INTISARI

Fenomena *Harmful Algal Blooms (HABs)* yang disebabkan oleh *Cyanobacteria*. telah menjadi permasalahan serius dalam ekosistem perairan, karena dapat meningkatkan toksisitas, menurunkan kualitas air, dan membahayakan organisme akuatik. Penelitian ini bertujuan untuk mengevaluasi efektivitas bahan organik sebagai agen alami dalam mitigasi *Cyanobacteria* dengan pengujian terhadap parameter kualitas air. Selain itu, penelitian ini juga mengkaji pemanfaatan teknologi *Autonomous Unmanned Surface Vehicle (USV)* sebagai *platform* penyemprotan otomatis untuk memperluas jangkauan aplikasi ekstrak secara efisien dan sistem pemantauan kualitas air di perairan. Penelitian ini dilakukan di Embung Tirtoagung, Margoagung, Seyegan, Sleman, Daerah Istimewa Yogyakarta dan implementasi dilakukan dengan pemindahan air ke media uji berupa kolam dan aquarium.

Metode yang digunakan meliputi pendekatan *Theory of Inventive Problem Solving (TRIZ),* eksperimen dengan rancangan faktorial dan analisis statistik menggunakan uji ANOVA satu arah, uji ANOVA dua arah, uji normalitas *Shapiro–Wilk*, uji korelasi *Pearson*, serta uji lanjut *Post Hoc Tukey HSD*. Pengamatan dilakukan dalam dua skala (Laboratorium dan Lapangan) pada skala Lapangan menggunakan dua media perlakuan, yaitu dua aquarium dengan volume masing-masing 250 liter dan kolam dengan volume 4000 liter, selama 12 hari dengan pengukuran parameter kualitas air seperti warna, kekeruhan, TDS, pH, nitrat, nitrit, fosfat, klorofil-a, dan *Optical Density (OD)* pada 560 nm.

Berdasarkan hasil penelitian dari observasi didapatkan Embung Tirtoagung mengalami *HABs* yang disebabkan oleh *Cyanobacteria* dengan spesies dominan *Anabaena sp*. dipermukaan badan air. Pada konsentrasi tinggi variasi 25%, 50%, dan 100% dapat menurunkan jumlah sel *Anabaena sp.* dalam 2 hari dengan persentase penurunan hingga 76%, 77%, dan 86%. Eksperimen skala Lapangan dengan ekstrak kayu (*Caesalpinia sappan*) dengan perebusan selama 30 menit pada suhu 95 derajat Celcius efektif menurunkan populasi *Anabaena sp.*, dengan dosis 0,05 gram/100 mL (dosis 50%) dengan pemekatan 1:10 masing-masing sebesar (97%) pada media aquarium dan (100%) pada media kolam. Mekanisme penurunan populasi ditunjukkan oleh adanya disintegrasi struktur sel dan ruptur dinding sel yang mengindikasikan terjadinya lisis akibat aktivitas *Reactive Oxygen Species (ROS).* Analisis statistik menunjukkan bahwa ekstrak memberikan pengaruh signifikan ($p < 0,05$) terhadap parameter warna, TDS, pH, dan nitrat, sementara parameter kekeruhan, nitrit, dan fosfat tidak menunjukkan perbedaan yang signifikan. Nilai warna menunjukkan peningkatan melebihi ambang baku mutu air minum, sedangkan parameter lain masih berada dalam batas aman. Penggunaan USV terbukti mampu meningkatkan efektivitas pemurnian sebesar 3% dibandingkan metode manual, serta dapat menjangkau area delapan kali lebih luas secara merata. Selain itu, USV juga mendukung sistem pemantauan kualitas air secara langsung melalui sensor kekeruhan dan kamera optik, meskipun sensor absorbansi warna mengalami gangguan akibat interferensi pigmen merah dari ekstrak kayu secang (*Caesalpinia sappan*). Berdasarkan temuan tersebut, ekstrak kayu secang (*Caesalpinia sappan*) terbukti sebagai alternatif organik yang efektif dan ramah lingkungan dalam mitigasi *Cyanobacteria* jenis *Anabaena sp.,* serta berpotensi untuk diintegrasikan dengan teknologi otonom seperti USV sebagai pendekatan inovatif dan aplikatif dalam pengelolaan kualitas air yang berkelanjutan.

