

Impact of Plastic Waste on the Human Health in Low-Income Countries: A Systematic Review

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Abstract

Background: Plastic pollution is the accumulation of waste composed of plastic and its derivatives all over the environment. Whether in the form of visible garbage or microparticles, as it slowly degrades, plastic pollution poses significant threats to terrestrial and aquatic habitats and the wildlife that call them home, whether through ingestion, entanglement or exposure to the chemicals contained in the material. Unfortunately, there is a lack of documentation on the impact of plastic waste on human health in low- and middle-income countries (LMICs). **Methods:** We searched five electronic databases (PubMed, Embase, Global Health, CINAHL and Web of Science) and gray literature, following the preferred reporting elements for systematic reviews and meta-analyses (PRISMA), for the impact of plastic waste on human health in developing countries. We included quantitative and qualitative studies written in English and French. We assessed the quality of the included articles using the Mixed Methods Appraisal tool (MMAT). **Results:** A total of 3779 articles were initially identified by searching electronic databases. After eliminating duplicates, 3167 articles were reviewed based on title and abstract, and 26

were selected for full-text review. Only three articles were retained. The three articles dealt with practices likely to lead to oral exposure to plastic chemicals in human health, as well as the level of awareness of participants concerning the possible impact of plastic on human health, namely, the use of plastic baby bottles, the use of microwaves to cook food and reheat precooked food, the use of plastic bottles to store water in the refrigerator, water purifier containers with plastic bodies and plastic lunch boxes, the reuse of plastic bags and the inadequacy of treatment facilities. **Conclusion:** Plastic waste poses different risks to human health at every stage of its life cycle. Hence, strategies must be adopted to raise public awareness of the dangers of plastic waste to their health. **Trial registration:** The review protocol is registered in the PROSPERO international prospective register of systematic reviews (ID = CRD42023409087).

Keywords

Human Population, Plastic Waste, Health Impact, Low-Income-Countries (Humans, Iatrogenic Disease, Plastics, Policy, Recycling, Waste Management)

1. Introduction

Plastic is an indispensable part of the modern lifestyle [1]. It is widely used because of its many properties, such as low energy content, durability, lightness, ease of distribution and plasticity [2]. Gradually, it has become dominant in human use, replacing glass, wood, and metal in a wide range of products, including everyday household supplies, technology, medical equipment, and packaging [3]. Worldwide, statistics on plastic waste show a dizzying increase in quantity over the last few years [4] [5]. Indeed, in recent years, global plastic production has risen considerably, from 2 million tonnes in 1950 to approximately 360 million tonnes in 2019 [6]. The favorable physicochemical characteristics of these materials make them ideal materials for various industries, from food packaging, automotive, electronics, textiles and building to construction and medicine. At this consumption rate, it is estimated that by 2050, up to 33 billion tonnes of plastic will accumulate worldwide [7]. This situation justifies the growing interest not only of public authorities but also of nongovernmental organizations and the scientific community in defining the contours of the phenomenon and reversing the trend. Many studies have focused on the impact of plastic waste on the environment and living beings [2] [8] [9]. They are composed of chemicals such as bisphenol A and bisphenol S, which penetrate biological systems and are toxic to health [10]. While some studies have focused on the general public's evaluation and perception of plastic consumption and their awareness of plastics' direct and indirect effects on human health [6], others have highlighted these effects in detail [2] [8] [11]. For example, plastic has been shown to cause endocrine disruption in infants [7] and to increase short-term mortality and morbidity in an urban community exposed to the atmospheric byproducts of a

large polyvinyl chloride plastic fire [12]. For pregnant women, exposure to harmful chemicals such as phthalates and bisphenol A (BPA) can lead to complications such as miscarriage, premature birth, low birth weight and developmental problems in the fetus [13] [14] [15]. For example, Phthalates have been associated with reproductive abnormalities in male offspring, while exposure to BPA has been linked to hormonal imbalances and congenital disabilities [13] [14] [15]. Other authors have studied the indirect effects of plastic waste on elements related to human health. Research shows that plastic waste affects soil health [16] [17], terrestrial and aquatic ecosystems [8] [18] [19], food systems [20] [21] and many other aspects of human life. Treating plastic waste is crucial for reducing environmental pollution and promoting sustainability. General methods currently employed to manage and treat plastic waste include recycling, incineration, pyrolysis, plasma arc gasification, biodegradation and upcycling [22] [23] [24]. Improving awareness about the harms caused by plastics and the availability of alternatives involves a multi-faceted approach that engages various stakeholders through education, community involvement, policy advocacy, and media campaigns [25] [26]. By implementing these strategies in a coordinated way, it is possible to significantly improve awareness about the harmful impacts of plastics and the benefits of sustainable alternatives, driving more responsible behavior changes among various populations.

Moreover, most of these scientific contributions have focused on developed countries, neglecting the consequences for developing countries. Furthermore, apart from the rare systematic reviews on the adverse effects of plastic waste use on human health in northern countries [8] [19] [20], to our knowledge, no research has systematically synthesized the existing knowledge on the subject. To fill this gap, we conducted a systematic literature review on the impact of plastic waste on human health in developing countries. As such, this study answers the following question: What is the impact of plastic waste on human health in low-income countries?

2. Methods

To search the scientific literature for relevant evidence on the impact of plastic waste on human populations in developing countries, we formulated the following research question: “What is the impact of plastic waste on human populations in developing countries?” The methodology followed the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMAP) [27] [28]. This systematic review protocol was registered in the Prospective Register of Systematic Reviews (PROSPERO) under the number (ID = CRD42023409087) of March 28, 2023.

2.1. The Eligibility Criteria

All original research articles on the impact of plastic waste on human health in low-income countries meeting the following eligibility criteria were included: 1)

research with a quantitative, qualitative or mixed design; 2) articles published in English or French; and 3) limited to low- or middle-income countries based on the World Bank Listing June 2022 [29]. The World Bank defines low-income economies as those with a gross national income (GNI) per capita of \$1025 (US dollars) and middle-income economies as those with a GNI per capita between \$1026 and \$4035 [30].

The exclusion criteria were as follows: 1) commentaries, review articles, letters, discussion papers, posters, conference abstracts, conference reports, dissertations and systematic reviews; and 2) studies written in languages other than English and French, articles without abstracts and inaccessible full text, and those not addressing the impact of plastic waste.

2.2. Information Sources

We searched the following electronic databases due to their wide range of scientific publications and multidisciplinary content. These include PubMed, CINAHL, Global Health, Embase and Web of Science. The search was limited to the English or French language and human subjects. Additional searches were carried out in the bibliography of the retained articles. Manual searches were also conducted in academic journals to identify other relevant studies.

2.3. Search Strategy

We used the PICO method to identify the keywords of the research question. We then developed a search equation adapted to search PubMed, CINAHL, Global Health, Embase and Web of Science (Table 1).

