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A Review of Challenges and Solutions to Green Synthesis of Carbon Quantum Dots by Hydrothermal Method

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ABSTRACT:

Carbon quantum Dots are recent development carbon nanotubes with small particle size less and better surface passivation. They have good fluorescence properties at different concentrations, pH and room temperature; therefore they are hopefully used for theranostic therapies with their strong fluorescence. CQDs are basically used for cancer diagnosis, enhances the drug targeting area specifically. Green synthesized CQDs are noticed to have better particle size than synthetically produced, also cost effective method proceeded by hydrothermal treatment, which is a challenging factor for CQDs synthesis (Figure 1). CQDs are an upgrading part in the field of nanotechnology, with several applications including genetic work, biosensing and cell catalysis.

Keywords: - Carbon Quantum dots, Green synthesis, Hydrothermal Method, Doxorubicin (DOX)

Introduction:

Carbon dots are small carbon based nanomaterials of size ranging below 10nm. The discovery of carbon dots aimed to have exploit fluorescence properties of carbon dots. Investigations also declared carbon dots as nanomaterials with excellent fluorescent properties and better surface passivation. **[1, 2, 3]**.Carbon dots are recent development in the field of nanotechnology. They are mainly used for anticancer and genetic activity. Carbon Dots with high stability, good conductivity, low toxicity, environment friendly (waste-control protection) and better optical properties enhance the drug delivery system *invivo*. The basic mechanisms responsible for fluorescence capability of carbon dots are much debated. Scientists have discovered evidence of size-dependent fluorescence features, implying that the emission is caused by quantum confidential effects on electronic transitions with the core of the dots. **[4, 5]**. Some other works have attributed that the fluorescence to recombination of surface-trapped charges **[6, 7]**, or proposed a form of coupling between core and surface electronic states **[8]**. Carbon dot's excitation-dependent fluorescence results in their distinctive emission tenability, which is mostly linked to the inhomogeneous distribution of their emission characteristics, **[9, 10]** due to polydispersity.

Carbon dots with diverse properties of its structure and components make it more attractive than other nanoparticles. The carbonyl moieties on the surface of the carbon dots provide high water solubility as well as biocompatibility. **[11]**. Carbon dots are also called as proton holders and acts as proton conducting nanoparticles due to such surface moieties. **[12]**. CDs also allow for chemical modification and surface passivation using different organic, inorganic, polymeric or biological components. The fluorescence and physical properties of carbon dots are both improved by surface passivation. Recently it was discovered that amine and hydroxamic acid functionalized carbon dots, introduced to different pH environment can produce tricolor i.e, yellow, green and red emission which can be preserved in ORMOSIL film matrix **[13]**. Carbon dots can withstand temperatures as high as 800°C, making its applications in high temperature environment **[14]**. Based on carbon, carbon quantum dots acts for good conductivity, benign chemical composition, photochemical and thermal stability. They can have a comparative study of preparation from green synthesis i.e., a more better and effective way of preparation of carbon dots rather than using synthetic process that may result in toxic or hazardous reactions.

Green synthesis is a technique for reducing or eliminating the use of hazardous compounds in the manufacture, design, and use of chemical products. It discusses source waste minimization, the use of catalysts instead of reagents, the use of renewable resources to enhance atom efficiency, the use of non-toxic reagents, and the use of solvent-free or recyclable ecologically friendly solvent systems. It helps in generating ultra small carbon dots with multi-surface functional groups. **[15]**. Green synthesis also can be performed by some natural resources like *Citrus grandis, citrus maxima, Solanum lycopersicum var, Prunus domestica, Dillemia indica linn vera, Aegle marmelos, Elaeocarpus floribundus, Bambusa valgaris* etc. to produce effective and fluorescent carbon dots.

Challenges and solutions:

The optical and electrochemical detection of carbon dots are of great interest to nanoresearchers in biomedical applications, but there are important challenging issues regarding their production. **[16]**. Increasing interest in the creation of these quantum dots can be expected by giving their sustainability

