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Occurrence and Physicochemical Characterisation of Analgesic Pharmaceutical Residues in Leachate from a Municipal Solid Waste Dumpsite in Lagos, Nigeria: A Baseline Environmental Screening Study

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Abstract

The occurrence of pharmaceutical residues in landfill leachate represents an increasingly recognised environmental concern, particularly in rapidly urbanising regions where pharmaceutical waste is co-disposed with general municipal solid waste. This study investigated the presence and concentrations of three widely consumed analgesic compounds — acetaminophen, ibuprofen, and diclofenac — in leachate samples collected from the Solous Dumpsite, Igando, Lagos State, Nigeria, one of the largest active municipal solid waste disposal sites in West Africa. Three leachate samples were collected from distinct points within the dumpsite during the wet season and subjected to liquid-liquid extraction (LLE) prior to quantification by high-performance liquid chromatography with ultraviolet detection (HPLC-UV). Key physicochemical parameters — including pH, electrical conductivity, turbidity, total dissolved solids (TDS), and total suspended solids (TSS) — were simultaneously characterised. All three target analytes were detected in at least one sample. Acetaminophen recorded the highest mean concentration (5.62 ± 5.53 µg/L), followed by ibuprofen (0.89 ± 0.073 µg/L) and diclofenac (0.57 ± 0.406 µg/L), establishing a rank order of acetaminophen > ibuprofen > diclofenac. Turbidity values (mean 65.67 NTU) substantially exceeded the WHO guideline threshold of ≤ 5 NTU, indicating significant particulate and organic pollution loading. These findings provide the first reported baseline data on analgesic pharmaceutical residues in leachate specifically from the Solous Dumpsite and underscore the need for improved pharmaceutical waste management, leachate treatment infrastructure, and binding regulatory standards for pharmaceutical contaminants in Nigerian landfill leachate.

1 Introduction

The global proliferation of pharmaceutical compounds in the environment has emerged as one of the most pressing challenges in contemporary environmental chemistry. Unlike conventional industrial pollutants, pharmaceuticals are intentionally designed to be biologically active at low concentrations, rendering them capable of exerting adverse effects on non-target organisms even when present at trace levels in environmental matrices (Fatta-Kassinos et al. 2011; Kümmerer 2010). Among the pharmaceutical classes of greatest environmental concern, non-steroidal anti-inflammatory drugs (NSAIDs) — including acetaminophen (paracetamol), ibuprofen, and diclofenac — occupy a particularly significant position due to their exceptionally high global consumption volumes, widespread over-the-counter availability, and documented persistence in aquatic and terrestrial environments (Cleuvers 2004; Santos et al. 2010). Globally, acetaminophen ranks among the most consumed pharmaceutical compounds, with annual production estimated in the tens of thousands of tonnes, while ibuprofen and diclofenac are similarly ubiquitous in household medicine supplies across both high-income and low-to-middle-income countries (OECD 2019). The environmental fate of these compounds following consumption and disposal is therefore a matter of considerable scientific and regulatory concern.

Landfill leachate has been increasingly identified as a significant, and historically underestimated, vector for the introduction of pharmaceutical residues into the broader environment. Leachate is generated when precipitation and moisture percolate through deposited solid waste, mobilising soluble

contaminants — including pharmaceutical compounds — into a complex, chemically heterogeneous liquid that may subsequently infiltrate shallow aquifers or discharge into adjacent surface water bodies (Eggen et al. 2010; Kjeldsen et al. 2002). The pharmaceutical load of landfill leachate is directly governed by waste composition: in settings where pharmaceutical products, expired medications, and pharmaceutical packaging are co-disposed with general municipal solid waste — as is standard practice across much of sub-Saharan Africa — leachate presents a concentrated source of bioactive chemical contamination that bypasses formal wastewater treatment infrastructure entirely (Fatta-Kassinos et al. 2011). Studies conducted in Europe and Asia have confirmed the presence of numerous pharmaceutical compounds in landfill leachate at concentrations ranging from nanograms to micrograms per litre, with NSAIDs consistently identified among the most frequently detected compound classes (Eggen et al. 2010; Brozinski et al. 2012).

In Nigeria, the convergence of rapid population growth, expanding pharmaceutical consumption, and severely constrained waste management infrastructure creates conditions of particular environmental risk. Lagos State, with a population exceeding 20 million and among the highest rates of over-the-counter analgesic use on the African continent, generates substantial volumes of pharmaceutical-contaminated municipal solid waste that are predominantly directed to open, unlined dumpsites operating without leachate containment or treatment systems (Adeyi and Majolagbe 2014). The Solous Dumpsite in Igando, Lagos, exemplifies this challenge: operational since 1996, receiving approximately 4,000 tonnes of solid waste daily, and situated within a densely populated residential area approximately 2.5 km from the Oba stream, the site represents a significant potential source of pharmaceutical contamination to local groundwater and surface water systems (Adeyi and Majolagbe 2014). Despite its environmental significance, empirical data on pharmaceutical residue concentrations in leachate specifically from this site remain absent from the peer-reviewed literature. While Nnodum et al. (2022, 2023) and Oluwatosin et al. (2016) have documented the occurrence of NSAIDs in Lagos wastewater, surface water, and sediments, leachate from municipal dumpsites has not been investigated as a discrete pharmaceutical contamination source in published studies from Nigeria, representing a clear and addressable gap in the regional environmental chemistry literature.

