



Review

Attitudes and Perceptions on the Agricultural Use of Human Excreta and Human Excreta Derived Materials: A Scoping Review

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Abstract: This study explicates the scope of published literature on the influence of attitudes and perceptions on the intention to use human excreta and human excreta derived materials in agriculture. Using a scoping review methodology, search results from Scopus and Web of Science were screened and synthesized using the DistillerSR web-based application. Out of the 1192 studies identified, 22 published articles met the inclusion criteria. Additional studies were identified by keyword enrichment, hand-searching, and snowballing in other electronic data bases. The benefit perception of the soil health, income, and yield was the main driver for positive attitudes. Perceived health risk and socio-cultural factors were reported as the main barriers to the use of human excreta derived materials in agriculture. Limited information, availability, collection, transport, and storage were the other reported perceived barriers. The influence of socioeconomic and demographic factors on farmers' attitudes and perceptions was inconclusive, which is potentially attributed to contextual and methodological differences. Social and behavior change communication through community mass campaigns and targeting interventions segregated by socioeconomic and demographic contexts is recommended for development interventions. Future empirical studies could focus on the influence of crop types, treatment processes, food preparation and processing on attitudes and perceptions.

Keywords: recovery and reuse; human excreta; attitude and perception; risk perception; benefit perception; health risk; circular economy



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Highlight

- Benefit perception is the main driver of positive attitudes towards human excreta derived materials
- Health risk perception is the main barrier to social acceptance of human excreta derived materials
- Acceptance of human excreta derived materials is limited by information and availability
- The effect of socioeconomic factors on attitudes and perceptions towards human excreta derived materials is inconclusive

1. Introduction

A circular approach to agriculture through the recovery and reuse of waste materials is important for sustainable agricultural development. Rapid population growth, urbanization, and nutrient mining coupled with the need to feed the rising global population have placed the recovery of mineral elements from human excreta and human excreta derived materials (HEDM) and their use in agriculture high on the global agenda [1]. The global population dynamic reached an important landmark in 2007 when the proportion of urban

population reached 50%, with an estimated increase of up to 60% by 2030 [2]. The United Nations Settlement Program estimated that this urban population figure would double by 2050 [3]. The urbanization trend is most rapid in developing countries causing informal settlements to fill up the rural-urban continuum, in such settlements, basic amenities, such as clean water and sanitation services, are non-existent and expensive to deliver [4]. The impact of urbanization on sanitation also places a huge burden on public utilities whose budgets are overstretched and inadequate to maintain and provide basic sanitation systems in urban areas [5]. Informal settlements and peri-urban areas often resort to unplanned waste management and disposal practices, such as open defecation [6], causing environmental challenges and various sanitation-related risks [7]. Even in built environments, where sanitation is functional, the nature of sanitation is often not hygienically safe [8].

Urbanization is one of the main causes of nutrient mining [9], making it difficult to achieve sustainable global agricultural food production [10]. Rapid urbanization and rising incomes in cities increase demand and consumption of highly processed nutrient-dense diets; a phenomenon referred to as “nutrition transition” in the nutrition parlance [11]. Nutrition transition intensifies the mining of nutrients from rural and peri-urban agricultural lands to urban centers where plant nutrients transported and consumed as food, are mined, excreted, and flushed down the end-of-pipe centralized sewer systems. The mining of nutrients disturbs the natural ecological cycle and nutrient balances. Approximately 60% to 70% of the soil nutrients mined from the farms are excreted in the environment as waste [12]. Returning the nutrients to the soil would restore the ecological balance and soil health [13]. Wolgast [14] estimated annual per capita nutrient production to be equivalent to 7.5 kg of NPK, micronutrients from about 520 kg of human excreta could organically produce 250 kg of grain, enough to feed one adult person per year [15–17]. Nutrient mining may also result in long-term productivity failure and serious health consequences related to micronutrient deficiency in developing countries [10]. The stripping of mineral elements from the soil poses a serious threat to food production, especially in the face of climate change, where soil nutrient loss leads to reduced water productivity [11].

Agricultural intensification, on the other hand, leads to the extraction of soil nutrients, soil degradation, and environmental pollution through the use of chemical fertilizers [18]. Soils with low organic matter also have a high capacity to fix phosphorus through absorption and precipitation, which reduces the efficiency of chemical fertilizers [19]. Empirical evidence shows that between 5% and 30% of the assimilable quantity of the total P applied using chemical fertilizers can be used by plants [20]. The global reserves for rock phosphate are also approaching their maximum production rate (peak phosphorus), making phosphorus recovery critical. In Europe, phosphate is a critical raw material [21], whose importance is exacerbated by its availability in geopolitically sensitive areas [22]. The use of human excreta in agriculture can supplement, complement or substitute for chemical fertilizers while replenishing soil health. Long-term trials with sewage sludge show high bioavailability of P-supplying chemical fertilizers to plants [23,24]. In contrast, biosolids are slow-release fertilizers that ensure a steady supply of P over a long time [20] with an additional positive effect of reducing greenhouse gas emissions when compared to inorganic fertilizers [25].

Agricultural intensification also leads to soil erosion and degradation [26], salinization, depletion of soil nutrients, and groundwater pollution [18]. Empirical findings from long-term trials over 13 years in India show an average paddy yield decline of about 18% associated with an increase in chemical fertilizer application of about 37% over the same period [27]. Good agricultural practices (such as conservation farming and application of organic matter) can help restore soil health [18]. Developing countries, especially in the sub-Saharan Africa continue to face degraded soils and very low fertilizer use [28]. Sheahan and Barrett [29] in their six country study show average fertilizer application rates of 26 kg per hectare justifying the need for alternative sources of fertilizers. Sustainable Development Goal (SDG) number 6 emphasizes clean water and sanitation, while Goal 12 focuses on responsible production and consumption in a way that minimizes waste [30].

Recovery of agricultural nutrients from human excreta could, therefore, help to achieve the SDGs and ensure sustainability. Achieving these goals requires a paradigm shift in the way human waste is processed, perceived, managed, and used. Multidisciplinary approaches, such as ecological sanitation, may offer a new way of redefining human excreta as wealth rather than waste [31]. Such approaches may usher in a new way of sanitation provision and waste management to communities that would otherwise not receive centralized sanitation due to unsuitable terrain and overstretched municipal budgets [32].

The history of the recovery and reuse of human excreta dates back to the early 9th century [33]. In Asia and South America, human excreta was ferried from populated urban areas to farmers until the second half of the 19th century [34]. The transportation of human excreta to farms led to a huge improvement in sanitation and agricultural production in populated towns [35]. Bracken et al. [36] suggested several reasons for the neglect of the approach. These include perceptions of health risk (miasma theory), rapid urbanization, bulkiness in transportation, a shift towards centralized sewage, and the advent of artificial fertilizers [36]. Drangert [37] used the phrase “urine blindness” to describe the negative attitudes towards human urine as an agricultural fertilizer Esrey et al. [38] devised the term “fecophobia” to describe the socio-cultural fear of feces among the Muslim community. The concept of fecophobia is related to the concept of dirt as “matter out of place” [39]. Perception, therefore, matters as what can be considered a valuable resource by one community may be considered waste by another. It also matters because one’s action is driven by perception.

The review of technologies used to recover HEDM is available in the literature in terms of the recovery pathways and processes [1,40,41] and regulations [22,42]. We provide a brief discussion of the findings of these and other studies in the discussion section. The general conclusion from these studies demonstrates the gap in and the importance of understanding perceptions and social acceptance of HEDM as a potential barrier for wide-scale commercialization [1,43]. Cost-benefit analysis can be useful in evaluating the economic, environmental, and health implications of recycling waste back to wealth using various recovery pathways [44]. A market demand analysis of the attributes of the end products using the discrete choice experiment can provide information for the commercialization of HEDM [16,45]. Understanding the “demand segment” of the recovery and reuse of HEDM in agriculture, however, remains an understudied and nascent area to this day [46,47].

Against this backdrop, this scoping review is the first attempt to synthesize published research on attitudes and perceptions towards the use of human excreta and HEDM in agriculture. In doing so, this review not only enriches the work by Roma et al. [48], who used the receptivity framework to discuss the use of urine as a fertilizer, but, it also updates the works of Ganesapillai et al. [49] and Lienert and Larsen [50] who reviewed the acceptance of “urine separation” and “ecological sanitation” approaches towards HEDM recovery. This review complements existing research by extending the scope of their work to include past and current research evidence, with a specific focus on the attitudes and perceptions of the use of all human excreta and HEDM in agriculture. The phrase “human excreta and HEDM” is deliberately used to include studies that investigate attitudes and perceptions on agricultural use of material derived from human excreta [51]. The “human excreta” in this review is limited to urine and fecal matter that can be recovered and used for agricultural purposes. This review also includes studies that investigated the use of urine and fecal matter directly without processing or treatment. The findings of this review may help to channel information required by decision makers in understanding the “demand segment” or social acceptance of circular nutrient economy initiatives.

The World Health Organization [52] has developed a methodology for identifying knowledge gaps and contextual behavioral patterns to inform more targeted interventions. While human excreta may present potential benefits to agricultural productivity, governments in developing countries continue to spend foreign currency importing inorganic fertilizer. The adoption of chemical fertilizers (through agricultural intensification as dis-

cussed above) remains low due to poorly developed input, credit, and output markets. Consolidating anecdotal evidence from different studies to evaluate the state of knowledge on the “demand segment” of the human excreta recovery pathway in agriculture could inform evidence-based decision making in program interventions and save foreign currency currently lost through chemical fertilizer imports and subsidies. While most empirical studies are contextual—conducted, and relevant in specific locations, this scoping review implements the preferred reporting system for meta-analysis and systematic reviews (PRISMA) methodology to consolidate and identify trends and patterns in the results. The importance of this study is not only limited to contributing evidence-based decision making; it also can be inform future empirical studies by identifying methodological gaps. The next section provides the theoretical perspectives that were used in this study to scope the literature.

2. Some Theoretical Imperatives

The theoretical foundations of the importance of attitudes and perceptions in predicting human behavior are rooted in the fields of social cognitive science and social psychology. The theory of planned behavior is a commonly used theory to predict human behavior [53]. Ajzen [54] posited that in addition to attitudes towards behavior, subjective norms and perceived behavioral control or self-efficacy could accurately predict human behavior. Self-efficacy refers to how well one perceives he/she can execute the attitude object, technology or behavior under investigation, subject to skills, resources, opportunities, etc. [55]. Bredahl et al. [56] in their theory, posited that in modeling behavioral intention, it is essential to extend the TPB to include perceived difficulty which includes the ease of using a technology and level of competence required and is linked to self-efficacy. This theory has been expanded to include the perceived risks and benefits. In this study, risk perception is defined as the subjective judgments of individuals about the probability of occurrence of negative outcomes from adopting a technology. The perceived risks can negatively influence attitudes, whereas perceived benefits have a positive impact on attitudes; that is, benefit perception is cognitively compensated by the perceived risk [56]. Farmers will be willing to try the using HEDM if the perceived benefits of increase in productivity can cognitively compensate for the perceived risks associated with the technology.

Research in social psychology has also evolved from the dominant social paradigm to incorporate environmental concerns that help explain human-environment interactions, using the New Ecological Paradigm (NEP) scale. The NEP has been incorporated into the social-psychological theories of attitude-behavior interactions [57]. The dominant social paradigm that preceded the NEP posits that resources are unlimited, and humans are superior to all other species [58]. The NEP challenged these principles by incorporating a measure of the nature of society–environment interactions and the reality of limits to growth while integrating environmental attitudes, values, beliefs, and worldviews [58]. Various modifications have been made to the NEP to capture validity, psychometric soundness, and cultural differences [59–61]. This review is, therefore, guided by these theoretical underpinnings to understand the role of attitudes and perceptions on the social acceptance of using HEDM in agriculture.

3. Review Methodology

This study employed a rigorous, iterative and comprehensive literature review methodology for conducting a scoping review as posited by Arksey and O'Malley [62] and as applied, for instance, by Lam et al. [63] and Corrin and Papadopoulos [64]. The methodology allows for transparency and reproducibility; it does not restrict search criteria or terms but instead offers a flexible, iterative, and reflexive search criteria to allow for a comprehensive review process [62,65–67]. A scoping review uses a structured methodology to answer research questions, identify research gaps and support evidence-based policy making by characterizing, screening, and summarizing research evidence [68]. The scoping review methodology used in this study is transparent and reproducible, and eliminates the typical

risk of cherry-picking research articles often associated with other review methods [69,70]. In doing so, it identifies gaps in the literature to inform future research [62].

The objective of the scoping review methodology is to provide a preliminary assessment of the size and scope of the body of knowledge available on the subject matter [71]. The outcomes of this study will, therefore, provide an imperative starting point for future empirical research and best practices for on-the-ground development initiatives in the recovery and reuse of human excreta and HEDM for agricultural use [72]. It is crucial at this point to draw a clear distinction between the scoping review methodology and other types of reviews. Different review types may focus on current matters (state of the art) on the subject or may aim to develop conceptual models without any degree of structural analysis [71]. Scoping reviews only aim to map and investigate the nature and extent of emerging research evidence by quantifying and characterizing literature through the use of study designs, among other essential study features [66,68,72]. Scoping reviews provide only a general overview of the available research evidence without providing a synthesized answer to a specific research question [73]. In the following sections, we discuss the five stages used in undertaking this scoping review.