After combining the PICO components, we have refined our search equation for greater efficiency and precision, which is now as follows:

(“Humans” [Mesh] OR “human population*” OR “Persons” [Mesh] OR “People” AND “Plastics” [Mesh] OR “plastic trash” OR “plastic waste*” AND “Health Impact Assessment” [Mesh] OR “Population Health” [Mesh] OR “Health effect*” OR “Health outcome*” OR “Health concern*” OR “Health impact*”).

Table 1. Identification of keywords.

PICO	keywords	Synonyms/free vocabulary	MESH TERMS
P	human, human population	People	“Humans” [Mesh], “Persons” [Mesh]
I/E	Plastic waste	plastics garbage, plastic trash	“Plastics” [Mesh]
O	health impact	Health effects, health outcomes, health concerns	“Health Impact Assessment” [Mesh] “Population Health” [Mesh]
S	“low-income countries”	developing countries, low-income areas	“Developing Countries” [Mesh]

We searched the PubMed, CINAHL, Global Health, Embase and Web of Science databases from January 31 to March 13, 2023. Overall, 3779 articles were retrieved from these five (5) electronic databases.

2.4. Recording of Studies

The searches were carried out on all five databases, and the articles identified in the searches were exported to Rayyan software. After removing duplicates, 3167 items were retained for review.

2.5. Study Selection

The selection of relevant articles about our research question and inclusion criteria was made gradually. Before the selection process, to improve its reliability, all reviewers participated in a preparatory meeting with an example taken from an article to facilitate reading. The selection process involved the title, abstract, and full text. Initially, the group leader divided the researchers into three subgroups (WSR, TB and AWVA; GA and NB; GKKP and CK) and selected articles based on their titles and abstracts. Of the 3167 articles examined, 3141 were excluded at this stage based on all the exclusion criteria. We obtained the full texts of the potentially eligible studies by at least one of the reviewers. We compared and validated the results through a consensus session. Disagreements were resolved by discussion and consensus involving all the investigators and with the help of a third reviewer if the disagreement could not be resolved. The articles selected based on their titles and abstracts were imported into the ZOTERO software.

Full-text articles were then selected in three stages. In the first stage, researchers were divided into two subgroups (WSR, GKKP, TB and AWVA) and (GA, CK and NB) to review at least one article and decide on their inclusion to harmonize views on the article selection and quality analysis grids. The researchers selected the remaining articles independently and separately in the second stage. The third stage involved comparing the selected articles to resolve discrepancies by consensus. To reach a consensus, six articles were evaluated by a senior team member (PN). A flow chart summarizing the study selection process was drawn. At the end of this process, twenty-six (26) full texts were retained after the titles and abstracts were read:

The characteristics of the excluded studies are also available in **Appendix 1**. Uncertainties and disagreements over inclusion were resolved by discussion between the seven (7) investigators. The following flowchart illustrates the selection process and is represented by **Figure 1**: [31].

2.6. Data Elements/Extraction

An extraction grid was developed by a reviewer (WSR) and validated by all team members. The subgroup data were independently extracted from the selected studies using the MMAT extraction grid [32]. Data were extracted according to the following variables : 1) title of the article, 2) name of the first author, 3) year of publication of the study, 4) location of the study, 5) aim or objectives of the

study, 6) type of study, 7) duration of the study, 8) data collection, 9) collection tools, 10) analysis methods, 11) primary results or main outcomes, 12) participants, 13) sex ratio and 14) sample size. Some of these extracted data are tabular in shape in the Results section.

2.7. Outcomes and Priorities

The main results focus on plastic waste's impact on developing countries' human population. Plastic waste can cause serious environmental and health hazards both directly and indirectly. The impact that plastics can have on human health has been the subject of numerous studies, with the main findings focusing on the following points:

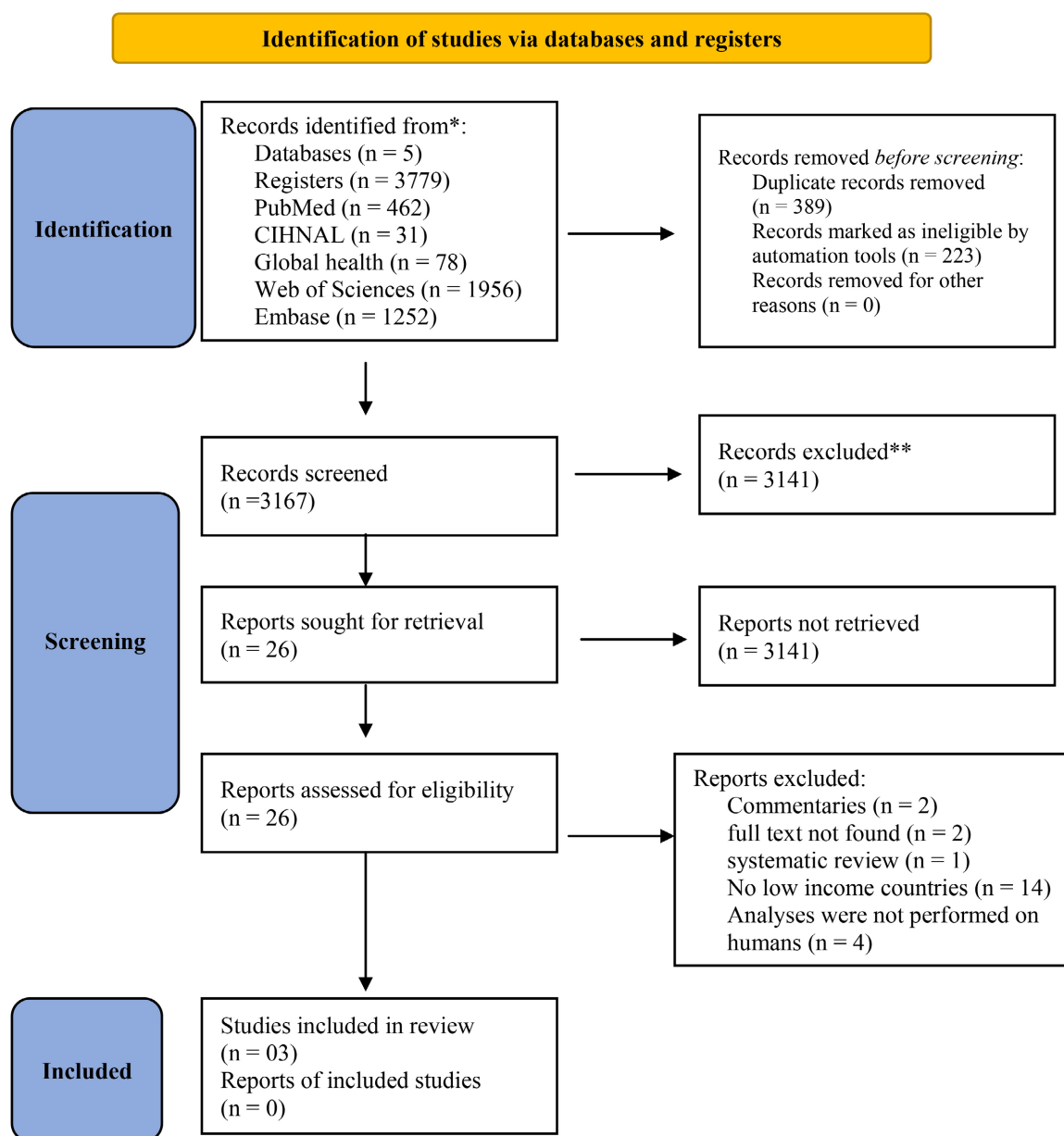


Figure 1. Adapted PRISMA flow chart.

