



INTISARI

Kendala efisiensi *backwash* (cuci balik) dialami sistem filtrasi air konvensional karena keterbatasan dalam penerapan kecepatan aliran tinggi yang berisiko menyebabkan terlepasnya media pasir dan stratifikasi. Kondisi ini memperpanjang durasi *backwash* dan mengurangi efisiensi operasional. Filter beton pasir hadir sebagai alternatif, karena mampu mengatasi keterbatasan tersebut dengan struktur media yang terikat dan kemampuan filtrasi yang sebanding dengan filter pasir. Namun, studi terdahulu mengindikasikan adanya pelepasan material filter selama proses *backwash* pada kecepatan tinggi dan menunjukkan potensi degradasi struktural pori. Penelitian ini bertujuan untuk mengkuantifikasi hubungan antara rasio pasir-semen terhadap permeabilitas filter beton serta pengaruh antara kecepatan *backwash* terhadap durabilitas pori media filter beton pada saat proses *backwash*.

Metodologi penelitian meliputi pembuatan benda uji, karakterisasi air, dan serangkaian pengujian: permeabilitas, porositas efektif, serta uji *backwash* selama 30 menit dengan lima variasi kecepatan aliran. Selama uji *backwash*, pengamatan perubahan tekanan dan pengukuran parameter kualitas air efluen (pH dan *Total Dissolved Solid*/TDS) dilakukan pada 13 interval waktu, diulang sebanyak tiga siklus. Analisis statistik menggunakan ANOVA dua faktor diterapkan untuk mengidentifikasi pengaruh siklus *backwash* dan rasio pasir-semen terhadap perubahan permeabilitas.

Setiap rasio pasir-semen memiliki karakteristik hidraulik yang khas, dengan rentang konduktivitas hidraulik (K) terukur 0,047 hingga 0,076 cm/s untuk $m=6,4$, 0,037 hingga 0,068 cm/s untuk $m=5,4$, dan 0,016 hingga 0,028 cm/s untuk $m=4,3$, pada rentang debit *backwash* 760,9 hingga 2500,7 cm³/s. Rasio pasir-semen 5,4:1 menunjukkan stabilitas K yang relatif lebih baik dan kemampuan pemulihan setelah penurunan awal. Konduktivitas hidraulik filter secara umum menurun seiring siklus *backwash*, mengindikasikan akumulasi penyumbatan dan/atau reorganisasi pori. Persentase selisih K antar rasio mengkonfirmasi hubungan non-linier antara rasio pasir-semen dan konduktivitas hidraulik, selisih antara $m=5,4$ dan $m=4,3$ jauh lebih lebar (42,24% hingga 61,35%) dibandingkan $m=6,4$ dan $m=5,4$ (5,73% hingga 31,27%), menunjukkan perbedaan struktur internal yang signifikan pada $m=4,3$. Analisis ANOVA mengkonfirmasi bahwa siklus *backwash* dan rasio pasir-semen keduanya secara signifikan memengaruhi perubahan konduktivitas hidraulik (nilai $p < 0,05$), tetapi tidak ada interaksi signifikan antar keduanya ($p > 0,05$). Pemantauan pH dan TDS efluen memberikan indikasi awal terjadinya *leaching* material, meskipun detailnya memerlukan analisis lebih lanjut.

Kata kunci: Filter beton pasir, Cuci balik, Permeabilitas, Rasio pasir-semen, Durabilitas pori



ABSTRACT

Conventional water filtration systems experience backwash efficiency limitations due to constraints in applying high flow velocities, which risk sand media dislodgement and stratification. This condition extends backwash duration and reduces operational efficiency. Concrete sand filters emerge as an alternative, capable of overcoming these limitations with their bound media structure and filtration capabilities comparable to sand filters. However, previous studies indicate the release of filter material during high-velocity backwash, suggesting potential structural pore degradation. This research aims to quantify the relationship between the sand-to-cement ratio and concrete filter permeability, as well as the effect of backwash velocity to pore durability of concrete filter media during the backwash process.

The research methodology encompassed specimen fabrication, water characterization, and a series of tests: permeability, effective porosity, and backwash tests conducted for 30 minutes with five variations in flow velocity. During backwash, observations of pressure changes and measurements of effluent water quality parameters (pH and Total Dissolved Solids/TDS) were performed at 13-time intervals, repeated over three cycles. A two-factor ANOVA statistical analysis was applied to identify the influence of backwash cycles and the sand-to-cement ratio on permeability changes.

Each sand-cement ratio exhibited distinct hydraulic characteristics. The measured hydraulic conductivity (K) ranged from 0.047 to 0.076 cm/s for $m=6.4$, 0.037 to 0.068 cm/s for $m=5.4$, and 0.016 to 0.028 cm/s for $m=4.3$, with backwash flow rates spanning 760.9 to 2500.7 cm³/s. The 5.4:1 sand-cement ratio demonstrated relatively better K stability and recovery capability after initial decline. Filter hydraulic conductivity generally decreased with successive backwash cycles, indicating an accumulation of clogging and/or particle rearrangement. The percentage difference in K among ratios confirmed a non-linear relationship between the sand-cement ratio and hydraulic conductivity, the disparity between $m=5.4$ and $m=4.3$ was significantly wider (42.24% to 61.35%) compared to that between $m=6.4$ and $m=5.4$ (5.73% to 31.27%), highlighting a substantial difference in the internal structure of $m=4.3$. ANOVA confirmed that both backwash cycles and sand-cement ratios significantly influenced changes in hydraulic conductivity ($p<0.05$), but no significant interaction between them was observed ($p>0.05$). Monitoring effluent pH and TDS provided initial indications of material leaching, though further detailed analysis is required.

Keyword: Concrete sand filter, Backwash, Permeability, Sand-cement ratio, Pore durability