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Research Article

Assessment of Microplastics and Additives Leaching from PVC, PP and PE Packaging Materials into Food and Water in Onitsha

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Abstract

Plastic packaging is widely used for food and water in Nigeria, yet data on microplastics MPs and chemical additives leaching from PVC, PP, and PE into consumables remain scarce. This study assessed MPs and additive migration from PVC, PP, and PE packaging materials commonly used in Onitsha Main Market. Twenty-four samples were purchased: 8 PVC water sachets/pipes, 8 PP takeaway bowls, 8 PE water sachets. Leaching experiments were done with distilled water and 3% acetic acid at 40 ℃ and 70 ℃ for 10 days to simulate storage. MPs were quantified by FTIR and microscope. Additives including phthalates, BPA, antioxidants, Pb and Cd were analyzed by GC-MS and AAS. Results showed MP counts ranged 42-310 particles/L, highest in PE 310±28 and lowest in PVC 42±9. Total phthalates leached: PVC 89.4 µg/L, PP 12.1 µg/L, PE 4.3 µg/L. DEHP in PVC exceeded EU migration limit of 60 µg/L at 70 ℃. Pb 0.18 mg/kg and Cd 0.09 mg/kg were detected in PVC only. Estimated Daily Intake EDI and Hazard Quotient HQ indicated HQ>1 for DEHP in infants consuming PVC-packaged water. ILCR for DEHP was 2.3×10−5. ANOVA showed significant difference between polymer types $p<0.001$ and temperature $p<0.001$. Findings indicate PVC poses highest risk. Regulatory monitoring and public awareness on safe plastic use are recommended.

Keywords

Micro Plastics, PVC, PP, PE, Leaching, Additives, Phthalates, Health Risk, Onitsha

1. Introduction

Global plastic production exceeded 400 million tonnes in 2024, with PE, PP, and PVC accounting for >70%. In Nigeria, PE sachets and bottles, PP bowls, and PVC pipes dominate food and water packaging. Micro plastics <5mm and chemical additives are emerging contaminants. Additives like phthalates, BPA, antioxidants, and metal stabilizers are not

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chemically bound and can migrate into food. PVC uses DEHP and Pb/Cd stabilizers. PP uses antioxidants. PE uses slip agents. [8]

Infants and low-income consumers in Onitsha rely heavily on sachet water and takeaway food in these plastics. High temperature storage and reuse increase leaching. Despite this, no study in Anambra State has quantified both MPs and additives from all 3 polymers. [5]

Aim: Assess MPs and additive leaching from PVC, PP, PE packaging into food simulants in Onitsha.

Objectives

1) Quantify MPs in leachates
2) Determine phthalates, BPA, Pb, Cd migration
3) iii Estimate EDI, HQ, ILCR for consumers
4) Compare effects of polymer type and temperature.

2. Literature Review

2.1. Global Production and Use of PVC, PP, PE in Food Contact

PE 36%, PP 21%, PVC 12% of global plastic demand. In Nigeria, 60% of sachet water uses PE, 80% of takeaway uses PP, and PVC is used in pipes and cling films. [14].

2.2. Sources and Formation of Microplastics from Packaging

Primary vs Secondary MPs. Mechanical stress, UV, and temperature cause fragmentation. Studies from China, India, Turkey reported 50-5000 MPs/L in bottled water. [9]

2.3. Chemical Additives in Polymers

PVC: DEHP, DBP, DINP as plasticizers. Pb, Cd, Ba, Zn as heat stabilizers. PVC is most additive-rich.

PP: Antioxidants Irganox 1010, Irgafos 168. Slip agents.

PE: UV stabilizers, slip agents. Generally fewer additives.

IARC and EFSA classifications discussed. [6]

Migration Mechanisms and Factors

Fick's Law of Diffusion. Temperature effect: migration doubles every 10 ℃ increase. Acidic foods increase leaching 3.5 times. Reuse increases surface degradation. [10]

2.4. Health Effects

DEHP: anti-androgenic, linked to male infertility. Pb: neurotoxicity in children <5yrs. Cd: kidney damage. MPs: oxidative stress, gut inflammation. [11]

2.5. Regulatory Framework

EU 10/2011: SML for DEHP 1.5 mg/kg. FDA 21CFR. NAFDAC Food Packaging Regulation 2022. SON NIS 544. Gaps in enforcement in Nigeria. [12]

2.6. Knowledge Gap

No study in South-East Nigeria has combined MP + additive analysis for all 3 polymers under realistic temperature conditions [2].

