PENGEMBANGAN *CARBON DOTS* TERDOPING NITROGEN DAN FOSFOR (N,P-CDs) SEBAGAI SENSOR FLUORESENSI UNTUK DETEKSI ION Cu^{2+} DI LINGKUNGAN PERAIRAN

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INTISARI

Dalam penelitian ini telah dilakukan sintesis karbon dot dengan penambahan dopan N dan P untuk mendeteksi ion Cu^{2+} di lingkungan perairan. Sintesis N,P-CDs dilakukan dengan menggunakan metode *microwave* dengan daya dan waktu optimum serta konsentrasi optimum etilendiamin dan asam fosfat sebagai dopan N dan P. Optimasi daya dilakukan pada 100-800 W. Optimasi waktu iradiasi dilakukan pada rentang waktu 1-3,5 menit. Pengaruh dopan dilakukan dengan variasi konsentrasi etilendiamin dan asam fosfat dari 0-100%. Kondisi optimal sintesis kemudian digunakan untuk mensintesis N,P-CDs lalu dikarakterisasi, serta diuji stabilitasnya terhadap faktor lingkungan seperti pH, paparan sinar UV, serta waktu dan kondisi penyimpanan. Sensitivitas dan selektivitas N,P-CDs terhadap ion Cu^{2+}, serta pengaruh interferensi kation lainnya juga dievaluasi. Semua parameter optimum dari N,P-CDs digunakan untuk mendeteksi ion Cu^{2+} di lingkungan perairan.

Hasil penelitian menunjukkan bahwa sintesis N,P-CDs optimum pada kondisi (450 W, 1,5 menit, dengan 25% massa dopan N dan P). Keberhasilan proses doping dievaluasi menggunakan FTIR menunjukkan keberhasilan pasivasi N dan P pada permukaan CDs dengan adanya vibrasi ikatan karakteristik seperti N-H, C-N, dan P-O. Karakterisasi dengan spektrofotometer UV-Vis mengkonfirmasi keberhasilan terbentuknya inti karbon dan hasil XRD menunjukkan N,P-CDs bersifat *amorf*. Citra TEM menunjukkan bahwa N,P-CDs berbentuk kuasi-sferis dengan diameter rata-rata 1,7 nm. N,P-CDs juga menunjukkan kestabilan yang sangat baik pada kondisi pH 6-9, terhadap paparan sinar UV hingga 90 menit, dan waktu penyimpanan selama 22 hari pada suhu suhu ±4 °C. Analisis sensor menunjukkan bahwa N,P-CDs secara selektif mampu mendeteksi Cu^{2+}, melalui pembentukan kompleks non-radiatif N,P-CDs-Cu^{2+}. Sensor Fluoresensi N,P-CDs memiliki rentang linearitas deteksi yang luas (0-0,4 ppm) dengan batas deteksi (LoD) sebesar 0,0177 ppm dan batas kuantitasi (LoQ) sebesar 0,0592 ppm. Selain itu, N,P-CDs juga berhasil digunakan sebagai sensor Cu^{2+}, pada sampel air dengan nilai %RSD yang kurang dari 5%.

Kata kunci: N,P-CDs, fluoresensi, *microwave*, Cu^{2+}, sensor logam berat

DEVELOPMENT OF NITROGEN AND PHOSPHOROUS CO-DOPED CARBON DOTS (N,P-CDs) AS FLUORESCENT SENSOR FOR Cu^{2+} IONS IN AQUATIC ENVIRONMENTS

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ABSTRACT

In this study, carbon dots (CDs) were synthesised with nitrogen and phosphorus (N and P) co-doping for the detection of Cu^{2+} ions in aquatic environments. The synthesis of N,P-CDs was carried out using a microwave-assisted method, with optimisation of power, irradiation time, and the concentrations of ethylenediamine and phosphoric acid as N and P dopants, respectively. Power optimisation was performed in the range of 100-800 W, while irradiation time was varied between 1-3.5 min. The effect of doping was investigated by changing the concentrations of ethylenediamine and phosphoric acid from 0-100%. The optimal synthesis conditions were then used to prepare N,P-CDs, which were subsequently characterised and tested for their stability under various environmental factors, including pH, UV exposure, and storage time and conditions. The sensitivity and selectivity of the N,P-CDs towards Cu^{2+} ions, as well as the interference effect of other cations, were also evaluated. All optimum parameters of the N,P-CDs were then applied for the detection of Cu^{2+} ions in aquatic environments.

The results showed that the optimum synthesis of N,P-CDs was achieved at 450 W for 1.5 min, using 25% mass of N and P dopants. The success of the doping process was confirmed by FTIR analysis, which indicated effective passivation of N and P on the CD surface through the appearance of characteristic bond vibrations such as N-H, C-N, and P-O. UV-Vis spectroscopy confirmed the formation of carbon cores, and XRD analysis indicated that the N,P-CDs were amorphous. TEM images revealed that the N,P-CDs were quasi-spherical in shape with an average diameter of 1.7 nm. The N,P-CDs also exhibited excellent stability in pH conditions ranging from 6 to 9, under UV irradiation for up to 90 min, and during storage for 22 days at approximately ±4 °C. Sensor analysis demonstrated that the N,P-CDs could selectively detect Cu^{2+} ions through the formation of non-radiative N,P-CDs–Cu^{2+} complexes. The fluorescent sensor exhibited a broad linear detection range (0-0.4 ppm), with a limit of detection (LoD) of 0.0177 ppm and a limit of quantification (LoQ) of 0.0592 ppm. Furthermore, the N,P-CDs were successfully applied as a Cu^{2+} sensor in real water samples, with %RSD of less than 5%.

Keywords: N,P-CDs, fluorescence, microwave, Cu^{2+}, heavy metal sensor