3.1. Research Questions

Scoping reviews share several characteristics with systematic reviews [71]. In specifying the research question or objective, Moher et al. [74] suggested that one has to address the research objective with reference to participants, interventions, comparisons, study designs, and outcomes. In this study we adopted the method method with regard to the following: participants (users of human excreta and HEDM in agriculture), interventions (human excreta reuse in agriculture), comparators (conventional chemical fertilizers or other organic manure), study design (quantitative, qualitative and mixed methods) and outcomes (perceptions and attitudes towards human excreta and HEDM). Other studies apply the setting, perspective, intervention, comparison, evaluation (SPICE) and the sample, phenomenon of interest, design, evaluation, research type (SPIDER) methodologies. Given these options, the method by specified Moher et al. [74] is the most commonly used in the survey literature [75,76]. The decision to focus on attitudes and perceptions of the end-users of human excreta was arrived at after considering the importance of resource recovery and reuse and its link to sanitation provision in most underserved communities, where dry sanitation is the only form of sanitation.

3.2. Identification of Relevant Studies, Data Sources and Search Strategy

The authors performed an initial search of pertinent literature using electronic databases with Title-Abstract-Key-word search in Scopus and Topic search in all the bibliometric databases in Web of Science, namely, WoS Core Collection, KCI Korean Journal Database, MEDLINE, Russian Science Citation Index, and Scielo Citation Index. The two databases were preferred because Web of Science was the dominant tool for citations analysis until the year 2004 when Scopus and Google Scholar were created, with the latter having data quality issues [77]. The errors and limitations of Google Scholar are a result of its automated document indexing [78]. This review restricted the Scopus and WoS searches to peer-reviewed English language articles published between 1945 and 15 February 2019. The restriction on the time of publication enables this review to focus on all studies conducted on attitudes and perceptions towards recovery and the use of human excreta and HEDM in agriculture.

The restriction of using only published research articles in peer reviewed journals and the exclusion of books, grey literature, dissertations and conference contributions allowed for methodological and quality assessment of the research evidence [79]. While grey literature may cover niche topics usually not covered by traditional literature, including it in this study would bring in incompleteness, inaccuracies and self-publication bias, as this literature often does not go through stringent peer-review publication processes [80].

Grey literature may not be indexed by traditional bibliometric databases which may limit efficiency and reproducibility of scoping reviews.

Exhaustive and comprehensive keywords, synonyms and Boolean operators were used in the search criteria to perform the search (see Table 1). This was conducted in an iterative manner to ensure that all the articles on the subject matter were extracted from the bibliometric databases. This study borrowed some keywords from related reviews, such as Lam et al. [63] and Corrin and Papadopoulos [64]. The snowballing technique was also applied to ensure that the keywords identified by the researcher from the retrieved articles were used to enrich the search strategy and make it more comprehensive. This is the iterative and important part of the search where the search syntax will continue to be modified, taking into account the Boolean operators. The authors used additional references suggested by some reviewers and hand-searched other articles through backward snowballing from the reference lists of related reviews and included articles [73,81,82]. The snowballing technique was also applied to hand-search relevant articles in other electronic databases including Google Scholar, factoring in the variability of databases in indexing, abstracting and breadth of information [46,62].

Table 1. Search query.

Database	Search Strategy	Search Results
Scopus	TITLE-ABS-KEY ("human waste" OR "faecal sludge" OR "human manure" OR "solid waste" OR "humanure" OR faec* OR fec* OR "human excreta and human excreta derived material") AND (attitude* OR perception* OR "health risk*" OR "Perceived benefit*" OR "Perceived risk*") AND (agriculture* OR farm* OR crop*)	795 document results
Web of Science	TOPIC: ("human waste" OR "faecal sludge" OR "human manure" OR "solid waste" OR "humanure" OR faec* OR fec* OR "human excreta") AND (attitude* OR perception* OR "health risk*" OR "Perceived benefit*" OR "Perceived risk*") AND (agriculture* OR farm* OR crop*)	690 document results

The Boolean operator * refers to the shortest possible keyword retrieved by the search syntax.

The results retained from each search of the electronic databases were exported to EndNote software or other referencing software for cleaning and preparation for importation. In EndNote, duplicate removal could be performed, followed by saving the references in an EndNote "Compressed Library" format (.enlx). The data could then be exported into a web-based informetric software application.

3.3. Study Selection

The DistillerSR Evidence Partners Incorporated, a web-based informetrics software application, was used to sort references, including removal of duplicates. Other available software includes the Cochrane's Covidence [83]. DistillerSR software allows for screening and extraction of articles based on the title, abstract, full text, and study characteristics such as study design, sample size, research methods, and outcomes. The DistillerSR user interface includes the review, reports, reference, workflow, users, and project tabs. It is in under the projects tab and in "File Manager" where you import the enlx format reference file from EndNote. The projects tab in DistillerSR allows the reviewer to import the references into a project. As a double check, the duplicate detection function was used to further recheck and quarantine duplicate references. The function gives an extreme precision option. The review tab allows for title, abstract and full text screening of each article retrieved using the search criteria described above. The review tab contains the data extraction, which is linked to the study characteristics as defined in the workflow. In the workflow, the built-in forms can be edited to suit the researcher's data extraction method.

For this study, the title screening form, abstract screen form, and the study characteristics form were used. The title and the abstract screening forms only used one question (Is

this reference potentially relevant to our study?), with Yes/No/Can't tell as the potential responses to use for screening purposes, as described below. The data extraction form was edited to include study characteristics with radio- and check box-type questions, such as study design, type of HEDM, study population, if the study investigated crop type-processing-cooking, validity checks, sample size, and the data analysis methods, with the responses being defined by the reviewer as explained in relevant sections below.

3.4. Relevance Screening and Eligibility Criteria

The study employed a multi-stage screening process based on the title, abstract, and full text of selected articles. Initial screening was performed based on the relevance of the titles of the articles. The second screening used the abstract to further screen the articles included for relevance. The selected relevant articles were then screened based on the full article review, where articles were further screened in or out based on the inclusion criteria (Table 2). The strength of DistillerSR is that it gives the opportunity to have more than one reviewer in the project to co-screen and there is a clever algorithm that deals with conflict between researchers. Each included article goes through the data extraction process, mining each piece of information required to complete the data extraction form. After completing this rigorous extraction process, the results of the survey-type questions are ready for downloading and reporting in the reports table. The results can be downloaded from the statistics-extraction-study characteristics in the reports tab and presented in a user-friendly scheme in MS Excel or MS Word format.

Table 2. Inclusion and exclusion criteria during article screening.

Article Inclusion Criterion
✓ The study investigated and reported the attitudes and perceptions of human excreta and/or HEDM for use in agriculture
✓ The study examined the factors affecting attitudes and perception of human excreta and HEDM use in agriculture
✓ The study was published in English
✓ The study was published in a peer-reviewed journal
✓ The study contains original results
✓ The study contains sufficient information to assess the validity of empirical methodology

Note: Articles that did not meet any one or more of the above criteria were excluded.

3.5. Charting the Data/Data Extraction

Arksey and O'Malley [62] opine that simply producing a summary of each included study may make it difficult for readers to make decisions based on the short profile of each study. This review applied a descriptive-analytical method by extracting data based on a common analytical approach within the framework of the traditional narrative review. The framework includes the name of author, publication year, location, study design, type of HEDM assessed, factors influencing attitudes and perceptions, and key results on perceptions and attitudes towards HEDM. While a standard scoping study does not allow for quality assurance [62], this study synthesized and triangulated the study designs, research methods, and findings of the articles reviewed. Thus, the fact that researchers may arrive at different conclusions due to different study designs, methods of data analysis, and context can be mitigated using this reporting framework.

3.6. Synthesizing and Reporting

This last stage of the scoping review framework helps to collate, summarize and report the results to identify key research findings and knowledge gaps while allowing the reader to understand the potential bias used in establishing the recommendations [62]. Grouping results by geographic location, type of intervention, sample size, participants, research methods, and major outcomes helps to identify contrasting and similar findings while

offering a consistent approach in reporting the results of the review. The review discussed the results based on the outcomes of the study to include the scope and maturity level of technologies used to recover human excreta derived material, the global and regional legal context and case studies on factors impacting wide-scale commercialization.

4. The Results

4.1. Search Results, Article Screening, and Inclusion

Following the search criteria (Table 1), a total of 795 articles were identified in Scopus and about 690 articles in Web of Science, for a total of 1485 publications. Duplication removal function in EndNote was used to remove a total of 223 duplications before exporting a total of 1262 articles to the DistillerSR web-based application. The duplicate detection function in DistillerSR quarantined an additional 70 duplicates. Finally, we used the title and abstract screening on 1192 unique articles, which excluded 1147 as irrelevant and failing to meet the title inclusion criteria. A total of 45 articles were then eligible for abstract and full-text screening. An additional 25 articles did not meet the full text eligibility or inclusion criteria (Table 2 and Figure 1). A total of 20 articles met the full text inclusion criteria and an additional two articles were included from hand-searching using the snowballing technique.

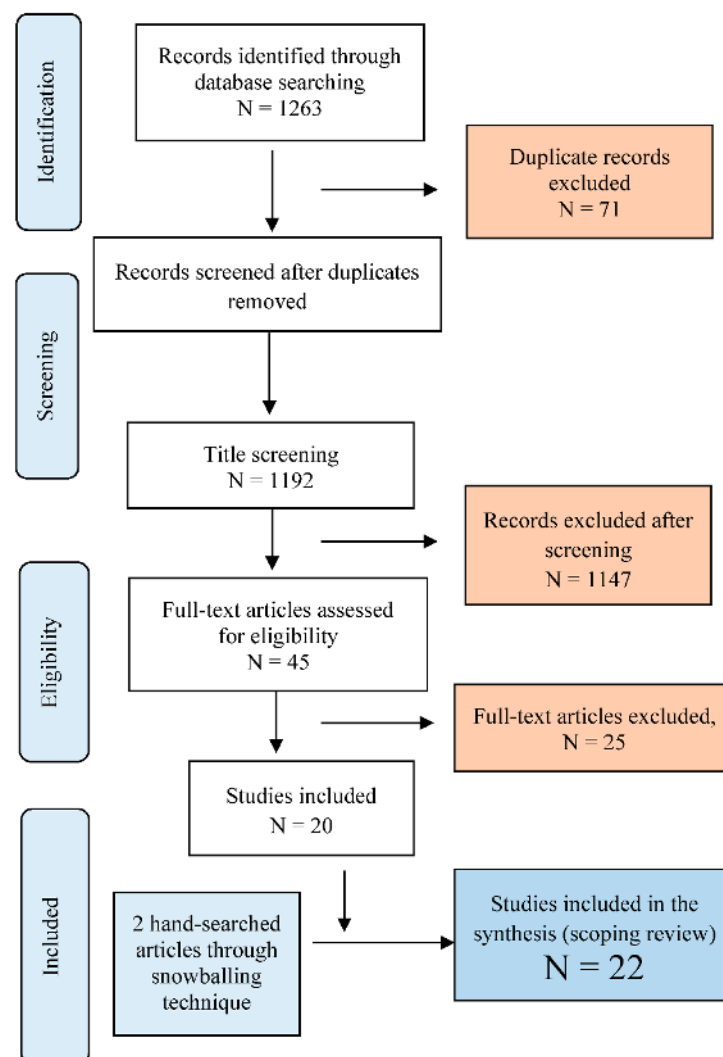


Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow chart.

4.2. Characteristics of Articles Included

All studies identified, except for one, were conducted in developing countries (Figure 2). This result may indicate the increasing need for developing countries to manage waste and provide basic sanitation strategies to meet sustainable development goals by 2030 [30]. The results also show an upward trend in the number of publications over the years from 2000 to 2018, which implies that understanding attitudes and perceptions on the use of HEDM in agriculture is indeed gaining impetus as a research agenda (Figure 3). There was at least one peer-reviewed publication per year on the attitudes and perceptions of end-users of HEDM in agriculture from 2013 to 2018. This growing trend may also indicate an increase in the importance of circular nutrient economy initiatives in research and development practice.