and ease of production and integration with other nanomaterials. Despite the fact that procedures and starting materials for their construction have been investigated, none or a small number of these nanostructures have yet to be commercialized, one of the important challenges is to optimize the production methodologies and improve the control over the sizes and morphologies of the produced particles; standardization of the fabrication processes should be accomplished. There are considerable differences in the functionalities of carbon-based sensors and their biocompatibility, with significant consequences. This standardization is critical because fluorescence characteristics and quantum yields are linked to the inclusive composition and the presence of residual chemical groups on carbon dots surfaces. Scaling up processes requires optimized synthetic procedures, and in this case, using simple, greener, environmentally friendly and cost-effective techniques is vital. It is incredibly intriguing to use synthetic methods that rely on renewable raw materials, but it also necessitates research for scale-up and commercial manufacturing. On the other hand, applying synthetic methods at lower temperatures (low-energy input) using earth-abundant starting ingredient is still an important challenge for the fieldworkers who conducted research. Photoluminescence is one of the most appealing properties of carbon dots, but it is highly dependent on the raw materials used in their manufacture and the presence of surface functionalities on these particles, made them particularly noticeable in carbon quantum dots produced from biomass and organic compounds. **[16]**. One of the most persistent issues has been to improve and develop the quantum yield of carbon quantum dots while taking full advantage of their inherent properties and to fine-tune their emission spectrum; the improvement in-precise sizes are barely available yet. It is vital to prepare Carbon quantum dots in a facile and greener manner with designed structure and size for proper investigations and biomedical applications. The sizes, morphologies, and properties of the final product are influenced by a number of significant elements, including the synthetic routes and carbon sources. Carbon dot sizes are critical for understanding quantum processes, as well as medicinal and optoelectronic applications. **[17]**. Recently, various pathways have been outlined for the fabrication of both pure and doped carbon quantum dots with varied morphologies and characteristics. Carbon quantum dots are synthesized by using discrete, sustainable, and environmentally friendly methods. The well-defined and atom-precise structures, for example, have not been documented in detail, thus restricting the profound evaluation of the relationships between structures and characteristics, detailed properties regulations, and comprehensive assessments of innovative synthetic approaches and applications. An all-inclusive consideration toward the optical characteristics of carbon dots is needed; additional theoretical assessments and a greater grasp of the mechanistic components are crucial.

Green chemistry is the application of important principles in the design, manufacture, and application of chemical products to decrease or eliminate the use or synthesis of hazardous compounds; none or less hazardous chemical synthesis, applying safer and non-toxic chemicals, solvents and processes are some of them [**19, 20]**; as an example, bio wastes can be applied as sustainable and cost-effective carbon sources for synthesizing carbon quantum dots. In a report, lemon peels discarded were used to make spherical water-soluble carbon quantum dots (about 1–3 nm), deploying a cost-effective hydrothermal strategy; the resulting stable carbon quantum dots were discovered to have oxygen-rich surface functions, were water soluble, and had outstanding photoluminescence characteristics, with a quantum yield of around 14%.**[16]**. The synthesized carbon quantum dots were utilized to produce a cost-effective, environmentally friendly, and highly sensitive fluorescent probe for the detection of Cr^{6+} ions. The water-soluble carbon quantum dots-based fluorescent probe could be used as a simple, quick, and convenient technique to accurately and precisely detect Cr^{6+} during water purification procedures. Furthermore, carbon quantum dots were immobilized over electrospun TiO2 nanofibers, and the photocatalytic activity of this TiO2-water-soluble carbon quantum dots composite was reported using methylene blue dye as a model pollutant; the photocatalytic activity being about 2.5 times more than that of titanium dioxide nanofibers **[18]**. A simple one-step hydrothermal process employing fresh Citrus aurantifolia juice resulted in a greener synthesis of water-soluble carbon quantum dots of size 0-10nm; these biocompatible carbon quantum dots can be potentially applied as anti-carcinogenetic agent, as well as in a variety of other analytical applications. Some other natural sources by hydrothermal synthesis of carbon dots are discussed in this review. (Table 1)

Hydrothermal method:

Hydrothermal method is an extensively used method for preparation of carbon dots. Most scientist use hydrothermal method as it is a simple and better way of preparing carbon dots. Hydrothermal method minimizes or prevents the toxic chemical reaction that may occur while preparing carbon dots. In this technique, an aqueous solution is used as a reaction system in a specific closed reaction vessel to create a high temperature or high pressure reaction environment. This is done by heating the reaction system and pressurizing it, or by using the vapour pressure that is generated itself. For the creation of nanomaterials, hydrothermal synthesis is the most often utilized approach. It's essentially a reaction-based solution technique. Nanomaterials can be formed at a wide range of temperatures in hydrothermal synthesis, from ambient temperature to extremely high temperatures.

Methodology:

There are currently no plans to clarify the fluorescence source of carbon dots on a global scale. Since 2005, a growing number of scientific researches on CDs have been released **[21]**. Out of many advantages of CDs, low cost synthesis process and quantum yield plays a vital role; therefore most of the scientists go for green synthesis. Some of the synthetic methods of CDs from natural sources are discussed in this review

Synthetic Methodology:

The primary goal of CDs synthesis is to fine-tune the size, surface, and fluorescence properties of the CDs. Adjusting the particle size of the CDs changes their fluorescence characteristics. Surface tuning techniques can be applied to CD groups to elicit distinct surface states. Due to the quantum confinement effect and the deviation in density and type of the sp^2 domain, CDs fluorescence qualities are largely determined by their size. The energy band gap of CDs can be controlled via size-tuning by increasing or decreasing the reaction time.

