

Appendix III

SPR framework for three study cities

Development of Microplastics Source-Path-Receptor (SPR) framework for Southeast Asian (SEA) Cities

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Summary

The Microplastic (MP) SPR frameworks were developed for a typical urban sewage management context in Southeast Asia (SEA) and subsequently adapted to the practical environmental management conditions of three study cities: Bangkok Metropolitan Administration (BMA), Ho Chi Minh City (HCMC), and Jakarta (JKT). These frameworks identify five primary sources of MP pollution: domestic sewage, industrial wastewater, atmospheric deposition, agricultural runoff, and livestock wastewater. The major pathways within urban systems include stormwater runoff, transport through sewer networks, and wastewater treatment plants. The key endpoints of MP accumulation were defined and quantified as retention on land surfaces, discharge into surface water bodies, and deposition with sludge. This document outlines the underlying assumptions used in establishing the MP SPR framework for Southeast Asian cities, presents the tailored frameworks for the study cities, and details the MP flux flowcharts that trace flows from each primary source through identified pathways to their respective endpoints. It further describes the MP mass balance models and specifies the data requirements and outputs for quantifying MP influxes.

1. Delineation of the boundary of study area

1.1 Boundary identification

Territory-based accounting theme for emission measurement is adopted. Territory-based accounting refers to systems and methods for tracking and allocating resources, expenses, or emissions based on defined geographical or economic regions, such as internal sales territories, administrative regions, or national boundaries. This approach distinguishes itself from residence-based accounting, which focuses on the characteristics of the residents rather than the location of the activity. In this project, the administrative boundaries of Bangkok Metropolitan Administration (BMA), Ho Chi Minh City (HCMC), and Jakarta (JKT) city are applied.

1.2 Land use classification (data for 2023 or 2024, land use type: urban build-up area, water surface, agricultural land: paddy land & upland agriculture, other naked soil surface)

Land use and land cover reclassification is carried support the quantification of areas corresponding to different MP sources in this work. Specifically, the land use of three study cities are classified into urban build-up area, water surface, paddy land, upland agriculture, other naked soil surface (including forest, grass land, and miscellaneous).

Conceptual framework of microplastics SPR in SEA cities.

1. The adapted framework is applied for BMA.

The Bangkok framework illustrates the integrated flow of pollutants and microplastics (MPs) through the city's urban water management system, highlighting the interaction between engineered infrastructures and natural hydrological pathways. Bangkok, a low-lying deltaic megacity situated on the Chao Phraya River floodplain, is characterized by its flat topography, tidal influence, and extensive canal network. The city operates a combined sewer system in which domestic sewage, industrial effluents, and stormwater runoff are conveyed through shared pipelines managed by the Bangkok Metropolitan Administration. Within this system, domestic sewage represents the most continuous source of pollution, with part of the flow directed to centralized wastewater treatment plants (WWTPs) and the remaining portion discharged untreated into canals. Industrial wastewater follows a similar pathway, with some effluent pretreated at industrial wastewater treatment plants (IWWTPs) and others released directly to the municipal drainage system. During rainfall events, storm runoff plays a significant role in resuspending deposited solids and mobilizing pollutants into the canal network. Atmospheric deposition also contributes diffuse inputs, as airborne particles accumulate on impervious surfaces and are washed into drains and canals. In peri-urban areas, agricultural runoff and livestock wastewater intermittently enter the system through surface runoff and land retention zones, particularly during the monsoon season. All these flows eventually converge within Bangkok's extensive canal system, which serves both as drainage infrastructure and as the final receiving water body before discharging into the Chao Phraya River. This framework demonstrates how the city's interconnected sewerage, drainage, and natural hydrological systems collectively influence the generation, transport, and retention of pollutants within a complex deltaic environment.

