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Managing Solid Waste In School Environment Through Composting Approach

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Abstract

This study aimed at improving solid waste disposal in schools by using the composting approach. The theory that underpinned this study was Reduce, Reuse, and Recycle (3R) theory, while the necessary data were gathered by using a synthesis and integration approach. The following three research questions were framed to guide the conduct of the study: How important is solid waste management in schools? What pedagogical techniques are most effective for promoting environmental sustainability by teaching composting in schools? What are the challenges involved in the composting process at school? The synthesis and integration approach assisted in integrating concepts from different sources and synthesizing those concepts to create a comprehensive and cogent argument in accordance with emerging themes. It was discovered that solid waste management in schools was particularly crucial since schools produced a lot of rubbish and that waste may affect the environment negatively. Composting is essential to improve school solid waste because it enhances soil health, decreases waste, and encourages sustainable agricultural methods. Three pedagogical techniques that could be utilized to facilitate the teaching and learning of composting in schools have evolved based on the theoretical framework and the literature provided. Project-based learning (PBL), hands-on learning, and inquiry-based learning were some of the new pedagogical strategies. However, some of the challenges with the composting process were identified as follows: difficulty in regulating the moisture level of the compost, keeping the proper balance of carbon and nitrogen in the compost pile, and inability to educate students and staff about the composting process.

Keywords: solid waste, management, composting, school environment, pedagogical practices, and sanitation

INTRODUCTION

Effective management of solid waste in schools is an urgent concern that demands immediate attention. Over time, the discourse surrounding solid waste has intensified due to population growth and increased human activity. Improper disposal of solid waste, particularly in developing countries, has led to indiscriminate waste disposal practices that harm the environment (James, 2016). Inadequate waste management, such as using poorly designed or operated open dumps and landfills, contributes to existing water and air pollution (National Association of Secondary School Principals (NASSP), 1974). Consequently, governments worldwide have allocated resources to raise awareness among communities and households about proper waste disposal (UNICEF & WHO, 2020). Efficient management of solid waste in schools can enhance sanitation, improve access to education, and facilitate effective teaching and learning (UNICEF & WHO, 2018).

According to Sustainable Development Goal 6, which aims to ensure the availability and sustainable management of water and sanitation for all, access to clean water, adequate sanitation, and personal hygiene should be provided to every individual by 2030. This goal emphasizes the importance of addressing sanitation concerns not only within communities and households but also within schools. To align with the principles and objectives of SDG 6, waste management facilities, especially in schools and public areas, should be established to enhance sanitation. Upgrading school facilities is essential to implementing and reinforcing waste management practices and fostering a healthy learning environment. Improved school facilities create an enriched learning space where students develop skills, knowledge, culture, and identity (Marques & Xavier, 2020). Moreover, they cultivate a friendly atmosphere conducive to understanding various aspects of the natural world and the environmental impact of human activities. By supporting students' new attitudes and ideals, schools can contribute to creating a vibrant society in addition to their academic endeavors (Avivah et al., 2022).

Many schools in Sub-Saharan Africa, as well as Eastern and South-Eastern Asia, lack basic sanitation provisions (UNICEF & WHO, 2018). It is evident that students often leave their surroundings littered with trash, including plastic, paper, and food scraps. According to UNESCO (2015), waste management can be effectively achieved through teamwork, with students playing a crucial role as future leaders. They need to actively engage in and be educated about sanitation issues in their communities and educational institutions, inspiring them to take action. Implementing sanitation measures in schools would not only improve students' health but also enhance enrollment rates (Bowen et al., 2007). Considering the unique organizational structures of schools, a composting approach has been identified as a potential solution. By conceptualizing composting methods tailored to schools, the littering of solid waste can be minimized, sanitation can be improved, and the environment can be safeguarded for future generations. This conceptual approach to composting has the potential to reshape students' behaviors regarding solid waste management, fostering a sense of responsibility while promoting a sustainable environment.