1) Exposure to BPA and BPS through the gut. Plastic contains chemicals that may enter the human body and harm human health.

2) Home waste storage is associated with houseflies in the kitchen ($r = 0.17$, $p < 0.0001$). The presence of houseflies in the kitchen during cooking is correlated with the incidence of childhood diarrhea ($r = 0.36$, $p < 0.0001$). Inadequate solid waste facilities result in the indiscriminate burning and burying of solid waste. There was an association between waste burning and the incidence of respiratory health symptoms among adults ($r = 0.25$, $p < 0.0001$) and children ($r = 0.22$, $p < 0.05$). Poor handling and disposal of waste are major causes of environmental pollution, which creates breeding grounds for pathogenic organisms and the spread of infectious diseases.

3) Health hazards associated with the use of plastic bags.

2.8. Quality Assessment of Included Studies

The methodological quality of the three studies included in this synthesis was assessed using the Mixed Methods Appraisal Tool (MMAT) (see **Appendix 2**). The MMAT is a critical appraisal tool designed for mixed systematic reviews, i.e., qualitative, quantitative and mixed methods studies. It assesses the methodological quality of five categories of studies: qualitative research, randomized trials, quantitative studies, descriptive studies and mixed-method studies [32] [33]. The MMAT criteria list includes two triage questions and five questions per study category. In addition, the document consists of indicators that explain and illustrate certain criteria. For each question, the authors answered by ticking “Yes,” “Do not know,” or “No.”

2.9. Data Synthesis and Analysis

The main results of the studies were analyzed and summarized in narrative form. A systematic narrative synthesis was carried out using the information presented in the text and tables to summarize and explain the characteristics and results of the included studies.

3. Results

3.1. Search Results

A total of 3779 articles were retrieved through various electronic database searches. After eliminating duplicates ($n = 612$), 3167 articles were reviewed based on title and abstract. Of these reviewed articles, 26 were retained for full-text review, and 23 articles were excluded for the following reasons: full texts not found ($n = 2$), articles excluded for comments ($n = 2$), a systematic review ($n = 1$), articles carried out outside developing countries ($n = 14$), and articles excluded because analyses were not carried out in humans but rather in animals or laboratory tests ($n = 4$). The flow and number of studies examined at each stage of this systematic review are presented according to the PRISMA diagram in **Figure 1**.

3.2. Characteristics of the Included Studies

The articles included were published in English between 1939 and 2023. **Appendix 1** provides a brief overview of the main characteristics of the included studies. The articles included in our systematic review used different types of studies, including cross-sectional studies and a quantitative randomized trial. The study duration and data collection periods varied from article to article.

All studies were conducted in middle- and low-income countries. All three articles were in English. The size of the study population was 1766, including 556, 25 and 960 participants. The sex ratio favored women in all three studies, with 0.9 and 0.6 in two (2) studies and an exclusively female presence in the other.

3.3. Quality Assessment

The studies were generally of high quality. Consensus responses to all MMAT methodological quality criteria were “yes” for the three included studies (**Appendix 2**).

3.4. Study Selection

The primary search strategy identified 3779 potentially relevant studies. After an initial screening based on abstract titles, 26 studies were selected for full-text review. At this stage, 23 studies were excluded, as summarized in **Appendix 3**. The methodological quality of the remaining three studies was assessed. No studies were excluded based on quality assessment.

3.5. Type of Study

The articles included in our systematic review included different types of studies, including cross-sectional studies (2) and randomized quantitative studies (1). The study duration and data collection periods varied. Details can be found in **Appendix 4**. The types of studies in our selected articles were all quantitative. The data collection methods used in all these studies included interviews with a structured questionnaire (2) and interviews with 960 female heads of household (1).

3.6. Year of Publication

The included articles were published as early as 2005 and as recently as 2021. One article was published in 2021, one (1) in 2013 and one (1) in 2005.

3.7. Description of the Studies

The three studies included in the review were conducted in India (Varanasi and Mangalore), and the last was in Ghana (Accra). The objectives of each of these articles are as follows:

- ✓ This cross-sectional survey aimed to assess the use of plastic in contact with food, awareness of the health hazards of plastic chemicals, and warning labels on plastic items among a sample population in Varanasi.
- ✓ This study examined household-level waste management and disposal practices in the Accra metropolitan area, Ghana.

- ✓ This study was performed to determine people's awareness of the health hazards associated with the use of plastic bags and their perceptions of legislation prohibiting plastic bags.

3.8. Quality Assessment of the Included Articles

To assess the quality of the articles included, we used the MMAT. The methodological quality of our three articles included in this synthesis was assessed using the mixed methods appraisal tool (MMAT). It is a critical appraisal tool designed for mixed systematic reviews, i.e., reviews that include quantitative, qualitative and mixed methods studies. It assesses five categories of methodological quality: qualitative research, randomized controlled trials, nonrandomized studies, quantitative descriptive studies and mixed-method studies. The tool is divided into two parts. First, the tool was suitable for this study because it was explicitly developed for the quality assessment of systematic reviews involving qualitative, quantitative and mixed-method designs. The MMAT criteria list includes indicators that explain and illustrate specific criteria. Our three articles evaluated were all quantitative studies. The articles involved 556 adult visitors, 960 female heads of household and 250 women (160) and men (90).

For each question, the authors answered by ticking "yes" or "no," "do not know," or "comments." Regarding the methodological quality of the articles, three studies scored 6/6 (100% high quality), indicating overall high methodological quality (see **Table 2**).

3.9. Main Results

3.9.1. Practices Likely to Result in Oral Exposure to Plastic Chemicals Such as BPA and BPS for Human Health

In our first article, the age of the participants ranged from 18 to 76 (**Table 3**) out of a total of 550. The participants interviewed were as follows: 246 students (44.24%), 102 housewives (18.34%), 104 public/private employees (18.70%) and 104 company employees (18.70%). More than half of the participants were women (53.23%), and 34.89% had a higher education [10] (**Table 3**).

This article discusses the practices that can lead to oral exposure to plastic chemicals such as BPA and BPS, as well as the participants' level of awareness of the possible impact of plastics on human health (**Table 4**).

✓ The use of plastic baby bottles [10]

Most participants were found to follow practices that were likely to result in oral exposure to plastic chemicals such as BPA and BPS. A total of 42.9% of the participants accepted using plastic bottles rather than substitutes for infant feeding. Of these, a significant number (71.2%;) were regular users who did not use any type of bottle other than plastic. A significant number (61.9%) of participants admitted that they were not concerned about the material of the toys (plastic/other) they chose for their children [10]. Plastic baby bottles, especially when used with hot liquids, can be the main source of infants' exposure to these toxic plastic chemicals.