This knowledge gap carries practical consequences. Communities residing adjacent to the Solous Dumpsite rely on shallow groundwater sources for domestic use, and without baseline data on pharmaceutical contamination in leachate, the risk to these water sources cannot be quantified, monitored, or regulated. Furthermore, Nigeria currently lacks binding regulatory standards for pharmaceutical residues in landfill leachate, meaning that contamination of this nature proceeds without formal oversight or enforcement. Generating baseline concentration data for analgesic pharmaceutical residues in dumpsite leachate is therefore a necessary first step toward establishing the evidence base required to inform policy, protect public health, and direct future remediation efforts.

This study addresses these gaps by determining the occurrence and concentrations of acetaminophen, ibuprofen, and diclofenac in leachate samples collected from the Solous Dumpsite using liquid-liquid extraction coupled with HPLC-UV analysis, and by characterising the physicochemical properties of the

leachate to contextualise the chemical environment in which these residues persist. The findings are discussed in relation to comparable regional and international studies and interpreted within the framework of environmental and public health risk. This work represents the first reported baseline investigation of analgesic pharmaceutical residues in leachate from this site and contributes to the growing body of evidence documenting pharmaceutical contamination of environmental matrices in Nigeria.

2 Materials and Methods

2.1 Study Area

The Solous Dumpsite is located in Igando, Lagos State, Nigeria, at coordinates 06°569'N–06°574'N latitude and 03°253'E–03°255'E longitude. The site has been operational since 1996 and covers approximately 3 hectares to a depth of 9 metres, receiving an estimated 4,000 tonnes of municipal and industrial solid waste daily. At the time of sample collection, the dumpsite had reached over 70% of its design capacity. The site is entirely surrounded by residential settlements and is situated approximately 2.5 km east of an abattoir and the Oba stream (Adeyi and Majolagbe 2014). No engineered leachate collection, containment, or treatment infrastructure is present at the site. A sketch map of the study area showing sampling locations is presented in Fig. 1.

2.2 Sample Collection

Leachate samples were collected from three spatially distinct points within the Solous Dumpsite during the wet season, in the months of July and September 2024. Sampling points were selected to represent different zones of the active waste body, accounting for variability in waste composition and leachate accumulation patterns. Pre-cleaned amber Winchester bottles were rinsed three times with sample leachate prior to collection. Samples were immediately sealed, stored at 4°C, transported to the laboratory within 24 hours of collection, and analysed within 72 hours. Three leachate samples were collected and designated Leachate 1, Leachate 2, and Leachate 3.

2.3 Physicochemical Analysis

Six physicochemical parameters were measured for each leachate sample: temperature (°C), pH, electrical conductivity (μS/cm), turbidity (NTU), total dissolved solids (TDS, mg/L), and total suspended solids (TSS, mg/L). Temperature was recorded in situ using a calibrated thermometer. pH was determined using an Oakton Ecotestr pH meter calibrated with standard buffer solutions at pH 4, 7, and 9. Electrical conductivity and TDS were measured simultaneously using a Jenway 4510 Conductivity/TDS Meter calibrated with 0.01 M potassium chloride (KCl) solution. Turbidity was measured in the laboratory using a calibrated turbidimeter. TSS was determined gravimetrically following vacuum filtration of a known sample volume through pre-weighed 0.45 μm glass-fibre membrane filters, oven-dried at 105°C to constant mass. All measured values were compared against World Health Organization (WHO) and United States Environmental Protection Agency (USEPA) reference values.

2.4 Sample Preparation and Liquid-Liquid Extraction

Prior to extraction, each 100 mL leachate sample was acidified to pH < 2 using 0.1 M hydrochloric acid (HCl) to suppress analyte ionisation and enhance partitioning into the organic phase. Each acidified sample was transferred quantitatively into a 500 mL separating funnel. An equal volume of a binary organic solvent mixture comprising dichloromethane (DCM) and n-hexane was added. The separating funnel was stoppered and shaken vigorously for five minutes with periodic venting to release pressure. Following phase separation, the lower organic layer was collected. The extraction procedure was repeated three times per sample to maximise analyte recovery. Combined organic extracts were concentrated to approximately 2 mL using a rotary evaporator, evaporated to near dryness under a gentle stream of nitrogen gas (N_2), and reconstituted in 1 mL HPLC-grade acetonitrile. Reagent-grade standards of acetaminophen, ibuprofen, and diclofenac were obtained from the National Agency for Food and Drug Administration and Control (NAFDAC), Nigeria.

2.5 HPLC-UV Analysis

Pharmaceutical residues were quantified using a reverse-phase high-performance liquid chromatography system with ultraviolet detection (HPLC-UV; Agilent 1260 Infinity II LC) housed at the Nigerian Institute of Medical Research (NIMR), Lagos. Chromatographic separation was achieved on a C18 reverse-phase analytical column. The mobile phase consisted of acetonitrile and ultrapure water (60:40 v/v) adjusted to pH 3.0 with phosphoric acid, delivered isocratically at 0.700 mL/min. Injection volume was 20 µL and column temperature was maintained at 30°C. Detection was performed at a UV wavelength of 230 nm (Nnodum et al. 2022). External calibration was performed using standard solutions at five concentration levels (2.5, 5.0, 10.0, 25.0, and 50.0 µg/mL) in acetonitrile. Sample concentrations were determined by interpolation from calibration curves. Analyte identity was confirmed by retention time matching against authenticated reference standards analysed under identical chromatographic conditions.