Microplastics Release Patterns, PE had highest MPs 310/L at 70 ℃. This agrees with [Wright 2021] who reported PE bottles release more MPs due to amorphous regions. PVC had lowest MPs but rough surface from extrusion. [14]

2.7. Additive Migration

DEHP 89.4 µg/L in PVC at 70 ℃ exceeds EU SML 60 µg/L. This is due to 20-40% DEHP loading in flexible PVC. No DEHP in PE/PP confirms they are not plasticized. BPA detected in PP 5.6 µg/L likely from polycarbonate contamination during recycling. Pb 0.18 mg/kg and Cd 0.09 mg/kg in PVC exceed WHO limits for food contact. This points to use of recycled e-waste PVC in sachet production around Onitsha. [20]

2.8. Effect of Temperature and pH

ANOVA: $F=42.3$, $p<0.001$ for temperature. 70 ℃ increased migration by 2.3times vs 40 ℃. Acidic simulant increased phthalates by 1.8 times. This is critical because Nigerians store hot akara, rice in PP bowls. [15]

2.9. Health Risk Implications

Infant HQ 1.24 for DEHP means potential endocrine disruption with daily exposure. ILCR $2.3\times10-5$ is 23 times above USEPA acceptable 10−6. For 1000 infants, 23 may develop cancer risk over lifetime. Compare with [7] in Delta: HQ 0.8. Our values are higher due to hotter climate + reuse.5.5 Economic and Policy Implications [17]

PVC sachets are cheapest at ₦10. Banning without alternatives will hurt low-income families. Recommend phased shift to PET or glass.

2.10. Materials and Method

2.10.1. Sample Collection

24 packaging materials from Onitsha Main Market:
PVC: 4 water sachets, 4 pipe offcuts
PP: 8 takeaway bowls
PE: 8 water sachets. All food-grade.

2.10.2. Leaching Experiment

2 simulants: Distilled water pH 7, 3% Acetic acid pH 3 to mimic acidic food.

2 temperatures: 40 ℃ [room storage] and 70 ℃ [hot food]

for 10 days. Ratio 1g plastic: 10ml simulant. [13]

Microplastics Analysis

Filtration through 0.45 µm membrane. Counted under stereomicroscope 40 times. Polymer type confirmed by FTIR.

2.13. Chemical Analysis

Additives extracted with DCM. GC-MS for 6 phthalates + BPA. AAS for Pb, Cd after acid digestion. LOD: 0.01 µg/L.

QA/QC

Blanks, triplicates. Recovery 88-105%.

2.14. Health Risk Assessment

For Adult 60kg, IR 2L/day and Infant 10kg, IR 1L/day

CDI=BW ×ATC ×IR ×EF ×ED

HQ=RfDCDI RfD DEHP: 0.02 mg/kg/day

ILCR=CDI ×CSF CSF DEHP: 0.014

3. Results

Table 1. *micro plastics count particles / in leachates.*

S/N	POLYMER	40^{oc} WATER	70^{oc} WATER	40^{OC} ACID	70^{OC} ACID
1	PVC	42 ±9^c	98 ±12^b	967 ±10^c	145 ±15^a
2	PP	78 ±11^b	165 ±18^a	102 ±13^b	210 ±22^a
3	PE	120 ±14^b	310 ±28^a	155 ±16^b	289 ±25^a

Table 2. *phthalates and BPA Migration ug/l at 70oc acid.*

S/N	ADDITIVE	PVC	PP	PE	EU LIMIT
1	DEHP	89.4 ±5.2	8.2 ±1.1	ND	60
2	DBP	21.3 ±2.4	3.9 ±0.8	4.3 ±0.9	300
3	BPA	ND	5.6 ±1.2	ND	50

Table 3. *Heavy metals in PVC mg/kg.*

S/N	METAL	PVC	WHO LIMIT
1	Pb	0.18 ±0.02	0.1
2	Cd	0.09 ±0.01	0.05

Table 4. *Health risk for DEHP at 70^{oc}.*

S/N	AGE GROUP	CDI/mg/kg/d	HQ	ILCR
1	ADULT	0.0029	0.145	4.1E-05
2	INFANT	0.0089	1.24	2.3E-05

HQ>1 for infants using PVC

Table 5. MP Count's particles/L.

S/N	POLYMER	40W	70W	40A	70A
1	PVC	42 ±9	98 ±12	67 ±10	145 ±15
2	PP	78 ±11	165 ±18	102 ±13	210 ±22
3	PE	120 ±14	310 ±28	155 ±16	289 ±25

4. Discussion

Micro plastics Release Patterns

PE had highest MPs 310/L at 70 ℃. This agrees with [Wright 2021] who reported PE bottles release more MPs due to amorphous regions. PVC had lowest MPs but rough surface from extrusion. [16]

Additive Migration

DEHP 89.4 µg/L in PVC at 70 ℃ exceeds EU SML 60 µg/L. This is due to 20-40% DEHP loading in flexible PVC. No DEHP in PE/PP confirms they are not plasticized. BPA detected in PP 5.6 µg/L is likely from polycarbonate contamination during recycling. Pb 0.18 mg/kg and Cd 0.09 mg/kg in PVC exceed WHO limits for food contact. This points to use of recycled e-waste PVC in sachet production around Onitsha. [18]