Top-Down Formation:

To make CDs, top-down and bottom-up processes are commonly utilized. Synthetic techniques are among the top-down methodologies for creating CDs from carbon precursors. Chemical or physical procedures are used to break down large carbonaceous materials or distribute them into little CDs in the top-down strategy. CDs have been manufactured using graphite [**22, 23]**, candle soot **[24]**, and other altered carbon precursors. Some of the methods utilized to synthesize CDs include high-energy ball milling **[25]**, electrochemical route **[26]**, and laser ablation **[27-29]**. Single-walled carbon nanotubes (SWCNTs) were refined from arc-discharge soot by oxidising it with nitric acid (HNO_3) and then extracting it with a NaOH solution, which was one of the initial processes in the fabrication of CDs. Sun et al. also assembled carbon nanoparticles using laser ablation on a carbon target using argon as the carrier gas. The product was previously passivated with organic chemicals, resulting in the dots **[30]**. The top-down method's larger benefits include cost-effective precursors and mass production **[31]**

Bottom-up Formation:

The bottom-up method refers to the large-scale carbonization and polymerization of small molecules onto CDs. Bottom-up procedures in the manufacturing of CDs include techniques such chemical vapour deposition (CVD) **[32],** solvo thermal **[33, 34],** combustion **[35],** microwave assisted methods **[36–38],** hydrothermal **[39–41],** and ultrasonic-assisted methods **[42–44].** The bottom-up approach has the advantage of having complete control over the product size and route. Bottom-up approaches are simpler, easier, greener, and faster for producing large quantities at a lower cost. Furthermore, tiny biomolecules that can be carbonized to generate green CDs are included in the maximum renewable sources.

Method of preparation:

For every researcher, preparing carbon dots is a recent development. Carbon dots are made using a variety of processes, including hydrothermal, Gel Filtration, Microwave and Ultrasonic. The hydrothermal method of carbon dot production is supported in this article. In comparison to other methods, the hydrothermal process has a number of advantages. It's a single-crystal synthesis process that relies on mineral solubility under high pressure. This approach is also ideal for growing huge, high-quality crystals while keeping composition under control. In the 19th century, geoscientist **H. De Senarmont** discovered hydrothermal synthesis. **[45]**.In hydrothermal synthesis, crystal development takes place in an autoclave, which is a steel pressure vessel with a nutrient and water. A temperature gradient is maintained between the two ends of the growing chamber. At the hotter end, the nutrient solute dissolves, while at the cooler end, it is deposited on a seed crystal, resulting in the development of the desired crystal. Autoclaves are steel cylinders with thick walls and a hermetic seal that must withstand high temperatures and pressure for an extended period of time. In addition, the material used in the autoclave must be solvent inert. The autoclave's closure is the most crucial component. The Bridgeman seal is the most well-known seal design. In the vast majority of hydrothermal experiments, steel corroding solutions are used. Corrosion of the autoclave's internal cavity is usually avoided by using protective inserts. They are either "contact" type inserts that fit into the internal cavity of the autoclave or "floating" type inserts that solely occupy the inner part of the autoclave. Depending on the temperature and solution used, inserts could be constructed of carbon-free iron, copper, silver, gold, platinum, titanium, glass, quartz or Teflon.

Methods of Hydrothermal Synthesis:

Temperature Difference Method:

In hydrothermal synthesis and crystal growth, it is the most often utilized process. The temperature in the crystal growth zone is lowered to achieve supersaturation. The nutrient is placed in the autoclave's lower section, which is loaded with a precise amount of solvent. To produce a temperature gradient, the autoclave is heated. The nutrient dissolves in the hotter zone, and convective action transports the saturated aqueous solution from the lower section to the upper part. The denser and cooler solution in the upper part of the autoclave descends as the counter flow of the solution ascends. As a result of the lower temperature, the solution becomes supersaturated in the top region, and crystallization begins.

Temperature reduction technique:

Crystallization occurs without a temperature differential between the growth and dissolution zones in this method. The super saturation is obtained in the autoclave by gradually lowering the temperature of the solution. The difficulty in controlling the growth process and inserting seed crystals is a downside of this approach. As a result, this approach is rarely employed.