2.6 Quality Assurance and Analytical Scope

This study was designed as a baseline environmental screening investigation. Formal method validation parameters — including limit of detection (LOD), limit of quantification (LOQ), and spike recovery efficiency — were not determined within the scope of this work, representing a recognised methodological limitation that is addressed in the Discussion. Procedural blanks (HPLC-grade water subjected to the full LLE–HPLC procedure) were prepared alongside each extraction batch. No target analytes were detected in procedural blank extracts, confirming the absence of laboratory cross-contamination.

3 Results

3.1 Physicochemical Characteristics of Leachate Samples

Physicochemical parameters measured across the three leachate samples are presented in Table 1. Leachate temperature ranged from 26.5–27.2°C (mean 26.87 ± 0.29°C). pH ranged narrowly from 7.43–7.46 (mean 7.45 ± 0.014), indicating consistently slightly alkaline chemistry across all sampling points. Electrical conductivity ranged from 200–205 µS/cm (mean 203 ± 2.52 µS/cm), below the WHO/USEPA upper reference of ≤ 400 µS/cm. Turbidity was markedly elevated (mean 65.67 ± 49.51 NTU), exceeding the WHO guideline value of ≤ 5 NTU by more than thirteenfold. TSS ranged from 132.22–180.84 mg/L (mean 156.21 ± 24.31 mg/L). TDS ranged from 410.11–476.16 mg/L (mean 439.49 ± 33.03 mg/L), within the WHO/USEPA reference range for leachate. Total solids ranged from 542.33–657.00 mg/L (mean 595.70 ± 57.75 mg/L). The leachate-to-groundwater conversion factor (mean 0.267 ± 0.066) fell below the WHO reference range of 0.5–0.9, suggesting limited but non-negligible potential for leachate migration under prevailing site conditions.

Table 1
Physicochemical parameters of leachate samples from the Solous Dumpsite, Igando, Lagos State, Nigeria

Parameter	Leachate 1	Leachate 2	Leachate 3	Mean ± SD	WHO/USEPA Reference
Temperature (°C)	27.2	26.5	26.9	26.87 ± 0.29	≤ 55
pH	7.46	7.43	7.46	7.45 ± 0.014	6.5–9.0
Conductivity (µS/cm)	204	205	200	203 ± 2.52	≤ 400
Turbidity (NTU)	99.9	97.1	ND	65.67 ± 49.51	≤ 5
TSS (mg/L)	132.22	155.56	180.84	156.21 ± 24.31	—
TDS (mg/L)	410.11	432.20	476.16	439.49 ± 33.03	2,000–60,000
Total Solids (mg/L)	542.33	587.76	657.00	595.70 ± 57.75	—
Conversion Factor	0.23	0.36	0.21	0.267 ± 0.066	0.5–0.9

ND not determined at this sampling point. SD standard deviation. WHO/USEPA reference values sourced from World Health Organization (2017*) and USEPA guidelines.*

3.2 Occurrence and Concentrations of Analgesic Pharmaceutical Residues

The concentrations of the three target analgesic compounds detected in leachate samples from the Solous Dumpsite are presented in Table 2. All three analytes — acetaminophen, ibuprofen, and diclofenac — were detected in at least one of the three samples, confirming the occurrence of analgesic

pharmaceutical residues in the leachate at this site. Acetaminophen was detected in Leachate 1 (13.138 µg/L) and Leachate 3 (3.720 µg/L), with a mean of 5.62 ± 5.53 µg/L (detection frequency: 2/3, 67%). Ibuprofen was detected in all three samples (0.833–0.989 µg/L; mean 0.89 ± 0.073 µg/L; 3/3, 100%). Diclofenac was detected in Leachate 2 (0.835 µg/L) and Leachate 3 (0.884 µg/L), with a mean of 0.57 ± 0.406 µg/L (2/3, 67%). The overall rank order of mean analyte concentration was: acetaminophen (5.62 µg/L) > ibuprofen (0.89 µg/L) > diclofenac (0.57 µg/L).

Table 2
Concentrations of analgesic pharmaceutical residues detected in leachate samples from the Solous Dumpsite

Analyte	Leachate 1 (µg/L)	Leachate 2 (µg/L)	Leachate 3 (µg/L)	Mean ± SD (µg/L)	Detection Frequency
Acetaminophen	13.138	ND	3.720	5.62 ± 5.53	2/3 (67%)
Ibuprofen	0.989	0.834	0.833	0.89 ± 0.073	3/3 (100%)
Diclofenac	ND	0.835	0.884	0.57 ± 0.406	2/3 (67%)

ND not detected. SD standard deviation calculated across all three samples with ND recorded as zero.

3.3 Chromatographic Calibration and Analyte Identification

Calibration curves for all three analytes exhibited strong linearity across the full concentration range (2.5–50.0 µg/mL). A representative chromatogram of the mixed standard solution at 25 µg/mL, showing characteristic retention times for acetaminophen (1.096 min), ibuprofen (1.444 min), and diclofenac (1.730 min), is presented in Fig. 2. Retention times remained consistent across all standard injections, confirming instrument stability throughout the analytical run.

3.4 Representative Sample Chromatograms

Representative HPLC-UV chromatograms of leachate extracts are presented in Figs. 3 and 4, illustrating detection of target analytes in Leachate 1 (highest acetaminophen concentration) and Leachate 3 (all three analytes detected), respectively. Analyte identification in sample chromatograms was confirmed by co-elution of peaks at retention times corresponding to those of authenticated standard solutions analysed under identical conditions. The elevated baseline signal and broader peak profiles observed in sample chromatograms relative to standard solutions reflect the influence of co-extractable organic matrix constituents characteristic of municipal solid waste leachate, consistent with the high turbidity and TSS values reported for these samples in Section 3.1.

