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Removal of vat dyes from colored wastewater by reverse osmosis process

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ABSTRACT. This research is dedicated to the study of effectiveness of reverse Osmosis process in removing anthrasol brown IBR (vat dye) and to a survey of the effects of such parameters as pH, temperature, and feed concentration. The experiment took use of 30 mg/L dye solutions where the final results demonstrated that the most ideal condition for the process was pH=4 and T= 25° C. 94% dye removal was realized following 4 passages through the membrane. Feed concentration was studied under optimal conditions which revealed that greater feed concentration had a little positive contribution to dye removal rate. *© 2014 Bull. Georg. Natl.Acad. Sci.*

***Key words**: reverse osmosis, vat dye, filtration, wastewater*

Nowadays, treatment of industrial wastewater is specially important in environmental studies and the wastewater from textile industries deserves to be specially considered as a most pollutant one. There are some hazardous elements such as the dyes, aromatic compounds and heavy metals in textile wastewaters. Vat dyes are among insoluble dyes commonly used in textile industry because of a high stability in the way that vat dye accounts for 15% of dye consumption in the aforesaid industry with most part of it going to cotton fiber dyeing[1]. Removal of vat dye from textile wastewater seems highly essential because its high stability and carcinogenic aromatic compounds .vat dye is normally water insoluble; however, it becomes water soluble (leuco) by some alkaline solutions such as sodium hydrosulfite and a reducing agent like rongalite[1]. by far, such processes as adsorption and biosludge have been used for vat dye removal[1,2,3]. However, this research takes use of reverse osmosis process for vat dye removing and at the same time it surveys the effects of some parameters like pH, temperature , and feed concentration on permeate water.

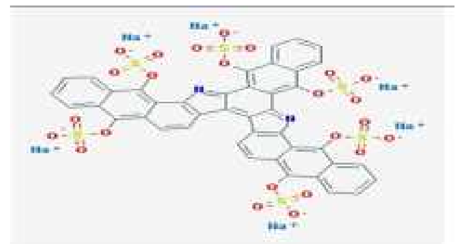
Reverse Osmosis process is a pressurized filtration process which has attracted much attention and interest because of its high efficiency. The aforesaid process has the potential of removing of up to 95% of particles in a solution and it can be a proper choice to wastewater treatment. Reverse Osmosis process operates based on a semi- permeable membrane with pores measuring about 0.5 nanometer each and it functions at a high operational press are. The aforesaid process has the ability to eliminate both organic materials and minerals[4]. Based on previous research RO (reverse osmosis) process has the ability to remove over 90% of reactive and acid dye particles and it has also the potential to reject such particles as those of sodium , calcium arsenic and to reduce such parameters as hardness and TDS[5-8].

2. Materials & Methods

2.1. Chemicals

The vat dye used in this research was anthrasol brown IBR from Alvan sabet Co. the characteristics of this dye was presented in table 1.

Table 1.vat dye characteristics

Name	Molecular weight(g\gmol)	Chemical formula	structure
Anthrasol brown IBR	1263	$C_{42}H_{16}N_2Na_6O_{24}S_6$	

sulfuric acid and Sodium hydroxide have been used for pH experiments.

2.2. Instruments

2.2.1. Membrane

The membrane used in this research was thin film composite (TFC) of TW30-1812-75 model; a product of filmtec company of the U.S. the membrane is made of polyamide and it has a spiral wound module. The following are part of the specifications of the product .

Table 2. Operating limits of membrane(TW30-1812-75)

Membrane type	Polyamide thin film composite
Maximum Operating temperature	45°C
Maximum operating pressure	10 bar
Maximum feed flow rate	2.0 gpm
Ph Range, continuous operation	2-11

2.2.2. RO System

This system includes the following components in addition to the membrane :

- Two fiber pre-filters (5 and 1 micron), products of Puretech company, for pretreatment
- Three housings for the membrane and the pre- filters
- A pressure tank, capacity 12 L
- An automatic shut off valve
- A one way valve
- Pressure meter
- A diaphragm pump (mod: up-7000, upright company) for supplying pressure

2.2.3. Spectrophotometer

Concentrations have been compared by UV/VIS spectrophotometer (PG Instrument,T80+) .

2.2.4. pH meter

The pH-meter used in the experiment was basic 20 made by CRISON Company.