1. *Theoretical framework*

The theory that underpinned this study was the theory of Reduce, Reuse, and Recycle (3R). This theory emerged from the environmental movement and has been promoted by various organizations, governments, and individuals over time (United Nations Environment Programme [UNEP], 2018). The 3R is a useful framework that can be followed in managing solid waste in the school environment (National Environment Agency [NEA], 2017). The details of the 3R theory are presented in Figure 1 as follows.

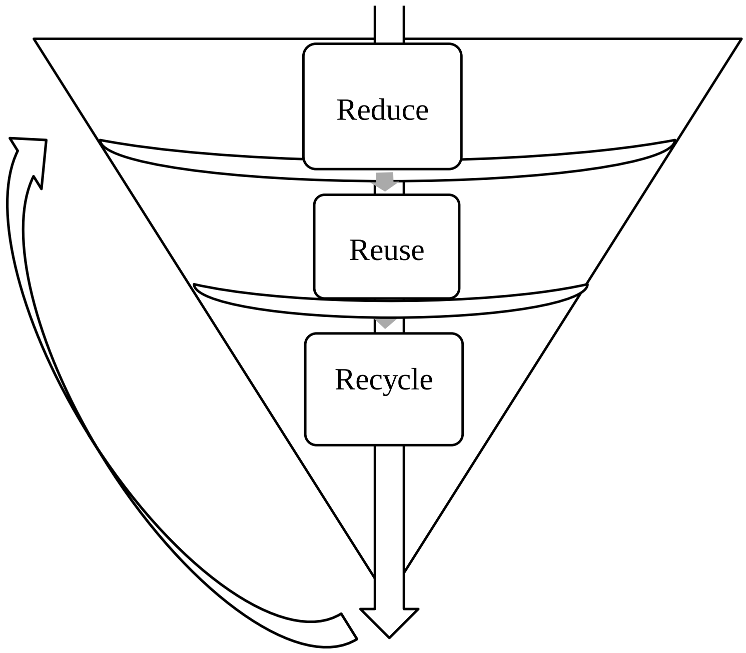

Figure 1: Reduce, Reuse, and Recycle (3R)

Reduce:

The initial phase of the 3R theory is the reduction of waste generation. Several reduction waste strategies can be adopted by schools managements for the accomplishment of this goal. Some of the strategies include;

i. Source Reduction: The goal of source reduction is to reduce the quantity of trash produced at the source. Schools may encourage staff and students to consume responsibly, use fewer single-use items, and use less packaging. For instance, schools may encourage the use of reusable water bottles rather than single-use plastic ones.
ii. Paperless Practices: Schools can decrease their use of paper by using digital platforms for communication, assignments, and administrative chores. The amount of paper used and the amount of waste produced can both be considerably decreased by using electronic documents and internet platforms.
iii. Conscious Purchasing: Schools can choose sustainable procurement methods by choosing products with little packaging and green features. Purchasing in bulk and picking durable goods can both help reduce solid waste in any environment.

Reuse:

The second component of the 3R principle is Reuse if possible. Schools can reduce waste and the demand for new resources by extending the life of their equipment and materials. The following are some strategies for encouraging reuse:

i. Donation and Exchange Programs: Schools can conduct exchange programs where students and teachers can swap items they no longer need. This can include books, stationery, uniforms, electronics, and other usable items. By facilitating the reuse of these items, schools may prevent them from ending up in landfills.
ii. Creative Projects: Encourage creative projects that involve reusing materials as a means of promoting reuse. Students may be assigned projects involving the repurposing of materials such as cardboard, plastic bottles, or old newspapers. This encourages creativity and an appreciation for reusing materials.
iii. Repair and Maintenance: Instead of throwing away broken or damaged items, schools can implement repair and maintenance programs. Repairing furniture, electronics, and other items can help them last longer and lessen the need for replacements.

Recycle:

The third element of the 3R theory is recycling. Recycling includes turning trash into fresh products, which lowers the demand for raw materials. The following strategies can be used in schools to encourage recycling:

i. Recycling Bins and Programs: Recycling bins with visible labels should be placed all around a school's compound, including the classrooms, halls, and outdoor spaces. Different recyclable items, such as paper, plastic, glass, and aluminum, should each have their own bin. Schools can also start recycling initiatives in association with neighborhood recycling facilities or waste management organizations.
ii. Awareness and Education: It is vital to educate students, instructors, and staff members about the value of recycling. In order to inform the school community about correct recycling procedures and the environmental advantages of recycling, schools might arrange workshops, seminars, and educational campaigns.
iii. Partnership with Recycling Companies: To encourage recycling, schools can work with nearby recycling businesses or groups to set up collection stations or schedule recurring garbage pickups from the school grounds.