4 Discussion

4.1 Physicochemical Profile and Its Implications for Pharmaceutical Behaviour

The physicochemical characteristics of the Solous Dumpsite leachate indicate a moderately mature, slightly alkaline waste-derived liquid with significant particulate loading. The near-neutral to slightly alkaline pH range (7.43–7.46) is consistent with methanogenic-phase leachate chemistry, in which anaerobic decomposition of organic waste produces alkaline by-products — principally ammonia — that buffer the leachate against acidification (Kjeldsen et al. 2002). This pH range has direct relevance to the behaviour of the target analgesic compounds: acetaminophen, ibuprofen, and diclofenac are weak acids with pKa values of approximately 9.5, 4.9, and 4.0 respectively. Under the slightly alkaline conditions recorded in this study, ibuprofen and diclofenac would exist predominantly in their ionised forms, theoretically reducing their tendency to partition into organic matter and increasing their mobility and bioavailability in the leachate matrix (Lonappan et al. 2016; Santos et al. 2010). The relatively low electrical conductivity (200–205 µS/cm), compared to values reported for heavily loaded landfill leachates (Nnodum et al. 2022; Oluwatosin et al. 2016), likely reflects dilution by wet-season precipitation infiltrating the open, uncovered waste body — an important contextual factor suggesting that wet-season sampling may underestimate peak pharmaceutical concentrations occurring under dry-season, low-dilution conditions.

The markedly elevated turbidity (mean 65.67 NTU), exceeding the WHO guideline of ≤ 5 NTU by more than thirteenfold, indicates a high burden of suspended particulate matter and colloidal organic material. Elevated turbidity in landfill leachate is characteristic of unmanaged sites receiving mixed municipal waste without engineered containment (Nnodum et al. 2022). Beyond its significance as a pollution indicator, high turbidity is mechanistically relevant to pharmaceutical fate: suspended organic particles can act as sorbents for hydrophobic pharmaceutical compounds, potentially retarding free migration through soil while simultaneously increasing the risk of pharmaceutical-laden particle transport during leachate overflow events common at open dumpsites during heavy rainfall.

4.2 Occurrence and Concentration of Analgesic Residues: Contextualisation

The detection of all three target analgesics in at least one leachate sample confirms that the Solous Dumpsite leachate constitutes an active source of analgesic pharmaceutical contamination. The rank order of mean concentration — acetaminophen > ibuprofen > diclofenac — mirrors the rank order of consumption and disposal rates for these compounds in Nigeria and is consistent with patterns reported in comparable studies from the region (Nnodum et al. 2022; Oluwatosin et al. 2016). Acetaminophen is the most widely consumed analgesic in Nigeria, available without prescription across virtually all retail pharmacies and general merchandise outlets, which directly translates into its dominant representation in municipal solid waste streams and dumpsite leachate (Ejeikwu and Folashade 2019).

The wide standard deviation associated with the acetaminophen mean (5.62 ± 5.53 µg/L), driven by the substantially elevated concentration at Leachate 1 (13.138 µg/L) relative to Leachate 3 (3.720 µg/L), reflects spatial heterogeneity inherent in open dumpsite leachate — a recognised feature of unmanaged sites (Kjeldsen et al. 2002). The elevated baseline and broader chromatographic peaks in sample extracts (Figs. 3 and 4) relative to the standard chromatogram (Fig. 2) further illustrate the influence of co-extracted matrix constituents on analyte signal profiles. The mean acetaminophen concentration (5.62 µg/L) is lower than values reported by Nnodum et al. (2023) in Lagos sediments (10.0 ± 2.5 µg/L) and Oluwatosin et al. (2016) in Lagos wastewater (12.0 ± 3.0 µg/L), consistent with the wet-season dilution effect discussed above.

Ibuprofen demonstrated the most consistent detection pattern, being present in all three samples within a narrow concentration range (0.833–0.989 µg/L), suggesting relatively uniform distribution within the leachate body and moderate resistance to degradation under prevailing anaerobic conditions. This aligns with the documented behaviour of ibuprofen in landfill environments, where its moderate hydrophobicity (log Kow = 3.97) facilitates partial sorption to organic matter while its ionised fraction remains mobile in the aqueous phase (Santos et al. 2010). The mean ibuprofen concentration (0.89 µg/L) is consistent with values reported by Nnodum and Yusuf (2022) in Lagos surface water (0.9 ± 0.1 µg/L), suggesting that leachate discharge from unmanaged dumpsites may contribute comparably to wastewater effluent as a source of ibuprofen in receiving water bodies — a hypothesis that warrants formal source-apportionment investigation in future work.

Although diclofenac was detected at the lowest mean concentration (0.57 ± 0.406 µg/L), its environmental significance is disproportionate to its concentration. Diclofenac has been designated a priority substance under the European Union Water Framework Directive and has been shown to cause renal toxicity and histopathological lesions in fish at environmentally relevant concentrations of ≥ 1 µg/L (Lonappan et al. 2016). The mean concentration detected in this study approaches but does not exceed this fish toxicity threshold under wet-season, diluted conditions. However, it is plausible that dry-season diclofenac concentrations at this site could exceed ecotoxicologically significant thresholds — a finding with direct implications for the ecological health of the Oba stream located 2.5 km from the dumpsite boundary.