Metastable-Phase Technique:

The differential in solubility between the phase to be grown and the phase serving as the starting material is the basis for this procedure. Under the growth conditions, the nutrient contains molecules that are thermodynamically unstable. The metastable phase's solubility exceeds that of the stable phase, causing the latter to crystallize as a result of the metastable phase's dissolution. This technique is frequently used in conjunction with the Temperature-difference method or the Temperature-reduction technique.

Hydrothermal Method uses:

A vast range of compounds, including elements, simple and complex oxides, tungstates, molybdates, silicates and carbonates are formed under hydrothermal conditions. Hydrothermal synthesis is often used to generate commercially valuable single crystals such as synthetic quartz, diamonds, and other single crystals. Rubies, Emeralds, alexandrite, quartz and other crystals can all be effectively developed in this way. The method has proven to be

particularly effective in the search for novel compounds with specific physical properties as well as in the systematic physiochemical investigation of complex multicomponent systems at high temperatures and pressures.

One of the advantages of the hydrothermal process over other forms of crystal formation is the ability to generate crystalline phases that are not stable at the melting point. Hydrothermal growth can also be used to develop materials with a high vapor pressure around their melting temperatures. The approach is also well suited to the formation of massive, high-quality crystals while retaining compositional control. The cost of the autoclaves required for this process is excessively costly, and there is no way to view the crystals because they grow when a steel tube is utilized. **[46]**.

Recent Advances of carbon dots:

Carbon dots have lately created wonderful preparation formulae or techniques that use natural ingredients and save money in a range of applications. Carbon sources for simple, affordable, and environmentally friendly synthesis of carbon nanomaterials could be readily available from natural bio-resources. Depending on the experimental settings, many types of carbon nanomaterials can be made from biowaste, such as porous carbon, carbon dots, and so on. The synthesis of carbon nanomaterials from biowaste, natural sources, and waste materials has been the subject of numerous investigations in recent years. **[47-51]** As carbon precursors, biowastes such as pineapple leaves, banana leaves, sugarcane bagasse, coconut leaves, coconut shells, coir, watermelon peel, pomelo peel, orange, areca nutshells, groundnut shells, and others have been employed. Despite the fact that many of the biowastes mentioned above have been used as carbon sources, there are still a variety of biowastes leftovers that can be utilized. This review will focus on the recent progress of fluorescent carbon nanomaterials generated from biowaste and organic compounds, as well as their sensing and environmental applications in recent years (2017 to present). This review paper is expected to contribute to the advancement of nontoxic nanomaterial development for substantial environmental applications. Graphene quantum dots (GQDs) and carbon-based nanoparticles are the two major types of fluorescent carbon nanomaterials. **[52–55]** Both are made up of 10 nm spherical particles, however their morphologies are different. The precursors utilized to make GQDs differ from those used to make carbon-based nanoparticles. In general, graphene-based materials are used to make GQDs, whereas carbon-based nanoparticles are made from other carbon nanomaterials (carbon nanotubes) or organic compounds. **[54]** GQDs contain a crystalline core made up of one or more graphene layers, while carbon-based nanoparticles have an amorphous or multilayered-crystalline core **[55]**. Carbon-based nanoparticles are classed as CQDs or carbon nanodots depending on the composition of the carbon core (CNDs). CNDs have an amorphous carbon core with no quantum confinement effect and no crystal lattice, whereas CQDs have a multilayer crystalline graphitic core with crystal lattice **[52-55]**. Carbon dots are a term used in various papers to describe amorphous carbon nanoparticles (C-dots). Recognizing and comprehending the differences between CQDs and CNDs (or C-dots) remains a challenge. As a result, all carbon-based quasi-spherical particles, including CQDs and CNDs, are referred to as carbon dots in this review.

Cancer therapy:

When it comes to diagnosis of cancer, the first role is to detect the cancer cells and eliminate them from the body. Various therapies and radiations are harmful to other cells of the body, therefore nanoparticles play an vital role in eliminating them, many fluorescent probes has been used like QDs**[57]**, UC NPs**[58],** silica NPs**[59]** etc. but due to their instability and poor fluorescent properties, they are unable to detect the cancer cells for prolong use. Carbon quantum dots with excellent fluorescent properties have been found to detect for proper theranostic therapy in cancer cells. **[56]** Moreover, CQDs play an important role for drug delivery, gene therapy and photo therapy for cancer treatment. (Figure 2)

Drug delivery:

CQDs are non-toxic and biocompatible, allowing them to be used in a variety of biomedical applications such as drug carriers, fluorescent tracers, and drug release control. The employment of CQDs as photo-sensitizers in photodynamic therapy to eliminate cancer cells is one example of this.