It can be established that the 3R approach encourages sustainable activities by placing a strong emphasis on lowering waste production, reusing materials, and recycling resources. Schools may dramatically reduce their environmental risks and help create a more sustainable future by putting the 3R principle into practice.

2. *Conceptual Framework*

This study was conceptualized based on emerging themes such as; the need for solid waste management, composting as a tool for solid waste management, and the challenges involved in composting. The details of the review are presented as follows.

a. Meaning of Composting

Composting has been defined in several ways by various writers, simplifying the concept for academics. NASSP (1974) defined composting as the biochemical breakdown of waste organic material into an inert, humus-like substance, including food, paper, and plant materials (leaves, grass clippings). According to Mengistu et al. (2017), composting entails the controlled breakdown of biodegradable organic matter by microbes. During this process, the organic material goes through a high-temperature stage that allows for the refining of the waste by removing pathogenic microorganisms. The United States Environmental Protection Agency (2016) has established that composting is an eco-friendly practice that can be incorporated in schools as a means of waste reduction and soil enrichment. According to the Composting Council (2021), the composting process involves collecting food scraps and other organic materials, such as leaves and twigs, and placing them in the compost bin. Over time, the materials decompose, and the resulting compost can be used as a natural fertilizer for gardens and plants. This requires minimal technological investment since it uses bio-oxidation to convert organic waste into usable organic matter. This process is good for enhancing soil quality for plant growth by regulating aeration, water status, and micro- and macronutrients.

Fecal sludge, for example, which is available in a school setting, has a high moisture content but a low carbon-nitrogen ratio, making it suitable for co-composting with other organic wastes like sawdust. Hence, co-composting is viewed as one of the waste treatment processes in which several waste kinds are processed (composted) together (WASH, 2016). Co-composting can be cited as a good example of a solid waste management technique for trash disposal and resource recovery (Latifah et al., 2015). For instance, composting feces and grass is useful because the two waste products complement one another well. For instance, feces have a high nitrogen concentration with a good amount of moisture, while organic or carbon nutrients can be found in the grass as well as good bulking qualities. Also, both wastes can be combined to create a valuable product, and the right combination of the two wastes guarantees the best carbon-nitrogen ratio to speed up the biodegradation process (Latifah et al., 2015).

b. Types of composting

Anaerobic composting: Anaerobic composting is the decomposition of biodegradable organic material without oxygen, releasing end products such as methane (CH4) and hydrogen sulfide (H2S) (Chan et al., 2011). However, the anaerobic breakdown of organic materials is frequently accompanied by the production of obnoxious fumes like indol and skatol. This type of composting requires little to no labor, but it usually takes a long time for the pile to mature, and it doesn't provide enough heat to properly destroy diseases and weed seeds. The soluble and easily degradable chemicals are broken down by mesophilic bacteria during the process, which typically occurs at temperatures between 8 oC and 45 oC.

Vermi-Composting: This refers to employing red worms to decompose organic waste (Camila, 2013). These specialist worms require their weight in organic material each day to survive. Castings, the substance that passes through the worms' bodies, can have five times the nitrogen, seven times the phosphorus, and eleven times the potassium of regular soil. For these worms to function properly, considerable attention must be taken. They function between 16 °C and 25 °C and are light-sensitive.

Aerobic composting: This is the process through which facultative aerobic organisms, primarily thermophilic, use a significant amount of oxygen to break down organic materials into relatively stable humus material under favorable climatic conditions (Chan et al., 2011). It is the commonly accepted method of stabilizing organic wastes and turning them into a useful, value-added compost product since it is the fastest way to produce high-quality compost. Higher temperatures (over 60 oC) can be achieved during this process, and the process also involves mesophilic and thermophilic microorganisms. According to research, this aerated thermophilic composting method can effectively inactivate pathogens. It creates a well-composted substance and has been proven to be a valuable and effective soil conditioner.

c. Composting processes

The composting processes, as cited in Li et al. (2020), and Raza et al. (2019), are presented as follows.