2.3. Analysis method

Based on the curves created by spectrophotometer, maximum absorbance (A) was realized at a wavelength of 350 nm (λmax) and every computation within our research was made at the aforesaid wavelength. Subsequently, the absorbance was determined at different concentrations of dye solution using spectrophotometer. Then, molar absorption coefficient was determined for the aforesaid dye taking use of beer- lambert formula:

$A = \varepsilon b C$ (1)

A: absorbance
ε : molar absorption coefficient
b: cell thickness
C: concentration

ε Was found to be 1.97×10^{-4} cm^2\mol for this vat dye based on the graph drawn (absorbance dependence on concentration) and the slope determined (b=1) .

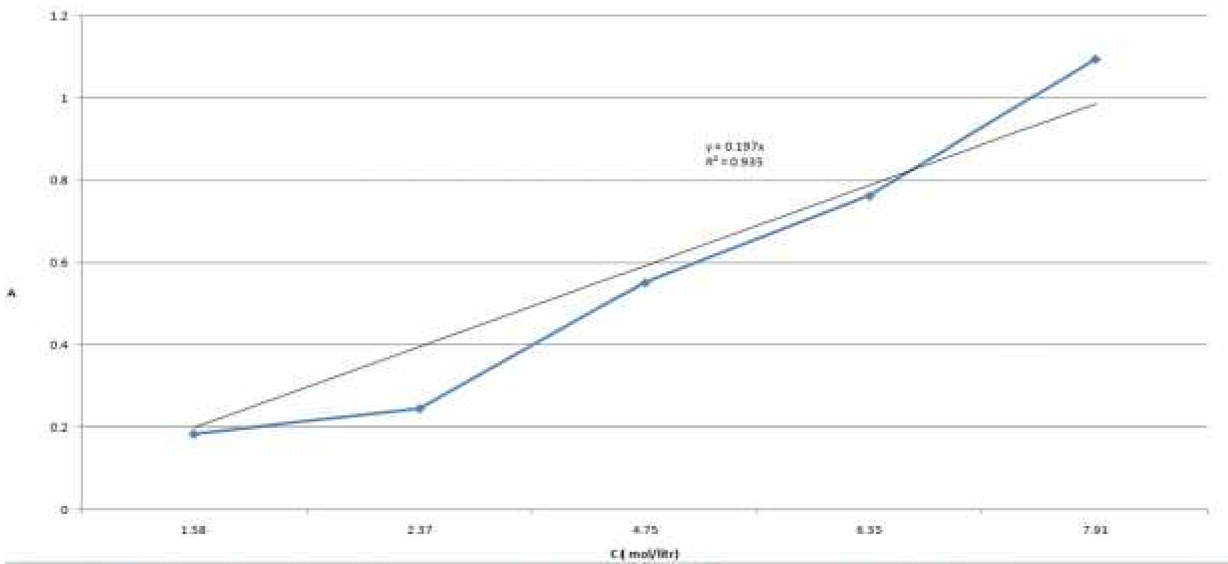


Fig1. absorbance dependence on concentration

Concentration of dye solution was 30mg/L in this research and the solution was pumped into reverse osmosis (Ro) system at a pressure of 4 bars. the removal rate was obtained by the equation below:

$R(\%) = (1 - C_P \backslash C_a) \times 100$ (2)

where C_p is concentration of permeate solution and C_a is feed concentration.

3.results and discussion

The effect of key operating parameters such as pH, temperature and feed concentration, was studied by this methods.

3.1. Effect of pH on dye removal efficiency

The pH rates of 30mg/ L , vat dye solutions in distilled water were set on the four values of 4,6.8, and 10 using H_2S04 and NaOH. With concentration (A) measured, the solutions were passed through the system. The concentration of permeate solution measured by using spectrophotometer was compared to the feed concentration. normal pH of the aforesaid dye solution is about 6.

The following diagram (Fig.2) illustrates the results from a survey of pH effect and a comparison of removal rates, according to which acidic condition (ph=4) provides for the best efficiency of the process.