Table 2. Criteria from the mixed methods appraisal tool.

Articles	S1	S2	S3	2.					4.				
				2.1	2.2	2.3	2.4	2.5	4.1	4.2	4.3	4.4	4.5
Assessment of Awareness Regarding Health Hazards of Plastic Chemicals and their Warning Label among a Sample Population of Varanasi City: A Cross-sectional Study	1	1	1								1	1	1
Usage of Plastic Bags and Health Hazards: A Study to Assess Awareness Level and Perception about Legislation Among a Small Population of Mangalore City	1	1	1								1	1	1
Environmental and health impacts of household solid waste handling and disposal practices in Third World cities: The case of the Accra Metropolitan Area, Ghana	1	1	1	1	1	1	1	1	1				

Table 3. Distribution of participants according to the demographic profile.

	Total
Gender	
Male	260
female	296
Education	
Higher Secondary School	154
Graduate	194
Postgraduate	190
Ph.D	18
Occupation	
Student	246
Housewife	102
Government/private employee	104
Own business	104

Table 4. Association of the level of awareness of plastic chemicals and their warning labels.

	Knowledge level	
	Yes	No
Informed about safe resin identification code/plastic code	18 (3.2)	538 (96.8)
Informed about toxic plastic chemical BPA	57 (20.5)	221(79.5)
Informed about “BPA-free” plastic or “food-grade plastic.”	35 (12.6)	243 (87.4)

✓ **Using microwaves to cook and reheat precooked food [10]**

Approximately 59.4% of participants used microwaves to cook food and re-

heat precooked food, and 27.3% admitted that they preferred plastic food containers for microwaving their food to containers made of other microwave-safe materials. Interestingly, these microwave users had no information or concerns about using food-grade plastic for microwaving [10].

✓ **Plastic food containers for microwaving food to containers made of other microwaveable materials [10]**

✚ **The use of plastic bottles to store water in the refrigerator water tank**

The use of plastic bottles for refrigerator water storage was reported by 84.9% of participants, while a statistically significant number of participants (64.4%) accepted the use of plastic overhead water tanks. In addition, 73% and 62.2% of the participants used water purifier containers with plastic bodies and plastic lunch boxes, respectively.

Approximately 60.1% of participants admitted to reusing nonrecyclable plastic bags and containers several times for food storage [10].

A significant number of participants (91.3%) stated that while drinking tea outside their homes, which is a widespread practice in their daily lives, they prefer tea in kulhad (a traditional clay cup without a handle), considering it a safer option for serving tea compared to plastic cups [10].

✚ **Water purifier containers with plastic bodies and plastic lunch boxes [10]**

A significant number of participants (91.3%) said that while drinking tea outside their homes, which is a widespread practice in their daily lives, they prefer tea in kulhad (a traditional clay cup without a handle), considering it a safer option for serving tea compared to plastic cups [10].

3.9.2. Participants' Level of Awareness of the Possible Impact of Plastics on Human Health [10]

Informed about the resin identification code/safe plastic code: 18, or 3.2%, were reported versus 96.8% uninformed.

- ✓ 20.5% of the respondents were informed about the toxic plastic chemical “bisphenol A,” whereas 79.5% were not disclosed.
- ✓ 12.6% of the participants were informed about “BPA-free” or “food-grade plastic,” and 87.4% were uninformed.
- ✓ Resin identification code information.

Assessing participants' level of awareness of the possible impact of plastic on human health revealed some interesting findings. Although 84.9% of the participants believed that in addition to being harmful to the environment, plastic is also detrimental to human health, a significant number of participants (72.3%) were unaware that their usual practices of cooking and storing food and drink in plastic containers could expose them daily to toxic plastic chemicals such as BPA and BPS. When explicitly asked, significantly fewer participants (12.6%) understood “BPA-free plastic” and “food-grade plastic,” and 20.5% of participants knew which toxic chemicals leached from plastic. Only 3.2% of participants correctly recognized “resin identification codes” [10] [30] [31] (See **Table 4**).

Most (97.1%) participants agreed that saying no to plastic can positively impact

health and the environment. Despite this, a significant number of these participants (44.2%) admitted to having increased or not decreased plastic use in recent years. Approximately 48.6% of the participants agreed with their reliance on plastic shopping bags, while others used shopping bags made from nonplastic materials [10].

Participants' awareness of plastic chemicals and health risks was assessed using an arbitrary scale described below. Participants were given a score of 0, 1 or 2 according to the number of correct answers to the questions. There were a total of 10 such questions. Participants who did not answer any of these questions correctly received a score of "0". Participants who answered $\leq 50\%$ of these questions correctly received a score of "1". Participants who answered more than 50% of the questions correctly received a score of "2" [10] (Table 5). Of the participants, 78.1% scored "1", indicating their partial knowledge of the health risks of using plastics, plastic chemicals, and warning labels. There were no statistically significant differences in awareness levels according to age, gender, education or occupation [10].

In this second article, the mean age of the 250 participants was 32.8 ± 10.8 years. The majority, 160 (64%), were women, and the majority, 187 (74.8%), had studied to the undergraduate level or above. Of the participants, 216 (86.4%) out of 250 were aware of at least one plastic health hazard. Of these 216 participants, 177 (81.9%) knew that plastics are not biodegradable, and 50 (23.1%) knew that plastics contain carcinogenic substances. The level of awareness of the hazards associated with the use of plastics was significantly greater among women ($p = 0.027$), participants educated to a degree level or above ($p = 0.004$) and professionals and semiprofessionals ($p < 0.001$) (Table 6) [34].

✓ Reusing plastic bags [34].

There were 50 (20%) participants who reused plastic bags for shopping after use; 33 (20.6%) of these 50 participants were women, and 17 (18.9%) were men ($p = 0.742$). Three (1.2%) participants disposed of plastic bags in open areas after use, and 197 (78.8%) participants disposed of plastic bags in garbage cans. Of the users, 138 (55.2%) felt that plastic bags were popular with customers because of their greater availability, 111 (44.4%) because of their durability, such as the ease of carrying liquid items, and 42 (16.8%) because they were lightweight [34].

All 179 (71.6%) participants knew that plastic bags were recyclable. The alternatives to plastic bags suggested by users were jute bags (76, 30.4%), biodegradable plastic bags (65, 26%) and paper bags (53, 21.2%). Only 13 (5.2%) participants used cloth bags instead of plastic bags for shopping. No fewer than 48 (19.2%) participants were in the habit of asking retailers for more plastic bags [34].

Table 5. Association of level of awareness (level of awareness has been described as awareness score 0 to 2) to the health hazards of plastic chemicals with sociodemographic variables of the participants [10].

variables	Score "0" (%)	Score "1" (%)	Score "2" (%)
Number of participants	8 (1.4)	434 (78.1)	114 (20.5)

Table 6. Distribution of participants' awareness of the dangers of using plastic bags [34].