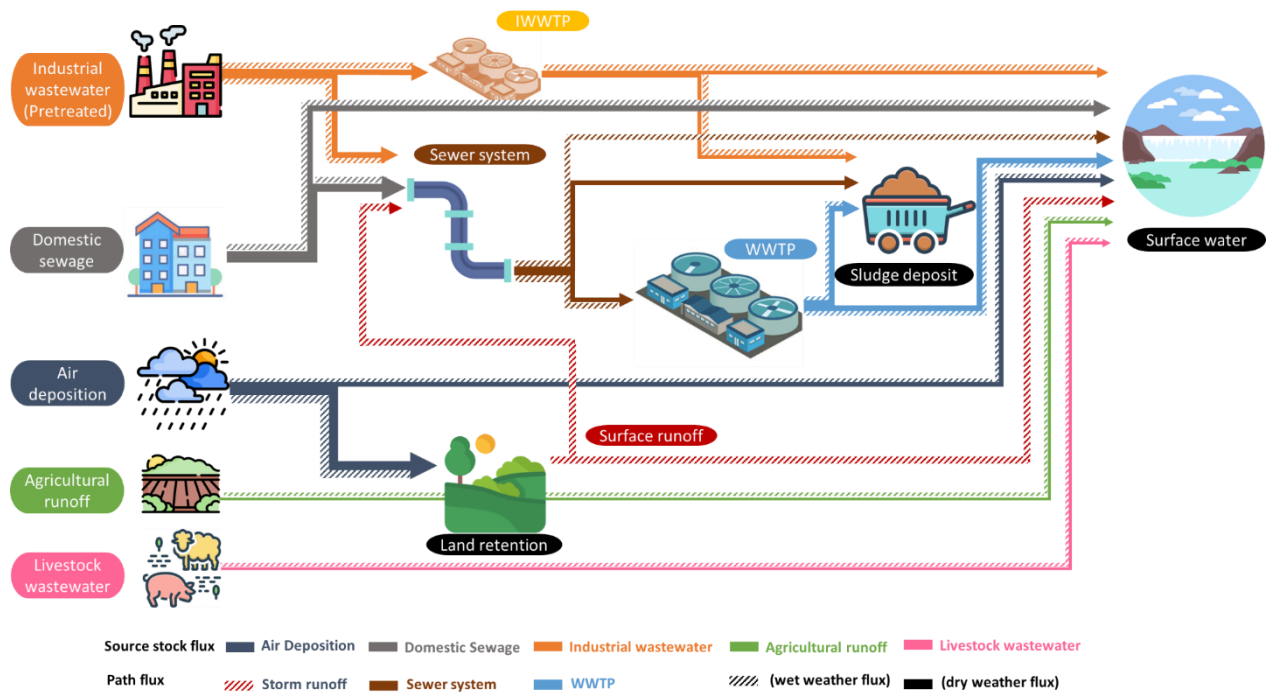


Fig. 1 Conceptual framework of microplastics SPR in SEA cities. The adapted framework is applied for BMA.

2. The adapted framework is applied for HCMC.

The framework illustrates the conceptual flow of microplastics (MPs) through the urban water system of Ho Chi Minh City (HCMC). It describes how pollutants from various sources domestic sewage, industrial wastewater, atmospheric deposition, agricultural runoff, and livestock wastewater are generated and transported through interconnected pathways toward surface waters. The city lies on the Saigon–Dong Nai River delta, characterized by flat terrain, tidal influence, and a tropical monsoon climate, which strongly affect runoff, overflow, and drainage behavior.

HCMC's drainage system consists of a mix of combine sewers, open canals, and ditches, which convey wastewater and stormwater across the urban area. Domestic and industrial wastewater enter the sewer system, where solids may settle, resuspend during rainfall, or be partially treated in wastewater treatment plants (WWTPs) and industrial WWTPs (IWWTPs). Meanwhile, surface runoff generated during rainfall mobilizes deposited particles and pollutants from roads, rooftops, and agricultural lands, carrying them into canals and rivers. Some of these flows are temporarily stored in low-lying retention areas before reaching surface waters.

Ultimately, all pathways converge toward the Saigon and Dong Nai Rivers, which act as the city's final receiving waters before discharge into the South China Sea. The framework highlights the close interaction between engineered infrastructure (sewers, treatment plants) and natural hydrological processes (rainfall, surface runoff, and tidal canals), providing an integrated understanding of how pollutants particularly MPs are transported, retained, and discharged within Ho Chi Minh City's urban water environment.