1) *Collection:* Organic waste materials such as food scraps, yard trimmings, and paper products are collected and mixed together.
2) *Preparation:* The organic materials are prepared for composting by shredding or chopping them into smaller pieces.
3) *Layering:* The organic materials are layered in a compost bin or pile. The layers should be a mix of "brown" materials such as dry leaves, shredded paper, or straw, and "green" materials such as fruit and vegetable scraps, grass clippings, or coffee grounds.
4) *Moisture:* The compost pile should be kept moist but not too wet. If the pile is too dry, it will not decompose properly. If it is too wet, it can become anaerobic and start to smell.
5) *Turning:* The compost pile should be turned regularly to aerate it and mix the materials together. This helps to speed up the decomposition process.
6) *Temperature:* As the organic materials decompose, the temperature in the compost pile will rise. It is important to monitor the temperature to ensure that it stays between 120-160 degrees Fahrenheit. This temperature range will kill weed seeds and pathogens and break down the organic materials quickly.
7) *Curing:* The finished compost is left to sit and mature, allowing for the decomposition process to stabilize and the compost to become fully "cooked". During curing, any remaining organic matter that has not yet broken down completely will continue to decompose, and the compost will become more homogeneous in texture and appearance.
8) Screening: the process of separating the finished compost from any remaining large, undecomposed materials such as sticks, rocks, and other debris. This is usually done using a screen or mesh with small holes that allow the compost to pass through but retain the larger materials.

9) *Maturation:* After several months, the compost will mature and become finished by turning a dark, crumbly, nutrient-rich soil amendment. It can be used in gardens, flower beds, or as a top dressing for lawns.

The basic steps involved in the composting process are further illustrated in the Figure 2.

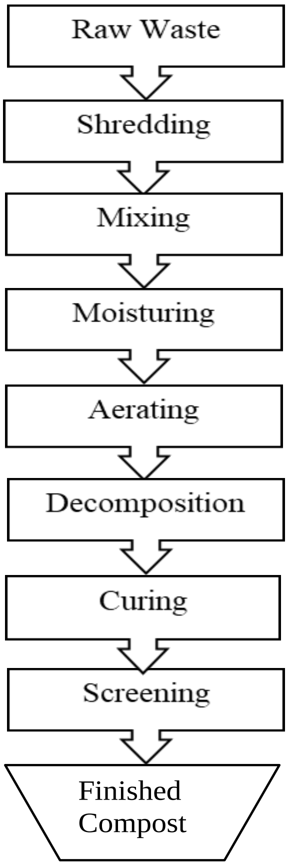

Figure 2: Composting process

It can be seen from Figure 2 that raw waste is first shredded to increase the surface area for decomposition. The waste is then mixed with other organic materials and moistened to create the right conditions for decomposition. Oxygen is added through aeration to encourage the growth of aerobic bacteria. The organic matter breaks down into smaller particles and eventually turns into finished compost through curing and screening.

d. Composting approach

There are many different composting strategies, each with benefits and drawbacks. As a result, the researchers are of the opinion that the selection of the approach would be based on the aims of a given project. Some of the composting approaches cited in Ayilara et al. (2020) are presented as follows.

The Indian composting approach: Bangalore, India, is where the Indian composting strategy was devised (Ayilara et al., 2020). This method involves excavating trenches that are about one meter deep and layering organic waste and night soil alternately (Misra et al., 2003). Finally, a 15 to 20-cm thick layer of rubbish has been piled over the pit. The materials are kept in the pit for three months without being rotated or irrigated. To decrease moisture loss and flies' growth, the volume of materials is lowered during this time, and more night soil and garbage are poured on top in alternate layers and covered with mud or dirt. The final output from this form of composting takes between six and eight months to produce (Misra et al., 2003). It is possible to advise using this method for composting night soil and waste, even though it is time consuming and costly to maintain.