	Aware (%)	Unaware (%)	Total	X2value, dF*value p
Gender				
Male	72 (80)	18 (20)	90	
Female	144 (90)	16 (10)	160	0.027
Education				
Higher Secondary School	13 (65)	7 (35)	20	
Graduate	34 (79.1)	9 (20.9)	43	
Postgraduate	121 (89)	15 (11)	136	
Ph.D	48 (94.1)	3 (5.9)	51	P 0.004
Occupation				
Housewife	98 (91.6)	9 (8.4)	107	
Student	12 (85.7)	2 (14.3)	14	
Skilled workers	30 (73.2)	11 (26.8)	41	
Semi-skilled/unskilled workers	4 (36.4)	7(63.6)	11	
Semi-professional/Professional	72 (93.5)	5(6.5)	77	
Number of participants	216 (86.4%)	34	250	P < 0.001

✓ Knowledge of legislation banning the use of plastic bags [34]

Overall, 213 (85.2%) participants were aware of the legislation banning the use of plastic bags, and 166 (77.9%) participants responded in favor of the legislation. Of the participants, 47 (22.1%) were against the legislation. The most common reason for opposition mentioned by 33 (70.2%) participants was the inconvenience caused when shopping. Professional status was found to significantly influence the perception of the legislation banning the use of plastic bags ($p = 0.01$). No other sociodemographic variables, such as age, gender or level of education, influenced the perception of legislation banning the use of plastic bags [34] (Table 7).

3.9.3. Waste Storage at Home [35]

The third article shows that most households store solid waste inside the home; only 22.6% of households store it outside (Table 8).

Household solid waste storage practices, particularly waste stored inside the house, are associated with houseflies in the kitchen during cooking [35].

Most households store their waste in open containers and plastic bags inside the house. Keeping waste at home is associated with houseflies in the kitchen. The presence of houseflies in the kitchen during cooking is correlated with the incidence of infantile diarrhea. More than 33.6% of respondents who disposed of their waste at collection points, 33.4% of those who disposed of their solid waste in empty yards and 44.4% of those who disposed of their waste in watercourses reported that flies were always present in the kitchen [35].

Table 7. Distribution of participants according to perceptions of the plastic bag ban [34].

	In favor of ban (%)	Not in favour of ban (%)	Total	X ² value, dF*value p
Gender				
Male	55 (74.3)	19 (25.7)	74	0.354
Female	111 (79.9)	28 (20.1)	139	
Education				
Higher Secondary School	39 (76.5)	12 (23.5)	51	0.959
Postgraduate	91 (78.4)	25 (21.6)	116	
PhD	36 (78.3)	10 (21.7)	46	
Occupation				
Housewife	62 (72.1)	24 (27.9)	86	P < 0.001
Student	8 (85.7)	1 (11.1)	9	
Skilled workers	28 (75.7)	9 (24.3)	37	
Semi-skilled/unskilled workers	4 (44.4)	5 (55.6)	9	
Semi-professional/ Professional	64(88.9)	8 (11.1)	72	
Number of participants	166()	47	213	

Table 8. Household solid waste disposal practices [35].

Waste storage	Number of households	Percentage
Do not store	217	22.6
Open container	370	38.5
Closed container	279	29.1
Plastic bag	94	9.8
Total	960	100

3.9.4. Inadequate Treatment Facilities [35]

Inadequate solid waste treatment facilities lead to indiscriminate incineration and landfilling of solid waste. There is a link between waste incineration and the incidence of respiratory health symptoms in adults and children [35]. Poor waste handling and disposal are major causes of environmental pollution, creating breeding grounds for pathogenic organisms and promoting the spread of infectious diseases. Improving access to solid waste collection facilities and services will contribute to achieving good environmental health in Accra [35].

4. Discussion

4.1. Summary of Main Findings

In this systematic review, we screened 3167 journal articles and selected three ar-

ticles containing quantitative information about the impact of plastic waste on human health in low-income countries. Plastic pollution threatens the environment, human health, and future generations. Humans are exposed to many toxic chemicals and microplastics through inhalation, ingestion, and direct skin contact throughout the plastic lifecycle. Although the health impacts of plastics are still a relatively new research area, scientific results indicate that the toxic chemical additives and pollutants in plastics threaten human health globally. Given the heterogeneity in quantitative study design and outcome measures, we could not conduct meta-analyses. Thus, we synthesized the findings narratively.

Generally, men engage in practices likely to result in oral exposure to plastic chemicals that harm their health. This may be due to a lack of information or misinformation about the possible impact of plastics on human health. Most of the participants in our study admitted to following common plastic container practices that can cause plastic chemicals to leach into their edible products. Washing plastic containers in the heat of a dishwasher can also leach chemicals and should, therefore, be avoided.

4.2. Comparison with Other Reviews

Plastic materials contain specific chemical compounds that can infiltrate the human body, leading to adverse health effects. Research indicates plastic chemicals are more hazardous to children's health, particularly infants. Moghadam *et al.* (2012) conducted a study on the impact of bisphenol A in BPA-free baby feeding bottles. They discovered that children's immaturity makes their gut more susceptible to damage triggered by these products [36]. The World Health Safety Agency banned BPA in baby cups and bottles due to increasing apprehension about the health risks of BPA [36].

Even though in current daily practices, plastic can release harmful chemicals and expose people to the impact of these chemicals on human health, the willingness to reduce the use of plastic routinely and to prefer plastic substitutes was not observed in most participants. Although most people have heard that plastic and microwaves are not mixed, it is uncommon for people to reheat their food in plastic containers, such as Tupperware.

Plastic bags preserve and store food in the home, collecting waste before disposal. The storage of waste in plastic containers within homes or their immediate vicinity promotes the presence of flies, which transmit germs, resulting in diarrhea. Domfeh *et al.* (1999) reported, in research conducted in Accra (Ghana), that infectious diseases leading to diarrhea and associated poor hygiene were frequently reported health issues in the city's outpatient health centers [35]. This situation may be explained by the fact that households do not have a home collection service, and those with a low capacity are inadequate. A lack of funding in the rapidly expanding cities of many low- and middle-income countries leads to extensive informal waste recycling [33]. According to a survey in Kinshasa, most respondents (69%) managed their waste by landfilling. Ninety-six

percent of respondents said no infrastructures were available for waste management [37].

Waste burning-related air pollution poses health hazards to nearby populations [33], exposing them to respirable airborne particles such as carbon monoxide, nitrogen oxide, and sulfur dioxide. A study in Jakarta [10] showed a correlation between uncollected garbage and the onset of respiratory illness in mothers and children who burned their garbage.

In rural areas, a few more affluent residents might have their waste collected and taken to alternative sites for disposal or burning. However, 34 out of 48 residents can burn waste in their backyards or dispose of it locally (in streets, riverbeds, scrubland or informal central landfills). Therefore, the open burning of garbage is a common risk reduction strategy, although the impacts on local air quality, human health, and climate remain primarily ignored [38].