DOX is an anticancer medication that has been used as a model in numerous studies to demonstrate the efficacy of various drug delivery systems. It's also been used to test CQD drug delivery with targeted distribution. **Ding et al**. **[60]** demonstrated that DNA-CQDs are suitable for the delivery of DOX and rhodamine 6G (Rh 6G). DNA-CQDs were useful for proper drug administration because of their stability in neutral pH and drug release in lower pH. The presence of N and P in DNA structure increased the PL of CQDs and allowed for imaging. For imaging and drug delivery, **Samantara et al. [61]** employed heteroatom doped CQDs. They discovered that the DOX medication in this system exhibited a non-covalent interaction with the CQDs. In acidic settings, CQDs release more drugs, according to their findings. The release in pH 5 was 97 percent after 46 hours, and in pH 7.4 it was 78 percent. They also demonstrated that as compared to free DOX, the amount of medication that reached the cells increased. For DOX distribution, **Bao et al. [62]** employed NPs made up of N doped CQDs (NCQDs), D-biotin, and methoxy polyethylene glycol amine (mPEG NH_2) in combination with oxidized sodium alginate (OAL). N-CQDs, which have a significant number of amine groups, were used as the crosslinking agent in OAL. D-biotin produced effective system targeting compared to free DOX. As a result, this approach reduced DOX adverse effects by allowing a lower dose of the medicine to be utilized for therapy. Furthermore, this approach stopped cancer cells from multiplying while causing no harm to healthy cells. The NPs remained in the cytoplasm and membrane, but the medication was able to penetrate the nucleus, according to their findings. For DOX drug delivery, **Wang et al. [63]** used GQDs coated with PEG. The findings revealed that in an acidic environment, such as a tumor, the hydrophobic interaction between DOX and GQD/PEG broke; allowing the medicine to be released by NPs. Protonation of the DOX NH2 group at lower pH causes it (acidic condition). The release of medication was higher even in the alkaline condition than in the neutral condition.

Gene therapy:

CDs, on the other hand, are useful as a vector for gene delivery. One of the most essential ways to cure diseases like cancer is through gene therapy. The gene delivery by NPs is influenced by a number of important parameters. Because phosphates are a source of negative charge in the DNA structure, positive charge on the surface of nanoparticles is required to form a complex. Furthermore, non-viral gene delivery techniques are limited by the difficulty

of transfecting NPs. Nonetheless, CDs have advantages, such as the ability to follow vectors using the PL features of dots. As a result, CDs can be used as gene vectors if the concerns with their use are resolved **[64]**.

Polymer coating is one of the most important changes made to non-viral vectors for gene therapy. The capacity of chitosan and PEG-coated graphene to deliver genes was investigated. Chitosan with a positive charge successfully condensed DNA. PEG also shields the vector against bodily agents such as proteins **[65]**. CDs conjugated with polyamidoamine (PAMAM) were utilized by **Ghosh et al. [66]** to cure the worst type of breast cancer, TNBC. Electrostatic interaction between positively charged polymer and negatively charged DNA leads to successful complexation, according to the researchers. The density of amine groups rose as the PAMAM polymer was raised, resulting in improved complexation capabilities. RGD peptide also boosted the ability to create complexes and increased the cellular absorption of NPs. **Cheng et al. [67]** used atom transfer radical polymerization (ATRP) to apply cationic poly-[2-(dimethylamino)ethylmethacrylate] (PDMAEMA) and zwitterionic poly[N-(3-(methacryloylamino)propyl)-N,N-dimethyl-N-(3-sulfopropyl) ammonium hydroxide] (PMPDSAH). The PDMAEMA formed a combination with DNA and condensed it to NPs of around 50 nm in size. PMPDSAH not only shielded the CDs from proteins, but it also aided in transfection efficiency.

Photo therapy:

Photo-thermal therapy (PTT) and photo-dynamic therapy (PDT), the two primary types of cancer phototherapies, have gotten a lot of attention in recent decades because of their advantages over standard treatment approaches. These treatments are non-invasive, have fewer side effects, have low systemic toxicity, and could be used to impact cancer cells in a targeted manner **[68].**

In PTT, a photothermal (PT) agent is used to heat aberrant cells or tissues selectively, whereas in PDT, the treatment is delivered by a sequence of photochemical processes triggered by photoactivated molecules or materials known as photosensitizers (PS) medicines. **Shibu et al. [69]**

Other applications of CQDs:

CQDs have advantages such as minimal toxicity and strong biocompatibility which renders them favorable materials for applications in bioimaging, biosensor and drug delivery. **[70]**. CQDs can be used in catalysis, sensors, and optronics, **[1]** because of their superior optical and electrical properties.