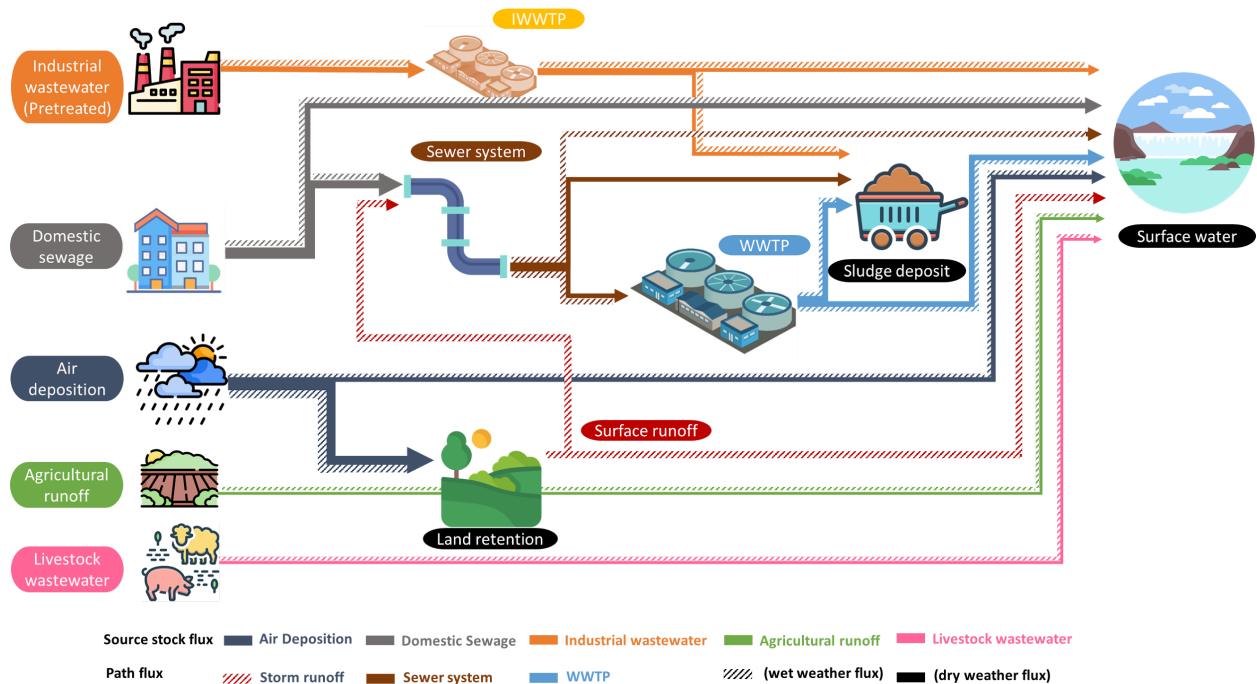


Fig. 2 Conceptual framework of microplastics SPR in SEA cities. The adapted framework is applied for CHMC.

3. The adapted framework is applied for JKT.

The framework illustrates the conceptual flow of pollutants and microplastics (MPs) within the urban water system of Jakarta, highlighting how major sources are transported through interconnected pathways toward surface waters. The five key sources include domestic sewage, industrial wastewater, atmospheric deposition, agricultural runoff, and livestock wastewater. These are distributed through both engineered systems and natural hydrological routes, reflecting Jakarta's complex and fragmented drainage structure.

Jakarta, a low-lying coastal megacity located on the Ciliwung–Cisadane River delta, faces the Jakarta Bay in the Java Sea. The city's flat terrain, tidal influence, frequent flooding, and tropical monsoon climate strongly influence wastewater transport and accumulation. Unlike cities with more integrated sewer systems, Jakarta's formal sewer coverage is limited, serving only small portions of the central area. Most domestic wastewater, including both greywater and blackwater, is discharged untreated through open drains, septic tank effluents, and neighborhood canals that flow directly to receiving waters.

