Given the global push for sustainability and escalating environmental concerns, the scientific community is increasingly throwing more impetus on incorporating green principles into polymer research. This shift from heavy reliance on petrochemical resources to bio-derived sources is reshaping the landscape of polymer development, thereby addressing the growing need for eco-friendly materials in diverse applications. Against this backdrop, the thesis aims to explore the fabrication, characterization, as well as performance assessment of bio-derived poly(ester amide)s and their nanocomposites, thereby invoking the usage of various carbon-based nanomaterials. Poly(ester amide)s are of particular interest on ground of their inherent advantages, and versatile properties which are inclusive of high flexibility, cost-effectiveness, excellent processability, high compatibility with other materials, etc. In order to fulfill the main objective of this study, a bio-based waterborne poly(ester amide) was prepared using citric acid, glycerol, and hexamethylene diamine as the prime reactants, utilizing an environmentally benign route of preparation devoid of usage of any amount of organic solvents. In turn, synthesis of poly(ester amide urethane) resin was conducted to introduce new features into the poly(ester amide) framework and address the shortcomings. Both the synthesis involved a one-pot strategy via melt polycondensation technique. Different analytical and spectroscopic methodologies were employed to assess the structural intricacies of the synthesized polymeric materials, followed by extensive evaluations of their thermal, mechanical, chemical resistance, and biodegradability attributes. Additionally, the poly(ester amide urethane) materials exhibited excellent performance under exposure to challenging environmental conditions, thereby displaying their potency as robust materials apt for outdoor applications. Correspondingly, the most suitable composition of the easily processable poly(ester amide urethane) was then selected for carrying out the fabrication of nanocomposites, utilizing different carbon-based nanomaterials to ensure sustainability in the overall poly(ester amide urethane) nanocomposites.

To further augment the performance of the bio-derived poly(ester amide resin), various reinforcing agents, viz., biochar particles with and without bentonite nanoclay particles, etc. were incorporated in order to facilitate the fabrication of polymer nanocomposites. The addition of these reinforcing agents significantly modified the properties of the poly(ester amide urethane) nanocomposites. Various diffraction, microscopic, as well as spectroscopic techniques were employed to characterize all the prepared nanomaterials and their respective polymer nanocomposites. In turn, all the polymer nanocomposites were subjected to evaluation for various properties, viz., thermal, mechanical, biodegradability variables, which were then compared with those of the pristine polymeric material to assess the influence of addition of nanomaterials. All the fabricated nanocomposites displayed improvements in the aforementioned properties due to their strong interfacial interactions between the reinforcing agent as well as the polymer matrix. Moreover, these interactions were strongly found to be influenced by the surface area and the surface functionalities of the prepared reinforcing agents. Furthermore, the thesis explored the notable efficacy of the polymer nanocomposites integrated with biochar particles in dye removal. The porous structure of the biochar material offered abundant binding sites for dye molecules, while the polymer matrix provided mechanical stability and reinforcement. This strategy not only tackles water pollution issues, but also harnesses bio-based materials, thereby fostering a more sustainable future. Under the same context, fabrication of another polymer nanocomposite via incorporation of modified biochar particles and bentonite nanoclay particles resulted in enhancing the adsorption capacity. Concurrently, it also aided in strengthening the composite unit while introducing customizable features on the other end. Thus, this well-structured system effectively captures heavy metal ions, zinc, lead, and copper from aqueous environments, thereby mitigating the inherent risks associated with these harmful contaminants.

In summary, the thesis showcases environmentally friendly synthesis methods for producing easily processable bio-derived poly(ester amide)s and their nanocomposites, using mostly bio-derived precursors and carbon-based nanomaterials. The resulting nanocomposites exhibit promising potential for a variety of applications, thereby effectively addressing the demands of contemporary material requirements.

Keywords: Bio-based poly(ester amide), reinforcing agents, biochar, nanocomposites, advanced applications, high-end performance