Microplastic Contamination in Deep Confined Aquifers of the Lower Chao Phraya Basin: Implications for Groundwater Resilience

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ABSTRACT

Confined aquifers are conventionally regarded as protected from surface-derived contaminants by low-permeability aquitards, yet the extent to which this protection holds for emerging contaminants such as microplastics (MPs) remains poorly tested. This study investigates MP occurrence and physical characteristics in seventeen wells tapping the Nakhon Luang and Nonthaburi confined aquifers of the Lower Chao Phraya Basin, Thailand, as part of a 2025/26 field campaign. Each 5 L groundwater sample was filtered, digested in 30% hydrogen peroxide, and separated by density in saturated sodium chloride solution, then counted and characterized under a stereomicroscope with hot-needle confirmation. Microplastics were detected in all seventeen wells, with concentrations ranging from 0.40 to 7.00 particles per litre (mean 2.25 ± 2.20, median 1.00). Of the 191 confirmed particles, fragments accounted for 54.5% and fibres 45.5%; no films were recorded. Green, white, and blue were the dominant colours, together accounting for 71.5% of characterized particles. Fourier-transform infrared spectroscopy on a representative subsample identified polyethylene and polypropylene as present polymer types. Despite the protective role of the confining Bangkok Clay, contamination was detected throughout the sampled wells, suggesting that borehole construction and well-casing integrity, rather than aquifer confinement alone, govern microplastic vulnerability in this system. These findings indicate that structural protection from surface contamination is partial rather than absolute, with implications for the long-term resilience of confined groundwater resources under increasing anthropogenic and climatic pressure. This baseline dataset provides a foundation for future spatial and predictive modelling of contamination drivers across the basin's confined aquifer system.

Keywords: microplastics/ groundwater/ confined aquifer/ Lower Chao Phraya Basin/ resilience

1. INTRODUCTION

Microplastics (MPs), plastic particles smaller than 5 mm, are now recognized as ubiquitous environmental contaminants detected across terrestrial, atmospheric, and aquatic compartments worldwide [1]. Global plastic production has risen from approximately 2 million tonnes in 1950 to more than 400 million tonnes annually, with continued growth projected [1]. While marine and surface water systems have received sustained scientific attention, groundwater remains a comparatively understudied compartment of the plastic pollution cycle, despite supplying an estimated 30% of global freshwater resources and serving as the primary drinking water source for more than two billion people [2]. Groundwater was historically regarded as naturally protected from particulate contaminants through filtration within soil and geological formations. This assumption is increasingly challenged by field evidence demonstrating that microplastics can infiltrate aquifer systems under specific hydrogeological and anthropogenic conditions [3]. Confined aquifers, isolated from the surface by low-permeability aquitards, are conventionally assumed to carry the lowest contamination risk among groundwater types. Yet this assumption rests principally on the behaviour of the aquifer matrix itself and does not fully

account for the artificial pathways introduced by groundwater abstraction infrastructure: water-well construction can bypass the aquitard layers that would otherwise provide natural protection to deeper and confined aquifers [4]. Microplastics have been documented even in deep, ostensibly well-protected groundwater: Kim et al. [5] detected MPs in wells on Jeju Island, Korea, at depths where the water table lay 143 m below ground surface. Thailand exemplifies the environmental pressures associated with rapid plastic consumption growth and inadequate waste management infrastructure characteristic of much of Southeast Asia [3]. The Lower Chao Phraya Groundwater Basin, encompassing the Nakhon Luang and Nonthaburi confined aquifers, is among the country's most heavily utilized groundwater systems, supplying drinking water, agriculture, and industry across one of Thailand's most densely populated and industrialized regions. The basin's aquifer units are vertically separated by the low-permeability Bangkok Clay, which restricts direct vertical fluid exchange under normal conditions. However, inter-aquifer migration pathways can exist where this confining layer is locally thin or discontinuous, where poorly sealed well casings create hydraulic short-circuits, or where sustained over-pumping induces downward hydraulic gradients [6]. A prior investigation of these aquifers reported MP concentrations of 0.10 to 2.70 particles per litre in the dry season and up to 4.00 particles per litre in the wet season, with the Nakhon Luang aquifer recording the highest mean concentration among the units sampled [6]. If confinement alone governed MP vulnerability, the Nakhon Luang and Nonthaburi aquifers would be expected to show minimal or no contamination. This study tests that expectation directly, reporting the occurrence, concentration, and physical characteristics of microplastics across seventeen wells within these two confined aquifers, with the findings considered in the context of well-construction pathways as an explanation for contamination in structurally protected groundwater.