Industrial wastewater contributes another major flow, especially from industrial zones. While some large factories have pretreatment systems, many small and medium enterprises discharge effluents directly into canals, bypassing centralized wastewater treatment plants (WWTPs). This distinguishes Jakarta's system from those of Bangkok or Ho Chi Minh City, where partial centralized treatment exists.

Atmospheric deposition remains a widespread diffuse input, with airborne microplastic particles settling over the city and being washed off by rainfall into surface runoff. Agricultural runoff and livestock wastewater occur mainly in peri-urban areas, contributing pollutants to drainage canals during wet-season flows or irrigation discharge. These rural and semi-urban areas act as additional diffuse sources that merge into the city's open drainage system.

Because Jakarta lacks an integrated sewer-pumping system, stormwater and runoff are largely gravity-fed directly into canals and rivers. Water and contaminants then flow into Jakarta Bay, which serves as the city's final receiving water body. The framework thus captures how surface runoff, untreated discharges, and limited treatment capacity together define Jakarta's urban water dynamics, where pollutants and MPs are continuously mobilized and conveyed from land-based sources to the aquatic environment.

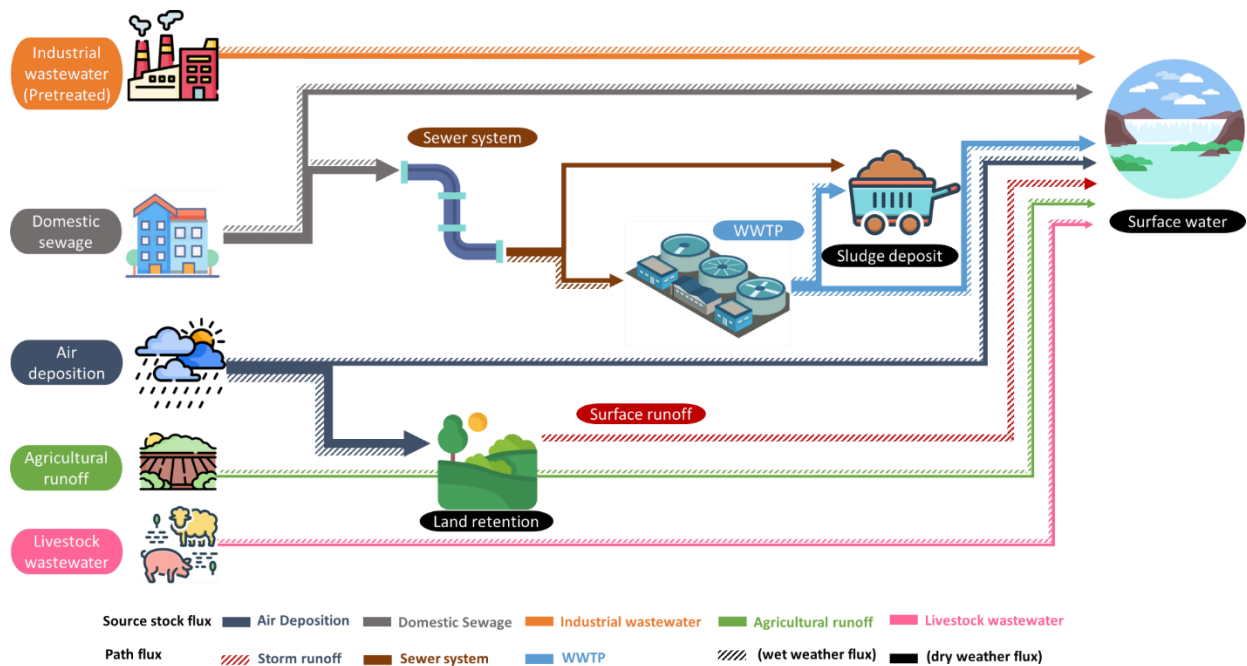


Fig. 3 Conceptual framework of microplastics SPR in SEA cities. The adapted framework is applied for JKT.