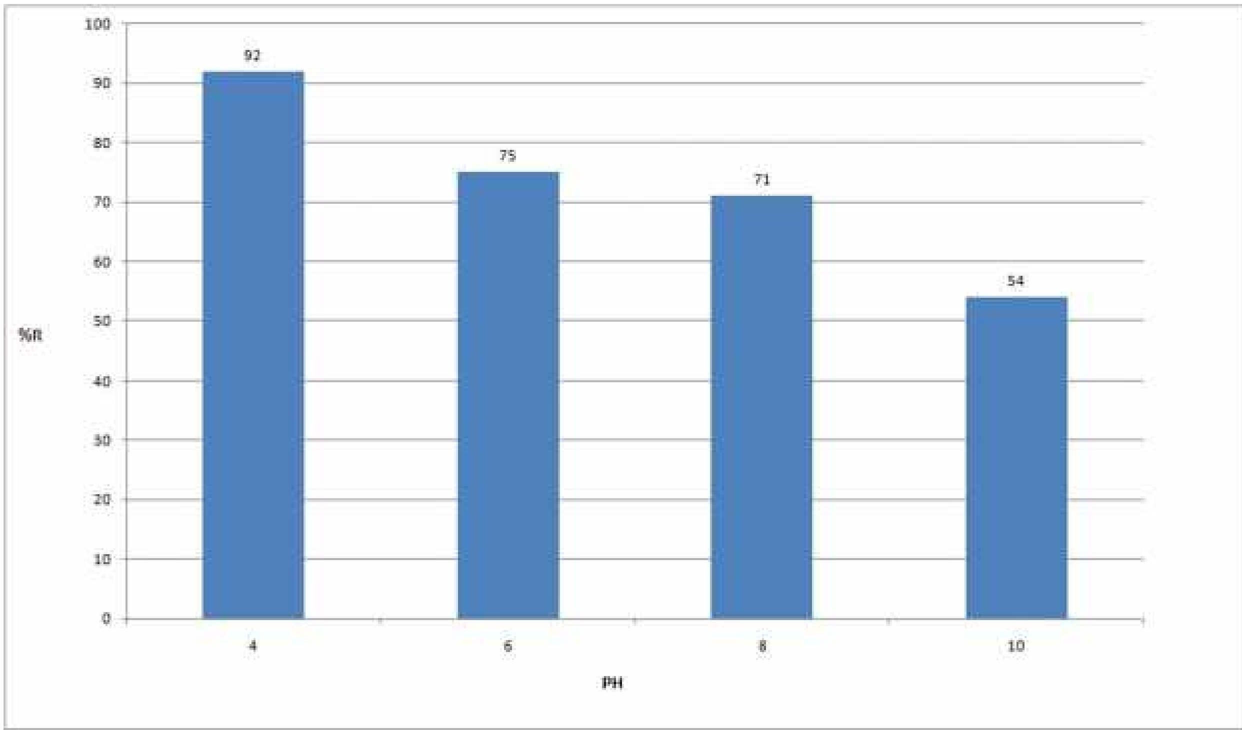


Fig2. Removal rate dependence on pH

The recent similar researches greater rejection was observed along with an increase in pH[5-7] . An example of this was a study of an acid dye that indicated the most optimal elimination by reverse osmosis at pH of 8.3 [5]. However, our research provided greater elimination (92%) at pH= 4.

Considering the mechanism of donan effect and negative charge of polyamide membranes, an increase in electrostatic repulsion between membranes and solution and hence a greater removal is expected with the addition of OH^- to dys solution. However, the opposite of this was observed in practice and the increase in concentration of H^+ brought greater removal. In fact, donan effect mechanism has had less efficiency in dye elimination and the dominant mechanism has been diffusion- solubility mechanism.

Both the solvent and the solubilized material are absorbed by the membrane under this mechanism. However, the degrees of diffusion into membrane by the aforesaid two agents are not the same considering molecular structure we may consider the dye to be in the form of RNa_6 ionized in water and taking the form of the following equation:

RNa_6 _ $R^{6-} + 6Na^+$

Part of R^{6-} ions are neutralized and its concentration is reduced with an increase in pH and addition of H^+. in accordance with le Chatelier's principle therefore the equation takes the course that will result in a compensation for a decrease in concentration. As a result, a greater portion of the dye is ionized and this brings greater solubility and diffusion of the dye into the membranes. On the other hand, with a reduction in concentration of negative ions in the solution the electrostatic absorbance between the membranes and the solution is increased and the trend of diffusion into the membranes is facilitated.

3.2. Effect of temperature on dye removal efficiency

The solutions were set on three different temperatures , i.e 25° C (lab temp) ,35° C and 45 °C and immediately passed through Ro system. removal rates were determined by using spectrophotometer in the same way as that of the previous procedure.

