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by Sanaul Haque

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Research Proposal

on

Textile Trash to Cancer Treatment: Upcycling Polyester Fabric Waste into Nitrogen-Doped Carbon Quantum Dots for Tumor-Targeting and Cancer Therapy

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Introduction:

In the past few decades' textile production and the export of textile goods has been a major economic driving force for Bangladesh. In recent years Bangladesh has emerged as one of the biggest exporters of textile products. Due to the vast production of various textile products in Bangladesh, the use of these textile products has significantly increased [1]. This leads to tremendous environmental concerns because most of the textile waste end up in landfills, water sources increasing microplastics and causing imbalance in ecology [2]. Among the various raw materials used in textile production 'Polyester fiber' is one of the widely used synthetic fibers. This non-renewable, thermoplastic polymer chemically known as Polyethylene terephthalate (PET) is synthesized through a condensation reaction between terephthalic acid (TPA) and ethylene glycol (EG), both of which are derived petroleum feedstock. The traditional or widely used methods for tackling this waste is to reintegrate the waste textile in the clothing lifecycle by mechanical, chemical or other means. This includes mechanically shred or chemically treat them to produce yarn or fiber, which will be again spun or weave or knitted into textile products [3]. These processes are scalable and useful but the product made from virgin raw material will always have a preference over recycled good among consumers. This experiment explores a complete innovative and nontraditional way of upcycling this PET waste into functional nanomaterials for their potential use in tumor targeting and cancer treatment.

Literature Review:

Recent studies found the effective use of modified Carbon Quantum Dots in tumor targeting and cancer treatment. N-CQDs (Nitrogen doped Carbon Quantum Dots) functionalized with molecules like folic acid that bind specifically to receptors overexpressed on cancer cell membranes. When these ligands are attached, the CQDs can actively recognize and bind tumor cells through receptor. N-CQDs can also act as therapeutic agents. When exposed to specific light like NIR (near-infrared), they can generate reactive oxygen species (ROS), such as singlet oxygen. These ROS damage cancer cell components, leading to apoptosis or necrosis [4].

The polyester fiber or PET serves an excellent precursor for QCDs. There have been few studies converting PET into QCDs, doping with various substances but explicitly utilizing polyester-based waste textile materials as PET source and specific doping and surface functionalization for tumor targeting and carcer treatment hasn't been experimented yet. This experiment utilizes the PET in polyester fabric to produce biomedical grade Nitrogen-Doped, surface passivated Carbon Quantum Dots designed for Tumor-Targeted Imaging and Cancer Therapy. This experiment will combine all the suitable studies and experiments into one ultimate pipeline for effective production of the nanomaterial. The process involves pretreatment, synthesis of CQDs [5], doping of Nitrogen [6], surface passivation with PEGylation (mPEG-NH_2) [7] and folic acid [8], purification and QC [9] and In vitro biological assays and PDT testing.

Research Principle:

Polyester fabric waste → ***N-doped CQDs*** → Tumor-targeted cancer imaging/therapy.

Project Pipeline:

Feedstock → Synthesis → Doping/Passivation → Purification/Characterization → Biological testing

Research Questions:

1. Can polyester fabric waste be efficiently converted into high-quality N-CQDs which will be suitable for biomedical applications?
2. How do doping and passivation strategies improve the optical and biocompatibility properties of N-CQDs for tumor imaging?
3. Can functionalized N-CQDs selectively target cancer cells and serve as dual-purpose agents for both imaging and therapy?

Proposed Pipeline's Methodology:

1. **Feedstock and pretreatment:** Strategic collection, washing of the polyester fabric will be done followed by mechanical shredding to produce pieces of 1-2 mm size. Then microwave will be applied assisted with glycosis to convert the long polymeric chain of PET to PET oligomers of lower DP (Degree of Polymerization).
2. **Synthesis of Carbon Quantum Dots:** Mixing the prepared PET oligomers with water or solvothermal solvent and add nitrogen precursor for N-doping (Nitrogen-doping). Then have to transfer the mixture to a Teflon lined autoclave and heat under hydrothermal conditions. Optimizing the temperature or time for maximize output of red or NIR (Near Infrared) emission and quantum yield.
3. **Doping of Nitrogen:** Adding Nitrogen precursor like urea or ethylenediamine during synthesis will introduces Nitrogen in the CQD (N-Doping) N-doping is known to shift emission and increase PDT activity.
4. **Surface passivation:** Surface passivation will be performed by PEGylation (mPEG-NH_2) to improve colloidal stability and circulation time, followed by covalent conjugation of a targeting ligand (e.g., folic acid) via standard carbodiimide chemistry (EDC/NHS) to enable receptor-mediated tumor targeting.
5. **Purification and basic QC:** Products will be purified by sequential centrifugation and dialysis (or ultrafiltration) to remove small molecular impurities. Purity and batch reproducibility will be monitored by UV–Vis/PL and elemental analysis per standard CQD purification workflows.
6. **In vitro biological assays and PDT testing:** Biological evaluation will include
    - cytotoxicity assays (MTT/AlamarBlue) on cancer and normal cell lines,
    - receptor-mediated uptake and imaging using confocal microscopy
    - photodynamic efficacy via ROS assays: intracellular ROS will be detected using DCFH-DA and extracellular singlet-oxygen production with Singlet Oxygen Sensor Green (SOSG), following prior CQD-PDT studies [4], [10], [11].

Expected Outcome:

- This experiment provides an innovative and sustainable approach for upcycling discarded polyester fabrics into highly fucntional nanomaterial rather than traditional methods of reintegrating the polyester into lower grade textile or appliances.
- Production of biocompatible, NIR-emitting Nitrogen doped Carbon Quantum Dots for tumor imaging.
- Proof-of-concept demonstration of dual-use theragnostic nanomaterials.

Potential limitation:

Differentiating the fabric in terms of composition and quality might reduce the reproducibility due to the batch-to-batch variability of textile waste feedstock. Scaling of the process can be challenging for biomedical-grade CQD production.

Project Timeline:

- Months 1–2: Fabric collection, pretreatment, and synthesis trials.
- Months 3–4: Doping optimization, surface passivation, and characterization.
- Months 5–6: In vitro cancer imaging and therapy assays.
- Month 7: Data analysis and proposal for journal submission.

Conclusion:

The growing production of textile goods in Bangladesh also increases the production of polyester, hence accelerating environmental wastage. This process not only reuses the nondegradable PET but also produces highly effective nanomaterials for advance biomedical application.

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