

**ASSESSING CONCENTRATION PATTERNS,
SOURCE APPORTIONMENT, AND EXPOSURE
RISKS OF PFAS IN INDOOR AND OUTDOOR
DUST IN IQUITOS, PERU**

UNDERGRADUATE THESIS



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for the Degree of Bachelor of Engineering (S.T.)
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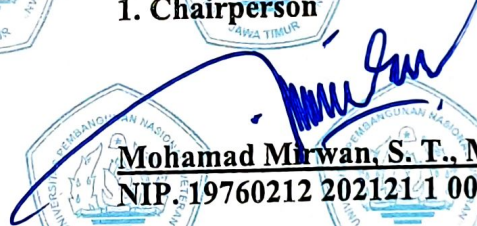
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PREFACE

Praise be to God Almighty, for His endless grace and blessings, the author has successfully completed this undergraduate thesis entitled "Assessing Concentration Patterns, Source Apportionment, and Exposure Risks of PFAS in Indoor and Outdoor Dust in Iquitos, Peru". This thesis was compiled as one of the requirements to obtain a Bachelor's degree in the Environmental Engineering Study Program, Faculty of Engineering and Science, Universitas Pembangunan Nasional "Veteran" Jawa Timur.

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The author realizes that this thesis is still far from perfect. Therefore, constructive criticism and suggestions are highly expected to improve this research. Hopefully, this thesis can provide benefits to readers and contribute to the field of Environmental Engineering.

Surabaya, 17th April 2026
Author

Nandina Salsabila Putri Santana

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ABSTRACT

Despite the ubiquitous threat of per- and polyfluoroalkyl substances (PFAS), comparative assessments of their accumulation across contrasting urban microenvironments remain notably scarce in developing Amazonian cities. To bridge this knowledge deficit, the occurrence, emission origins, and exposure hazards of settled dust were systematically evaluated across diverse enclosed facilities and ambient public spaces in Iquitos, Peru. Forty-three particulate samples (29 indoor, 14 outdoor) were quantified via liquid chromatography-tandem mass spectrometry (LC-MS/MS), coupled with advanced receptor modelling. Spatial analysis revealed that interior zones act as heavier pollution sinks dominated by specific fluorotelomers (6:2 diPAP and 8:2 diPAP), whereas exterior environments were heavily characterized by 6:2 fluorotelomer sulfonate (6:2 FTS), which constituted over half of the ambient analyte mass. Multivariate apportionment leveraging Positive Matrix Factorization (PMF) and Principal Component Analysis (PCA) delineated a bifurcated emission landscape. Interior contamination was linked to six complex sources ranging from legacy furniture coatings to modern electronics containing LiTFSI while exterior pollution was driven by three primary factors: industrial surfactant runoff, vehicle-related abrasion, and waste degradation. Furthermore, toxicological modelling highlighted severe pediatric vulnerabilities in both settings, with Hazard Quotients for specific compounds (such as PFOA indoors and 6:2 FTCA outdoors) exponentially exceeding safe thresholds. Ultimately, this dual-matrix investigation provides foundational evidence of pervasive fluorinated contamination in the region, demonstrating that both internal infrastructures and external high-traffic zones serve as critical repositories requiring targeted regulatory action.

Keywords: PFAS, Indoor and Outdoor Dust, Iquitos, Source Apportionment, Risk Assessment

ABSTRAK

Meskipun ancaman per- and polyfluoroalkyl substances (PFAS) ada di mana-mana, penilaian komparatif mengenai akumulasinya di berbagai lingkungan mikro perkotaan yang kontras masih sangat jarang dilakukan di kota-kota berkembang di kawasan Amazon. Untuk menjembatani kesenjangan pengetahuan ini, keberadaan, sumber emisi, dan bahaya paparan dari debu yang mengendap dievaluasi secara sistematis di berbagai fasilitas tertutup dan ruang publik terbuka di Iquitos, Peru. Sebanyak empat puluh tiga sampel partikulat (29 dalam ruangan, 14 luar ruangan) dikuantifikasi menggunakan liquid chromatography-tandem mass spectrometry (LC-MS/MS), yang dikombinasikan dengan pemodelan reseptor tingkat lanjut. Analisis spasial mengungkapkan bahwa zona interior bertindak sebagai tempat pengendapan polusi yang lebih berat dan didominasi oleh fluorotelomer spesifik (6:2 diPAP dan 8:2 diPAP), sedangkan lingkungan eksterior sangat dikarakterisasi oleh 6:2 fluorotelomer sulfonat (6:2 FTS), yang menyusun lebih dari separuh massa analit ambien. Kontribusi sumber (source apportionment) multivariat yang memanfaatkan Positive Matrix Factorization (PMF) dan Analisis Komponen Utama (PCA) menggambarkan dua pola emisi yang berbeda. Kontaminasi dalam ruangan dikaitkan dengan enam sumber kompleks mulai dari pelapis furnitur lama hingga barang elektronik modern yang mengandung LiTFSI sementara polusi luar ruangan didorong oleh tiga faktor utama: limpasan surfaktan industri, abrasi terkait kendaraan, dan degradasi limbah. Lebih lanjut, pemodelan toksikologi menyoroti kerentanan yang parah pada anak-anak di kedua pengaturan tersebut, dengan Nilai Kuosien Bahaya (Hazard Quotient/HQ) untuk senyawa tertentu (seperti PFOA di dalam ruangan dan 6:2 FTCA di luar ruangan) secara eksponensial melampaui ambang batas aman. Pada akhirnya, investigasi matriks ganda ini memberikan bukti mendasar mengenai kontaminasi senyawa berfluorinasi yang tersebar luas di wilayah tersebut, serta menunjukkan bahwa infrastruktur internal dan zona eksternal berlalu lintas tinggi berfungsi sebagai reservoir kritis yang memerlukan tindakan regulasi yang tepat sasaran.

Kata kunci: PFAS, Debu Dalam dan Luar Ruangan, Iquitos, Pembagian Sumber, Penilaian Risiko