Kata kunci: *Caesalpinia sappan; Harmful Algal Blooms (HABs); Reactive Oxygen Species* (ROS); kualitas air; *Unmanned Surface Vehicle* (USV).

ABSTRACT

The phenomenon of *Harmful Algal Blooms (HABs)* caused by *Cyanobacteria* has become a serious problem in aquatic ecosystems, because it can increase toxicity, reduce water quality, and harm aquatic organisms. This study aims to evaluate the effectiveness of organic materials as natural agents in mitigating *Cyanobacteria* by testing water quality parameters. In addition, this study also examines the use of technology *Autonomous Unmanned Surface Vehicle (USV)* as *platform* automatic spraying to efficiently expand the reach of extract applications and water quality monitoring system in aquatic media. This research was conducted at the Tirtoagung Reservoir, Margoagung, Seyegan, Sleman, Yogyakarta Special Region, and implemented by transferring water to test media in the form of ponds and aquariums.

The methods used include *Theory of Inventive Problem Solving (TRIZ)*, experiment approach with factorial design and statistical analysis using one-way ANOVA test, two-way ANOVA test, normality test *Shapiro–Wilk*, correlation test *Pearson,* and further testing *Post Hoc Tukey HSD*. Observations were conducted on two scales (Laboratory and Field) on a field scale using two treatment media, those are two aquariums with a volume of 250 liters each and a pond with a volume of 4000 liters, for 12 days with measurements of water quality parameters such as color, turbidity, TDS, pH, nitrate, nitrite, phosphate, chlorophyll-a, and *Optical Density (OF)* at 560 nm.

Based on the research results from observations, it was found that the Tirtoagung Reservoir experienced *HABs* which is caused by *Cyanobacteria* with dominant species *Anabaena sp*. on the surface of the water body. At high concentrations, variations of 25%, 50%, and 100% can reduce the number of cells *Anabaena sp.* in 2 days with a percentage decrease of up to 76%, 77%, and 86%. Field scale experiment testing with wood extract (*Caesalpinia sappan*) by boiling for 30 minutes at a temperature of 95 degrees Celsius effectively reduces the population *Anabaena sp.,* with a dose of 0.05 grams/100mL (50% dose) with a concentration of 1:10, each of which is (97%) in aquarium media and (100%) in pond media. The mechanism of population reduction is indicated by the disintegration of cell structure and rupture of cell walls which indicates the occurrence of lysis due to the activity of *Reactive Oxygen Species (ROS).* Statistical analysis showed that the extract had a significant effect ($p < 0.05$) on color, TDS, pH, and nitrate parameters, while turbidity, nitrite, and phosphate parameters did not show significant differences. The color value showed an increase exceeding the drinking water quality standard threshold, while other parameters were still within safe limits. The use of USV was proven to be able to increase purification effectiveness by 3% compared to manual methods, and can cover an area eight times wider evenly. In addition, USV also supports a direct water quality monitoring system through a turbidity sensor and optical camera, although the color absorbance sensor experienced interference due to interference from the red pigment from sappanwood extract (*Caesalpinia sappan*). Based on these findings, sappanwood extract (*Caesalpinia sappan*) has been proven to be an effective and environmentally friendly organic alternative in mitigation *Cyanobacteria* type *Anabaena sp.*, and has the potential to be integrated with autonomous technologies such as USVs as an innovative and applicable approach to sustainable water quality management.

Keywords: *Caesalpinia sappan*; Harmful Algal Blooms (HABs); Reactive Oxygen Species (ROS); water quality; Unmanned Surface Vehicle (USV).