Vessel Composting: This refers to composting inside a container, structure, or other enclosed space. To speed up the composting process, this strategy relies on a range of forced aeration and mechanical rotation approaches (Gonawala & Jardosh, 2018). The vessel composting method can be labor- and money-intensive.

Windrow Composting: When windrow composting is being done, the raw materials are placed in long, thin stacks or windrows that are regularly turned. Aeration of the setup is made possible by the materials' mixing. For solid materials like manure, a conventional windrow composting setup should start at the height of 3 feet, and for fluffy materials like leaves, it should start at a height of 12 feet (Gonawala & Jardosh, 2018). Although it is expensive and difficult to support, it retains heat quickly.

Vermicomposting: This method uses earthworms to decompose biodegradable organic materials (Gonawala & Jardosh, 2018). By eating them, earthworms can practically decompose every type of organic material. They are allowed to eat their body weight each day. For instance, 0.1-kilogram earthworms can consume 0.1 kilograms of waste every day. The worms' excretions, known as "castings," are nitrate-rich and contain accessible forms of phosphorus, potassium, calcium, and magnesium, all of which increase soil fertility. (Bhat, 2018). The growth of bacteria and actinomycetes is facilitated by the presence of earthworms in the soil.

Sheet Composting: Sheet composting makes use of decomposed organic matter without the use of a composting pile. In this method, organic elements such as leaves, garden debris, grass clippings, weeds, and vegetation are thinly scattered directly into the soil as mulch. Instead of a heap or container, organic wastes are tilled into the ground with a hoe, spade, or garden fork and left to decay. One or more layers of organic material(s) are placed over the growth area, watered thoroughly, and allowed to decompose until planting time. More organic ingredients are added to the lower layers, which degrade completely (Misra et al., 2003). This approach is simple and inexpensive.

Static Composting: This is a common composting procedure in which trash is aerobically degraded using passive aeration (small and infrequent turnings or static aerations such as perforated poles or pipes). This process takes time. However, it is a simple way of composting with low operational and capital costs as compared to vermicomposting, windrow composting, vessel composting, and Indian Bangalore composting. This approach requires merely the creation of a pile of raw materials and requires little effort and equipment. The passive passage of air through the pile, which slowly destroys the organic waste, is the primary source of aeration (Gonawala & Jardosh, 2018).

Berkley Rapid Composting: This approach expedites the composting process, especially when the compost material is between 0.5 and 1.5 inches in size (Ayilara et al., 2020). Because soft, succulent tissues disintegrate quickly, they do not need to be cut into very small pieces. To improve decomposition, the harder the tissues, the smaller they must be sliced. Nothing should be added to a pile once it is started since it takes a certain amount of time for the initial components to break down, and everything added needs to start from the beginning breakdown stage, increasing the decomposition period for the entire pile (Misra et al., 2003).

e. Factors Affecting Composting

Compost stability and maturity are crucial components of the composting process. Environmental elements, including temperature, moisture content, pH, and aeration, should be properly maintained for compost to mature. Elements like the carbon-nitrogen ratio, particle size, and nutrient content are also crucial determinants of compost quality (Ayilara et al., 2020).

Temperature: Based on temperature gradients and the effects of different temperatures on different microorganisms, four major microbiological phases erupted as follows.

- The mesophilic phase
- The thermophilic phase
- The cooling phase
- The maturation phase

The microbial breakdown of organic matter at mesophilic temperatures starts the composting process. Vigorous respiration raises the temperature in the pile to a level that mesophiles cannot survive in, but thermophiles can (Lin et al., 2018). The diversity of species is also thought to be declining as a result of this shift. Spore formers (Bacillus spp.) are the predominant bacteria in the thermophilic phase, but thermophilic fungi have also been discovered (Lin et al., 2018).

In general, one of the most crucial factors in the composting process is temperature. The temperature should be higher than 55 °C for at least two weeks during the composting process to improve the elimination of non-spore-producing pathogens, such as Salmonella and E. coli (Han et al., 2014). The oxidation of organic particles during composting raises the temperature. The pace of metabolic activity, the degree of oxidation, and the rate of heat transmission from the composting material all affect how much the temperature rises.