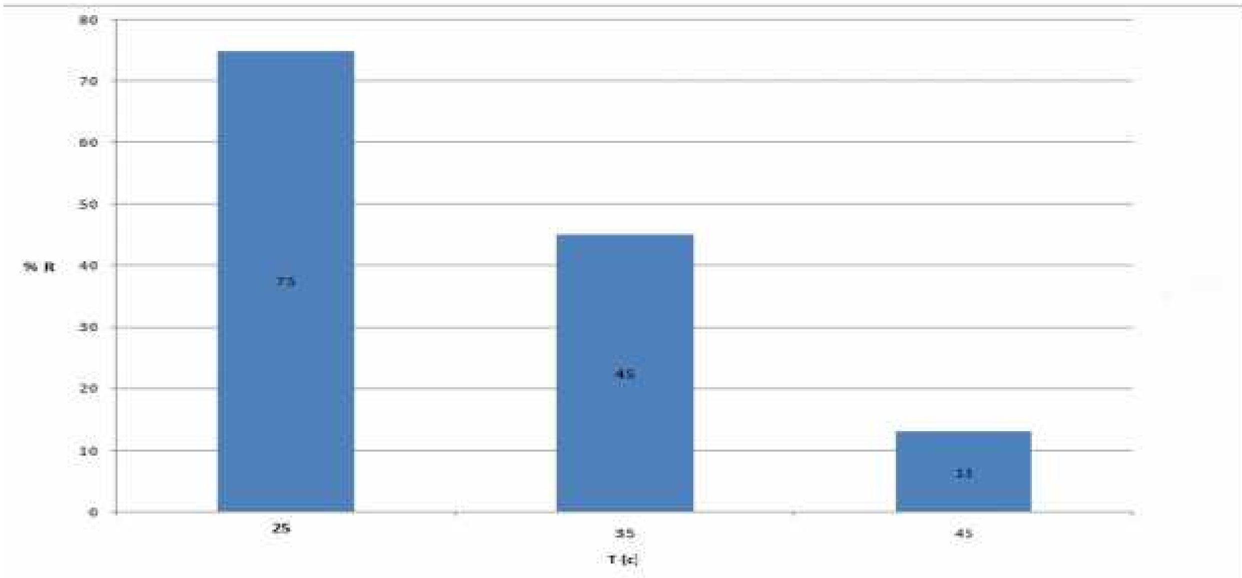


Fig3. Removal rate dependence on temperature

It is observed in the diagram that the ambient temperature (25° C) is the most ideal for this process and that an increase in temperature brings a considerable reduction to elimination rate, similar conditions are observed in a identical research [5], in the way that both acidic dye and reactive dye are subject to better removal rate at 26° C than at 39° C and in a further research the best performance of the system was realized at the lowest temperature.

In fact, due to the temperature increasing , the membrane pores expand and vat dye particles can pass through the membrane comfortably .

3.3 Effect of passage number on dye removal efficiency

After the first passage through the membrane the permeate was again applied to the membrane. after determination of concentration ,the procedure was repeated until a total removal of over 90% was reached. This procedure was intended to determine the number of passages needed before a total removal of over 90% is reached. Figure 4 illustrates the result.