4.3 Environmental and Public Health Implications

The detection of all three analgesic compounds in leachate from the Solous Dumpsite demonstrates that this site functions as an active and unregulated pharmaceutical contamination source with potential consequences for groundwater and surface water quality in the surrounding peri-urban community. Operating without any engineered leachate containment liner, pharmaceutical-contaminated leachate is free to percolate through the unsaturated zone and reach shallow aquifers used by surrounding residents for domestic purposes. Long-term, low-level exposure to NSAIDs in groundwater has been associated with sub-lethal effects on aquatic organisms, disruption of microbial community composition, and potential contributions to environmental antimicrobial resistance (Kümmerer 2010; Fatta-Kassinos et al. 2011).

Formal ecological risk quotients (RQs) were not calculated due to the absence of locally validated predicted no-effect concentration (PNEC) values for Nigerian aquatic ecosystems — a limitation that future studies at this site should address. Nevertheless, the concentrations detected in this investigation are consistent with those reported in studies that have calculated provisional RQs for NSAIDs in West African environmental matrices and found low-to-medium risk classifications for ibuprofen and diclofenac under wet-season conditions (Nnodum et al. 2023). Risk assessments based solely on wet-season data may consequently underestimate the true magnitude of pharmaceutical contamination at this site.

4.4 Limitations and Methodological Considerations

The sample size of three leachate samples is sufficient to confirm analyte occurrence and characterise approximate concentration ranges but limits the statistical robustness of reported means and precludes formal inferential comparison between sampling points. The absence of formal method validation data — LOD, LOQ, and spike recovery percentages — is a recognised constraint of this baseline screening study; concentration values should therefore be interpreted as indicative rather than definitive quantitative measurements. The elevated baseline and matrix-influenced peak profiles evident in sample chromatograms relative to standard solutions (Figs. 2–4) indicate the presence of co-extractable interferences that may affect quantification accuracy; this underscores the value of matrix-matched calibration or SPE-based cleanup in future investigations. Sampling was conducted exclusively during the wet season, precluding conclusions about seasonal concentration dynamics. Future investigations should incorporate SPE-based extraction with validated recovery data, expanded spatial sampling across a minimum of six to nine sampling points, paired wet-season and dry-season campaigns, and formal ecological risk quantification using locally derived PNEC values.

5 Conclusion

This study provides the first reported baseline data on the occurrence and concentrations of analgesic pharmaceutical residues — specifically acetaminophen, ibuprofen, and diclofenac — in leachate from the Solous Dumpsite, Igando, Lagos State, Nigeria. All three target compounds were detected in at least one of the three leachate samples analysed, confirming that this active, unmanaged municipal solid waste disposal site constitutes a measurable source of analgesic pharmaceutical contamination in the peri-urban Lagos environment. The rank order of mean concentration — acetaminophen (5.62 µg/L) > ibuprofen (0.89 µg/L) > diclofenac (0.57 µg/L) — reflects established patterns of analgesic consumption and disposal in Nigeria and is broadly consistent with NSAID occurrence data reported in comparable environmental matrices from the Lagos region. Substantially elevated turbidity values, exceeding the WHO guideline threshold by more than thirteenfold, underscore the severity of the pollution burden at this site and the potential for contaminant transport to adjacent groundwater and surface water systems. HPLC-UV chromatograms confirmed reliable analyte identification across both calibration standards (Fig. 2) and complex leachate extracts (Figs. 3 and 4).

These findings carry clear environmental and public health significance for communities residing in proximity to the Solous Dumpsite, who depend on shallow groundwater sources potentially vulnerable to leachate infiltration. The absence of engineered leachate containment at the site, combined with the absence of binding Nigerian regulatory standards for pharmaceutical residues in landfill leachate, means that contamination of this nature proceeds without formal monitoring, oversight, or enforceable mitigation. This study provides the empirical baseline necessary to begin addressing that regulatory and monitoring gap and contributes to the growing body of evidence documenting pharmaceutical contamination of environmental matrices across Nigeria.

Future research at this site should prioritise multi-matrix investigations spanning leachate, soil, and shallow groundwater; paired dry-season and wet-season sampling campaigns; expanded spatial sampling; and formal ecological risk quantification using locally derived PNEC values. Development of cost-effective leachate treatment strategies appropriate to the Nigerian low-resource context — including activated carbon adsorption and constructed wetland systems — represents an equally urgent research priority. It is further recommended that the Federal Ministry of Environment and the Lagos State Environmental Protection Agency (LASEPA) consider establishing provisional guideline values for pharmaceutical residues in municipal landfill leachate as a first legislative step toward protecting groundwater resources in Nigeria's most densely populated urban environment.

Declarations

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Ethics approval Not applicable. This study involved environmental sample collection from a public waste disposal site and did not involve human participants or animal subjects.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contributions M.B. Adeyemo: conceptualisation, sample collection, laboratory analysis, data curation, original draft preparation. K.A. Yusuf: supervision, methodology review, writing — review and editing, correspondence.