2. METHODOLOGY

2.1 Study Area

The Lower Chao Phraya Groundwater Basin covers approximately 55,000 km² of central Thailand's most economically significant region. The basin comprises multiple confined aquifer units separated by the Bangkok Clay (Figure 2). This study focuses on the Nakhon Luang aquifer (approximately 100–150 m below ground surface) and the Nonthaburi aquifer (approximately 150–200 m below ground surface) [16]. Land use across the basin is dominated by agriculture (approximately 55%) and urban development (approximately 25%), creating a heterogeneous landscape of potential anthropogenic microplastic sources. Seventeen wells were selected for this analysis from a broader 2025/26 field campaign across the basin: eight tapping the Nakhon Luang aquifer and nine tapping the Nonthaburi aquifer (Figure 1).

2.2 Sample Collection

Groundwater samples were collected in accordance with the USGS National Field Manual for the Collection of Water-Quality Data, Chapter A4 [7], and ISO 5667-11:2009 [8]. At each well, water was retrieved using a stainless-steel bailer tied with polypropylene rope, lowered in six to seven successive draws and transferred into a stainless-steel bucket until 5 L had been collected; this volume was filtered for every sample. The collected water was passed through a stainless-steel sieve set (5 mm and 63 µm mesh), and the sieve was rinsed with distilled water to transfer retained material into a glass sample bottle for laboratory processing.

