This chapter discuss overall conclusion of the thesis.

7.1. Overall Conclusion

Water bodies have been continuously polluted by metal ions and dangerous organic dyes as outline of this rapidly increasing industrialization and urbanization. As a result, the health of people, ecosystems, and other living organisms has been adversely harmed by these toxic pollutants. Thus, it is considered imperative to eliminate such dangerous pollutants from water for the benefit of both human life and the ecological balance.

Thus, the purpose of this endeavour is to develop adsorbents. It has been employed to remove inorganic (metal ions) and organic (dyes) pollutants using the modified adsorbent.

In Chapter 1 cover an overview of water pollution and its sources. Discussion removing new technologically methods and adsorbents like, Ion exchange resin and TMA salt.

In Chapter 2 explores the research's materials, procedures, uses of characterization techniques, Fourier transform infrared spectroscopy (FTIR), X-ray diffraction studies (XRD), UV-visible absorption spectroscopy (UV-Vis), Thermogravimetric analysis (TGA), Field emission scanning electron microscopy (FESEM), energy dispersive X-ray (EDX) and explain the adsorbent's physicochemical behaviour.

In Chapter 3, Amberlite IRA-400(Cl^-) resin was treated with Na_2EDTA to create modified cationic resin (MCR) adsorbent. Using a diversity of physicochemical methods, the resultant adsorbent materials were extensively characterized. To evaluate the fractional attainment of equilibrium, the distribution coefficient (K_d), which has been determined for metal ion exchange in aqueous or electrolytic solutions, is utilized at various time intervals. Using the Langmuir model, the transition and heavy metal ions have been adsorbed onto the MCR in a monolayer of adsorption. As seen by the greater positive value of $\Delta H°$, the sorption mechanism of heavy metal ions (Pb^{2+}) and transition metal ions (Cu^{2+}) onto the MCR has been determined to be endothermic. The metal ion exchange process is more spontaneous when $\Delta G°$ and $\Delta S°$ have higher negative and positive values, respectively. Time has shown that the Second-order model of kinetics fits the adsorption data extremely well. When compared to other approaches documented in the literature, the metal ion exchange process established through MCR can be more successful.

In Chapter 4, analyzes the adsorbent attributes of Amberlite IRA-400(Cl^-) resin on the removal of AY 49 and RO 12. A range of physicochemical techniques were employed to thoroughly characterize the adsorbent materials. Through batch tests, the dose of adsorbent (80 mg), initial concentration (50 mg/L), duration (40 min), and sorption of AY 49 and RO 12 on adsorbent were tuned to be natural pH (AY 49 (4.15) and RO 12 (4.07). Relating the Freundlich equation to substitute models has shown that it is a more accurate description of the dye adsorbed onto Amberlite IRA-400(Cl^-) resin in a multilayer adsorption. According to kinetics research, pseudo-second-order kinetics are best displayed by the adsorption. The following is a presentation of the dye affinity series: AY 49 > RO 12. Thermodynamic analyses demonstrated the endothermic and spontaneous nature of the sorption process. It was shown that AY 49 and RO 12 dye could be effectively removed by Amberlite IRA-400(Cl^-) resin. This kind of colour appears to be effectively removed from wastewater using this resin. It implies that the anion exchanger Amberlite IRA-400(Cl^-) resin can be a promoting adsorbent for the treatment of textile wastewater.

In Chapter 5, the innovative modified adsorbent Ce-ATMP was synthesized through the execution of the sol-gel technique. The produced Ce-ATMP's intriguing ion-exchange characteristics have been investigated using physico-chemical and instrumental research techniques. The examined metal ions exhibit a strong affinity of metal ion towards produced Ce-ATMP, which is corroborated by the adsorption isotherm and thermodynamic characteristics. Owing to the reported selectivity orders, $Cu^{2+} > Ni^{2+} > Zn^{2+} > Co^{2+}$ and $Pb^{2+} > Cd^{2+} > Hg^{2+}$ respectively, were the transition metal and heavy metal ions. The process of ion exchange is considered feasible and spontaneous when there is a higher negative value of $\Delta G°$, indicating endothermicity since to the increased dehydration of metal ions to occupy a location on the exchanger that requires energy supply. An elevated positive value of $\Delta S°$ was attributed to randomness, after the high degree of disorder experienced by the resin matrix as an outcome of the ion exchange process. In light of this, $\Delta G°$, $\Delta H°$, and $\Delta S°$ also assist the observed trend. Thus, the efficiency of Ce-ATMP's binary and ternary metal separation processes indicates that it has enormous potential for usage as a promising cation exchanger.

In Chapter 6, synthesized using the sol-gel approach to create the novel modified adsorbent Sn-ATMP. The adsorbent underwent a thorough characterization (ICP-CHN, FTIR, SEM, EDS, TGA, UV and XRD) in the initial phase of the study. Chemical and thermal stability of the sorbent material Sn-ATMP is good. Solution's pH, dosage, initial dye concentration, contact time, Temperature were all tuned. Excellent absorptivity of the Sn-ATMP for MB, MG and CV, RHB is indicated by the achievement of maximum adsorption, at equilibrium (99.7% and 88.66%), (100% and 90.1%) being reached within the first 50 minutes (MB, MG) and 60 minutes (CV, RHB) of contact. The adsorption pattern of cationic dyes onto adsorbent is as follows: CV > MB > RHB > MG. The Langmuir equilibrium isotherm is completely suited by the sorption of MB, MG, CV, and RHB by the Sn-ATMP. The pseudo-second-order model explains the kinetics of the MB, MG, CV, and RHB adsorption on Sn-ATMP. Upon determining ΔG°, ΔH°, and ΔS°, it became evident that the sorption process was exothermic and spontaneous. Finally, utilizing HCl for MB, RHB and EDTA for MG, CV to regenerate Sn-ATMP following the adsorption of dyes in preparation for potential reuse. Overall, the results of the adsorption studies demonstrated the effectiveness of Sn-ATMP as an adsorbent in the removal of cationic dyes, such as MB, MG, CV, and RHB, from aqueous solution, and its widespread application in the treatment of waste water containing dyes.