Have you ever heard about quantum dots (QDs)? The discovery with development of quantum dots was awarded the 2023 Nobel Prize in Chemistry. Today, QDs are found in television screens or in LED lamps. Their light can also drive chemical reactions and can even illuminate tumour tissue for a surgeon. Quantum dots are particles so tiny that their size is measured on the nanoscale (<10 nm). To give an idea of how small that is, a quantum dot is about a million times smaller than the head of a pin. One of the most remarkable phenomena associated with quantum dots is their size-dependent emission of light, which is a result of quantum confinement. Larger quantum dots (5-6 nm) emit redder light, while smaller dots (2-3 nm) emit bluer light. The discovery of QDs opened up the field of nanotechnology, where the properties of a material change based on its size. In particular, QDs can be divided into two sub-groups, i.e., semiconductor quantum dots and carbon quantum dots (CQDs). The former ones have some restrictions, such as their high toxicity because of heavy metal (Cd, Pb) content, thus limited applications. The latter are quasi-spherical nanoparticles made mostly of carbon cores and shells full of oxygen-containing functionalities, which cause their excellent water affinity, biocompatibility, and enhanced optic properties. Recently, biomass-derived CQDs have garnered a lot of interest and are thought to be the best and most environmentally friendly to synthesize efficient CQDs. Even though, to some extent biomass sources have been used to produce CQDs, these synthesis methods typically encountered issues related to inadequate control over the homogeneity, quality, particle size, and optical properties of CQDs. Besides, the CQDs frequently do not operate well because of their poor compatibility with the carbon skeleton.

Therefore, the main objective of the proposed research is to find facile and efficient strategies to embed quantum dots into bio-based carbon material to obtain new, attractive material for various applications, with particular consideration of energy storage systems. Special attention must be paid to the well-developed specific surface area and suitable pore size distribution of such carbon since it is a key to the enhanced performance of an electrical double layer capacitor.

Firstly, a salt matrix assisted hydrothermal synthesis for the preparation of lignin-based hydrochar embedded with carbon quantum dots is proposed. The presence of CQD will be verified with several physicochemical techniques, e.g., transmission electron microscopy, and fluorescence spectroscopy. Nevertheless, bio-based carbon precursors are difficult to manage and have a tendency to become less porous during the proceeding. Therefore, elemental analysis and ^{31}P nuclear magnetic resonance will be utilized for the characterization of precursors. Then, in the carbonization process supported by salt-template presence, a suitable structure/texture of the material will be achieved, and self-embedded carbon quantum dots will work as an electron transfer passage. Such material will be investigated by more advanced physicochemical techniques, i.e., Raman spectroscopy, nitrogen sorption at 77K, X-ray photoelectron spectroscopy, and temperature-programmed desorption-mass spectrometry. Finally, the lignin-based porous carbon material self-embedded by quantum dots can be used for investigation of the charge transfer process at electrode/electrolyte interface in an aqueous medium. The prediction is that the perfectly tailored structure of carbon material consisting of an optimal volume of micropores/mesopores with well-distributed carbon quantum dots, will cause the attraction of ions from the electrolyte to the polar binding sites of the material, thus resulting in a more accessible surface area and shorter ionic diffusion pathway during charging the electrical double layer.

To conclude, bio-carbon based porous materials decorated by quantum dots offer many applications in various fields due to their unique physicochemical properties.