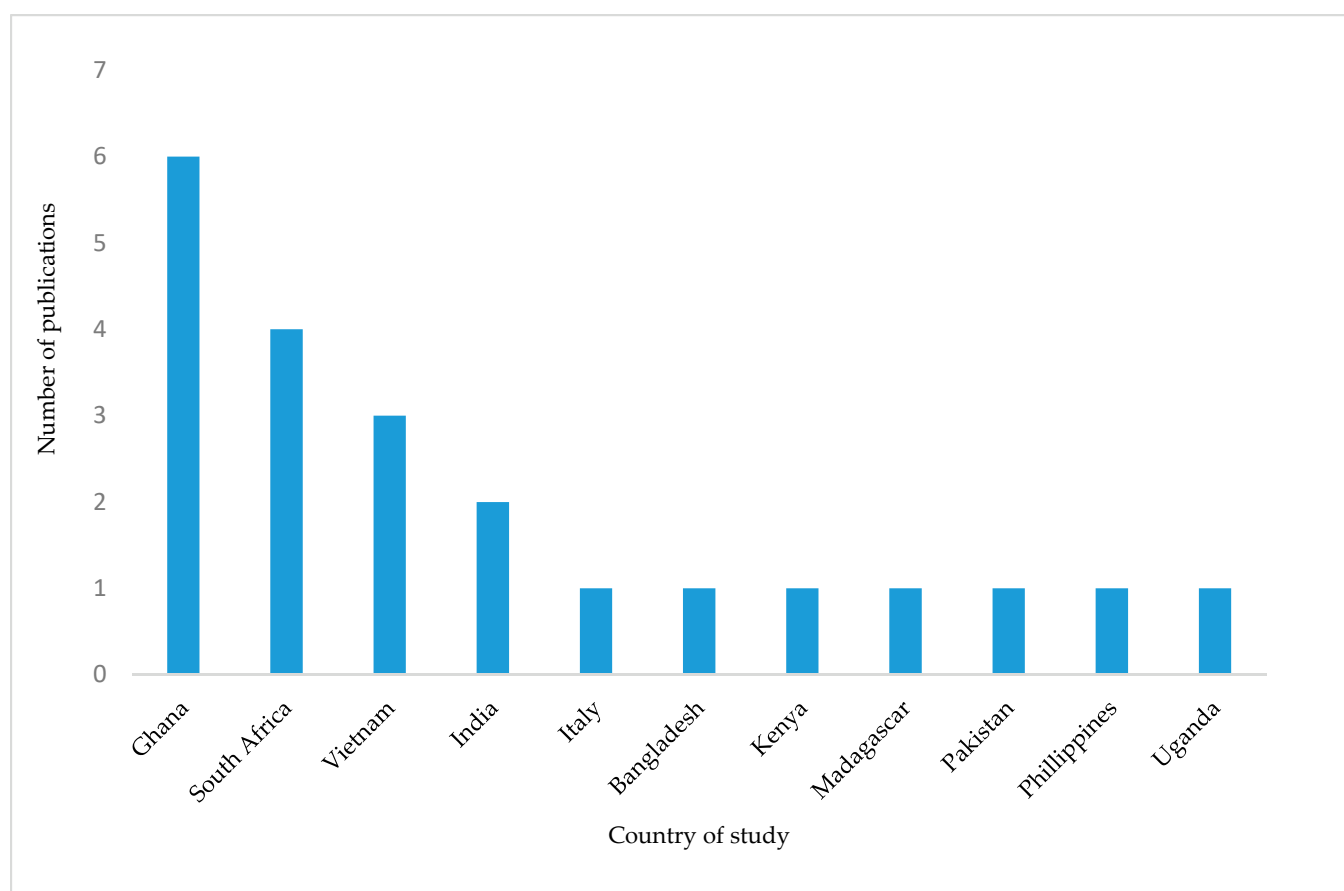


Figure 2. Number of publications by country of study.

An analysis of results based on the type of HEDM reported in the study showed that 13 articles did not specify the HEDM type nor the technology process used to recover the HEDM (Figure 4). The second most common type of human excreta was human urine ($n = 5$), followed by wastewater ($n = 3$), composted feces ($n = 2$), and lastly feces ($n = 1$). Some studies reported more than one type of human excreta, for instance, urine and human feces, without describing the recovery process of the end-product. None of the included studies evaluated the impact of the different treatment alternatives on the attitudes and perceptions of farmers. Although the perceptions (of farmers and consumers) could be expected to vary for the different types of HEDM treatment, proving or disproving this, remains an important area for further research in the future as explained in the discussion of results.

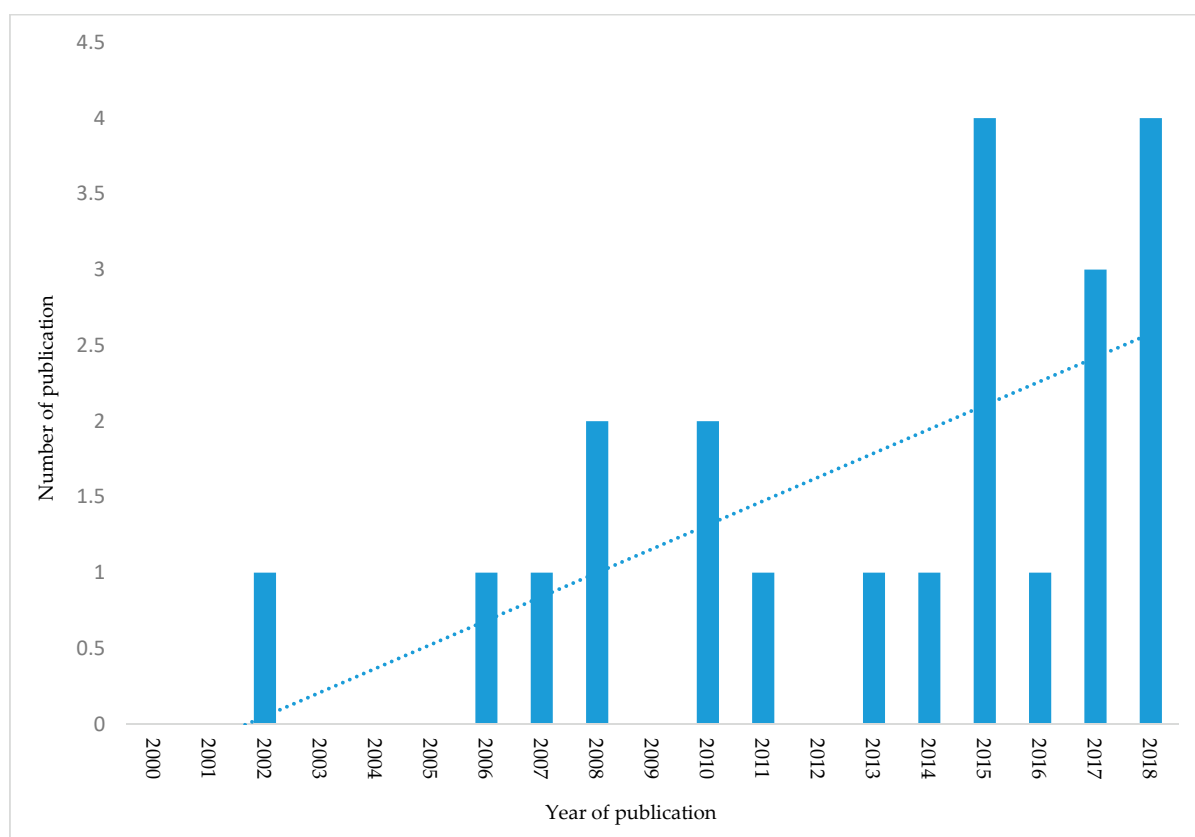


Figure 3. Number of publications by year.

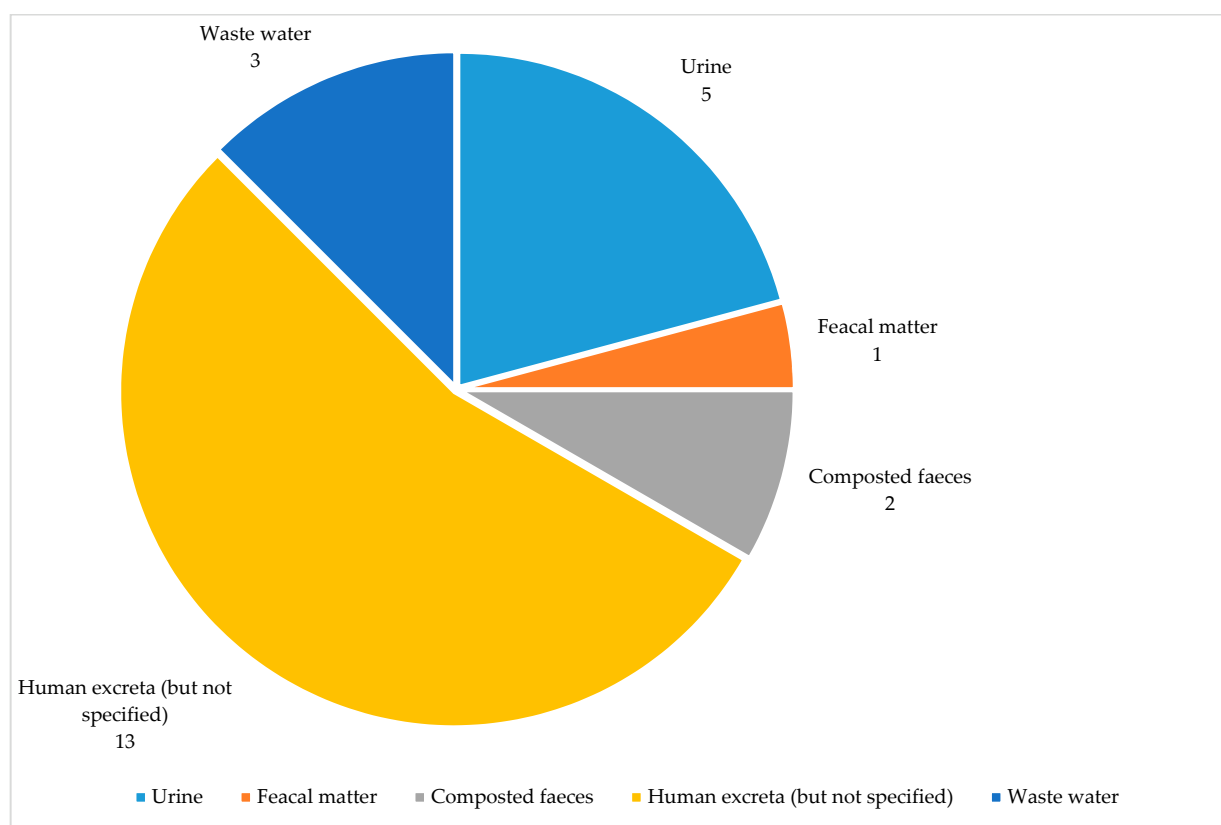


Figure 4. Number of publications by type of human excreta and HEDM reported.

The included studies were also analyzed to understand the nature of the study participants. The results show that a total of twelve studies reported the study participants to be farmers. However, some of these studies specified farmers while others included other types of participant consumers (Figure 5). The second most common type of participants included rural farming communities, while seven studies defined the study participants as peri-urban farmers. Only two studies specified university students as participants, while two articles investigated the attitudes and perceptions of consumers (Figure 5). The nature of the study participants may help to accurately target interventions based on the contextual results.

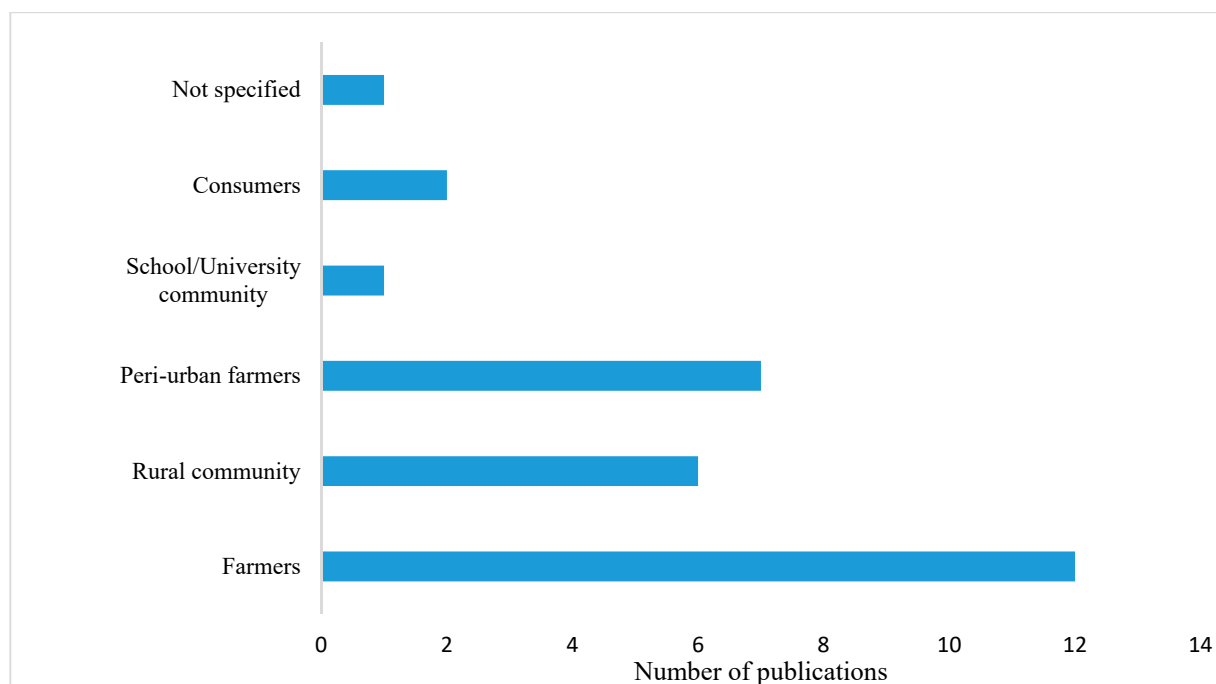


Figure 5. Number of publications by type of study participant.

