

PENGEMBANGAN *FLUORESCENT SENSOR* BERBASIS NITROGEN, SULFUR, FOSFOR *TRI-DOPED* KARBON DOT (N,S,P-CDs) UNTUK *ASSESSMENT* ION LOGAM Fe^{3+} DI LINGKUNGAN PERAIRAN

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INTISARI

Pengembangan N,S,P-CDs sebagai *fluorescent sensor* telah dilakukan dan dievaluasi karakter dan kemampuannya dalam mendeteksi ion logam Fe^{3+} di lingkungan perairan. N,S,P-CDs disintesis dari asam sitrat (CA) sebagai sumber karbon, asam merkapto suksinat (MSA), *o*-asam fosfat (PA), dan etilendiamin (EN) menggunakan metode *microwave*. Penelitian ini diawali dengan optimasi kondisi sintesis seperti waktu dan daya iradiasi *microwave*, jumlah penambahan asam MSA sebagai sumber doping S, PA sebagai sumber doping P, serta EN sebagai sumber doping N. N,S,P-CDs yang disintesis dengan kondisi optimum, dihitung nilai *quantum yield*-nya (QY), serta dievaluasi stabilitas intensitas fluoresensinya terhadap pH, kekuatan ion (NaCl dan KCl), lama paparan sinar UV, dan waktu penyimpanan dalam suhu ± 4 °C. Selektivitas, interferensi ion lain, dan sensitivitas N,S,P-CDs dalam mendeteksi ion Fe^{3+} juga dievaluasi sebagai parameter kelayakan *fluorescent sensor* dapat diaplikasikan ke sampel lingkungan perairan.

Hasil penelitian ini menunjukkan bahwa sintesis N,S,P-CDs optimum pada kondisi (60 detik, 450 W, 100 mg CA, 30 mg MSA, 25 mg PA, dan 50 mg EN) yang secara efektif meningkatkan %QY dari 1,61% (CDs) menjadi 53,03% (N,S,P-CDs). Keberhasilan proses doping dievaluasi menggunakan XPS dengan munculnya puncak N_{1s} , S_{2p} , dan P_{2p} , serta didukung oleh data FTIR. *Defect* struktur, morfologi, dan komposisi N,S,P-CDs dievaluasi menggunakan spektroskopi Raman, XRD, HR-TEM, SAED, dan EDS. Morfologi N,S,P-CDs berbentuk kuasi-sferis dengan diameter rata-rata 3,4 nm. N,S,P-CDs memiliki fotostabilitas yang baik pada rentang pH 3-9, kekuatan ion (NaCl dan KCl) hingga 1 M, paparan UV selama 120 menit, dan penyimpanan dalam suhu ± 4 °C selama 6 minggu. Mekanisme *quenching* dikaitkan dengan afinitas Fe^{3+} dan gugus permukaan N,S,P-CDs yang dapat dengan mudah membentuk kompleks dan agregat non-radiatif. *Fluorescent sensor* memiliki rentang linear dari 0-10 μM , dengan *limit of detection* (LoD) sebesar 0,1570 μM dan *limit of quantification* (LoQ) sebesar 0,5234 μM , serta selektivitas yang tinggi, bahkan dengan kehadiran ion interferensi lainnya. N,S,P-CDs berhasil diaplikasikan sebagai *fluorescent sensor* untuk *assessment* ion Fe^{3+} dari beberapa sampel air lingkungan dengan presisi yang tinggi (%RSD < 5%).

Kata Kunci : Karbon dot, Fe^{3+} , fluoresensi, *quenching*, *fluorescent sensor*.

DEVELOPMENT OF FLUORESCENT SENSOR BASED ON NITROGEN, SULFUR, PHOSPHORUS TRI-DOPED CARBON DOTS (N,S,P-CDs) FOR Fe^{3+} METAL IONS ASSESSMENT IN AQUATIC ENVIRONMENTS

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ABSTRACT

The development of N,S,P-CDs as a fluorescent sensor has been conducted and evaluated for its characteristics and ability to detect Fe^{3+} metal ions in aquatic environments. N,S,P-CDs were synthesized from citric acid (CA) as a carbon source, mercapto succinic acid (MSA), o-phosphoric acid (PA), and ethylenediamine (EN) using the microwave method. This research began with the optimization of synthesis conditions such as microwave irradiation time and power, the amount of MSA acid added as a source of S doping, PA as a source of P doping, and EN as a source of N doping. N,S,P-CDs synthesized under optimal conditions were characterized by their quantum yield (QY) value and evaluated for the stability of their fluorescence intensity against pH, ionic strength (NaCl and KCl), duration of UV exposure, and storage time at $\pm 4^{\circ}C$. The selectivity, interference from other ions, and sensitivity of N,S,P-CDs in detecting Fe^{3+} ions were also evaluated as parameters to assess the feasibility of the fluorescent sensor for application to water environmental samples.

The results of this research show that the optimum synthesis of N,S,P-CDs under conditions (60 seconds, 450 W, 100 mg CA, 30 mg MSA, 25 mg PA, and 50 mg EN) effectively increased the %QY from 1.61% (CDs) to 53.03% (N,S,P-CDs). The success of the doping process was evaluated using XPS with the appearance of N_{1s} , S_{2p} , and P_{2p} peaks, supported by FTIR data. The defect structure, morphology, and composition of N,S,P-CDs were evaluated using Raman spectroscopy, XRD, HR-TEM, SAED, and EDS. The morphology of N,S,P-CDs is quasi-spherical with an average diameter of 3.4 nm. N,S,P-CDs have good photostability in the pH range of 3-9, ionic strength (NaCl and KCl) up to 1 M, UV exposure for 120 minutes, and storage at $\pm 4^{\circ}C$ for 6 weeks. The quenching mechanism is associated with the affinity of Fe^{3+} and the surface groups of N,S,P-CDs, which can easily form non-radiative complexes and aggregates. The fluorescent sensor has a linear range from 0-10 μM , with a limit of detection (LoD) of 0.1570 μM and a limit of quantification (LoQ) of 0.5234 μM , as well as high selectivity, even in the presence of other interfering ions. N,S,P-CDs were successfully applied as a fluorescent sensor for the assessment of Fe^{3+} ions in various environmental water samples with high precision (%RSD < 5%).

Keywords : Carbon dots, Fe^{3+} , fluorescence, quenching, fluorescent sensor.