This systematic review emphasizes the hazards of using and disposing of plastic containers. These containers come in various shapes and sizes, serving multiple purposes, such as holding food, drinking water, and household waste. The use of plastics poses health risks due to the penetration of chemical substances into the intestines and lungs, resulting in various health issues.

It is worth mentioning that while the hazards of plastics are well documented, there is a regrettable lack of awareness and information among the public. Emphasis should be placed on increasing awareness among various people about the harm caused by plastics and the availability of alternatives.

This systematic literature review confirmed that plastics threaten human health and the environment. The quality of the studies reviewed was intriguingly methodological. Behavior-change communication must be enhanced with the public, governmental organizations, and nongovernmental organizations. However, developing countries have undertaken minimal work on plastic waste hazards, and necessary measures to improve human and environmental protection are either lacking or poorly enforced.

4.3. Study Limitations

Our study of the impact of plastic waste on human health has several limitations. First, we may have omitted relevant studies by retaining only articles published in English or French. We may have missed some relevant studies, as unpublished and gray literature is inaccessible in most low- and middle-income countries.

5. Conclusions

Plastic waste is a ubiquitous by-product of human activity and has a detrimental impact on human health. Extensive research has been conducted in this area, revealing that plastic waste releases harmful substances that humans can inhale, as well as substances that can contaminate food. Unfortunately, people are generally uninformed about the hazards inherent in plastic waste and the available alternatives to plastics.

Conducting awareness-raising activities on the dangers of misusing plastics and plastic waste among the population is crucial to encourage a shift in behavior, ultimately leading to improved protection of human health and the environment.

Data Availability Statement

We used data from published primary studies, and the datasets presented in this article are not readily available. Therefore, information and access requests should be addressed to the corresponding authors mentioned in the primary articles.

Author Contributions

PN conceived and supervised the study. WSR drafted the manuscript and synthesized the results. All the authors selected the studies and extracted the data. WSR, GKKP, GA, CK, and PN extensively reviewed the manuscript. All the authors read, provided feedback, and approved the final version of the manuscript.

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Conflict of Interest

The authors declare that the research was conducted without commercial or financial relationships. There is no conflict of interest.

References

- [1] Sharma, P., Bhagat, P., Mandal, M. and Singh, T. (2021) Assessment of Awareness Regarding Health Hazards of Plastic Chemicals and Their Warning Label among a Sample Population of Varanasi City: A Cross-Sectional Study. *Journal of Pharmacy and Bioallied Sciences*, **13**, S1428-S1433. <https://doi.org/10.4103/jpbs.jpbs.240.21>
- [2] Rustagi, N., Pradhan, S.K. and Singh, R. (2011) Public Health Impact of Plastics: An Overview. *Indian Journal of Occupational and Environmental Medicine*, **15**, 100-103. <https://doi.org/10.4103/0019-5278.93198>
- [3] North, E.J. and Halden, R.U. (2013) Plastics and Environmental Health: The Road Ahead. *Reviews on Environmental Health*, **28**, 1-8. <https://doi.org/10.1515/reveh-2012-0030>
- [4] Chanda Chansa Thelma, C.T., Chitondo, L. and Ngulube, L. (2024) Plastic Pollution: Causes, Effects, and Solutions. *International Journal of Research Publication and Reviews*, **5**, 6570-6581.
- [5] Ziani, K., Ioniță-Mîndrican, C.B., Mititelu, M., Neacșu, S.M., Negrei, C., Moroșan, E., *et al.* (2023) Microplastics: A Real Global Threat for Environment and Food Safety: A State of the Art Review. *Nutrients*, **15**, Article No. 617. <https://doi.org/10.3390/nu15030617>
- [6] Shanmugam, V., Das, O., Neisiany, R.E., Babu, K., Singh, S., Hedenqvist, M.S., *et al.* (2020) Polymer Recycling in Additive Manufacturing: An Opportunity for the Cir-

- cular Economy. *Materials Circular Economy*, **2**, Article No. 11.
<https://doi.org/10.1007/s42824-020-00012-0>
- [7] Lamb, J.B., Willis, B.L., Fiorenza, E.A., Couch, C.S., Howard, R., Rader, D.N., et al. (2018) Plastic Waste Associated with Disease on Coral Reefs. *Science*, **359**, 460-462.
<https://doi.org/10.1126/science.aar3320>
- [8] Adeniran, A.A. and Shakantu, W. (2022) The Health and Environmental Impact of Plastic Waste Disposal in South African Townships: A Review. *International Journal of Environmental Research and Public Health*, **19**, Article No. 779.
<https://doi.org/10.3390/ijerph19020779>
- [9] Barbir, J., Leal Filho, W., Salvia, A.L., Fendt, M.T.C., Babaganov, R., Albertini, M.C., et al. (2021) Assessing the Levels of Awareness among European Citizens about the Direct and Indirect Impacts of Plastics on Human Health. *International Journal of Environmental Research and Public Health*, **18**, Article No. 3116.
<https://doi.org/10.3390/ijerph18063116>
- [10] Sharma, P., Bhagat, P., Mandal, M. and Singh, T. (2021) Assessment of Awareness Regarding Health Hazards of Plastic Chemicals and Their Warning Label among a Sample Population of Varanasi City: A Cross-Sectional Study. *Journal of Pharmacy and Bioallied Sciences*, **13**, Article No. 1428.
https://doi.org/10.4103/jpbs.jpbs_240_21
- [11] Berger, E., Potouridis, T., Haeger, A., Püttmann, W. and Wagner, M. (2015) Effect-Directed Identification of Endocrine Disruptors in Plastic Baby Teethers. *Journal of Applied Toxicology*, **35**, 1254-1261. <https://doi.org/10.1002/jat.3159>
- [12] Upshur, R., James, M.L., Richardson, E., Brunton, G., Hunter, W. and Chambers, L. (2001) Short-Term Adverse Health Effects in a Community Exposed to a Large Polyvinylchloride Plastics Fire. *Archives of Environmental Health: An International Journal*, **56**, 264-270. <https://doi.org/10.1080/00039890109604452>
- [13] Gardener, H., Nguyen, V. and Hoepner, L.A. (2022) Phthalate and Bisphenol A Exposures during Pregnancy: Findings from the National Children's Study. *Environmental Research*, **214**, Article ID: 114122.
<https://doi.org/10.1016/j.envres.2022.114122>
- [14] Wang, Y. and Qian, H. (2021) Phthalates and Their Impacts on Human Health. *Healthcare*, **9**, Article No. 603. <https://doi.org/10.3390/healthcare9050603>
- [15] Zurub, R.E., Cariaco, Y., Wade, M.G. and Bainbridge, S.A. (2024) Microplastics Exposure: Implications for Human Fertility, Pregnancy and Child Health. *Frontiers in Endocrinology*, **14**, Article ID: 1330396.
<https://doi.org/10.3389/fendo.2023.1330396>
- [16] Perković, S., Paul, C., Vasić, F. and Helming, K. (2022) Human Health and Soil Health Risks from Heavy Metals, Micro(Nano)Plastics, and Antibiotic Resistant Bacteria in Agricultural Soils. *Agronomy*, **12**, Article No. 2945.
<https://doi.org/10.3390/agronomy12122945>
- [17] Brevik, E.C., Slaughter, L., Singh, B.R., Steffan, J.J., Collier, D., Barnhart, P., et al. (2020) Soil and Human Health: Current Status and Future Needs. *Air, Soil and Water Research*, **13**, 1-23. <https://doi.org/10.1177/1178622120934441>
- [18] Chae, Y. and An, Y.J. (2017) Effects of Micro- and Nanoplastics on Aquatic Ecosystems: Current Research Trends and Perspectives. *Marine Pollution Bulletin*, **124**, 624-632. <https://doi.org/10.1016/j.marpolbul.2017.01.070>
- [19] Chae, Y. and An, Y.J. (2018) Current Research Trends on Plastic Pollution and Ecological Impacts on the Soil Ecosystem: A Review. *Environmental Pollution*, **240**, 387-395. <https://doi.org/10.1016/j.envpol.2018.05.008>