Oxygen (aeration): The primary process of composting is the biological oxidation of recently created organic waste materials by microbial metabolism into a stable organic residue. The majority of organisms that degrade organic matter are aerobic, which means they require oxygen to exist. Heat, microbial biomass, carbon dioxide, and water are all created throughout the process. Because aerobic decomposition is the recommended method for composting (Diaz et al., 2002), oxygen availability in the compost heap is critical. Some functions of aeration in composting are the following.

- Aeration supports aerobic metabolism.
- It controls temperature.
- It removes moisture as well as carbon dioxide and other gases.

According to Nduka and Nwankwoala (2018), insufficient aeration encourages the growth of anaerobic zones and the production of unpleasant odors. However, excessive aeration suppresses microbial activity due to reduced moisture and accompanying cooling. It is recommended that the oxygen concentration of the circulating air in windrows not drop 18% below. However, there aren't many experimental studies to back up this recommendation (Nduka & Nwankwoala, 2018). Forced aeration, physical rotating of the mass, and natural convection are the three primary aeration methods that deliver oxygen during composting. However, depending on the initial composting material utilized, the ideal rotation frequency may vary.

Moisture Content: The composting pile's moisture content is a significant environmental variable because it serves as a conduit for transporting dissolved nutrients necessary for microorganisms' physiological and metabolic processes (Kumar et al., 2010). Very low moisture content levels would result in early dryness during composting, which would halt the biological process and produce composts that were physically stable but biologically unstable (Han et al., 2014). On the other side, excessive moisture may result in water buildup that will cause anaerobic conditions and stop the composting process. The majority of materials may be composted most efficiently when their moisture content is between 50% and 70%; however, some materials can be composted more successfully when their moisture content is between 25% and 80% on a wet basis (Han et al., 2014). The moisture content of compost is impacted differently by the porosity of the reactor feed, open-air area, aeration, temperature, and other pertinent physical factors. In this instance, moisture refers to the weight loss that occurs after the sample has been dried to a constant weight at 105 °C for 24 hours. Bacterial metabolic activity is dramatically decreased when the moisture content drops below 40%. Since oxygen maintenance is not a problem when anaerobic composting is used, the maximum moisture content is less significant. Even though the composting process first generates high temperatures lasting a few days for the eradication of harmful organisms, the ideal moisture content for maximum oxygen consumption rates has been characterized as being between 50 and 70%, depending on the nature of the composting materials (Diaz et al., 2002).

pH: For the majority of biological processes in composting, a pH range between 5.5 and 8.0 standard pH Units is ideal (Kikuchi, 2004). While fungi prefer an acidic pH range, bacteria function best at a pH that is close to neutral. Ammonia gas may be produced at high pH levels, which can have negative effects on odor, microbial population growth, and compost product quality. Extreme pH has a direct impact on microbial activity and, more specifically, microbial enzymes, which in turn has an impact on the composting process. The development of the humus boosts the pH-buffering capacity.

Carbon-Nitrogen Ratio (C/N): The presence of carbon and nitrogen impacts how organic matter decomposes. The carbon-nitrogen ratio shows how much of each element is present in another (Kumar et al., 2010). Carbon-nitrogen ratios between 25 and 30 are ideal for the microbial degradation of organic material in composting processes. In other words, there should be 25 to 30 parts carbon to 1 part nitrogen in the materials piled up. This range of the carbon-nitrogen ratio is often in line with what has been found for agricultural soils. Raw sawdust has a carbon-nitrogen ratio of 511, while night soil has a carbon-nitrogen ratio of 6 to 10 (6-10). When the C/N ratio is low, as it is in night soil, the microbiological breakdown produces excess ammonia, which elevates the pH and promotes ammonia volatilization. If the carbon-nitrogen ratio is too high, the process becomes nitrogen limited. A pile with too much carbon will decay too slowly, whereas a pile with too much nitrogen may emit an odor. Carbon combines with nitrogen to form cell protoplasm, which provides energy to bacteria. As a result, carbon is more important than nitrogen. Nitrogen deficit can also cause substantial organic acid production from carbonaceous waste, which lowers pH and slows microbial activity while also limiting growth and biomass. During the composting process, the C/N ratio fluctuates due to the loss of carbon as carbon dioxide during microbial respiration.