Bioimaging:

The fluorescence emissions and biocompatibility of CQDs make them ideal for bioimaging. **[71]**. CQDs containing solvents can be injected into a living body for obtaining in vivo images,further which can be used for detection or diagnosis purposes. Organic dye-conjugated CQDs, for example, could be useful as H_2S fluorescence probes. In the presence of H_2S, the organic dye-conjugated CQDs' blue emission may be changed to green. The organic dye-conjugated CQDs could therefore visualize variations in physiologically relevant amounts of H_2S using a fluorescence microscope. **[72]**.

Sensing:

CQDs, for their versatility in modification, high water solubility, non-toxicity, strong photo stability, and outstanding biocompatibility are useful as biosensor carriers in biosensing. **[1]**. Visual monitoring of cellular copper **[73]**, glucose **[74]**, pH **[75]**, trace amounts of H_2O_2 **[76]** and nucleic acid **[77]** could be accomplished with biosensors based on CQDs and CDs-based materials. Nucleic acid lateral flow tests are a good illustration of this. The fluorescence of CQDs is sensitive to pH, local polarity, and the presence of metal ions in solution, making them ideal for nanosensing applications such as pollution monitoring. CQDs have shown to offer a lot of potential in biosensing applications. Biomarkers with non-standard numbers or fluctuations in the body, such as peptides, glucose, UA, DA, DNAs, enzymes, proteins, antigens, and hormones, can be connected to disorders **[78]**. **Garcia et al. [79]** used gold-modified CQDs to create a DNA bio-sensor. 25mer or 100mer DNA probes were employed for sensing the CFTR gene. They might be able to develop a sensor with a high selectivity and a detection limit of 0.16 nM. **Huang et al. [80]** created a nanocomposite bio-sensor based on CQDs, Au, and Pd for sensing of colitoxin genes. The immobilization of single-stranded DNA by carboxyl ammonia between the carboxyl group of the nanocomposite and the amino group of the (S1) probe DNA provides the basis for the sensing mechanism. **Ji et al. [81]** looked into using N-CQDs to measure blood glucose. N-CQDs and chitosan were combined in a compound. Glucose oxidase (GOx) was immobilized as a result of the amino-carboxyl processes, and it was able to detect the quantity of glucose in the blood with a detection limit of 0.25 mM.

Catalysis:

Because of the versatility of functionalization with different groups of CQDs, they can absorb light of various wavelengths, which opens up new possibilities for photo-catalysis applications. **[82]**. Under UV-Vis irradiation, the photo-catalytic H_2 development of CQDs-modified P_{25} TiO_2 composites was enhanced. To improve the separation efficiency of the electron-hole pairs in P_{25}, CQDs act as a reservoir for electrons. **[83]**.

Optronics:

CQDs could be employed in dye-sensitized solar cells **[84]**, organic solar cells **[1]**, supercapacitors **[85]**, and light-emitting devices **[86]**, among other applications. CQDs are utilized as a photo-sensitizer in dye-sensitized solar cells, resulting in a considerable increase in photoelectric conversion efficiency **[87]**. A hybrid silica-based solution incorporating CQD can be utilized as a transparent fluorescent paint. **[88]**.

Conclusion:

Nanoscience advances are of current interest for advanced and developed detection and individualized therapy of different complicated diseases (particularly malignancies). Semiconductor quantum dots, in particular, have been created as novel platforms for high-throughput quantitative studies of numerous biomarkers in cells and clinical tissue samples (ex vivo), in vivo evaluations of cells with illnesses, and potentially targeted and traceable drug delivery. Quantum dots have tremendous potential in biomedical, bioimaging, and photo luminescent applications and they can be used as promising fluorescent probes for imaging with low cytotoxicity, as well as bioanalysis and related sectors. Carbon quantum dots have attracted a lot of attention because of their good biocompatibility, chemical inertness, and photo bleaching resistance. Additionally, for special and specific applications, their optical features can be changed by size control, chemical doping, and functionalization. Because of their cost-effectiveness, ease of production, and minimal environmental impact, biomass-based carbon quantum dots have become important carbon materials. However, it appears that many researches are still left for preparing carbon quantum dots from microorganisms, particularly cyanobacteria, as carbon sources; which may lead to the creation of luminous carbon quantum dots.