- [20] Yates, J., Deeney, M., Rolker, H.B., White, H., Kalamatianou, S. and Kadiyala, S. (2021) A Systematic Scoping Review of Environmental, Food Security and Health Impacts of Food System Plastics. *Nature Food*, **2**, 80-87. <https://doi.org/10.1038/s43016-021-00221-z>
- [21] Ouédraogo, A., Akoudjin, M., Somda, M.B., Comboigo, S.M., Karambiri, S.M., Boma, S., *et al.* (2022) Impact des déchets plastiques dans l'alimentation des ruminants domestiques: Cas de l'élevage urbain et périurbain de la ville de dori, Région du sahel. *ESJ Natural/ Life/ Medical Sciences*, **18**, 349. <https://doi.org/10.19044/esj.2022.v18n40p349>
- [22] Eyeberu, A., Getachew, T., Sertsu, A., Sisay, M., Bayes, Y., Debella, A., *et al.* (2022) Teenage Pregnancy and Its Predictors in Africa: A Systematic Review and Meta-Analysis. *International Journal of Health Sciences*, **16**, 47-60.
- [23] Qian, Q. and Ren, J. (2024) From Plastic Waste to Potential Wealth: Upcycling Technologies, Process Synthesis, Assessment and Optimization. *Science of the Total Environment*, **907**, Article ID: 167897. <https://doi.org/10.1016/j.scitotenv.2023.167897>
- [24] Homolka, Z. (2019) Treatment of Plastic Wastes Using Plasma Gasification Technology. These, University of Nebraska-Lincoln, Lincoln. <https://digitalcommons.unl.edu/honorsthesis/114>
- [25] Evode, N., Qamar, S.A., Bilal, M., Barceló, D. and Iqbal, H.M.N. (2021) Plastic Waste and Its Management Strategies for Environmental Sustainability. *Case Studies in Chemical and Environmental Engineering*, **4**, Article ID: 100142. <https://doi.org/10.1016/j.csee.2021.100142>
- [26] Prata, J.C., Silva, A.L.P., Da Costa, J.P., Mouneyrac, C., Walker, T.R., Duarte, A.C., *et al.* (2019) Solutions and Integrated Strategies for the Control and Mitigation of Plastic and Microplastic Pollution. *International Journal of Environmental Research and Public Health*, **16**, Article No. 2411. <https://doi.org/10.3390/ijerph16132411>
- [27] Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., *et al.* (2015) Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols (PRISMA-P) 2015: Elaboration and Explanation. *BMJ*, **349**, G7647. <https://doi.org/10.1136/bmj.g7647>
- [28] Tricco, A.C., Lillie, E., Zarin, W., O'Brien, K.K., Colquhoun, H., Levac, D., *et al.* (2018) PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine*, **169**, 467-473. <https://doi.org/10.7326/M18-0850>
- [29] World Bank (2022) New World Bank Country Classifications by Income Level: 2022-2023. <https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2022-2023>
- [30] World Bank (2020) Low Middle Income Countries WB 2020.
- [31] Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., *et al.* (2021) The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *BMJ*, **372**, N71. <https://doi.org/10.1136/bmj.n71>
- [32] Pluye, P., Cargo, M., Robert, E., Bartlett, G., Cathain, A., Griffiths, F., *et al.* (2011) A Pilot Mixed Methods Appraisal Tool (MMAT) for Systematic Mixed Studies Reviews. Colloquium Abstracts. <https://abstracts.cochrane.org/2011-madrid/pilot-mixed-methods-appraisal-tool-mmat-systematic-mixed-studies-reviews>
- [33] Hong, Q.N., Gonzalez-Reyes, A. and Pluye, P. (2018) Improving the Usefulness of a

- Tool for Appraising the Quality of Qualitative, Quantitative and Mixed Methods Studies, the Mixed Methods Appraisal Tool (MMAT). *Journal of Evaluation in Clinical Practice*, **24**, 459-467. <https://doi.org/10.1111/jep.12884>
- [34] Joseph, N., Kumar, A., Sumanth, M.M., Ganesh, S.K. and Raghavendra Babu Yellapur, P. (2016) Usage of Plastic Bags and Health Hazards: A Study to Assess Awareness Level and Perception about Legislation among a Small Population of Mangalore City. *Journal of Clinical and Diagnostic Research*, **10**, LM01-LM04. http://jcdmr.net/article_fulltext.asp?issn=0973-709x&year=2016&volume=10&issue=4&page=lm01&issn=0973-709x&id=7529
- [35] Boadi, K.O. and Kuitunen, M. (2014) Environmental and Health Impacts of Household Solid Waste Handling and Disposal Practices in Third World Cities: The Case of the Accra Metropolitan Area, Ghana. *Journal of Environmental Health*, **68**, 32-36.
- [36] Moghadam, Z.A., Mirlohi, M., Pourzamani, H. and Malekpour, A. (2012) Bisphenol A in “BPA Free” Baby Feeding Bottles. *Journal of Research in Medical Sciences*, **17**, 1089-1091.
- [37] Mujinga, Kapemba, A., Mabika, Kalanga, W., Nkashama Mukenge, J.C., Mwamba Tshiala Bebal, V. and Kidimbu Diakese Sacree, I. (2023) Problem of Plastic Packaging in Kinshasa: Household Ecological Behavior Adoption Factors. *Revue Française D'Economie et de Gestion*, **4**, 292-316.
- [38] Mihai, F.C., Gündoğdu, S., Markley, L.A., Olivelli, A., Khan, F.R., Gwinnett, C., et al. (2021) Plastic Pollution, Waste Management Issues, and Circular Economy Opportunities in Rural Communities. *Sustainability*, **14**, Article No. 20. <https://doi.org/10.3390/su14010020>

