Manajemen Kesehatan dan Keselamatan Kerja (K3) dalam Pengendalian Paparan Extended Spectrum ?-Lactamase (ESBL) E. coli terhadap Pekerja di Peternakan: Pendekatan One Health = Occupational Safety and Health (OSH) Management in Controlling Extended Spectrum Î²-Lactamase (ESBL) E. coli Exposure to Workers in Farms: A One Health Approach

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Abstrak

Paparan biologis akibat resistensi antimikroba (AMR), khususnya ESBL E. coli di peternakan, menjadi ancaman kesehatan kerja dan global. Kesehatan dan Keselamatan Kerja (K3) berperan penting dalam melindungi pekerja dari risiko tersebut. Studi ini bertujuan mengidentifikasi hotspot ESBL E. coli di peternakan terpadu dan merancang intervensi optimal berbasis logika fuzzy untuk meningkatkan K3 dalam kerangka One Health. Studi ini menggunakan metode HAZOP – Delphi untuk menentukan 12 lokasi pengambilan sampel secara sistematis. Sebanyak 134 sampel dari berbagai sumber di peternakan dikumpulkan untuk isolasi dan karakterisasi ESBL E. coli, termasuk analisis genom utuh (WGS) terhadap 18 isolat. Paparan pekerja terhadap feses diukur melalui studi eksperimental, dengan memperkirakan fecal ingestion rate. Risiko paparan E. coli dan ESBL E. coli dianalisis menggunakan pendekatan QMRA dan metode William T. Fine. Skenario intervensi K3 – One Health dirancang dan diprioritaskan menggunakan logika fuzzy dua tahap untuk menentukan strategi perlindungan pekerja yang paling efektif. ESBL E. coli ditemukan pada 34,6 (45/130) contoh uji, konsentrasi tertinggi pada pupuk asal unggas (7,4 log CFU/g) dan feses broiler (6,7 log CFU/g). Analisis WGS menunjukkan adanya gen pembawa kode resisten dan peluang E. coli patogen ekstraintestinal (ExPEC E. coli). Hotspots utama ditetapkan pupuk asal unggas, feses broiler dan feses itik, seluruhnya berada di peternakan unggas. Rata-rata incidental fecal ingestion rate oleh pekerja bervariasi dari 0,3 – 23,5 mg/hari (unggas) dan 6,8 - 8,6 mg/hari (ruminansia). Setelah paparan ESBL E. coli dihitung dari perkalian antara konsentrasi bakteri dengan fecal ingestion rate, diperoleh nilai tertinggi berasal dari pupuk unggas (median >5.000 log10 CFU/d, skor risiko William T. Fine 80 - 110). Usulan intervensi berupa program kontrol K3 – One Health meliputi: substitusi (alat semi-otomatis, reduksi fecal ingestion rate 50%), kontrol teknik (penyimpanan pakan di silo mereduksi paparan E. coli 81,1 – 87,6%; modifikasi pengomposan mereduksi ESBL E. coli 40 - 63%; barrier rumah kompos mereduksi E. coli hampir 100%), dan pemakaian APD (mengurangi ingesti sekitar 99%). Pekerja di area unggas menjadi prioritas, dan program K3 – One Health yang mengkombinasikan reduksi paparan 60 - 100% dengan pemilihan biaya menengah hingga tinggi dipilih berdasarkan logika fuzzy. Diproyeksikan intervensi terpilih mampu mengurangi paparan E. coli dan ESBL E. coli dengan rata-rata reduksi sebesar 62,6% [60.5 – 64.7% CI]. Keberhasilan program juga ditopang oleh platform logika fuzzy dan strategi adaptif lintas sektor peternakan.

.....This comprehensive study aimed to identify hotspots of ESBL E. coli in an integrated farm and develop optimal intervention scenarios using fuzzy logic to enhance occupational health and safety (OHS) within the One Health framework. Biological exposure due to antimicrobial resistance (AMR), particularly ESBL E. coli in farms, poses a threat to occupational and global health. OHS plays a crucial role in protecting

workers from these risks. This study employed the HAZOP–Delphi method to systematically determine 12 sampling locations. A total of 134 samples from various farm sources were collected for ESBL E. coli isolation and characterization, including whole genome sequencing (WGS) of 18 isolates. Worker exposure to stool was measured experimentally by estimating fecal ingestion rates. The risk of exposure to E. coli and ESBL E. coli was analyzed using QMRA and the William T. Fine methods. OHS–One Health intervention scenarios were designed and prioritized using a two-stage fuzzy logic approach to determine the most effective worker protection strategies. ESBL E. coli was detected in 34.6% (45/130) of samples, with the highest concentrations found in poultry fertilizer (7.4 log CFU/g) and broiler stools (6.7 log CFU/g). WGS analysis revealed the presence of resistance genes and the potential presence of extraintestinal pathogenic E. coli (ExPEC). Key hotspots were identified as poultry fertilizer, broiler stools, and duck stools, all located in poultry farms. The average incidental fecal ingestion rates by workers ranged from 0.3–23.5 mg/day (poultry) and 6.8–8.6 mg/day (ruminants). Exposure to ESBL E. coli, calculated by multiplying bacterial concentration with ingestion rate, was highest from poultry manure (median >5,000 log CFU/day; William T. Fine risk score: 80–110). Proposed interventions for the OHS–One Health program include substitution (semi-automatic tools reducing ingestion rate by 50%), engineering controls (feed storage in silos reducing E. coli exposure by 81.1–87.6%; composting modifications reducing ESBL E. coli by 40–63%; compost house barriers reducing E. coli by nearly 100%), and use of PPE (reducing ingestion by ~99%). Poultry area workers were prioritized, and the selected OHS–One Health program combined 60–100% exposure reduction with medium-to high-cost options, chosen via fuzzy logic. The projected outcome was an average reduction in E. coli and ESBL E. coli exposure by 62.6% [CI: 60.5–64.7%]. The program will be succeeded by fuzzy logic platform adaptation and dynamic cross-sectoral strategies in livestock farming.