CHAPTER 1
INTRODUCTION

1.1 Background

Per- and polyfluoroalkyl substances (PFAS) constitute a large class of synthetic chemicals that have been extensively incorporated into consumer products, industrial processes, and firefighting foams due to their exceptional resistance to oil, water, and heat. PFAS are highly persistent, bioaccumulative, and increasingly linked to serious adverse health outcomes, including endocrine disruption, immunotoxicity, and elevated cancer risk. Their extreme resistance to degradation has earned them the designation "forever chemicals," as they can persist for decades while continuously cycling among air, water, soil, dust, and biota, creating long-term and difficult-to-control exposure pathways (Hofman et. al., 2026).

Recent evidence underscores the urgency of addressing PFAS transport through the atmosphere. PFAS preferentially accumulate at the air–water interface (AWI), facilitating their enrichment in surface microlayers and subsequent transfer into aerosols. This process enhances atmospheric transport and deposition, ultimately contributing to the contamination of terrestrial environments and drinking water sources (Fang et. al., 2026). As a result, human exposure is no longer limited to contaminated food and water but increasingly occurs via inhalation of PFAS-laden particles that settle into outdoor dust. Despite this emerging understanding, airborne and dust-associated PFAS pathways remain insufficiently characterized in many regions of the world.

Outdoor dust has therefore emerged as a critical but under-studied medium for PFAS exposure. Dust readily adsorbs PFAS originating from consumer products, industrial emissions, and atmospheric deposition, particularly in densely populated and industrialized areas. Studies from North America, Europe, and Asia demonstrate substantial spatial variability in PFAS concentrations in dust, reflecting differences in industrial activity, consumption patterns, and urban density (Ehsan et. al.2023; Yamazaki et. al., 2023). In contrast, data from Latin America are extremely limited. This lack of information is especially concerning in countries such as Peru, where rapid urbanization, uneven industrial development, and variable environmental governance may create complex and poorly understood exposure scenarios.

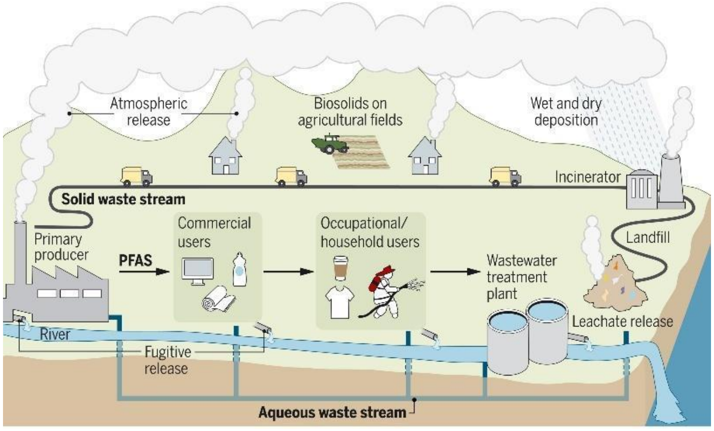

Figure 1.1 The PFAS Life Cycle
Source: Evich et. al., 2022

While outdoor pathways are increasingly recognized, indoor environments represent an equally urgent concern. Given that individuals spend approximately 90% of their time indoors, PFAS accumulation in indoor air and dust may constitute a dominant exposure route. Studies in China have reported indoor PFAS concentrations one to two orders of magnitude higher than outdoor levels, with strong correlations between PFAS in household dust and human serum, indicating dust ingestion as a major exposure pathway. Similarly, the U.S. Indoor PFAS Assessment (IPA) Campaign identified inhalation of indoor air as accounting for over 65% of non-dietary PFAS intake, driven largely by neutral precursor compounds such as fluorotelomer alcohols (FTOHs), which can biotransform into more persistent ionic PFAS. Alarmingly, investigations in U.S. childcare facilities revealed elevated PFAS concentrations in indoor dust and nap mats, with exposure estimates indicating that children face disproportionately higher risks due to hand-to-mouth behavior and close contact with contaminated surfaces. These findings collectively highlight indoor dust as a critical and often overlooked vector of PFAS exposure, particularly for vulnerable populations.