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Figures

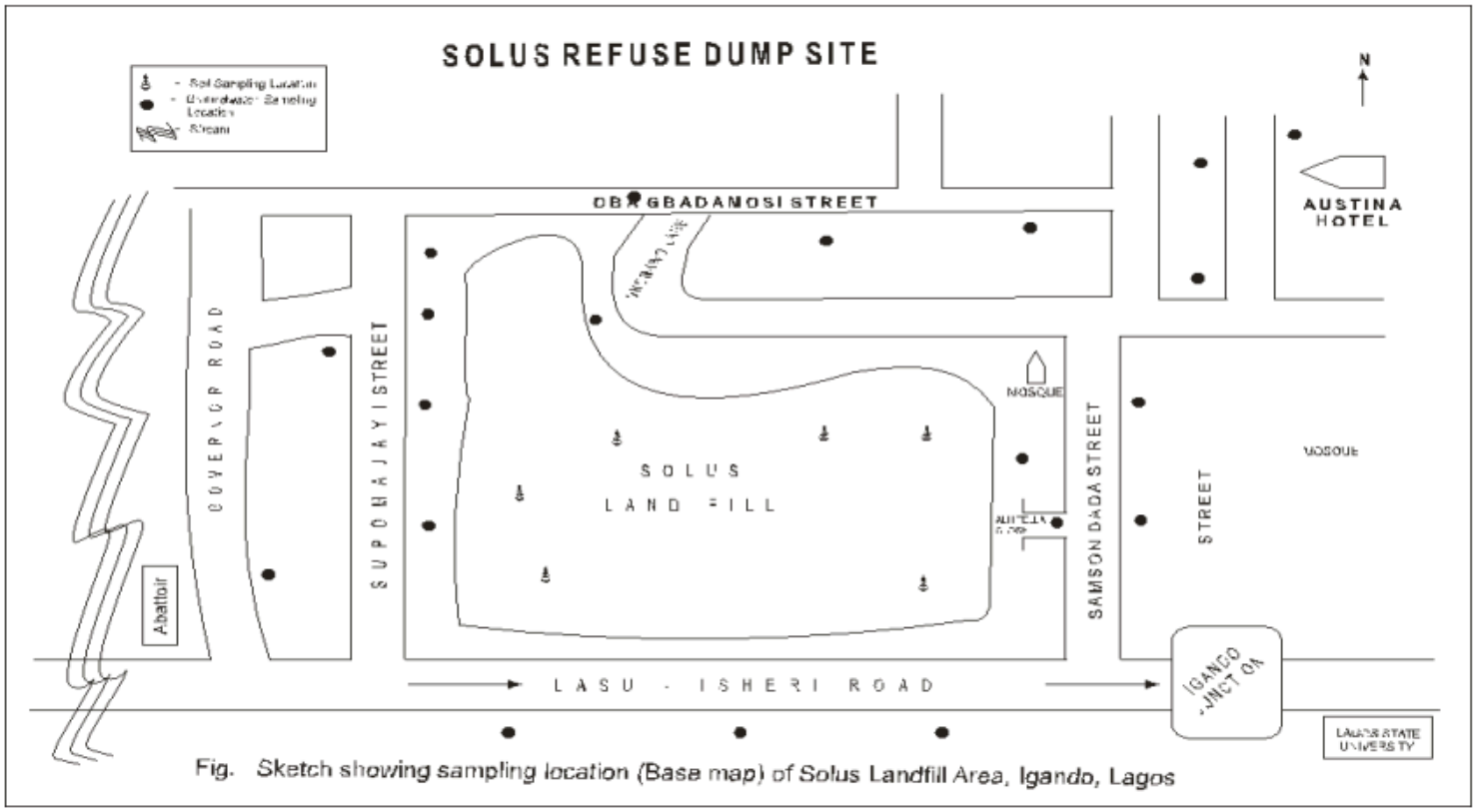

Fig. Sketch showing sampling location (Base map) of Solus Landfill Area, Igando, Lagos

Figure 1

Sketch map of the Solous Dumpsite study area, Igando, Lagos, Nigeria, showing the spatial layout of the landfill, surrounding landmarks, and sampling location zones. Adapted from site survey data (Adeyi and

Majolagbe 2014).