It is also important to note that most included studies ($n = 16$) investigated the attitudes and perceptions of farmers on human excreta and HEDM use for different crop types (Table 3). Other included articles distinguished between comestible and inedible crops ($n = 5$), cooked and uncooked ($n = 1$), while a total of five articles did not separate or specify the attributes of the crop fertilized or investigated. Attitudes and perceptions may vary depending on whether the crop is consumed, as this has implications on the contamination pathway and pathogen load in terms of microbial risk assessment. Ten out of 22 included studies did not indicate the influence of crop type or purpose on attitudes and perceptions of farmers. The remaining 12 articles found that the reluctance of farmers to use human excreta and HEDM to grow comestible crops was due to perceived health risks [60,84–88]. Three studies found the reason for poor acceptance of the use of HEDM on edible crops resulted from perceived rejections by consumers when marketing [85,89,90]. One study found potential direct exposure to HEDM for leafy vegetables to be another reason for poor acceptance of HEDM use on edible crops [15].

Table 4 groups articles according to study design, including those that used cross-sectional data, focus group discussions, key informant interviews, and mixed methods. Mixed methods in this review included a mix of focus group discussions, cross-sectional data, and key informant interviews. The results show that 11 out of 22 articles used cross-sectional data and some personal interviews, while eight studies used mixed methods, and only one study used focus group and key informant interviews. We also analyzed the sample sizes reported as well as the methods used to analyze the data. The results show that the sample sizes spanned from a minimum sample size of 60 to a maximum sample

size of 480 participants for the cross-sectional studies, resulting in a mean sample size of 214 participants. The studies that used mixed methods had a sample size spanning from a minimum of 35 to a maximum of 700, giving a mean sample size of 245 participants. Only one of the included studies did not specify the number of participants. None of the studies reported the sample size calculation method and the rationale behind using the adopted sample sizes.

The study also grouped the data analysis methods into descriptive statistics, inferential statistics, and econometric modeling. Descriptive statistics were defined in this study to include narrative reporting of qualitative data and measures of central tendency and position, such as means, the medians, and graphical representation for quantitative data. Inferential statistical methods included analytical methods such as exploratory factor analysis, Chi-square or Fisher's exact tests, t-tests and analysis of variance, and other non-parametric statistics. Econometric modeling was defined to include confirmatory factor analysis, structural equation modeling, and regression analysis [91]. The results show that most studies used descriptive statistics ($n = 21$), followed by inferential statistics ($n = 8$) and econometric modeling ($n = 3$).

4.3. General Perceptions and Attitudes

Most of the findings demonstrated positive attitudes and perceptions towards the use of human excreta and HEDM in agriculture. Most farmers expressed willingness to use human excreta and HEDM for different reasons. Two of the studies reported that artificial fertilizers are more expensive than human excreta [15,90], suggesting a perceived economic benefit in using human excreta. Other perceived benefits were reported in six out of the 22 studies which reported that soil health improvement was the common driver of positive attitudes towards the use of human excreta and HEDM in agriculture [86,90,98,101–103]. In six out of the 22 studies, farmers were more willing to use human excreta in agricultural production if treated or sanitized as the use of fresh excreta was associated with bad smell, visual repulsiveness and various kinds of potential diseases [15,85,89,90,96,104]. This type of negative risk perception could be mitigated using different treatment technologies, pelletizing, packaging and certification to make the products safe and visually appealing. One paper demonstrated that farmers were particularly keen to visually inspect the unprocessed human excreta before use [104], reinforcing the importance of product attributes on the willingness to accept them.

Perceived benefits were associated with the soil nutritive value of human excreta and cost-savings [15,101]. The use of human urine as a fertilizer was perceived to reduce economic risk and was associated with perceived benefits such as low cost and improved yield, household income, and food security [84]. One study found that the use of excreta in agricultural production contributed to more than three times the income of non-users [96]. Some farmers thought that the use of human excreta and wastewater could be associated with a reduction in production costs [105,106]. Positive attitude to human excreta use in agriculture was also associated with being a nature-loving person compared to self-comfort [15]. Contradictory results showed no significant difference between attitude towards the environment as measured by the new ecological paradigm scale for the use of human excreta in agriculture [60]. The effects of ecological disposition on social acceptance requires further empirical work to understand whether environmental literacy has an impact on social acceptance.

Table 3. Influence of crop type and purpose on attitudes and perceptions.

First Author Surname (Year)	Whether the Study Investigated (and If So) the Effect of Crop Type on the Attitudes and Perceptions towards HEDM
Khalid [15]	<ul style="list-style-type: none"> Participants used HEDM on cereal and did not wish to use it on leafy vegetables because they perceived different exposure pathways to HEDM because of the edible parts of the latter
Moya et al. [22]	<ul style="list-style-type: none"> The study did not investigate whether there will be a change in attitudes and perception because of the difference in crop types
Mugivhisa et al. [92]	<ul style="list-style-type: none"> Same as Moya et al. [22]
Buit and Jansen [89]	<ul style="list-style-type: none"> 25% of the farmers find HEDM acceptable for food crops compared to non-food crops 20% considered the use of HEDM to be less suitable for food crops because of the feeling of disgust 50% viewed acceptance to be influenced by factors other than crop type such as consumer reluctance to buy the crops fertilized with HEDM
Mugivhisa and Olowoyo [87]	<ul style="list-style-type: none"> 83% would not eat spinach grown from human urine 81% would not eat maize grown from urine The reluctance to eat crops fertilized with HEDM was due to the perceived health risk
Appiah-Effah et al. [93]	<ul style="list-style-type: none"> Same as Moya et al. [22]
Lagerkvist et al. [94]	<ul style="list-style-type: none"> Same as Moya et al. [22]
Okem et al. [95]	<ul style="list-style-type: none"> Same as Moya et al. [22]
Mariwah and Drangert [85]	<ul style="list-style-type: none"> 36% would not use HEDM on their crops even if the HEDM were treated 54% would never use HEDM on their crops 42% agree that crops fertilized with HEDM are suitable for consumption 28% would eat such crops Health risk and unpleasant smell as well as poor acceptance of HEDM fertilized crops
Cofie et al. [96]	<ul style="list-style-type: none"> Same as Moya et al. [22]
Mojid et al. [90]	<ul style="list-style-type: none"> Some farmers preferred to fertilize leafy vegetables with HEDM as it provided good vegetative growth for leaves Others preferred to use on rice only because their land was only suitable for rice Perceived health risks and marketability of vegetables prevented farmers from wanting to use HEDM on leafy vegetables

Table 3. Cont.

First Author Surname (Year)	Whether the Study Investigated (and If So) the Effect of Crop Type on the Attitudes and Perceptions towards HEDM
Duncker et al. [97]	<ul style="list-style-type: none"> • Same as Moya et al. [22]
Jensen et al. [98]	<ul style="list-style-type: none"> • Only the main crop of rice had HEDM applied to the field because of the limited availability
Knudsen et al. [99]	<ul style="list-style-type: none"> • Same as Moya et al. [22]
Phuc et al. [100]	<ul style="list-style-type: none"> • Same as Moya et al. [22]
Danso [47]	<ul style="list-style-type: none"> • Same as Moya et al. [22]
Ignacio et al. [86]	<ul style="list-style-type: none"> • 56% and 76% thought urine and fecal matter respectively can be sanitized into fertilizer • 83% and 78% thought urine and fecal matter should not be used for edible crops and would never buy or eat crop produced using HEDM • The change in perception was due to perceived health risk
Simha et al. [101]	<ul style="list-style-type: none"> • Participants thought HEDM should not be used for comestible crops • Perceived change in taste of food crops
Andersson [84]	<ul style="list-style-type: none"> • Some farmers perceived great taste on edible crops • The change in perception was due to perceived health risk for crops eaten raw and unpeeled, especially HIV.
Nimoh et al. [88]	<ul style="list-style-type: none"> • 63% of participants would use human excreta on their crops • 58% thought crops fertilized with HEDM can be eaten • 12% would never eat crops grown with HEDM • Perceived health risks were the main reason for influencing negative attitudes
Simha et al. [60]	<ul style="list-style-type: none"> • 55% thought of urine as fertilizer • 44% would eat crops grown from urine fertilizer • The change in perception was due to perceived health risk

Table 4. Characteristics and key findings of the studies included in the scoping review.

First Author Surname (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta Product	Main Findings and Conclusions
Khalid [15]	Pakistan	Farmers	Mixed methods	50	Greywater, Treated feces, Urine Wastewater Fresh excreta	<ul style="list-style-type: none"> Religion and socio-cultural factors affect the use of human excreta in agriculture. Human excreta used on annual crops like wheat, maize, and barley but not for vegetable farming because of direct consumption. Human excreta use related to being close to nature and environment. Artificial fertilizers considered expensive and affected the taste of the end product negatively. Fresh excreta more repulsive, smelly and contains pathogens and disease-carrying agents.
Moya et al. [104]	Madagascar	Rural farmers	Cross-sectional study	81	Human excreta (but not specified)	<ul style="list-style-type: none"> Changing current farming practice to include human excreta use may imply risk-taking. About 88% willing to use human excreta fertilizers after visual inspection. Approximately 16% not willing to use human excreta and human excreta-derived fertilizers. About 59% prefer vermicomposting over the compost
Mugivhisa et al. [92]	South Africa	Farmers	Cross-sectional study	60	Dry sewage, human feces, and human urine	<ul style="list-style-type: none"> Human excreta were unacceptable because of smell, unhygienic and fear of pathogens and diseases. Female farmers ranked the source of fertilizers as: animal droppings > animal urine > human feces > sewage > human urine. Male farmers ranked the source of fertilizers as: chicken droppings > cow dung > animal urine > sewage > human urine > human feces. Those with no education ranked chicken droppings (93%) > cow dung (84%) > animal urine (66%) and human urine (27%). Those with tertiary education rated sewage and human feces positively. Approximately 50% willing to change to organic farming provided education and information is available.

Table 4. Cont.

First Author Surname (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta Product	Main Findings and Conclusions
Buit and Jansen [89]	Ghana	Peri-urban farmers and consumers	Mixed methods	35	Human excreta (fresh feces vs. dried feces)	<ul style="list-style-type: none"> Although farmers had negative perceptions of fresh human feces, dried or treated feces, they are still acceptable. Human excreta reflect personal moral badness—a reminder of one’s badness. Dried or treated feces perceived as more neutral. Dried or treated feces reduce contagion and link to the socioeconomic status of the owner. Perception of health risks not the major issue of concern for treated fecal fertilizers. Changing physical appearance and smell may increase acceptance, even among “faecophobic” farmers.
Mugivhisa and Olowoyo [87]	South Africa	School/University community	Cross-sectional study	225	Urine	<ul style="list-style-type: none"> About 87% unaware of the uses of human urine as a fertilizer. Approximately 83% would not eat spinach while 81% would not eat maize fertilized with urine. Roughly 38% eat vegetables fertilized with animal urine compared to human urine. Respondents attached negative attitudes to human urine-fertilized crops mainly for health reasons. Younger students were willing to change their attitudes if there is guaranteed safety of using urine.
Appiah-Effah et al. [93]	Ghana	Peri-urban farmers	Cross-sectional study	150	Composted feces	<ul style="list-style-type: none"> Around 34% aware of fecal sludge as fertilizer, but only 4% use it on their farms. Perception of excreta as waste was the main reason for the negative attitude towards fecal sludge compost, but the cultural beliefs not a barrier to the use of fecal sludge.
Lagerkvist et al. [94]	Kenya	Peri-urban farmers	Cross-sectional study	125	Human excreta (but not specified)	<ul style="list-style-type: none"> Cultural factors and non-pecuniary aspects related to the use of human feces as fertilizer. Information and training is essential to increase confidence about the use of composted human feces.

Table 4. Cont.

First Author Surname (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta Product	Main Findings and Conclusions
Okem et al. [95])	South Africa	Peri-urban farmers/rural community	Cross-sectional study	473	Urine	<ul style="list-style-type: none"> Approximately 5% of farmers using urine in agriculture attributed to limited awareness. About 10% were aware of urine as a fertilizer. The potential barriers to urine included health risks, smell, and the opinions of peers. Participatory trials and promotional campaigns crucial to improving farmers' awareness and acceptance.
Mariwah and Drangert [85]	Ghana	Farmers	Mixed methods	150	Human excreta (but not specified)	<ul style="list-style-type: none"> Study results show a generally negative attitude towards fresh excreta. Roughly 84% considered human excreta as waste not suitable for use Around 97% perceived health risks in handling human excreta Roughly 72% thought excreta should not be handled in any way Female farmers were more negative with mean attitude scores of 1.52 compared to male farmers (1.82). Educated farmers had a positive attitude with mean attitude scores of 2.66 (no formal education = 1.44). Religion showed significant difference among religious groups with Muslims and Christians more conservative than traditional religions. Open discussions with residents were suggested as preconditions for acceptance.
Cofie et al. [96]	Ghana	Farmers	Cross-sectional study	60	Human excreta (but not specified)	<ul style="list-style-type: none"> No cultural and religious barriers to excreta use in agriculture. 70% used unsterilized excreta. Excreta users had three times the net income of non-users. Treated excreta was attested not to contaminate crops. Experience, farm size, income, health risk, and agronomic benefits significantly affected excreta use. Excreta availability in recommended quantity and quality and precautionary education reported improving perception.

Table 4. Cont.