Effect of Temperature and pH

ANOVA: F=42.3, p<0.001 for temperature. 70 ℃ increased migration by two times vs 40 ℃. Acidic simulant increased phthalates by 1.8x. This is critical because Nigerians store hot akara, rice in PP bowls. [23]

Health Risk Implications

Infant HQ 1.24 for DEHP means potential endocrine disruption with daily exposure. ILCR 2.3×10−5 is 23x above USEPA acceptable 10−6. For 1000 infants, 23 may develop cancer risk over lifetime. Compare with [7] in Delta: HQ 0.8. Our values are higher due to hotter climate + reuse. [19]

Economic and Policy Implications

PVC sachets are cheapest at ₦10. Banning without alternatives will hurt low-income families. Recommend phased shift to PET or glass.

PE released most MPs due to low crystallinity. PVC released least MPs but highest chemicals. Temperature significantly increased migration p<0.001, confirming hot food in plastics is risky. [11]

DEHP in PVC exceeded EU limit, consistent with use of recycled PVC in sachets of Pb/Cd likely from stabilizers, compared to Turkey 2023 study, our DEHP is times higher. [22]

Infant HQ>1 is critical because of low BW and bottle feeding. ILCR 10−5 is within USEPA concern range. This aligns with SDG 3 and 12.

5. Conclusion

This study assessed microplastics and additives leaching from PVC, PP, and PE packaging materials commonly used for food and water in Onitsha, Anambra State. The results demonstrate that polymer type, temperature, and pH significantly influence the release of MPs and chemical additives. PE packaging released the highest concentration of microplastics with 310 ±28 particles/L at 70 ℃, indicating that PE is the major contributor to MP pollution from food contact. However, PVC posed the greatest chemical risk due to the migration of DEHP, Pb, and Cd. DEHP concentration of 89.4 µg/L in PVC leachate at 70 ℃ exceeded the EU specific migration limit of 60 µg/L. Pb 0.18 mg/kg and Cd 0.09 mg/kg in PVC also exceeded WHO limits for food contact materials. Health risk assessment revealed that infants are the most vulnerable group.

The HQ of 1.24 for DEHP in infants indicates a potential non-carcinogenic health risk, while ILCR of 2.3×10−5 suggests a lifetime cancer risk above USEPA acceptable limits. The findings confirm that reuse of plastic packaging and exposure to high temperature, which is common practice in Onitsha, increases human exposure to hazardous substances. In conclusion, while all three polymers contribute to contamination, PVC requires urgent regulatory attention due to toxic additives, and PE requires attention due to high MP release. These findings provide baseline data for policymakers in Nigeria and contribute to achieving SDG 3: Good Health and Well-being and SDG 12: Responsible Consumption and Production.

6. Recommendation

Based on the findings of this study, the following recommendations are made:

Regulatory Enforcement by NAFDAC and SON: NAFDAC should enforce stricter monitoring of food contact plastics, especially recycled PVC. A total ban should be placed on the use of recycled PVC containing Pb and Cd stabilizers for food and water packaging. SON should ensure that all plastic packaging meets NIS 544 standards before market approval. [21]

Public Education and Awareness: The Anambra State Ministry of Health and NGOs should conduct sensitization campaigns in Onitsha Main Market. Consumers should be educated to avoid pouring hot food >60 ℃ into PP bowls and PE sachets, and to avoid reusing single-use PE water sachets. [4]

Industry and Manufacturing Practices: Plastic manufacturers should phase out DEHP and heavy metal stabilizers in flexible PVC. They should be encouraged to adopt safer alternatives such as DINCH or citrates. Use of food-grade virgin polymers should be promoted. [3]

Promotion of Safer Alternatives: Government and private sector should subsidize alternatives such as glass bottles, stainless steel containers, and biodegradable packaging to reduce dependence on plastics, especially for infant feeding. [25]

Waste Management and Circular Economy: NESREA and ASWAMA should strengthen plastic waste collection and recycling infrastructure in Onitsha to prevent environmental fragmentation into MPs. Investment in chemical recycling of PVC is recommended. [1]

Further Research: Future studies should assess breast milk and infant formula contamination, and conduct longitudinal cohort studies on children exposed to plastic additives in South-East Nigeria. [24]

Author Contributions

Anyanwu Chidinma Gogo: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources

Anyanwu Benedict Chinoye: Formal Analysis, Investigation

Obioha John: Data curation, Methodology

Conflicts of Interest

We declare that there are no conflicts of interests as rather this paper and such not stated in the Conflict-of-interest section.

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