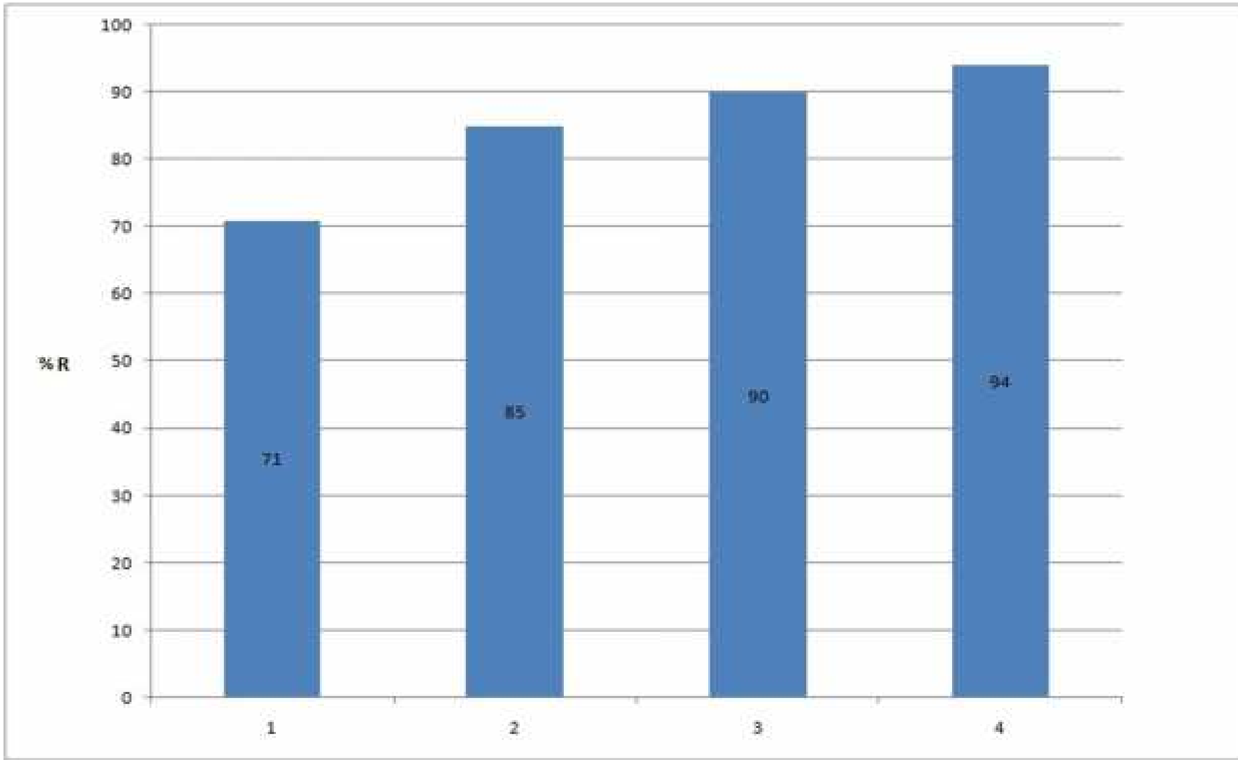


Fig4. Removal rate dependence on number of passages

according to the data obtained after 4 passages of dye solution through the system a removal rate of 94% takes place and a high quality permeate is obtained, this concept can be helpful in designing of Ro system and economic study of the process. It reveals approximate conditions of consecutive and serial application of membranes in a system.

3.4. Effect of Feed concentration on removal efficiency under optimal conditions

It has already been revealed that pH=4 and a temperature of 25° C create the highest rate of elimination, therefore, the aforesaid conditions may be taken as the most optimal conditions for the best performance (the highest removal rate). Removal rates for three dye solutions at concentrations of 10mg/L, 20mg/L and 30mg/L were measured under of aforesaid optimal conditions the results of which are illustrated by the diagram (Fig.5) .