First Author Surname (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta Product	Main Findings and Conclusions
Mojid et al. [90]	Bangladesh	Peri-urban farmers	Cross-sectional study	416	Wastewater	<ul style="list-style-type: none"> • Most farmers realized the benefits of wastewater to plants. • Farmers lack knowledge of optimum fertilizer adjustments and doses. • Freshwater was associated with high pumping costs and use of chemical fertilizers compared to wastewater. • Peri-urban and sugar mill farmers perceived odd smell, skin infection and other occupational hazards. • Farmers felt a strong need to treat wastewater before use. • Training on precautionary information and food safety considered necessary for acceptance.
Duncker et al. [97]	South Africa	Rural community	Focus group discussion	Not reported	Human urine and feces	<ul style="list-style-type: none"> • Rural people were aware of the nutritional value of human feces but not urine. • Few farmers were willing to use feces on their garden crops. • The study suggested the importance of changing attitudes on excreta use. • Health perceptions and attitudes are more important than beliefs. • Male farmers were less willing to eat food from excreta compared to female farmers.
Jensen et al. [98])	Vietnam	Farmers	Mixed methods	417	Human urine and feces	<ul style="list-style-type: none"> • Approximately 90% of participants used excreta as fertilizer. • About 94% composted the excreta before use. • Farmers expressed concern over health risks with human excreta. • Various diseases were associated with bad smell (miasma theory). • There is a need for revision of guidelines on ways of reducing the time needed to sanitize excreta through composting.
Knudsen et al. [99]	Vietnam	Farmers	Mixed methods	68	Wastewater and human excreta	<ul style="list-style-type: none"> • Health risk perceptions with excreta use thought to be inevitable. • Hygiene and health concerns were considered women's issues. • Excreta from family and peers was considered more acceptable than from distant people or unknown sources. • Health promotional campaigns considered essential to increase safety acceptance and awareness.

Table 4. Cont.

First Author Surname (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta Product	Main Findings and Conclusions
Phuc et al. [100]	Vietnam	Rural farmers	Mixed methods	75	Human excreta (but not specified)	<ul style="list-style-type: none"> • Around 85% used composted waste in agriculture. • About 28% composted waste 3 to 6 months while 18% composted human excreta for more than six months. • 66% of farmers spread wastes with bare hands as it was considered convenient. • Highly educated farmers used gloves compared to those with low education. • Sustainable interventions to reduce the health effects of using human excreta recommended.
Danso [47]	Ghana	Peri-urban farmers	Mixed methods	700	Composted feces	<ul style="list-style-type: none"> • Majority of farmers had positive perceptions and expressed willingness to use and pay for excreta. • Positive perceptions were related to prior experience. • Farmers recommended field trials and education on the use of the product. • Farmer groups, landscape designers and real estate developers are a potential market for human excreta.
Saliba et al. [102]	Italy	Farmers and consumers	Cross-sectional study	480	Wastewater	<ul style="list-style-type: none"> • There was a high acceptance of the use of wastewater by farmers (59%) and consumers (87%). • Farmers are willing to exploit the benefits of excreta. • Negative attitude resulted from perceived health risks. • Invest in infrastructure and wastewater management and inform the public on potential benefits of excreta use.
Ignacio et al. [86]	Philippines	Rural farmers	Cross-sectional study	167	Human excreta (but not specified)	<ul style="list-style-type: none"> • Approximately 50% of the farmers were aware of the fertilizer value of human excreta. • About 25% prefer to utilize human excreta for food production. • Knowledgeable farmers were willing and displayed a more positive attitude towards excreta use.

Table 4. Cont.

First Author Surname (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta Product	Main Findings and Conclusions
Simha et al. [101]	India	Farmers	Cross-sectional study	120	Human excreta (but not specified)	<ul style="list-style-type: none"> • Around 59% expressed a positive attitude towards the use of urine and 46% of human feces. • Preferred that the neighbors could use theirs, but would not provide urine to their friends, family, and colleagues. • Farmers appreciate soil quality improvement and cost savings. • The burning of crops, fear of being mocked, and uncertainty over consumer demand drove negative attitudes. • Female farmers were more positive than male farmers. • Older farmers had a more positive attitude while income, social class, and experience showed no significant difference among farmers. • Trust between the source of information and users of human excreta was essential in designing and planning implementation programs.
Andersson [84]	Uganda	Rural farmers	Mixed methods	140	Urine	<ul style="list-style-type: none"> • Urine fertilizer was a low-cost and low-risk product that contributed to high yield, income, and food security. • Social norms and cultural perceptions are not absolute barriers to the adoption of human excreta. • Availability, collection, transportation, storage and lack of application knowledge were potential barriers. • The study found that bad smell, fear of diseases, witchcraft, social exclusion, norms, taboos, and uncertainty about long-term effects of human excreta on the soil drove negative attitudes. • Group action by farmers to negotiate norms and taboos and develop new procedures and practices may increase the acceptance.

Table 4. Cont.

First Author Surname (Year)	Country of Study	Target Group	Study Design	Sample Size	Human Excreta Product	Main Findings and Conclusions
Nimoh et al. [88]	Ghana	Peri-urban farmers	Mixed methods	400	Human excreta (but not specified)	<ul style="list-style-type: none"> • The majority disagreed with the notion of excreta as waste and therefore were willing to use it in agriculture. • The majority agreed that excreta use had health risks. • Information and discussion on risks and benefits to improve farmers' knowledge.
Simha et al. [60]	India	University community	Cross-sectional (web-based)	1252	Human urine	<ul style="list-style-type: none"> • Positive attitude observed towards human excreta—68% mentioned that human urine should be recycled. • Approximately 55% considered human urine as valuable fertilizer, but 44% would eat food fertilized with human excreta. • About 65% perceived some health risk, while 80% believed excreta could be sanitized to reduce risk. • Consumer environmental attitudes did not influence attitude towards urine use.

4.4. Perceived Barriers to the Adoption of Human Excreta and HEDM in Agriculture

The perceived barriers were mainly related to health risks associated with human excreta and HEDM use in agriculture. A total of twelve studies concluded that health risk perception is the main barrier to the use of excreta-based fertilizers [87,90,95,98,99,102,103,106]. Two studies showed that health risk perception was not a barrier to the use of human excreta and HEDM in agriculture, especially when the excreta was treated [89,93]. The health concerns included fear of awful smell, handling, skin infections, and many other occupational hazards [107]. Most farmers believed that training on the handling and sanitizing or treatment of human excreta is necessary to reduce health risks [108].

Other perceived barriers included socio-cultural factors, religion, norms, pecuniary factors, and taboos in six studies [15,48,84,85,89,94]. Visual contact with human excreta was considered a reminder of one's internal badness and a taboo [89]. Cultural beliefs and religiosity were not perceived as barriers to human excreta and HEDM use in agriculture in two studies [93,96]. A total of three studies found that limited availability, collection, transport, storage, and lack of knowledge on the application of human excreta were potential barriers to the use of human excreta [84,94,96], suggesting technology and self-efficacy constraints. These studies recommended that making sure that human excreta and HEDM is available in sufficient quantities and suggested that higher quality would improve the use of these products.

Other studies found that precautionary measures and education on safe handling to potentially reduce health risk could improve attitudes as well as farmer confidence on human excreta and HEDM [94]. Providing training could increase awareness of the precautionary handling of food, which may change negative attitudes on crops grown for consumption [90]. Making information available to farmers was thought to improve their knowledge of the risks and benefits of excreta use in agriculture [88]. The idea of switching to a new farming practice implied taking on risks associated with adopting a new and unknown farming practice [104]. In another study, about 50% of the participants were willing to use human excreta, and training and information on HEDM use in agriculture were provided [92].

In six studies, the majority of the participants were not aware of the fertilizer value of human excreta and HEDM in agriculture, and this acted as a barrier to their use [86,87,93,95,99,102]. Coinvestigation by engaging the community, for instance, on pathogen determination through action research allows for co-production and co-development of ideas required for enhancing social acceptance of HEDM. The co-development of knowledge with the community could be achieved through community campaigns, on-farm demonstrations, field days, and lead farmers among other inclusive and participatory approaches. Including farmers in transdisciplinary innovation platforms, for instance, can accelerate social acceptance by creating space for social learning.

4.5. Socioeconomic and Demographic Factors

Various socioeconomic factors influence the attitudes towards the use of human excreta and HEDM in agriculture. The social economic predictors include age, experience, education, farm size, income, agronomic benefits, and gender of the participants. Experience, income, farm size, and agronomic benefits significantly influence the use of human excreta in agriculture [96]. In Ghana, positive perceptions were significantly related to experience [47]. A more recent study in India reported contradictory results where experience had no significant effect on social acceptance [60]. Age is another factor influencing attitudes towards excreta use. One included study in South Africa concluded that younger farmers were more willing to use human excreta compared to older farmers [87]. In another study in India, the results showed contradictory results, where older farmers expressed a more positive attitude compared to younger farmers [101]. The last two examples may be related to different contextual differences (India versus South Africa) or differences in study characteristics as illustrated in Table 3.

Attitudes towards human excreta and HEDM use can also be related to the level of education of the study participants [109]. Two studies reported the positive influence of education on attitudes [85,92]. Educated farmers had higher mean attitude scores (2.66) compared to those with no formal education (1.44) [85]. Farmers with tertiary education rated human excreta higher than animal manure when compared to those with no education [100]. Lastly, in terms of gender, female and male respondents did not show a significant difference in their ranking of animal and human excreta [92]. In another study in South Africa, female farmers had a more negative attitude than male farmers [85], although in another study in South Africa, male farmers were found to be less willing to eat food fertilized with human excreta when compared to female farmers [103]. In a more recent study in India, female farmers were found to be more positive than male farmers [101]. The inconclusive nature of gender, age, experience among other social economic predictors can indicate the importance of contextual and methodological differences on the study results.

5. Implications of the Study for Research, Policy, and Development Practice

The synthesis conducted in this study demonstrates evidence of perceived health risk as the potential barrier to the acceptance of human excreta and HEDM in agriculture. The available research evidence of occupational health risks associated with the use of human excreta includes diarrhea, parasitic, skin, and bacterial infection, as well as epilepsy, making the use of untreated human excreta and wastewater potentially harmful to farmers [63]. The WHO sanitation safety planning manual for safe use of excreta provides steps towards achieving health objectives in line with the WHO guidelines [110]. The manual includes comprehensive exposure-group assessments for the sanitation service chain to include maintenance, cleaning, operations or emptying workers, farmers and consumers of the end products [110].

The manual also includes risk identification training to include hazard types, exposure routes, risk control and mitigation measures through interactive training [111]. The pilot testing of the sanitation safety planning manual in Portugal, India, Philippines, Peru, Vietnam, and Uganda concluded that health risk reduction could be an easy task even in low-income settings [111]. The piloting exercise identified practical measures to manage risks of improper human excreta handling when used as agricultural fertilizer, namely, restriction on the use of wastewater treatment sludges on food crops, processing or cooking food before consumption, handwashing hygiene, and promotion of the use of protective clothing during application [111]. There is growing evidence that pharmaceutical and personal care products can be taken up from soil nutrient solutions by plants, although evidence of accumulation under realistic field concentrations remains inadequate [112–114]. The evidence that some pharmaceutical and personal care products have high bioaccumulation factors present in roots suggests caution should be used for HEDM in tuber crops [115], although the WHO safety plan provides some guidelines on crop selection.

On the other hand, scientific research on the best-bet recovery technologies for specific contexts remains an ongoing discussion, especially potential of full nutrient recovery and contaminant elimination of pathogens, organic pollutants and heavy metals. Technology readiness level (TRL) analysis shows that the most mature technologies are crystallization/precipitation of dissolved P from sludge digester supernatant (DHV Crystalactor[®], AirPrex[®] and Ostara[®]) and wet chemical or acid extraction of P from mono-incineration ash (RecoPhos[®]) [1,40]. Source separating sanitation technologies such as urine diversion and dehydration toilets, may reduce pathogen load, heavy metals, and organic pollutants in the feedstock and final product [116–121]. For instance, full-scale struvite and ammonium sulfate production from urine (SaNiPhos[®]) in the Netherlands, is sourced from source separating technologies [41,43]. Urine storage and co-composting are also among the technologies that have the highest readiness level (9) [122]. The use of locally available materials (such as coconut shells [123], pine bark, zeolite, and wood chips) as sorbents could help remove micro pollutants while facilitating extraction of N-rich urea from solutions by absorption processes [124]. More recently, Simha et al. [125] and Senecal

et al. [126] demonstrated the effect of alkaline treatment in reducing pathogen load and volume of urine (reducing transport costs) while recovering more than 6% of the nitrogen from the urine.

The inconclusive effect of socio-cultural factors (such as cultural norms, religion, beliefs, and taboos) and socioeconomic and demographic factors on perceptions could be due to the contextual differences of the studies. Other contextual factors could include the role of the head of the household, age, and study design, which could skew the outcomes. While, in India, age and gender had a positive effect on attitudes and perceptions, with older farmers being more positive, in South Africa, younger farmers were more positive towards HEDM. The results, however, indicated the importance of education in influencing positive attitudes and perceptions. Promoting training initiatives through field campaigns may facilitate the scaling of innovations of development projects [127,128].

The desirable attributes of the final product also determine whether farmers will find it more appealing and accept it or will be disgusted and display negative attitudes. Certification, fortification, and labeling increase farmers' willingness to accept and pay for HEDM [16,45]. Comlizer, an example of a blend of compost and inorganic fertilizers developed in Ghana, reported higher nitrogen and phosphorus uptake, soil organic matter, nutrient uptake, water use efficiency, and crop yield than chemical fertilizers [129,130]. Pelletizing compost, for instance, is important as it improves product structure and bulk density, which reduce the costs associated with handling, transport, and storage [45,131,132]. Understanding farmers' willingness to pay for these attributes remains a nascent research area of research, although an important one for understanding financial feasibility. Complete demand assessment will only occur when we can estimate willingness to use (quantity) and willingness to pay (price).