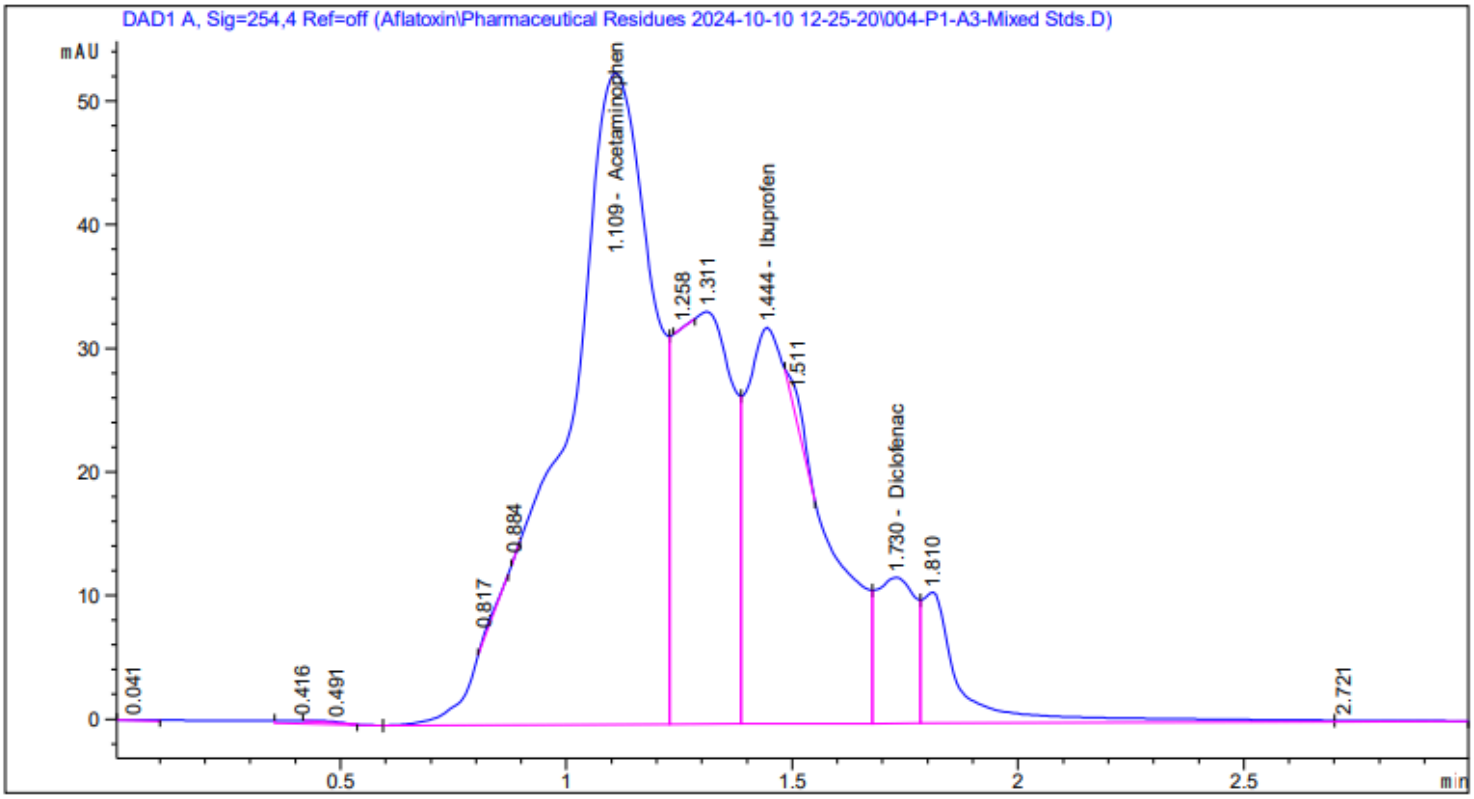

Figure 2

Representative HPLC-UV chromatogram of the mixed analgesic standard solution at 25 µg/mL. Identified peaks: acetaminophen (Rt = 1.096 min), ibuprofen (Rt = 1.444 min), diclofenac (Rt = 1.730 min). Conditions: C18 column; mobile phase acetonitrile/water 60:40 v/v, pH 3.0; flow rate 0.700 mL/min; detection at 230 nm; injection volume 20 µL.