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Abbreviations:

- CDs- Carbon Dots

- CQDS- Carbon Quantum Dots
- CNDs- Carbon nanodots
- CVD- Chemical vapour deposition
- CFTR- Cystic fibrosis transmembrane regulator
- DA- Dopamine
- DNA- Deoxyribonucleic acid
- DOX- Doxorubicin
- GQDs- Graphene Quantum Dots
- GOx- Glucose oxidase
- H_2S- Hydrogen Sulphide
- HS-Hydrosulfide
- HNO_3- Nitric acid
- NPs- Nanoparticles
- N-CQDS- Nitrogen Carbon Quantum Dots
- ORMOSIL- Organically modified silica or silicate
- PTT- Photothermal therapy
- PEG- Polyethylene glycol
- PDT- Photo-dynamic therapy
- QDs- Quantum Dots
- RGD- Arginylglycylaspartic acid
- SWCNTs- Single-walled carbon nanotubes
- TiO2- Titanium Dioxide
- TNBC- Triple Negative Breast Cancer
- UC NPs- Up-conversion nanoparticles

Table 1: Examples of carbon dots by hydrothermal synthesis from different natural sources

Sources	**Reaction time**	**Size (nm)**	**Quantum Yield (%)**	**Application**	**Reference**
Apple juice	150 °C, 12 h	4.5	4.27	Imaging of mycobacterium and fungal cells	89
Allium fistulosum	120 °C, 3 h	11.67	-	Solar cells	90
Bee pollens	180 °C, 24 h	1–2	9.1	Cellular imaging and catalysis	91
Bamboo leaves	200 °C, 6 h	3.6	7.1	Cu^{2+}	92
Carrot	170 °C, 12 h	2.3	7.60	Drug delivery	93
Chionanthus retusus	180 ◦C, 6 h	5	9	Metal ion sensing and imaging of fungal cells	94
Coriander leaves	240 °C, 4 h	2.4	6.48	Sensoring of Fe^{3+} and cellular imaging	95
Coccinia indica	180 °C, 7 h	5.2	30.0	Detection of Hg^{2+}, Cu^{2+}, $Pb^{2+,}$ Fe^{3+}	96
Cherry Tomatoes	180 °C, 6 h	7	9.7	Trifluralin Herbicide	97

Date kernel	200 C, 8 h3994	2.5	12.5	Sensing of drugs and cellular imaging	98
Dunaliella salina	200 °C, 3 h	4.7	8	Hg (II), Cr (VI), cell imaging	99
Gardenia fruit	180 °C, 5 h	2.1	10.7	Hg^{2+} and cysteine	100
Garlic	200°C, 3 h	11	17.5	Cellular imaging and free radical scavenging	101
Grape Skin	190 °C, 3 h	4.0 ± 1.5	18.67	PA	102
Gum tragacanth	180 °C, 12 h	3.4	66.74	Au^{3+}	103
Kidney beans	450°C for 2 h	20–30	84	Cellular imaging	104
Lemon juice	280°C, 12 h	50	24.89	Optoelectronics and bioimaging	105
Lemon peel	200 °C, 12 h	1-3	14	Cr^{6+}	106
Miscanthus grass	180 °C, 4 h	4-8	11.6	Fe^{3+}	107
Mint leaves	200 °C, 5 h	4	-	$Fe^{3+,}$ ascorbic acid	108
Onion waste	120 °C, 15 lbs pressure	15	28	Sensoring of Fe^{3+} and cellular imaging	109
Orange juice	200 °C, 11 h	0.5-3.0	31.7	Hg^{2+}	110
Oyster mushroom	200 °C, 25 h	6.54	12.51	o-NA, p-NA, m-NA, p-NP	111
Papaya juice	(125, 150 and 170) °C, 12 h	3	7.0	Cellular imaging	112
Peach gum	180 °C, 16 h	2-5	28.46	$Au^{3+,}$cell imaging	113
Prunus mume	180 °C, 5 h	9	16	Cellular imaging	114
Prunus persica	180 °C, 5 h	8	15	Cellular imaging and oxygen reduction reaction	115
Pseudo-stem of banana	180 °C, 2 h	1-3	48	Sensing Fe^{+3}, Imaging of Hela and MCF-7 cells.	116
Saccharum officinarum	120 °C, 3 h	3	5.76	Cellular imaging of bacteria and Yeast.	117
Strawberry	180 °C, 12 h	5.2	6.3	Fluorescent probes for mercury ions detection	118
Sugarcane molasses	250 °C, 12 h	1.9	8.2	Sensoring of Fe^{3+} and cellular imaging	119
Seville orange	130 °C, 12 h	4.8	13.3	Fe^{3+}	120
Spinach leaves	200 °C, 2 h	5.6	-	Fe^{3+}	121
Snake gourd peels	180 °C, 12 h	5	28.6	Fe^{3+}	122
Sweet potato	180°C, 18 h	3.39	8.64	Fe^{+3} sensing and cellular imaging	123