Each country and region will have to create policies that are enabling and consistent with the reuse of human excreta that redefines human excreta from waste to wealth, while creating incentives for sustainable business models. Wide-scale commercialization of HEDM can be hindered by prevailing challenges such as inconsistent global regulations, market availability, availability of composting material, the logistics of collection, the price of compost, and the availability of advanced testing laboratories, especially in low-income countries [22]. The Global Good Agricultural Practice (Global GAP) manual, which is the widely adopted standard for food safety and protection of the welfare of farmworkers, was reported as a major barrier for the use of HEDM on horticultural exports in Kenya [22]. Therefore, creating a harmonized global regulatory and legislative environment that supports the recovery and reuse of human excreta remains an important consideration.

6. Conclusion and Future Research Directions

6.1. Conclusions

The social acceptance of human excreta and HEDM in agriculture remains an essential step towards creating a circular nutrient economy in agricultural systems. This review endeavored to synthesize the available evidence in understanding attitudes and perceptions of human excreta and HEDM in agriculture using the best practices for conducting scoping reviews, namely, the preferred reporting items for systematic reviews and meta-analysis. Many studies found that there were positive attitudes and perceptions towards human excreta and HEDM use in agriculture, notwithstanding evidence of potential barriers. The commonly reported barrier was health risk perceptions, although there were other factors, such as socio-cultural norms, religiosity, visual repulsiveness, and socioeconomic factors. These results were not consistent in all studies as some of the studies showed insignificant effect of the predictors of attitudes and perceptions. This can be attributed to contextual and methodological differences.

Providing training through community promotional behavior-change communication, on-farm participatory demonstration trials, health campaigns, and participatory demonstration trials could help to enhance knowledge, awareness, and social acceptance and therefore mitigate perceived barriers. A discussion of the findings of this study demonstrates vari-

ous important factors for ensuring the wide-scale commercialization of waste-recovered fertilizers. These factors include an understanding of the scope of recovery technologies by combining complementary recovery pathways and processes. The review found that horticultural exporters do not currently approve crops grown using human excreta derived fertilizers for exporting to the European market, based on the stipulations of the Global GAP.

6.2. Future Research Directions

While this scoping review provided an assessment of the scope, nature, and extent of the stock of knowledge on the attitudes and perceptions of human excreta reuse in agriculture thus far, it also identified various issues that require further investigation. More empirical work is required to validate the findings of this study in different contexts, especially in least developing countries where providing sanitation can easily be linked to resource recovery and reuse through ecological sanitation technologies. Further work on cost-benefit analysis of HEDM recovery pathways is required, especially incorporating the environmental and health benefits of decentralized sustainable sanitation and nutrient recovery technologies. Empirical work on willingness to pay for HEDM is also required, especially using choice experiment models to estimate demand for various product attributes suggested in this study.

The scope of this review was limited to only peer-reviewed articles published in the English language. The existence of various languages other than English in other databases, such as Google Scholar shows possible exclusion of some relevant articles published in other languages [77]. Future reviews could include more languages and grey literature. Our focus on published peer-reviewed articles can be thought of as quality assurance. To reinforce this quality assurance, we ensured that all included studies were from accredited journals. While the bibliometric databases selected may differ in terms of their archiving, abstracting, and indexing, we used the two bibliometric databases that provided the broadest coverage for the subject matter. Future reviews can build on this work to perform a wider search of online electronic bibliometric databases when performing systematic reviews and meta-analysis of attitudes and perceptions of farmers (as producers and consumers) towards excreta and HEDM use in agriculture.

Some of the included studies did not clarify whether the use of HEDM came from different treatment alternatives or if the material came from stabilized waste. As explained in the discussion section, we can hypothesize that the attitudes and perceptions would differ based on the different treatment alternatives used to recover the end-product, as this has implications on the quality of the HEDM. Future empirical work may investigate the effect of varying product attributes and treatment alternatives on participant perceptions. None of the studies investigated the effect of the processing or cooking of food produced using HEDM on consumer perceptions, which could be an interesting area for future research.

Crops that are equally contaminated in terms of exposure pathways but are consumed cooked may present a change in perceptions of HEDM reuse when compared to crops that are consumed raw, such as cucumbers, carrots, lettuce, and spinach. Lastly, the effect of socioeconomic and demographic factors in forming attitudes and perceptions towards human excreta and HEDM requires future investigation, building on the results of this study. Systematic and meta-analysis studies that allow for quantitative assessment of the results from studies with similar characteristics could provide more information on the nature of the relationship between socioeconomic and demographic factors on general attitudes and risk perceptions towards human excreta and HEDM use.

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References

- Harder, R.; Wielemaker, R.; Larsen, T.A.; Zeeman, G.; Öberg, G. Recycling nutrients contained in human excreta to agriculture: Pathways, processes, and products. *Crit. Rev. Environ. Sci. Technol.* **2019**, *49*, 695–743. [CrossRef]
- Population and Sustainable Development in the Post-2015 Agenda. *Report of the Global Thematic Consultation on Population Dynamics*; UNFPA: New York, NY, USA, 2014.
- The New Urban Agenda, A/RES/71/256, Habitat III and United Nations*; United Nations: New York, NY, USA, 2017. Available online: <http://habitat3.org/the-new-urban-agenda/> (accessed on 1 February 2021).
- Kobel, D.; del Mistro, R. Valuing the non-user benefits of improving water and sanitation in informal settlements: A study of Cape Town. *Urban Water J.* **2015**, *12*, 248–261. [CrossRef]
- McGinnis, S.M.; McKeon, T.; Desai, R.; Ejelonu, A.; Laskowski, S.; Murphy, H.M. A systematic review: Costing and financing of water, sanitation, and hygiene (WASH) in schools. *Int. J. Environ. Res. Public Health* **2017**, *14*, 442. [CrossRef]
- Panchang, S.V.; Vijay Panchang, S. Demand for improved sanitation in an urban informal settlement in India: Role of the local built environment. *Int. J. Environ. Health Res.* **2019**, *29*, 194–208. [CrossRef] [PubMed]
- Winter, S.; Dzombo, M.N.; Barchi, F. Exploring the complex relationship between women's sanitation practices and household diarrhea in the slums of Nairobi: A cross-sectional study. *BMC Infect. Dis.* **2019**, *19*, 1–13. [CrossRef]
- Jenkins, M.W.; Cumming, O.; Cairncross, S. Pit latrine emptying behavior and demand for sanitation services in Dar Es Salaam, Tanzania. *Int. J. Environ. Res. Publ. Health* **2015**, *12*, 2588–2611. [CrossRef] [PubMed]
- Ball, B.C.; Hargreaves, P.R.; Watson, C.A. A framework of connections between soil and people can help improve sustainability of the food system and soil functions. *Ambio* **2018**, *47*, 269–283. [CrossRef]
- Jones, D.L.; Cross, P.; Withers, P.J.A.A.; Deluca, T.H.; Robinson, D.A.; Quilliam, R.S.; Harris, I.M.; Chadwick, D.R.; Edwards-Jones, G. REVIEW: Nutrient stripping: The global disparity between food security and soil nutrient stocks. *J. Appl. Ecol.* **2013**, *50*, 851–862. [CrossRef]
- Moomaw, W.; Griffin, T.; Kurczak, K.; Lomax, J. *The Critical Role of Global Food Consumption Patterns in Achieving Sustainable Food Systems and Food for All, a UNEP Discussion Paper*; United Nations Environment Programme, Division of Technology, Industry and Economics: Paris, France, 2012.
- Jönsson, H.; Vinnerås, B. Adapting the nutrient content of urine and faeces in different countries using FAO and Swedish data. In *Proceedings of the 2nd International Symposium on Ecological Sanitation*, Lübeck, Germany, 7–11 April 2003.
- Kudeyarova, A.Y.; Bashkin, V.N. Study of landscape- agrogeochemical balance of nutrients in agricultural regions (Part I: Phosphorus). *Water. Air Soil Pollut.* **1984**, *21*, 87–95. [CrossRef]
- Wolgast, M. *Rena Vatten: Om Tankar i Kretslopp/ Clean Water: About Tanks in Circulation*; Creanom: Sollentuna, Sweden, 1992; ISBN 9789163015014.
- Khalid, A. Human excreta: A resource or a taboo? Assessing the socio-cultural barriers, acceptability, and reuse of human excreta as a resource in Kakul Village District Abbottabad, Northwestern Pakistan. *J. Water Sanit. Hyg. Dev.* **2018**, *8*, 71–80. [CrossRef]
- Agyekum, E.O.; Ohene-yankyera, K.; Keraita, B.; Fialor, S.C.; Abaidoo, R.C.; Health, D.; Dd, P.O.B. Willingness to pay for faecal compost by farmers in Southern Ghana. *J. Econ. Sustain. Dev.* **2014**, *5*, 18–25.
- Malkki, S. Human faeces as a resource in agriculture. *Conf. Pap.* **1997**, *21*, 36–43.
- Sasmal, J.; Weikard, H. Soil Degradation, Policy Intervention and Sustainable Agricultural Growth. *Q. J. Int. Agric.* **2013**, *52*, 309–328.
- Kwesi Asomaning, S. Processes and factors affecting phosphorus sorption in soils. In *Sorption in 2020s*; IntechOpen: London, UK, 2020.
- Andreoli, C.; Pegorini, E.; Fernandes, F.; Santos, H. Land application of sewage sludge. In *Sludge Treatment and Disposal*; Von Sperling, M., Andreoli, C., Fernandes, F., Eds.; IWA Publishing: London, UK, 2007; pp. 162–206.
- Hudcová, H.; Vymazal, J.; Rozkošný, M. Present restrictions of sewage sludge application in agriculture within the European Union. *Soil Water Res.* **2019**, *14*, 104–120. [CrossRef]
- Moya, B.; Parker, A.; Sakrabani, R. Challenges to the use of fertilisers derived from human excreta: The case of vegetable exports from Kenya to Europe and influence of certification systems. *Food Policy* **2019**, *85*, 72–78. [CrossRef]