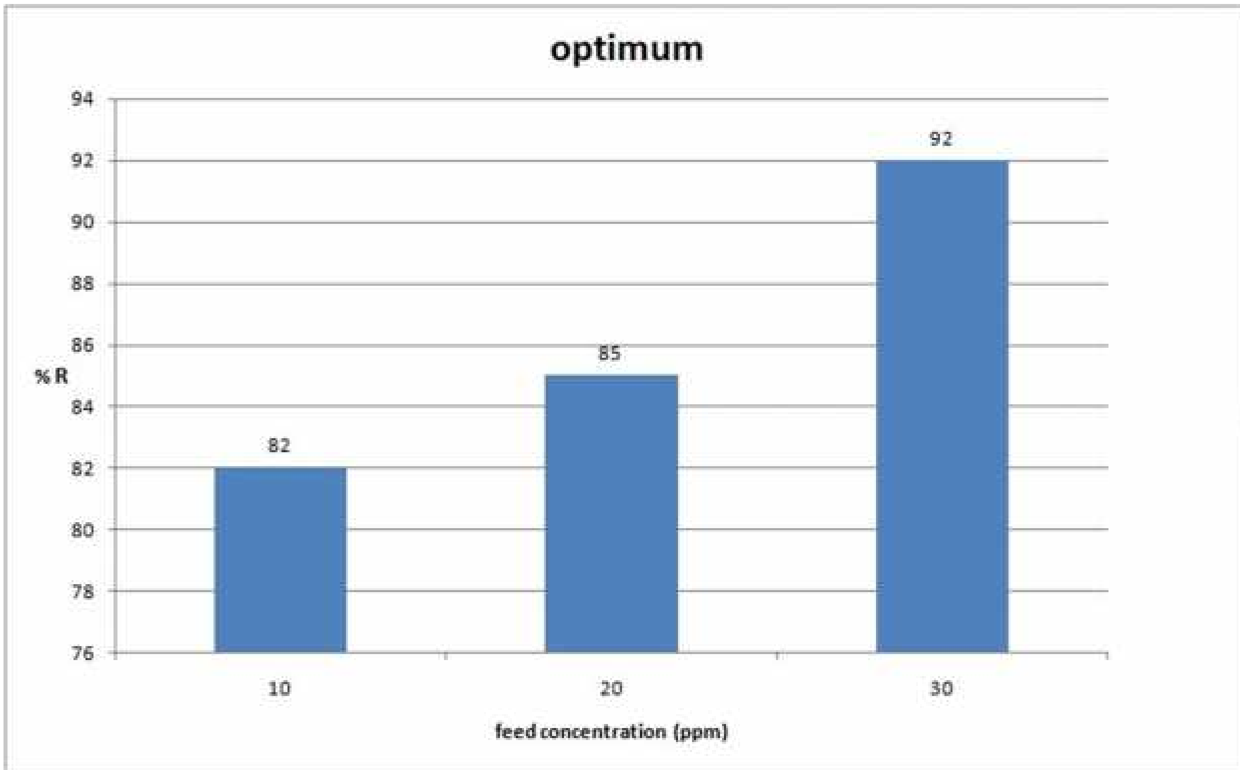


Fig5. Removal rate dependence on feed concentration (under optimal conditions)

Similar conditions occurred in another study [5] and both acidic and reactive dyes had greater removal rates with an increase in feed concentration. It was revealed in a further research [10] that an increase in concentration of arsenic in feed solution resulted in an increase in removal rate.

Fouling and concentration polarization are the concepts which should be considered in justification of the aforesaid issue , concentration polarization and fouling are developed on membranes surface respectively on a temporary basis and permanently with an increase in feed concentration and this brings an increase to osmotic pressure. This phenomenon results in filling of membranes pores and dye particles pass hardly through the membrane of course but fouling may reduce permeate flux in a long term with an increase in feed concentration.

4. Conclusion

Reverse osmosis process can generally be a proper way to industrial wastewater treatment provided that there are optimal conditions for this.

As for temperature it can be said decidedly that a temperature approximately with in the limits of ambient temperature (25° C) is optimal temperature of this process.

As for pH however, there is no such a certainty and as observed, the dye used in the experiment demonstrated a different behavior from that of other dyes and had the greatest removal rate at an acidic pH (4). Therefore, there is a need for specific experiments to determine the proper pH for any certain dye. The effect of dye concentration in feed solution is a further import and parameter. Within the context of low concentration solutions a solution with a greater concentration brings greater elimination. However ,fouling and the decrease in permeate flow rate should be kept in mind.

Therefore, choices of most optimal concentration (30mg/L for this experiment) and membranes wash up in proper times are very important. Finally, numerous passages of solution through membrane and conservative and serial utilization of membranes are important factors in promotion of removal rate and improvement of permeate quality and they help a designer to choose the best and most economical method in designing reverse osmosis system. As observed, we achieved a 94% removal rate after 4 passages through the membranes in this experiments .

Acknowledgments

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მოხსნა საღებავები ფერადი კანალიზაციის საპირისპირო პროცესი

ამ ეთმობა შესწავლა ეფექტურობის საპირისპირო პროცესი მოხსნის

ყავისფერი (დღგ საღებავი) და კვლევის შედეგების ისეთი პარამეტრები, როგორც, და საკვების კონცენტრაცია. ექსპერიმენტი აიღო გამოყენება 30 მგ / ლ საღებავი გადაწყვეტილებები, სადაც საბოლოო შედეგები აჩვენა, რომ ყველაზე იდეალური პირობა პროცესი იყო = 4 და T = 25 ° C. 94% საღებავის მოცილება განხორციელდა, შემდეგ 4 მეშვეობით გარსის. კონცენტრაცია სწავლობდა ქვეშ ოპტიმალური პირობების შედეგად აღმოჩნდა, რომ დიდი კონცენტრაცია ჰქონდა პატარა პოზიტიური წვლილი საღებავი მოცილება განაკვეთი

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