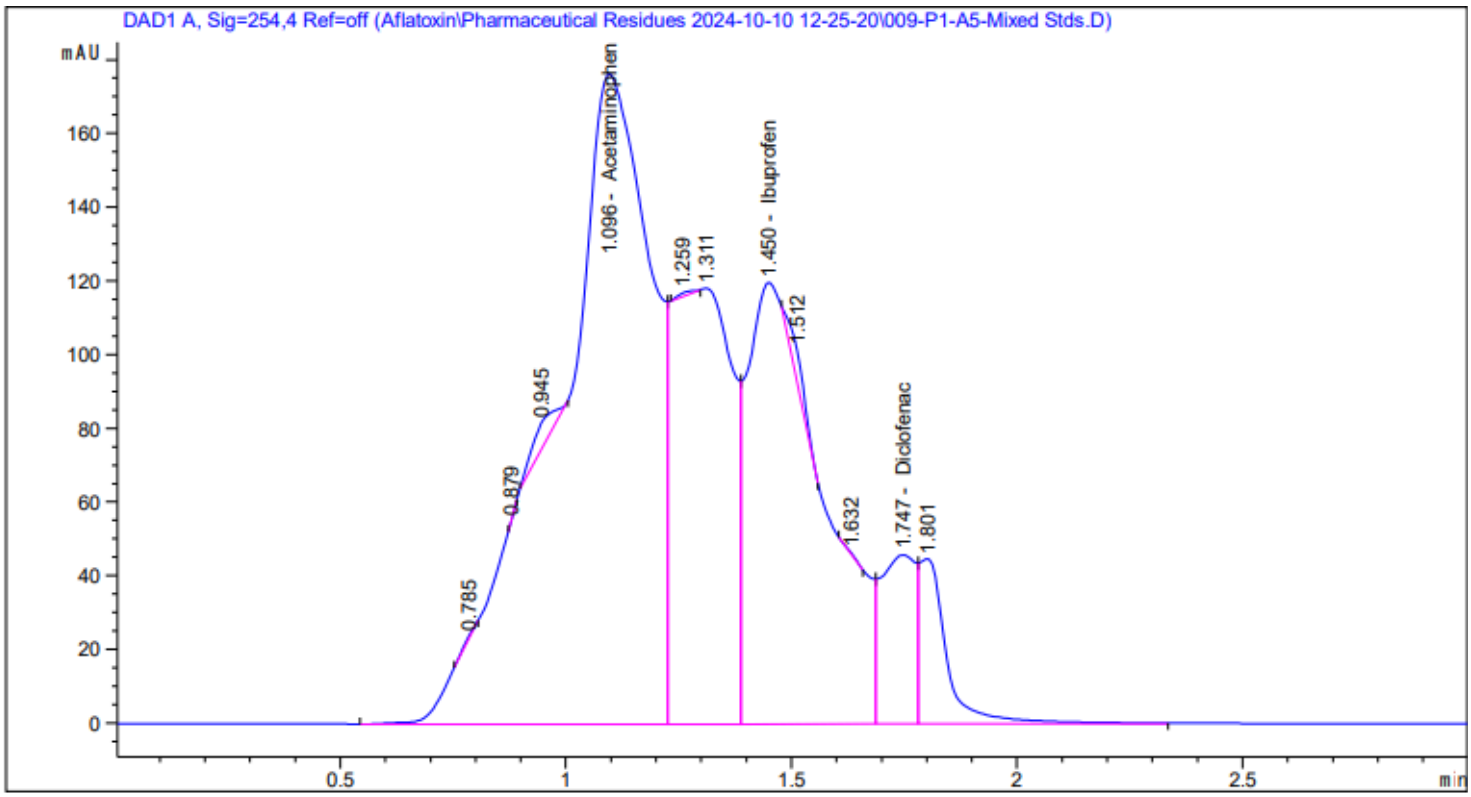

Figure 3

HPLC-UV chromatogram of the LLE extract of Leachate 1 from the Solous Dumpsite. Detected peaks: acetaminophen (Rt ≈ 1.096 min, 13.138 µg/L) and ibuprofen (Rt ≈ 1.450 min, 0.989 µg/L). Diclofenac was below the detection threshold in this sample. The elevated baseline reflects co-extractable organic matrix from the leachate.

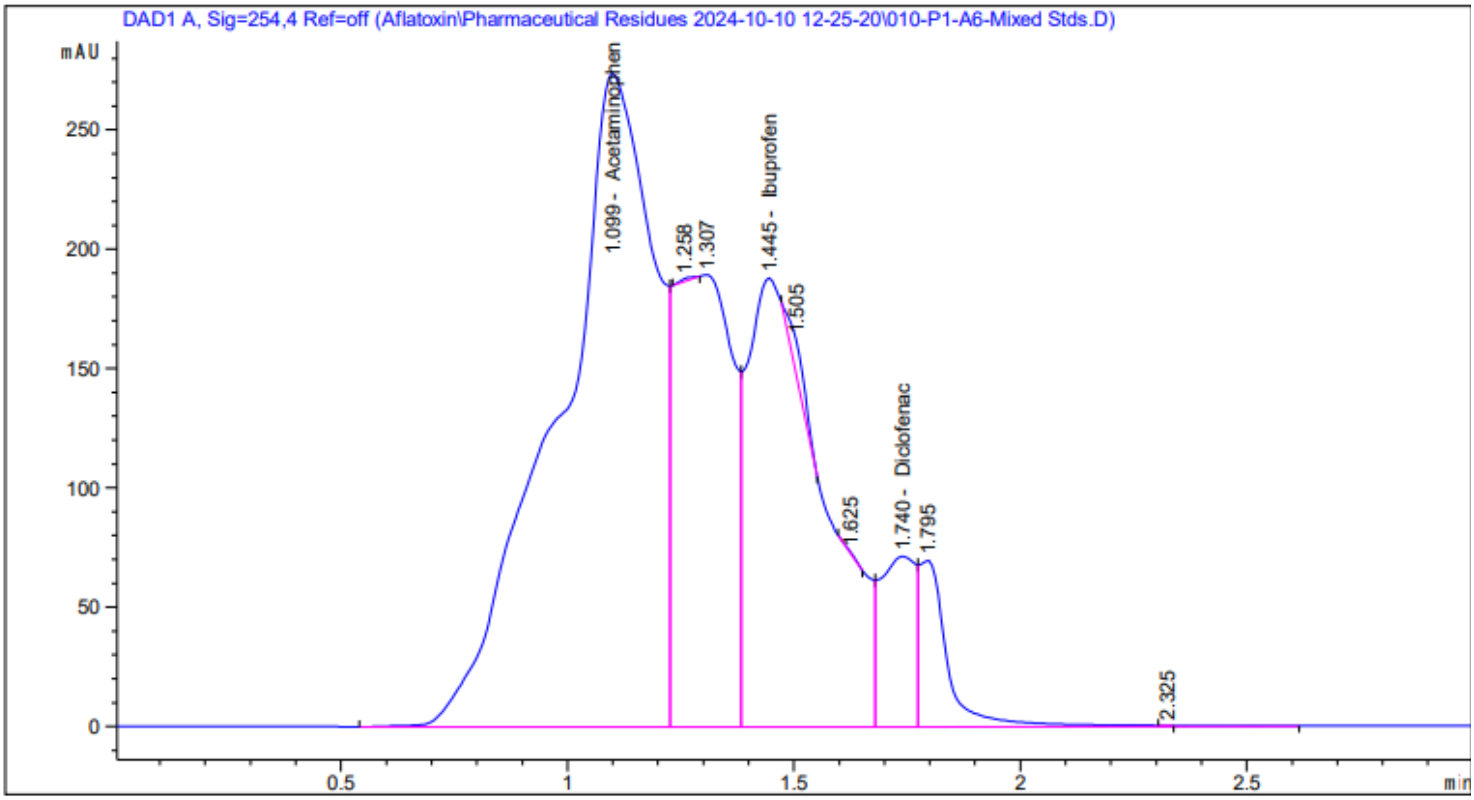

Figure 4

HPLC-UV chromatogram of the LLE extract of Leachate 3 from the Solous Dumpsite, in which all three target analytes were detected: acetaminophen (Rt ≈ 1.099 min, 3.720 µg/L), ibuprofen (Rt ≈ 1.445 min, 0.833 µg/L), and diclofenac (Rt ≈ 1.740 min, 0.884 µg/L). Peak areas were interpolated from external calibration curves.