APPENDICES

Appendix 1: Study Characteristics

Number	First Author Name	Year of Publication	Study Design
Assessment of Awareness Regarding Health Hazards of Plastic Chemicals and Their Warning Label among a Sample Population of Varanasi City: A Cross-Sectional Study	Parul Sharma	2021	A Cross-sectional Study (étude transversale)
Usage of Plastic Bags and Health Hazards: A Study to Assess Awareness Level and Perception about Legislation among a Small Population of Mangalore City	NitiN Joseph	2013	A Cross-sectional Study (étude transversale)
Environmental and Health Impacts of Household Solid Waste Handling and Disposal Practices in Third World Cities: The Case of the Accra Metropolitan Area, Ghana	Kwasi Owusu Boadi	2005	Quantitative randomizée

Appendix 2: Mixed Methods Appraisal Tool (MMAT) Version 2018

Study Category	Methodological Quality Criteria	Answers			
		Yes	No	Don't Know	Comments
Screening Questions (for All Types)	S1: Are the clear research questions?				
	S2: Do the collected data allow to address the research questions?				
	Assessment of methodological quality with the MMAT cannot be pursued if the answer is "no" or "do not know" to one or both questions.				
1) Qualitative Study (ONLY)	1.1. Is the qualitative approach appropriate to answer the research question?				
	1.2. Are the qualitative data collection methods adequate to address the research question?				
	1.3. Are the findings adequately derived from the data?				
	1.4. Is the interpretation of results sufficiently substantiated by data?				
	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?				
2) Quantitative Randomized Controlled Trials (ONLY)	2.1. Is randomization appropriately performed?				
	2.2. Are the groups comparable at baseline?				
	2.3. Are there complete outcome data?				
	2.4. Are outcome assessors blinded to the intervention provided?				
	2.5. Did the participants adhere to the assigned intervention?				

Continued

3. Quantitative Nonrandomized Controlled Trials (ONLY)	3.1. Are the participants representative of the target population?
	3.2. Are measurements appropriate regarding?
	3.3. Are there complete outcome data?
	3.4. Are the confounders accounted for in the design and analysis?
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?
4. Quantitative Descriptive (ONLY)	4.1. Is the sampling strategy relevant to address the research question?
	4.2. Is the sampling representative of the target population?
	4.3. Are the measurements appropriate?
	4.4. Is the risk of nonresponse bias low?
	4.5. Is the statistical analysis appropriate to answer the research question?
5. Mixed Methods (ONLY)	5.1. Is there an adequate rationale for using a mixed methods design to address the research question?
	5.2. Are the different components of the study effectively integrated to answer the research question?
	5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
	5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
	5.5. Do the different components of the study adhere to the quality criteria each tradition of the methods involved?

Appendix 3: Remisons De L'exclusion Des Articles

N°	Articles	Reasons for Refusal
1	Assessing the levels of awareness among european citizens about the direct and indirect impacts of plastics on human health	No low income countries (study conducted in Europe)
2	Bisphenol A: Invisible pollution	Commentary
3	Chemistry, lung toxicity and mutagenicity of burn pit smoke-related particulate matter	The analyses were not performed on humans, but rather on mice.
4	From properties to toxicity: Comparing microplastics to other airborne microparticles	Systematic review

Continued

5	Health impacts of plastic packagings	Full text not available
6	Human Health and Soil Health Risks from Heavy Metals, Micro(nano)plastics, and Antibiotic Resistant Bacteria in Agricultural Soils	No low income countries (study conducted in Europe, Asia and North America) Systematic review
7	Human health concerns regarding microplastics in the aquatic environment—From marine to food systems.	no low income countries and Systematic review
8	Human health risk and food safety implications of microplastic consumption by fish from coastal waters of the eastern equatorial Atlantic Ocean	The aim of the article is simply to study the type of plastic found in the bellies of certain fish regularly consumed by humans. The pathophysiology of the effect on human health has not been reported.
9	Inception cohort study of workers exposed to toluene diisocyanate at a polyurethane foam factory: initial one-year follow-up.	No low income countries (Study conducted in Eastern Europe)
10	Ingested microplastics pose a potentially serious risk to the gastrointestinal microenvironment	Full text not available, comment
11	International quantification of microplastics in indoor dust: prevalence, exposure and risk assessment	No low income countries (The scope of the study includes developed countries)
12	Men's Health in Industries: Plastic Plant Pollution and Prevalence of Prediabetes and Type 2 Diabetes Mellitus	No low income countries (study conducted in Riyadh, Saudi Arabia)
13	Micro- and nanoplastics in edible fruit and vegetables. The first diet risks assessment for the general population OK	No low income countries (study carried out in Italy), the article also aims simply to study the type and quantity of plastic found in fruit regularly consumed by humans. The pathophysiology of the effect on human health has not been reported.
14	Microplastics in human food chains: Food becoming a threat to health safety	Nonempirical study, this is a commentary
15	Most plastic products release estrogenic chemicals: A potential health problem that can be solved	Analyses have not been performed on humans. These are more laboratory tests. The pathophysiology of the effect on human health has not been reported.
16	Nanoplastics affect the inflammatory cytokine release by primary human monocytes and dendritic cells	No low income countries (study conducted in Germany)
17	Overview of microplastics in the environment: type, source, potential effects and removal strategies	No low-income countries
18	Quantification analysis of microplastics released from disposable polystyrene tableware with fluorescent polymer staining	No low income countries : (study conducted at Shanghai Xingya in China)
19	Short-term adverse health effects in a community exposed to a large polyvinylchloride plastics fire	No low-income countries
20	Toxicity evaluation of E-waste plastics and potential repercussions for human health	No low income countries (study conducted in Shenzhen metropolis modern in southeast China)
21	Phthalates and other additives in plastics: human exposure and associated health outcomes	No low-income countries (Michigan/USA study)

Continued

		No low-income countries.
22	Effect-directed identification of endocrine disruptors in plastic baby teethers	The tests were carried out on children's plastic teething toys. These are laboratory tests. The article describes the effects on endocrine gland function. This is the exposure risk that has been calculated.
23	Worker health risk of heavy metals in pellets of recycled plastic: a skin exposure model	Analyses of the presence of heavy metals on recycled plastic with which workers are in contact were carried out in the laboratory using artificial sweat).

Appendix 4: Types, Methods and Timing of Studies

Articles	Study Types	Collection Methods	Collection Time
Assessment of Awareness Regarding Health Hazards of Plastic Chemicals and Their Warning Label among a Sample Population of Varanasi City: A Cross-Sectional Study	A cross-sectional Study	Interview	August-13
Usage of Plastic Bags and Health Hazards: A Study to Assess Awareness Level and Perception about Legislation among a Small Population of Mangalore City	A cross-sectional Study	pretested structured interview schedule	June and August 2003
Environmental and Health Impacts of Household Solid Waste Handling and Disposal Practices in Third World Cities: The Case of the Accra Metropolitan Area, Ghana	Quantitative random	Interviews with 960 females heads of households	No precision