parameters investigated were the pH, turbidity, zeta potential, biological oxygen demand (BOD) and the total organic content (TOC).

Experimental
The experimental procedure started by creating synthetic LDGW samples.They were prepared by mixing 0.500 g Detergent/Washing agent (ARIEL gel concentrated, Mountain Spring, Proter and Gamble), 1.00 g Softener (LENOR Sensitive Softener, Proter and Gamble), 0.200 g corn oil (VFI GmbH, Austria), and 0.300 g standard nutrient broth (Scharlau, Spain) for every 1 L of tap water at 40 °C from Debrecen, Hungary.
Initially, 100 mL of synthetic GW was used as sample volume. The measured sample was added to a beaker equipped with a magnetic stirrer and stirred at 800 rpm to ensure sample homogenization is preserved. A selected volume of coagulant was added to the 100 mL GW and the mixture was stirred for 30 seconds after which a sub-sample was extracted using a syringe from the total volume and let to settle for 5 minutes thereafter pH, zeta potential and turbidity were measured. This process was repeated with different volumes of coagulant everytime to create a dose-response curve and from which the optimum volume of coagulant needed for the range of zeta potential between -5mV and +5mV can be determined and used in larger volumes.
At a second stage of the experiment and from the collected data of the adequate volume range of coagulant found with 100 mL samples, we prepared a 4L sample and used the Flocculator

(Jar-test) to perform the coagulation-flocculation process in detailed version. The flocculator has an automatic mixing parameter with different speeds and require a volume of 500 mL in each beaker. After filling each beaker with 500mL of our synthetic GW, we add the coagulant and we activate the automatic stirrer at full speed (300 rpm) for 5 min and then we turn to the slow mixing in different speeds: 10 rpm, 60 rpm, 90rpm and 120 rpm and we repeat the same experiment for two different slow mixing times: 15 min and 30 min in order to find the best condition for which the polyelectrolyte performs the best.
After slow mixing is done, the mixture is left to settle and sediment for 20 minutes. pH, zeta potential, turbidity and TOC were then measured and after which we proceeded with a filtration process and remeasured the mentioned parameters.

Figure 1: Jar Test during coagulation-flocculation process

At a third stage, we have used 2 solutions HCl (0.1 mol/dm3) and NaOH (0.1 mol/dm3)
in order to adjust the LDGW to different pH values 5, 7 and 10. Before and after adjusting the pH, different doses of the polymer is added to each 100 ml of solution in order to determine the optimum PE dose each time with each pH alongside with measuring zeta potential, TOC, pH and Turbidity in order to compare between all results obtained.

Results and discussion

This section provides results obtained using the cationic polyelectrolyte (PE) as a main coagulant. To determine the dose at which optimum coagulation occurs a series of zeta potential dose-response curves are created. The results were plotted, and we found that the optimal range is between 2.8 mL and 4.7 mL of polyelectrolyte per 100 mL of LDGW (concentration of 28 mg/L and 47mg/L respectively) and the 0 mV zeta potential value at around 3.8 mL volume of stock coagulant solution which is equal to around 19 mL of polyelectrolyte dose per 500 mL of LDGW.

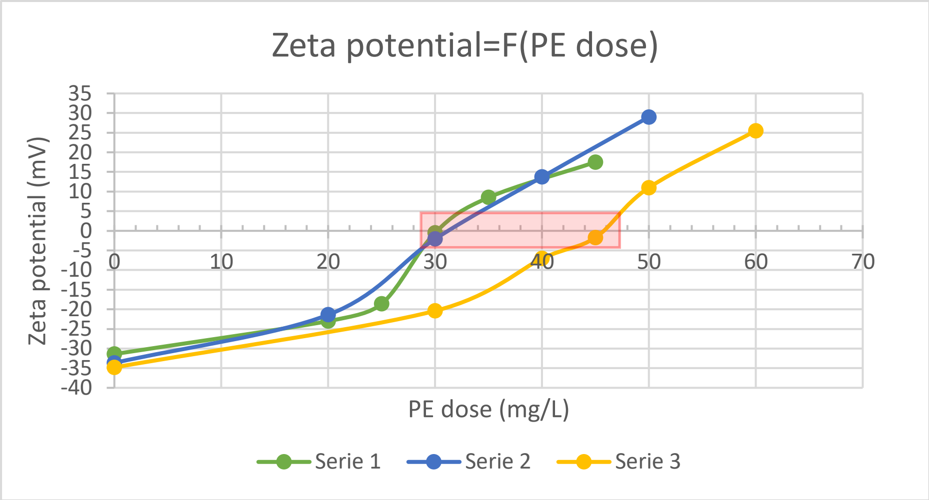

Figure 2: Dose-response curve

At a second stage, using the Flocculator (Jar-Test), with bigger volumes, we have obtained that the best conditions for which the polyelectrolyte performs the best is for 15 mL which is a lower optimum dose than that expected which again shows the impact and the importance of flocculation on the PE performance. Then we proceeded to use different flocculation time and speed to determine its impact on the polyelectrolyte performance and we found that zeta potential in almost all conditions is close to 0 mV which proves in one side the effectiveness of the chosen polyelectrolyte dose and the importance of the flocculation process. For a flocculation speed of 120 rpm and flocculation time of 30 min, the turbidity is very close to that of tap water used in the experiment (4.75 NTU) and this shows the importance of mixing speed that differs from one polyelectrolyte (coagulant) to the other and in this case it is shown that a 120 rpm speed seems to be the right flocculation speed for this cationic polyelectrolyte used. However, for the TOC, the results shows similar results regardless of the time and speed change which shows that PE can be more effective in removing insoluble components.