Peru represents a pressing and understudied context for investigating PFAS contamination in both indoor and outdoor dust. Major urban centers, including Lima, are undergoing rapid population growth and industrial expansion (Fabry & Maertens, 202), conditions that may intensify PFAS emissions and accumulation in urban environments. At the same time, rural and peri-urban regions are not necessarily insulated from PFAS exposure, as imported consumer goods and long-range atmospheric transport can introduce contamination even in areas with limited industrial activity. Indoor settings, ranging from private residences to childcare facilities and workplaces, are likewise expected to exhibit distinct PFAS profiles shaped by product use, building materials, and occupant behavior. In this context, dust functions as both an integrative indicator of local PFAS contamination and a direct exposure medium via inhalation, ingestion, and dermal contact.

To address these critical knowledge gaps, this study focuses on Iquitos, a rapidly expanding urban center in the Peruvian Amazon. Its tropical climate, relative geographic isolation, and increasing urbanization provide a unique opportunity to investigate PFAS exposure pathways in a setting that is largely absent from the current global literature.

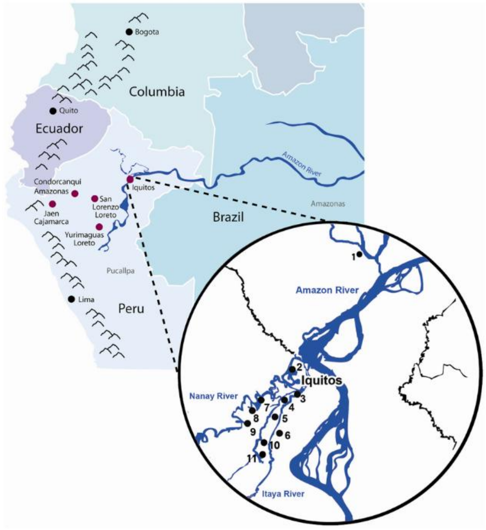

Figure 1.2 Map of Iquitos and the Peruvian Amazon
Source (Gamboa et. al., 2010)

This study evaluates PFAS concentrations in indoor and outdoor dust from Iquitos by comparing spatial patterns, identifying potential sources, and estimating inhalation exposure for both adults and children. By generating the first location-specific evidence for this region, the findings aim to inform environmental health risk assessments and support the development of more effective chemical management and regulatory strategies in Peru and across Latin America.

1.2 Problem Statements

1. How was the PFAS concentration from indoor and outdoor dust in Iquitos, Peru?
2. What was the source apportionment of indoor and outdoor PFAS in dust in Iquitos, Peru?
3. How was the exposure assessment of PFAS in indoor and outdoor dust to adults and children in Iquitos, Peru?

1.3 Objectives

1. Identify PFAS concentrations from indoor and outdoor dust in Iquitos, Peru.

2. Calculate the exposure assessment of PFAS in indoor and outdoor dust to adults and children in Iquitos, Peru.
3. Analyse the source apportionment of indoor and outdoor PFAS in dust in Iquitos, Peru.

1.4 Benefits

1. Researcher
   Provides practical experience in assessing PFAS concentration patterns, source apportionment, and inhalation exposure risks in both indoor and outdoor dust.
2. Institution
   Strengthens institutional expertise in emerging contaminant research by producing one of the first integrated case studies on indoor and outdoor PFAS in Iquitos, Peru.
3. Science and Technology
   Advances global understanding of PFAS distribution in different microenvironments and contributes methodological insights into source apportionment and exposure assessment.
4. Society
   Raises public awareness of PFAS contamination in daily living spaces and highlights potential health risks, supporting evidence-based environmental policy and protection measures in Iquitos, Peru.

1.5 Scopes

1. 29 indoor dust samples and 14 outdoor dust samples from different areas in Iquitos, Peru.
2. This research identifies 15 selected PFAS compounds and quantifies them via LC-MS/MS.
3. The primary data will only consist of PFAS quantity and profiles. Another dataset was used as secondary data.
4. Samples are taken with a single sampling period (9-11 January 2026); hence, results represent a snapshot in time rather than long-term trends.
5. The sampling method was done manually using a vacuum cleaner with a brush.