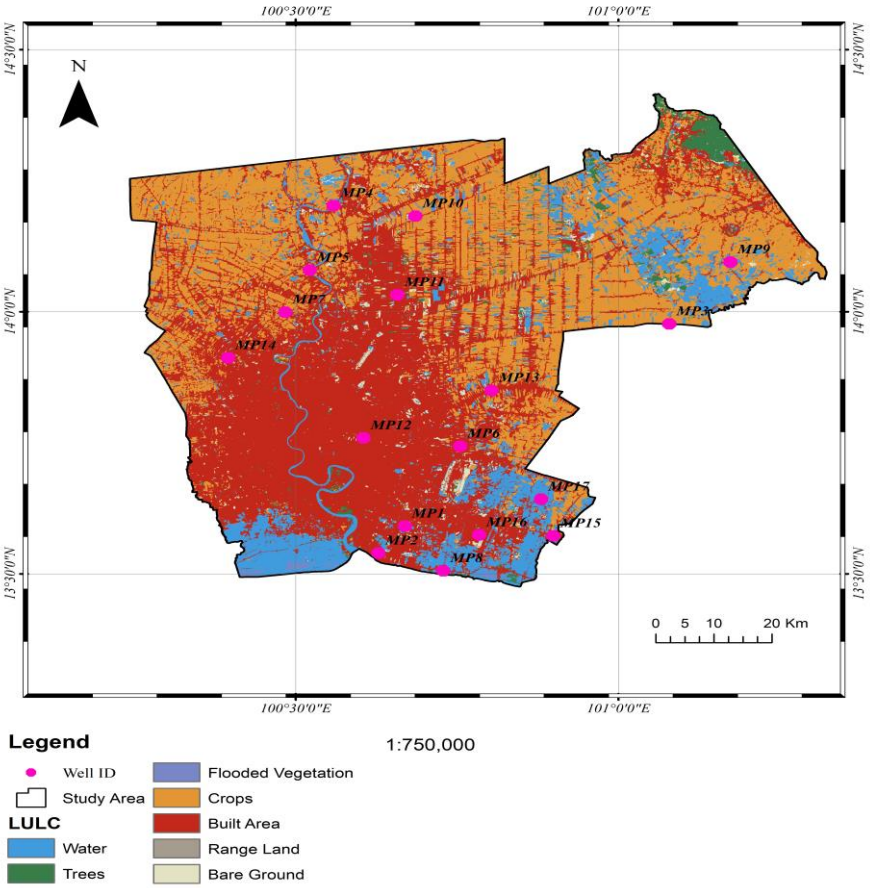

Figure 1. Study area and locations of the seventeen sampled wells

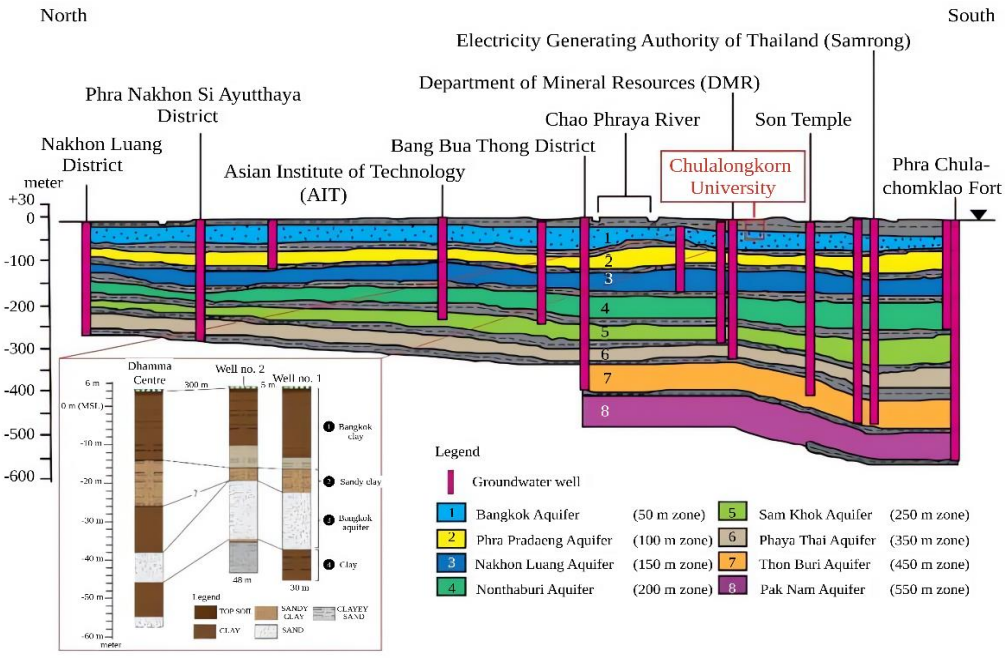

Figure 2. Subsurface stratigraphy and aquifer system of the Lower Chao Phraya Plain (adapted from Chokchai et al. [15])

2.3 Laboratory Analysis

Filtered material was digested in 30% hydrogen peroxide for 24 hours to remove organic matter [9]. Density separation was performed using saturated sodium chloride solution (~1.2 g/cm³), which floats low-density polymers including polyethylene and polypropylene [10]. Particles were identified and enumerated under a stereomicroscope at 10×–30× magnification, classified by shape, colour, and transparency. Suspected plastic particles underwent the hot-needle test, in which particles that melted or deformed on contact with a heated needle were confirmed as plastic [11]. Owing to constraints on available instrument time, polymer identification by Fourier-transform infrared spectroscopy, conducted in accordance with ASTM E1252 [12], was performed on a representative subsample of particles selected to span the range of colours observed across the field campaign.

2.4 Quality Assurance and Quality Control

Contamination control measures included non-synthetic clothing, rinsing of equipment with distilled water between sites and processing steps, and field, air, and sieve blanks processed alongside environmental samples. Recovery efficiency, assessed through spiking trials, was 94.79%. The polypropylene rope used in bailer deployment is acknowledged as a potential procedural contamination source and is addressed in Section 3.4.