Trapa bispinosa peel	90°C, 2 h	5-10	1.2	Cellular imaging	124
Walnut shell	(100,140) °C, 12 h	3.4	-	Cellular imaging	125
Water Chestnut and onion	180°C, 4 h	3.5	3:2	Sensing of Cu (II) and Imaging of Coenzyme A	126
Winter melon	180 °C, 2 h	4.5–5.2	7.51	Cellular imaging	127

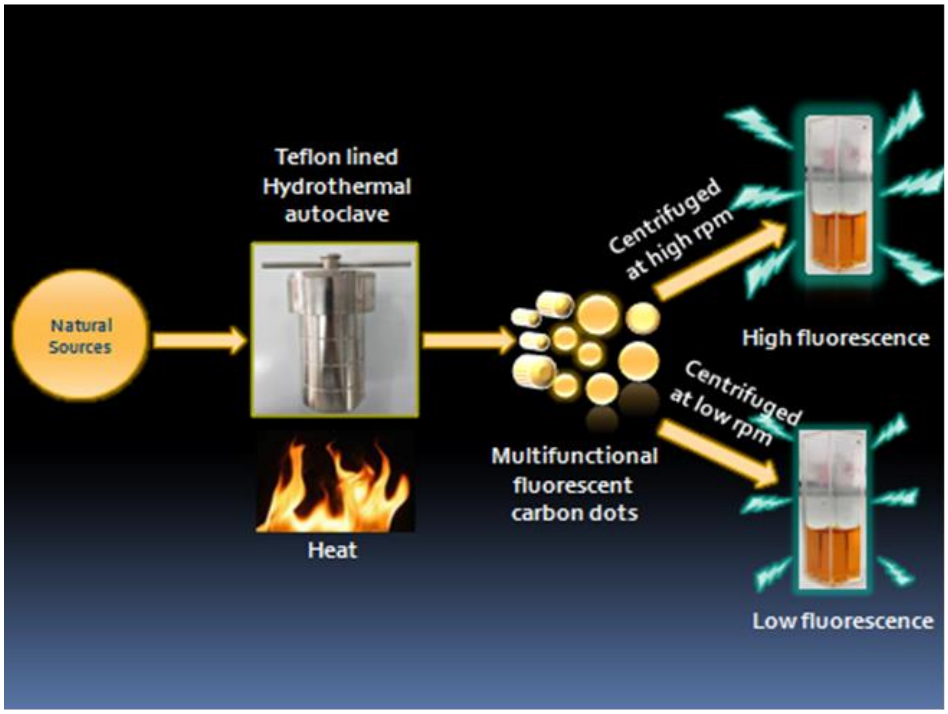

Figure 1: Graphical abstract

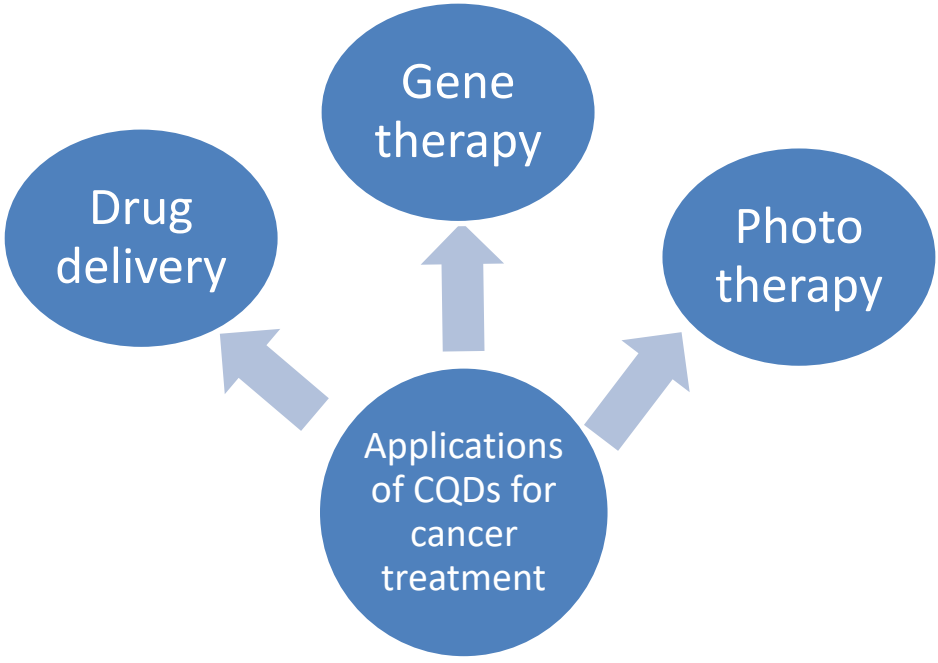

Figure 2: Three main cancer treatment techniques using nanotechnology