Particle Size Decomposition: Several bulking ingredients have been utilized during the composting process. Fibrous carbonaceous materials with low moisture content are often used as bulking materials (Miner et al., 2001). These components, which are often dry, aid in keeping compost aerated. There are many different kinds of bulking materials, such as sawdust, wood shavings, rice husk, coconut fruit fiber, maize cob, dried grass, hay, or straw, organic solid waste, and many more. Bulking materials typically utilized in composting operations include sawdust, straw, peat, rice hulls, cotton gin trash, manure, discard fractions, yard wastes, wood chips, and a range of other wastes. Similarly, materials that can be composted include fecal (sewage) sludge, industrial wastes (such as food, pulp, and paper), yard and garden wastes, municipal solid wastes (up to 70% organic matter by weight), soft pruning, clippings, and leaves, kitchen waste like fruit peelings, egg shells, and paper that has been shredded, mixed with grass cuttings, and used sparingly. Fecal sludge can be raised in pH by adding inorganic elements like lime or ash to aid composting. Bulking materials' relatively smaller particles have more surface area for soil organisms to work on. Generally, raw materials will turn into compost more quickly, the smaller the particle size.

3. Research questions

The study seeks to find answers to the following questions.

1) How important is solid waste management in schools?
2) What are the effective pedagogical practices for teaching composting in schools to ensure environmental sustainability?
3) What are the challenges involved in the composting process in schools?

METHODOLOGY

The researchers adopted the synthesis and integration approach to conduct this study. This is a dynamic approach that involves synthesizing and integrating ideas from diverse sources in order to construct a cohesive and extensive argument. The synthesis and integration approach was essential for connecting relevant ideas and concepts to form a comprehensive understanding of the subject matter (Creswell, 2014). The researchers identified connections between the various themes that emerged across the literature. To apply this approach, the researchers gathered information from various sources such as; academic journals, conference proceedings, reports, and relevant online resources like Eric and Google Scholar by using the keywords as follows; solid-waste, management, composting, school environment, pedagogical practices, and sanitation.

The search aligned with the eight steps of the synthesis and integration approach outlined in Creswell 2014. In step 1; research questions were formulated to guide the synthesis and integration approach, In step 2; a decision was taken on the framework for synthesizing and integrating the research findings. This involved identifying key themes, concepts, or categories that would help organize the data, step 3; a comprehensive search, was done to locate relevant studies and literature that addressed the research question. This involved using appropriate databases, as mentioned above, and the library, step 4; the quality and relevance of the identified studies were assessed, and further selection studies that met the inclusion criteria and provided valuable insights into the research problem, step 5; to extract relevant data from the selected studies, a data extraction form was used to capture key information, step 6; the researchers further looked for similarities, differences, and relationships among the findings to develop a comprehensive synthesis, step 7; the findings from different studies were integrated to create a coherent and comprehensive understanding of the research problem, step 8; the synthesis findings were presented in a clear and organized manner.

FINDING AND DISCUSSION

1. Need for solid waste management in school

Solid waste management is a critical aspect of environmental protection and public health. It was found that the management of solid waste in schools is particularly important because schools generate a large amount of waste, and the waste could pose a negative environmental effect. Sahu and Khatua (2021) agreed that schools generate significant amounts of waste, including food waste, paper, plastics, and other materials. Improper management of this waste can have detrimental effects on the environment and human health. Furthermore, solid waste can attract pests and rodents, leading to unhygienic conditions in the school environment. Therefore, proper management of solid waste in schools is essential to ensure a healthy and safe learning environment. Moreover, solid waste management in schools can also promote environmental awareness and education among students. According to Guneysu and Emgin (2021), effective solid waste management practices in schools can lead to a more sustainable future by reducing waste and promoting recycling and composting. Additionally, teaching students about waste management can instill in them an understanding of the importance of environmental conservation. Several studies have highlighted the benefits of implementing solid waste management programs in schools. For instance, in their study, Mehta et al. (2020) found that implementing a waste management program in schools not only reduced waste generation but also led to a decrease in greenhouse gas emissions. Similarly, Gupta et al. (2021) found that implementing a solid waste management program in schools led to a significant reduction in waste generation and improved the overall cleanliness of the school environment.