23. Glæsner, N.; van der Bom, F.; Bruun, S.; McLaren, T.; Larsen, F.H.; Magid, J. Phosphorus characterization and plant availability in soil profiles after long-term urban waste application. *Geoderma* **2019**, *338*, 136–144. [CrossRef]
24. Lemming, C.; Oberson, A.; Magid, J.; Bruun, S.; Scheutz, C.; Frossard, E.; Jensen, L.S. Residual phosphorus availability after long-term soil application of organic waste. *Agric. Ecosyst. Environ.* **2019**, *270–271*, 65–75. [CrossRef]
25. Rahman, N.; Bruun, T.B.; Giller, K.E.; Magid, J.; Ven, G.W.J.; Neergaard, A. Soil greenhouse gas emissions from inorganic fertilizers and recycled oil palm waste products from Indonesian oil palm plantations. *GCB Bioenergy* **2019**. [CrossRef]
26. Van den Born, G.; de Haan, B.; Pearce, D.; Howarth, A. *Technical Report on Soil Degradation*. European Commission. 2000. Available online: https://ec.europa.eu/environment/enveco/economics_policy/pdf/studies/soil.pdf (accessed on 1 February 2021).
27. Sasmal, J. *The Adoption of Modern Technology in Agriculture a Micro Level Study in West Bengal*; University of Calcutta: Calcutta, India, 1992.
28. Druilhe, Z.; Barreiro-Hurlé, J. *Fertilizer Subsidies in Sub-Saharan Africa*; ESA Publications: ESA Working Papers 288997; Food and Agriculture Organization of the United Nations, Agricultural Development Economics Division, ESA: Rome, Italy, 2012.
29. Sheahan, M.; Barrett, C.B. Ten striking facts about agricultural input use in Sub-Saharan Africa. *Food Policy* **2017**, *67*, 12–25. [CrossRef]
30. *Transforming Our World: The 2030 Agenda for Sustainable Development*. A/RES/70/1; UN: New York, NY, USA, 2015. Available online: <https://www.refworld.org/docid/57b6e3e44.html> (accessed on 1 February 2021).
31. Simha, P.; Ganesapillai, M. Ecological Sanitation and nutrient recovery from human urine: How far have we come? A review. *Sustain. Environ. Res.* **2017**, *27*, 107–116. [CrossRef]
32. Roefs, I.; Meulman, B.; Vreeburg, J.H.G.; Spiller, M. Centralised, decentralised or hybrid sanitation systems? Economic evaluation under urban development uncertainty and phased expansion. *Water Res.* **2017**, *109*, 274–286. [CrossRef]
33. Ebrey, P.; Walthall, A.; Palias, J. *Modern East Asia: A Cultural, Social and Political History*; Cengage Learning: Boston, MA, USA, 2006.
34. King, F.H. *Farmers of Forty Centuries*; Dover Publications: Mineola, NY, USA, 1972; pp. 1–136.
35. Brown, A.D.D. *Feed of Feedback: Agriculture, Population Dynamics and the State of the Planet*; International Books: Utrecht, The Netherlands, 2003.
36. Bracken, P.; Wachtler, A.; Panesar, A.R.; Lange, J. The road not taken: How traditional excreta and greywater management may point the way to a sustainable future. *Water Sci. Technol. Water Supply* **2007**, *7*, 219–227. [CrossRef]
37. Drangert, J.O. Urine blindness and the use of nutrients from human excreta in urban agriculture. *Geojournal* **1998**, *45*, 201–208. [CrossRef]
38. Drangert, J.O. Fighting the urine blindness to provide more sanitation options. *Water SA* **1998**, *24*, 157–164.
39. Esrey, S.A.; Gough, J.; Rapaport, D.; Sawyer, R.; Simpson-Hébert, M.; Vargas, J.; Winblad, U. *Ecological sanitation-Revised and Enlarge Edition*; Jones, S., Winblad, U., Eds.; Swedish International Development Cooperation Agency: Stockholm, Sweden, 1998.
40. Douglas, M. *Purity and Danger. An Analysis of the Concepts of Pollution and Taboo*; ARK, Ed.; Taylor & Francis e-Library: London, UK; New York, NY, USA, 1966; ISBN 0-203-12938-5.
41. Egle, L.; Rechberger, H.; Krampe, J.; Zessner, M. Phosphorus recovery from municipal wastewater: An integrated comparative technological, environmental and economic assessment of P recovery technologies. *Sci. Total Environ.* **2016**, *571*, 522–542. [CrossRef]
42. Egle, L.; Rechberger, H.; Zessner, M. Overview and description of technologies for recovering phosphorus from municipal wastewater. *Resour. Conserv. Recycl.* **2015**, *105*, 325–346. [CrossRef]
43. Hukari, S.; Hermann, L.; Nättorp, A. From wastewater to fertilisers—Technical overview and critical review of European legislation governing phosphorus recycling. *Sci. Total Environ.* **2016**, *542*, 1127–1135. [CrossRef] [PubMed]
44. Wielemaker, R.C.; Weijma, J.; Zeeman, G. Harvest to harvest: Recovering nutrients with new sanitation systems for reuse in urban agriculture. *Resour. Conserv. Recycl.* **2018**, *128*, 426–437. [CrossRef]
45. Radin, M.; Jeuland, M.; Wang, H.; Whittington, D. *Benefit-Cost Analysis of Community-Led Total Sanitation: Incorporating Results from Recent Evaluations*; Guidelines for Benefit-Cost Analysis Project; Cambridge University Press: Cambridge, MA, USA, 2019.
46. Danso, G.K.; Otoo, M.; Ekere, W.; Ddungu, S.; Madurangi, G. Market feasibility of faecal sludge and municipal solid waste-based compost as measured by farmers’ willingness-to-pay for product attributes: Evidence from Kampala, Uganda. *Resources* **2017**, *6*, 31. [CrossRef]
47. Gwara, S.; Wale, E.; Odindo, A.; Buckley, C. Why do we know so much and yet so little? A scoping review of willingness to pay for human excreta derived material in agriculture. *Sustainability* **2020**, *12*, 6490. [CrossRef]
48. Danso, G.; Fialor, S.C.; Drechsel, P. Farmers’ perception and willingness to pay for urban waste compost in Ghana. In *Proceedings of the Waste Management and the Environment*; Almorza, D., Brebbia, C.A., Sales, D., Popov, V., Eds.; WIT Press: Southampton, UK, 2002; pp. 231–241.
49. Roma, E.; Benoit, N.; Buckley, C.; Bell, S. Using the Receptivity model to uncover ‘urine blindness’: Perceptions on the re-use of urine. *Waste Manag. Res.* **2013**, *31*, 648–654. [CrossRef] [PubMed]
50. Lienert, J.; Larsen, T. High acceptance of urine separation in seven European countries: A review. *Environmental Sci. Technol.* **2010**, *44*, 556–566. [CrossRef] [PubMed]
51. Ganesapillai, M.; Simha, P.; Gupta, K.; Jayan, M. Nutrient Recovery and recycling from human urine: A circular perspective on sanitation and food security. *Procedia Eng.* **2016**, *148*, 346–353. [CrossRef]

52. Andreev, N.; Ronteltap, M.; Boincean, B.; Lens, P.N.L. Lactic acid fermentation of human excreta for agricultural application. *J. Environ. Manag.* **2018**, *206*, 890–900. [[CrossRef](#)] [[PubMed](#)]
53. WHO Advocacy, Communication and Social Mobilization for TB Control. *A Guide to developing Knowledge, Attitude and Practice Surveys*; WHO: Geneva, Switzerland, 2008; ISBN 978-92-4-159617-6.
54. Barjolle, D.; Gorton, M.; Milošević Đorđević, J.; Stojanović, Ž. (Eds.) *Food Consumer Science: Theories, Methods and Application to the Western Balkans*; Springer Science Business Media Dordrecht: München, Germany, 2014.
55. Ajzen, I.; Processes, H.D.; Ajzen, I.; Processes, H.D. The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* **1991**, *211*, 179–211. [[CrossRef](#)]
56. Matsumori, K.; Iijima, K.; Koike, Y.; Matsumoto, K. A decision-theoretic model of behavior change. *Front. Psychol.* **2019**, *10*, 1042. [[CrossRef](#)] [[PubMed](#)]
57. Bredahl, L.; Grunert, G.K.; Frewer, L. Consumer attitudes and decision—Making with regard to genetically engineered food products—A review of the literature and a presentation of models for future research. *J. Consum. Pol.* **1998**, *21*, 251–277. [[CrossRef](#)]
58. Stern, P.C.; Dietz, T.; Guagnano, G.A. The new ecological paradigm in social-psychological context. *Environ. Behav.* **1995**, *27*, 723–743. [[CrossRef](#)]
59. Dunlap, R.E.V.L.; van Liere, K.D.; Mertig, A.G.; Jones, R.E. Measuring endorsement of the new ecological paradigm: A revised NEP Scale. *J. Soc. Issues* **2000**, *56*, 425–442. [[CrossRef](#)]
60. Hernes, M.I.; Metzger, M.J. Understanding local community's values, worldviews and perceptions in the Galloway and Southern Ayrshire Biosphere Reserve, Scotland. *J. Environ. Manag.* **2017**, *186*, 12–23. [[CrossRef](#)] [[PubMed](#)]
61. Simha, P.; Lalander, C.; Ramanathan, A.; Vijayalakshmi, C.; McConville, J.R.; Vinnerås, B.; Ganesapillai, M. What do consumers think about recycling human urine as fertiliser? Perceptions and attitudes of a university community in South India. *Water Res.* **2018**, *143*, 527–538. [[CrossRef](#)] [[PubMed](#)]
62. Ogunbode, C.A. The NEP scale: Measuring ecological attitudes/worldviews in an African context. *Environ. Dev. Sustain.* **2013**, *15*, 1477–1494. [[CrossRef](#)]
63. Arksey, H.; O'Malley, L. Scoping studies: Towards a methodological framework Scoping Studies: Towards a methodological framework. *Int. J. Soc. Res. Methodol.* **2007**, *1*, 19–32.
64. Lam, S.; Nguyen-Viet, H.; Tuyet-Hanh, T.T.; Nguyen-Mai, H.; Harper, S. Evidence for public health risks of wastewater and excreta management practices in Southeast Asia: A scoping review. *Int. J. Environ. Res. Public Health* **2015**, *12*, 12863–12885. [[CrossRef](#)]
65. Corrin, T.; Papadopoulos, A. Understanding the attitudes and perceptions of vegetarian and plant-based diets to shape future health promotion programs. *Appetite* **2017**, *109*, 40–47. [[CrossRef](#)]
66. Colquhoun, H.L.; Levac, D.; O'Brien, K.K.; Straus, S.; Tricco, A.C.; Perrier, L.; Kastner, M.; Moher, D. Scoping reviews: Time for clarity in definition, methods, and reporting. *J. Clin. Epidemiol.* **2014**, *67*, 1291–1294. [[CrossRef](#)]
67. Levac, D.; Colquhoun, H.; O'Brien, K.K. Scoping studies: Advancing the methodology. *Implement. Sci.* **2010**, *5*, 69. [[CrossRef](#)]
68. Pham, M.T.; Rajić, A.; Greig, J.D.; Sargeant, J.M.; Papadopoulos, A.; McEwen, S.A. A scoping review of scoping reviews: Advancing the approach and enhancing the consistency. *Res. Synth. Methods* **2014**, *5*, 371–385. [[CrossRef](#)] [[PubMed](#)]
69. Peters, M.D.J.; Godfrey, C.M.; Khalil, H.; McInerney, P.; Parker, D.; Soares, C.B. Guidance for conducting systematic scoping reviews. *Int. J. Evid. Based. Healthc.* **2015**, *13*, 141–146. [[CrossRef](#)] [[PubMed](#)]
70. Rudnicka, A.R.; Owen, C.G. An introduction to systematic reviews and meta-analyses in health care. *Ophthalmic Physiol. Opt.* **2012**, *32*, 174–183. [[CrossRef](#)] [[PubMed](#)]
71. White, H.; Waddington, H. Why do we care about evidence synthesis? An introduction to the special issue on systematic reviews. *J. Dev. Eff.* **2012**, *4*, 351–358. [[CrossRef](#)]
72. Grant, M.J.; Booth, A. A typology of reviews: An analysis of 14 review types and associated methodologies. *Health Info. Libr. J.* **2009**, *26*, 91–106. [[CrossRef](#)] [[PubMed](#)]
73. Munn, Z.; Peters, M.D.J.; Stern, C.; Tufanaru, C.; McArthur, A.; Aromataris, E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med. Res. Methodol.* **2018**, *18*, 1–7. [[CrossRef](#)] [[PubMed](#)]
74. Sucharew, H. Methods for research evidence synthesis: The scoping review approach. *J. Hosp. Med.* **2019**, *14*, 416. [[CrossRef](#)] [[PubMed](#)]
75. Moher, D.; Shamseer, L.; Clarke, M.; Ghersi, D.; Liberati, A.; Petticrew, M.; Shekelle, P.; Stewart, L.A.; Group, P. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst. Rev.* **2015**, *4*, 1–9. [[CrossRef](#)]
76. Eriksen, M.B.; Frandsen, T.F. The impact of patient, intervention, comparison, outcome (PICO) as a search strategy tool on literature search quality: A systematic review. *J. Med. Libr. Assoc.* **2018**, *106*, 420. [[CrossRef](#)] [[PubMed](#)]
77. Methley, A.M.; Campbell, S.; Chew-Graham, C.; McNally, R.; Cheraghi-Sohi, S. PICO, PICOS and SPIDER: A comparison study of specificity and sensitivity in three search tools for qualitative systematic reviews. *BMC Health Serv. Res.* **2014**, *14*, 1–10. [[CrossRef](#)]
78. Mongeon, P.; Paul-Hus, A. The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics* **2016**, *106*, 213–228. [[CrossRef](#)]
79. Martín-Martín, A.; Orduna-Malea, E.; Thelwall, M.; Delgado López-Cózar, E. Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. *J. Informetr.* **2018**, *12*, 1160–1177. [[CrossRef](#)]