Table 1: Results of the coagulation-flocculation process under different conditions

	Speed (rpm)	Dose (mL)	Zeta potential (mV)	TOC (mg/L)	pH	Turbidity (NTU)	Slow Mixing (min)
1	60	15	-1.89	55.28	8.30	18.56	15
2	90	15	-1.63	53.33	8.39	11.56	15
3	120	15	-1.35	51.14	8.43	8.51	15
4	60	15	-1.28	51.02	8.28	11.37	30
5	90	15	-1.61	51.97	8.29	6.93	30
6	120	15	-1.13	51.54	8.29	5.05	30

At a last step, the pH test proved that the pH level has indeed a direct effect on the performance of the polymer, for the raw solution with a pH equal to 7.88, the polymer optimum amount (mg/L) that coincides with zeta potential between -5mV and +5mV is shown to be in a range of [37..42], for the higher value of pH =10, there is almost no change in the optimum amount of PE [36,5..42], However in lower values of pH 7 and 5, it is clear that the supposed to be an optimum amount is now more than enough to neutralize the solution as the zeta potential decreased and so did the optimum amount of PE that now became in the range of [35..38] and [24,5..26] respectively.

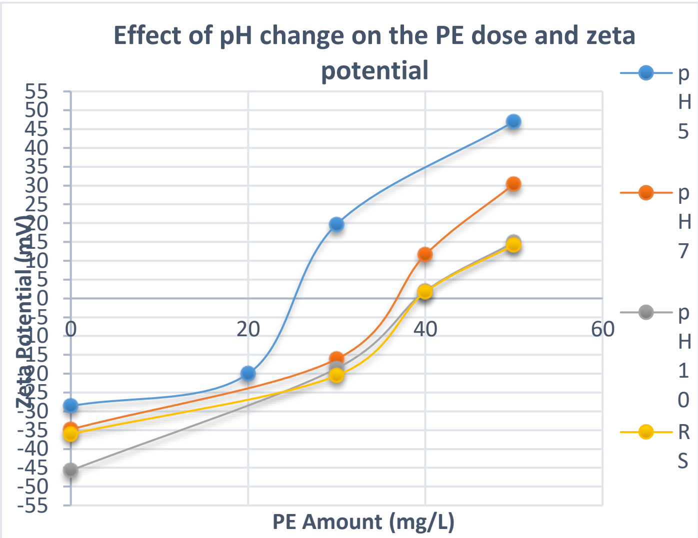

Figure 3: Dose-response curve under different pH values

The TOC values have shown a decrease in all pH levels, For the raw sample and pH 7 the TOC level (around 50 mg/L) is almost the same as that of the raw sample and it can be explained by the fact that they have pretty close pH levels (pH 7.88 and pH 7). however when the pH is either more alkaline (pH 10) or more acidic (pH 5), the TOC level decreased even further and we can notice a more Natural Organic Matter (NOM) removal efficiency when the optimum PE dose is applied (TOC around 40 mg/L) which proves the importance of adjusting the right pH level prior to the use of the proper dose of coagulant.

Based on the measured values, the PE proved its efficiency in LDGW treatment in different pH ranges which is an important advantage in the water treatment sector that the coagulant can work in neutral environment. Moreover, it is also important to note that in real LDGW, pH is usually more alkaline (9-11), which in this case, the PE according to the results found, is expected to work in an effective way as well.

Conclusion

The coagulation-flocculation process using Polyelectrolyte as the main coagulant instead of metal salts followed by a filtration process using a slow sand filter resulted in a successful laundry greywater treatment according to the measured quality parameters of BOD, TOC Turbidity of 6 mg/L, 7.61 mg/L, 1.6 NTU respectively. These results are aligned with the range of limit values set by the international regulations and standards of greywater reuse.
A further investigation of the efficiency of the cationic polyelectrolyte in treating laundry greywater under different pH ranges (5,7 and 10) showed that the optimum dose of PE was reduced from 38 mg/L to ~ 25 mg/L in lower pH (around 5) which can be a cost effective

solution to use less chemicals in wastewater treatment as according to previous results obtained in university of Debrecen, an amount of 248.75 mg/L of iron(III) chloride and 18 mg/L for polyelectrolyte was needed to treat mixed greywater and 295 mg/L and 325 mg/L to treat laundry greywater.
It is interesting to test different types of polyelectrolyte especially stronger base cationic ones that can retain a high positive charge at high pH values on real laundry greywater which is usually more alkaline (around 9-11) and determine if it is cost effective comparing it with using metal salts since polyelectrolytes are usually more expensive.

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