PENGEMBANGAN KARBON DOT TERDOPING NITROGEN DAN BORON (N,B-CDs) SEBAGAI *FLUORESCENT NANOSENSOR* UNTUK MONITORING ION Fe(III) DI LINGKUNGAN PERAIRAN

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INTISARI

Fluorescent nanosensor berbasis N,B-karbon dot (N,B-CDs) telah dikembangkan untuk mendeteksi mendeteksi ion Fe(III) di lingkungan perairan. Sintesis N,B-CDs dilakukan menggunakan metode *microwave*. Optimasi sintesis dilakukan dengan memvariasikan daya, waktu iradiasi, serta konsentrasi etilendiamin dan natrium tetraborat sebagai dopan N dan B. Daya iradiasi dioptimasi pada rentang 100-800 W, sedangkan waktu iradiasi dioptimasi pada rentang 1-7 menit. Pengaruh dopan dievaluasi dengan memvariasikan konsentrasi etilendiamin dan natrium tetraborat dari 0-100% (b/b asam sitrat). Kondisi optimal sintesis kemudian digunakan untuk mensintesis N,B-CDs lalu dikarakterisasi, diuji *quantum yield* (QY) yang dihasilkan, serta stabilitasnya terhadap faktor lingkungan seperti pH, keberadaan *ionic strength* (NaCl), paparan sinar UV, waktu dan kondisi penyimpanan. Selain itu, sensitivitas dan selektivitas N,B-CDs terhadap ion Fe(III), serta pengaruh interferensi kation dan anion lainnya juga dievaluasi. Semua parameter optimum dari N,B-CDs digunakan untuk mendeteksi ion Fe(III) dalam lingkungan perairan.

Hasil penelitian menunjukkan bahwa N,B-CDs pada kondisi optimum (450 W, 2 menit, dengan 75% massa dopan B dan 50% massa dopan N) secara efektif meningkatkan QY dari 1,61% (CDs) menjadi 42,59% (N,B-CDs). Spektra FTIR menunjukkan keberhasilan pasivasi N dan B pada permukaan CDs dengan adanya vibrasi ikatan karakteristik seperti N-H, C-N, C-B, dan B-O. Karakterisasi dengan spektrofotometer UV-Vis, Raman, XRD, SAED, dan EDS mengkonfirmasi keberhasilan terbentuknya inti karbon grafen terhibridisasi sp^2 dan pasivasi permukaan pada N,B-CDs. Citra TEM menunjukkan bahwa N,B-CDs berbentuk kuasi-sferis dengan diameter rata-rata 3,70 nm. N,B-CDs juga menunjukkan kestabilan yang sangat baik pada kondisi pH 5-9, dalam keberadaan NaCl hingga konsentrasi 2 M, terhadap paparan sinar UV hingga 90 menit, dan waktu penyimpanan selama 2 bulan (suhu ±4 ^oC). Analisis sensor menunjukkan bahwa N,B-CDs secara selektif mampu mendeteksi Fe(III) melalui pembentukan kompleks non-emisif N,B-CDs-Fe^{3+}. *Fluorescent nanosensor* N,B-CDs memiliki rentang linearitas deteksi yang luas (0-60 ppm) dengan batas deteksi (LoD) sebesar 0,1258 ppm dan batas kuantitasi (LoQ) sebesar 0,4193 ppm. Selain itu, N,B-CDs juga berhasil digunakan sebagai sensor Fe(III) pada sampel air dengan %*Recovery* antara 86,18-109,84% dan nilai %RSD yang kurang dari 5%.

Kata kunci : N,B-CDs; *microwave*; ion Fe(III) ; sensor logam berat; fluoresensi

THE DEVELOPMENT OF NITROGEN AND BORON-DOPED CARBON DOTS (N,B-CDs) AS FLUORESCENT NANOSENSORS FOR MONITORING Fe(III) ION IN AQUATIC ENVIRONMENTS

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ABSTRACT

A fluorescent nanosensor based on N,B-carbon dots (N,B-CDs) has been developed for the detection of Fe(III) ions in aquatic environments. The synthesis of N,B-CDs was conducted via *microwave*-assisted methods. Optimization of the synthesis process involved adjusting parameters such as power, irradiation duration, and the concentrations of ethylenediamine and sodium tetraborate as N and B dopants. Power levels were optimized within the range of 100-800 W, while irradiation duration was fine-tuned between 1 to 7 minutes. The influence of dopants was evaluated by varying the concentrations of ethylenediamine and sodium tetraborate from 0-100% (w/w of citric acid). Subsequently, the optimal synthesis conditions were applied for N,B-CDs fabrication, followed by thorough characterization, assessment of quantum yield (QY), and evaluation of stability against environmental factors like pH, ionic strength (NaCl), UV exposure, time, and storage conditions. Additionally, the sensitivity and selectivity of N,B-CDs towards Fe(III) ions, as well as the interference effects of other cations and anions, were also assessed. Employing the optimized parameters, the N,B-CDs were effectively utilized for Fe(III) ion detection in water environments.

The research results indicate that under optimal conditions (450 W, 2 minutes, with 75% mass of B dopant and 50% mass of N dopant), N,B-CDs effectively enhanced the QY from 1.61% (in CDs) to 42.59% (in N,B-CDs). FTIR spectra showed successful passivation of N and B on the surface of CDs, evidenced by characteristic bond vibrations such as N-H, C-N, C-B, and B-O. Characterization through Raman, XRD, SAED, and EDS confirmed the successful formation of graphene carbon core hybridized with sp^2 and surface passivation in N,B-CDs. TEM images revealed that N,B-CDs exhibited quasi-spherical shapes with an average diameter of 3.70 nm. N,B-CDs also demonstrated excellent stability under pH conditions of 5-9, in the presence of NaCl up to a concentration of 2 M, against UV exposure for 90 minutes, and storage for up to 2 months (at approximately ±4 °C). Sensor analysis demonstrated that N,B-CDs selectively detected Fe(III) through the formation of non-emissive complexes N,B-CDs-Fe^{3+}. The fluorescent nanosensor N,B-CDs had a wide linear detection range (0-60 ppm) with a detection limit (LoD) of 0.1258 ppm and a quantification limit (LoQ) of 0.4193 ppm. Furthermore, N,B-CDs were successfully utilized as Fe(III) sensors in water samples, with %Recovery ranging from 86.18% to 109.84% and %RSD values less than 5%.

Keywords: N,B-CDs; *microwave*; Fe(III) ion; heavy metal sensor; fluorescence