80. Adams, R.J.; Smart, P.; Huff, A.S. Shades of grey: Guidelines for working with the grey literature in systematic reviews for management and organizational studies. *Int. J. Manag. Rev.* **2017**, *19*, 432–454. [\[CrossRef\]](#)
81. Benzie, K.M.; Premji, S.; Hayden, K.A.; Serrett, K. State-of-the-evidence reviews: Advantages and challenges of including grey literature. *Worldviews Evidence-Based Nurs.* **2006**, *3*, 55–61. [\[CrossRef\]](#) [\[PubMed\]](#)
82. Wohlin, C. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In Proceedings of the ACM International Conference Proceeding Series, London, UK, 13–14 May 2014.
83. Badampudi, D.; Wohlin, C.; Petersen, K. Experiences from Using Snowballing and Database Searches in Systematic Literature Studies. In *Proceedings of the 19th International Conference on Evaluation and Assessment in Software Engineering—EASE'15, April 2015*; ACM Press: New York, NY, USA, 2015; pp. 1–10.
84. Moffa, M.; Cronk, R.; Feifar, D.; Dancausse, S.; Padilla, L.A.; Bartram, J. A systematic scoping review of hygiene behaviors and environmental health conditions in institutional care settings for orphaned and abandoned children. *Sci. Total Environ.* **2019**, *658*, 1161–1174. [\[CrossRef\]](#) [\[PubMed\]](#)
85. Andersson, E. Turning waste into value: Using human urine to enrich soils for sustainable food production in Uganda. *J. Clean. Prod.* **2015**, *96*, 290–298. [\[CrossRef\]](#)
86. Mariwah, S.; Drangert, J.-O.O. Community perceptions of human excreta as fertilizer in peri-urban agriculture in Ghana. *Waste Manag. Res.* **2011**, *29*, 815–822. [\[CrossRef\]](#)
87. Ignacio, J.; Alvin Malenab, R.; Pausta, C.; Beltran, A.; Belo, L.; Tanhueco, R.; Era, M.; Eusebio, R.; Promentilla, M.; Orbecido, A. Perceptions and attitudes toward eco-toilet systems in rural areas: A case study in the philippines. *Sustainability* **2018**, *10*, 521. [\[CrossRef\]](#)
88. Mugivhisa, L.L.; Olowoyo, J.O. An assessment of university students and staff perceptions regarding the use of human urine as a valuable soil nutrient in South Africa. *Afr. Health Sci.* **2015**, *15*, 999–1010. [\[CrossRef\]](#) [\[PubMed\]](#)
89. Nimoh, F.; Ohene-Yankyera, K.; Poku, K.; Konradsen, F.; Abaidoo, R.C. Farmers perception on excreta reuse for peri-urban agriculture in southern Ghana. *J. Dev. Agric. Econ.* **2014**, *6*, 421–428.
90. Buit, G.; Jansen, K. Acceptance of human feces-based fertilizers in fecophobic Ghana. *Hum. Organ.* **2016**, *75*, 97–107. [\[CrossRef\]](#)
91. Mojid, M.A.; Wyseure, G.C.L.; Biswas, S.K.; Hossain, A.B.M.Z. Farmers' perceptions and knowledge in using wastewater for irrigation at twelve peri-urban areas and two sugar mill areas in Bangladesh. *Agric. Water Manag.* **2010**, *98*, 79–86. [\[CrossRef\]](#)
92. Mugivhisa, L.L.; Olowoyo, J.O.; Mzimba, D. Perceptions on organic farming and selected organic fertilizers by subsistence farmers in Ga-Rankuwa, Pretoria, South Africa. *African J. Sci. Technol. Innov. Dev.* **2017**, *9*, 85–91. [\[CrossRef\]](#)
93. Appiah-Effah, E.; Nyarko, K.B.; Adum, L.; Antwi, E.O.; Awuah, E. Perception of peri-urban farmers on fecal sludge compost and its utilization: A case study of three peri-urban communities in ashanti region of Ghana. *Compost Sci. Util.* **2015**, *23*, 267–275. [\[CrossRef\]](#)
94. Zheng, Z. (Eric); Pavlou, P.A. Research note—Toward a causal interpretation from observational data: A New bayesian networks method for structural models with latent variables. *Inf. Syst. Res.* **2010**, *21*, 365–391. [\[CrossRef\]](#)
95. Simha, P.; Lalander, C.; Vinnerås, B.; Ganesapillai, M. Farmer attitudes and perceptions to the re-use of fertiliser products from resource-oriented sanitation systems—The case of Vellore, South India. *Sci. Total Environ.* **2017**, *581*, 885–896. [\[CrossRef\]](#) [\[PubMed\]](#)
96. Jensen, P.K.; Phuc, P.D.; Knudsen, L.G.; Dalsgaard, A.; Konradsen, F. Hygiene versus fertiliser: The use of human excreta in agriculture—A Vietnamese example. *Int. J. Hyg. Environ. Health* **2008**, *211*, 432–439. [\[CrossRef\]](#) [\[PubMed\]](#)
97. Saliba, R.; Callieris, R.; Agostino, D.D.; Roma, R.; Scardigno, A. Stakeholders' attitude towards the reuse of treated wastewater for irrigation in Mediterranean agriculture. *Agric. Water Manag.* **2018**, *204*, 60–68. [\[CrossRef\]](#)
98. Duncker, L.C.; Matsebe, G.N. Prejudices and Attitudes Toward Reuse of Nutrients from urine Diversion Toilets in South Africa. In Proceedings of the Proceedings of the 33rd WEDC International Conference, WEDC, Accra, Ghana, 7–11 April 2008; Jones, H., Ed.; Loughborough University: Loughborough, UK, 2008; pp. 108–113.
99. Cofie, O.; Adeoti, A.; Nkansah-Boadu, F.; Awuah, E. Farmers perception and economic benefits of excreta use in southern Ghana. *Resour. Conserv. Recycl.* **2010**, *55*, 161–166. [\[CrossRef\]](#)
100. Chapeyama, B.; Wale, E.; Odindo, A. The cost-effectiveness of using latrine dehydrated and pasteurization pellets and struvite: Experimental evidence from South Africa. *African J. Sci. Technol. Innov. Dev.* **2018**, *10*, 451–461. [\[CrossRef\]](#)
101. Tran-Thi, N.; Lowe, R.J.; Schurer, J.M.; Vu-Van, T.; MacDonald, L.E.; Pham-Duc, P. Turning poop into profit: Cost-effectiveness and soil transmitted helminth infection risk associated with human excreta reuse in Vietnam. *PLoS Negl. Trop. Dis.* **2017**, *11*, e0006088. [\[CrossRef\]](#) [\[PubMed\]](#)
102. Lagerkvist, C.J.; Shikuku, K.; Okello, J.; Karanja, N.; Ackello-Ogut, C. A conceptual approach for measuring farmers' attitudes to integrated soil fertility management in Kenya. *NJAS Wageningen J. Life Sci.* **2015**, *74–75*, 17–26. [\[CrossRef\]](#)
103. Okem, A.E.; Xulu, S.; Tilley, E.; Buckley, C.; Roma, E. Assessing perceptions and willingness to use urine in agriculture: A case study from rural areas of eThekweni municipality, South Africa. *J. Water Sanit. Hyg. Dev.* **2013**, *3*, 582. [\[CrossRef\]](#)
104. Moya, B.; Parker, A.; Sakrabani, R.; Mesa, B. Evaluating the efficacy of fertilisers derived from human excreta in agriculture and their perception in Antananarivo, Madagascar. *Waste Biomass Valorization* **2017**, *10*, 1–12. [\[CrossRef\]](#)
105. Knudsen, L.G.; Phuc, P.D.; Hiep, N.T.; Samuelson, H.; Jensen, P.K.; Dalsgaard, A.; Raschid-Sally, L.; Konradsen, F. The fear of awful smell: Risk perceptions among farmers in Vietnam using wastewater and human excreta in agriculture. *Southeast Asian J. Trop. Med. Public Health* **2008**, *39*, 341–352. [\[PubMed\]](#)

106. Phuc, P.D.; Konradsen, F.; Phuong, P.T.; Cam, P.D.; Dalsgaards, A. Practice of using human excreta as fertilizer and implications for health in Nghean Province, Vietnam. *Southeast Asian J. Trop. Med. Public Health* **2006**, *37*, 222–229. [[PubMed](#)]
107. Memon, A.G.; Naeem, Z.; Zaman, A.; Zahid, F. Occupational health related concerns among surgeons. *Int. J. Heal Sci.* **2016**, *10*, 279–291. [[CrossRef](#)]
108. Samuel, F. Excreta-related infections and the role of latrines to control the transmission in Ethiopia. *J. Community Med. Heal. Educ.* **2016**, *6*, 496.
109. Hosseinneshad, F. A Study of the new environmental paradigm scale in the context of Iran. *Eur. J. Sustain. Dev. Res.* **2017**, *1*, 1–8. [[CrossRef](#)]
110. World Health Organization. *Sanitation Safety Planning: Manual for Safe Use and Disposal of Wastewater, Greywater and Excreta*; World Health Organization: Geneva, Switzerland, 2015; ISBN 9789241549240.
111. Winkler, M.; Jackson, D.; Sutherland, D.; Payden; Lim, J.U.; Srikantiah, V.; Fuhrmann, S.; Medlicott, K. Sanitation safety planning as a tool for achieving safely managed sanitation systems and safe use of wastewater. *WHO South-East Asia J. Public Heal.* **2017**, *6*, 34. [[CrossRef](#)] [[PubMed](#)]
112. Wu, X.; Dodgen, L.K.; Conkle, J.L.; Gan, J. Plant uptake of pharmaceutical and personal care products from recycled water and biosolids: A review. *Sci. Total Environ.* **2015**, *536*, 655–666. [[CrossRef](#)] [[PubMed](#)]
113. Bartrons, M.; Peñuelas, J. Pharmaceuticals and personal-care products in plants. *Trends Plant Sci.* **2017**, *22*, 194–203. [[CrossRef](#)] [[PubMed](#)]
114. Carter, L.J.; Garman, C.D.; Ryan, J.; Dowle, A.; Bergström, E.; Thomas-Oates, J.; Boxall, A.B.A. Fate and uptake of pharmaceuticals in soil-earthworm systems. *Environ. Sci. Technol.* **2014**, *48*, 5955–5963. [[CrossRef](#)] [[PubMed](#)]
115. Holling, C.S.; Bailey, J.L.; Vanden Heuvel, B.; Kinney, C.A. Uptake of human pharmaceuticals and personal care products by cabbage (*Brassica campestris*) from fortified and biosolids-amended soils. *J. Environ. Monit.* **2012**, *14*, 3029–3036. [[CrossRef](#)] [[PubMed](#)]
116. Udert, K.M.; Buckley, C.A.; Wächter, M.; McArdell, C.S.; Kohn, T.; Strande, L.; Zolig, H.; Fumasoli, A.; Oberson, A.; Etter, B. Technologies for the treatment of source-separated urine in the eThekweni Municipality. *Water SA* **2015**, *41*, 212–221. [[CrossRef](#)]
117. Udert, K.M.; Etter, B.; Gounden, T. Promoting sanitation in South Africa through nutrient recovery from urine. *Gaia* **2016**, *25*, 194–196. [[CrossRef](#)]
118. Mohammad, S.; Uddin, N.; Muhandiki, V.S.; Sakai, A.; Al, A.; Marium, S.; Uddin, S.M.N.; Muhandiki, V.S.; Sakai, A.; Al Mamun, A.; et al. Socio-cultural acceptance of appropriate technology: Identifying and prioritizing barriers for widespread use of the urine diversion toilets in rural Muslim communities of Bangladesh. *Technol. Soc.* **2014**, *38*, 32–39.
119. Kumwenda, S.; Msefula, C.; Kadewa, W.; Ngwira, B.; Morse, T. Estimating the Health Risk Associated with the Use of Ecological Sanitation Toilets in Malawi. *J. Environ. Public Health* **2017**, *2017*. [[CrossRef](#)]
120. Roma, E.; Philp, K.; Buckley, C.; Xulu, S.; Scott, D. User perceptions of urine diversion dehydration toilets: Experiences from a cross-sectional study in eThekweni municipality. *Water SA* **2013**, *39*, 305–311. [[CrossRef](#)]
121. Abarghaz, Y.; Mustapha Mahi, M.; Werner, M.C.; Bendaou, N.; Fekhaoui, M. Ecological sanitation in Morocco promotion of the urine-diversion dehydration toilets-case of Dayet Ifrah. *Am. J. Environ. Sci.* **2012**, *8*, 212–219.
122. Zhou, X.; Li, Z.; Zheng, T.; Yan, Y.; Li, P.; Odey, E.A.; Peter, H.; Mohammad, S.; Uddin, N. Review of global sanitation development. *Environ. Int.* **2019**, *120*, 246–261. [[CrossRef](#)] [[PubMed](#)]
123. Ganesapillai, M.; Simha, P.; Zabaniotou, A. Closed-loop fertility cycle: Realizing sustainability in sanitation and agricultural production through the design and implementation of nutrient recovery systems for human urine. *Sustain. Prod. Consum.* **2015**, *4*, 36–46. [[CrossRef](#)]
124. Hina, K.; Hedley, M.; Camps-Arbestain, M.; Hanly, J. Comparison of pine bark, biochar and zeolite as sorbents for NH₄⁺-N removal from water. *Clean Soil Air Water* **2015**, *43*, 86–91. [[CrossRef](#)]
125. Simha, P.; Senecal, J.; Nordin, A.; Lalander, C.; Vinnerås, B. Alkaline dehydration of anion-exchanged human urine: Volume reduction, nutrient recovery and process optimisation. *Water Res.* **2018**, *142*, 325–336. [[CrossRef](#)] [[PubMed](#)]
126. Senecal, J.; Nordin, A.; Simha, P.; Vinnerås, B. Hygiene aspect of treating human urine by alkaline dehydration. *Water Res.* **2018**, *144*, 474–481. [[CrossRef](#)] [[PubMed](#)]
127. Lukuyu, B.; Place, F.; Franzel, S.; Kiptot, E. Disseminating improved practices: Are volunteer farmer trainers effective? *J. Agric. Educ. Ext.* **2012**, *18*, 525–540. [[CrossRef](#)]
128. Kiptot, E.; Karuhanga, M.; Franzel, S.; Nzigamasabo, P.B. Volunteer farmer-trainer motivations in East Africa: Practical implications for enhancing farmer-to-farmer extension. *Int. J. Agric. Sustain.* **2016**, *14*, 339–356. [[CrossRef](#)]
129. Vaish, B.; Srivastava, V.; Kumar Singh, P.; Singh, P.; Pratap Singh, R. Energy and nutrient recovery from agro-wastes: Rethinking their potential possibilities. *Environ. Eng. Res.* **2019**, *25*, 623–637. [[CrossRef](#)]
130. Cofie, O.; Adamtey, N. Nutrient Recovery from Human Excreta for Urban and peri-urban agriculture. In Proceedings of the WEDC International Conference. SuSanA Food Security Working Group, Addis Ababa, Ethiopia, 15 April 2009; Water Management Institute: Colombo, Sri Lanka, 2009; p. 12.
131. Pampuro, N.; Caffaro, F.; Cavallo, E. Reuse of animal manure: A case study on stakeholders' perceptions about pelletized compost in Northwestern Italy. *Sustainability* **2018**, *10*, 2028. [[CrossRef](#)]
132. Rahmani, M.; Hodges, A.W.; Kiker, C.F. Compost users' attitudes toward compost application in florida. *Compost Sci. Util.* **2004**, *12*, 55–60. [[CrossRef](#)]