3. RESULTS AND DISCUSSION

3.1 Microplastic Occurrence and Concentration

Microplastics were detected in all seventeen sampled wells, a 100% detection frequency across both the Nakhon Luang and Nonthaburi aquifers. Concentrations ranged from 0.40 to 7.00 particles per litre (mean 2.25 ± 2.20, median 1.00). The nearly eighteenfold difference between the least and most contaminated wells indicates that contamination is unevenly distributed even within a single confined aquifer system. These concentrations fall within the global range reported for groundwater generally [13] and are broadly consistent with prior measurements of the same aquifer system [6].

3.2 Particle Morphology and Colour

Of the 191 confirmed particles, fragments were the dominant morphology at 54.5% (n=104), followed by fibres at 45.5% (n=87); no films were recorded. This fragment-fibre dominance is broadly consistent with regional groundwater microplastic studies [6], [14]. Colour characterization identified green (27.9%), white (23.6%), and blue (20.0%) as the dominant colours, together accounting for 71.5% of characterized particles.

3.3 Polymer Composition

Within the representative FTIR subsample, particles from two wells returned confirmed polymer identifications: a translucent yellow fibre from well GWA15 was identified as polypropylene, and a green fragment and blue fibre from well NB71 were identified as polyethylene. A second green fragment from the same well returned a possible secondary match to polystyrene. These results confirm the presence of polyethylene and polypropylene, both established as globally common polymer types in groundwater microplastic studies [3], [14]. The finding that particles of similar colour and morphology returned different polymer identifications underscores that colour is not a reliable proxy for polymer type, and that these results characterize the range of polymers present within the sampled subset rather than a quantitative distribution across all 191 confirmed particles.

3.4 Implications for Groundwater Resilience in Confined Aquifers

The detection of microplastics across all seventeen wells sampled, spanning two confined aquifer units separated from the surface by the Bangkok Clay, does not support the expectation that confinement alone provides substantial protection against microplastic contamination. Well construction represents an artificial pathway that bypasses the natural aquitard by design; where casing seals are imperfect, contamination can migrate along the borehole independent of the surrounding aquifer's confinement [4]. This mechanism has direct precedent in the study basin, where poorly sealed well casings and locally discontinuous confining clay have been identified as plausible inter-aquifer migration pathways [6]. The long residence times characteristic of confined systems may further allow microplastics introduced during construction or historical pumping events to persist and accumulate given the resistance of most polymers to degradation. A portion of the measured contamination may also be attributable to the sampling procedure itself: the polypropylene rope used to deploy the bailer is a direct, identifiable potential source of polypropylene contamination and cannot be fully excluded as a contributor to the polypropylene identification reported in Section 3.3. These findings suggest that the resilience conventionally attributed to confined aquifers should not be assumed to extend uniformly to all contaminant types or transport pathways, and that well-construction and maintenance standards may represent as significant a determinant of groundwater microplastic vulnerability as aquifer-scale confinement itself — a finding directly relevant to groundwater management under increasing abstraction pressure and climatic variability.

4. CONCLUSIONS

Based on laboratory experiments and data analysis in this study. Some conclusions were drawn as follows:

1. Microplastics were detected in all seventeen wells sampled across the Nakhon Luang and Nonthaburi confined aquifers, with concentrations ranging from 0.40 to 7.00 particles per litre (mean 2.25 ± 2.20, median 1.00).
2. Fragments (54.5%) and fibres (45.5%) were the dominant particle morphologies, with green, white, and blue as the dominant colours, together accounting for 71.5% of characterized particles.
3. Polymer identification on a representative subsample confirmed the presence of polyethylene and polypropylene.
4. The presence of microplastics throughout confined, clay-bounded aquifer units indicates that confinement provides partial rather than absolute protection from contamination, with well-construction integrity identified as a plausible contributing pathway.
5. These baseline findings provide a foundation for future spatial and predictive modelling of contamination drivers across the basin's confined aquifer system.

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