Kumar and Samadder (2019) argued that low-income countries must implement sustainable and innovative solid waste management practices, such as community-based waste management and public-private partnerships, to achieve sustainable development. In support of this, Purnomo and Sasongko (2020) found that waste-to-energy conversion can significantly reduce the volume of waste and generate renewable energy. However, the technology must be integrated with other waste management practices to achieve sustainable waste management. Chiemchaisri et al. (2021) suggest that the Indonesian government needs to strengthen its policy implementation and engage with stakeholders to achieve sustainable waste management. A similar finding was arrived at by Wambu and Oyaro (2020) in China, highlighting the need to adopt a circular economy approach to solid waste management to minimize waste generation and promote resource recovery.

2. Pedagogical practices of teaching composting in school

Based on the theoretical framework and the existing literature presented above, pedagogical practices for teaching composting in school could emerge to facilitate the teaching and learning of composting. One such approach was Project-based learning (PBL). The PBL was investigated by Shah and Qureshi (2021) as a method of teaching composting to high school learners in India. The researchers discovered that this strategy was successful in fostering students' interest in environmental issues as well as their knowledge and understanding of composting. Bhowmik et al. (2020) added that learners in the PBL group had considerably higher levels of knowledge, positive attitudes, and real composting habits compared to the pupils receiving standard training. Ma et al.'s (2019) supported that the PBL group had significantly higher levels of composting understanding and more optimistic environmental attitudes compared to the control group. According to Khairuddin et al. (2020), the PBL group had much greater levels of critical thinking and problem-solving skills than the group receiving traditional education. Therefore, PBL could be adapted to teaching learners in school.

Hands-on learning is another pedagogical strategy that could be extracted for teaching composting in schools. In Australia, Williams, Raine, and Knox (2017) taught composting to elementary school children using a practical method. The researchers discovered that this strategy was successful in boosting composting understanding and in fostering favorable attitudes toward the environment. According to Bennett & Hogarth (2009), many students find that learning by doing is more effective since it enables them to put their theoretical understanding into practice. Another study supports the idea that practical teaching methods might encourage pupils to have a sense of accountability and ownership. Students are more likely to take an active interest in the environment and the effects of their behaviors on it if they are participating in the composting process (Lynch & Cortese, 2010). Reddy and Ghosh (2018) establish that hands-on activities give students a chance to think critically and hone their problem-solving abilities in this context. A hands-on approach, however, might not be practical for many students or settings. For instance, urban students might not have access to outside space for composting, or students with disabilities can find the physical demands of composting challenging (Kirschner et al., 2006).

Furthermore, Inquiry-based learning emerged as a pedagogical approach to teaching composting. Middle school students in the United States participated in inquiry-based learning activities connected to composting as part of a study by Adedokun and Parker (2018). The researchers discovered that this strategy was successful in raising composting understanding and in boosting students' interest in environmental education. According to Gerber et al. (2019), IBL was used to instruct middle school pupils on composting, and found that the participants expressed a higher sense of ownership and engagement in the learning process. Brevik et al. (2014) concurred that the IBL method proved successful in transforming students' perspectives on composting and their capacity to apply composting principles to practical situations. Ahmed et al. (2018) concluded that the IBL technique was successful in enhancing students' comprehension of composting and their capacity to apply composting concepts in daily life. They utilized IBL to teach composting to primary school pupils.

3. Challenges involved in composting

The benefits of composting have been widely studied, and research consistently shows that composting can help to reduce waste, improve soil health, and support sustainable agriculture practices. One study published in the Journal of Environmental Management found that composting can help to divert significant amounts of waste from landfills, thereby reducing greenhouse gas emissions and conserving natural resources (Bernal-Barragánet al., 2019). Another study published in the journal Agronomy demonstrated that compost can improve soil fertility and increase crop yields, making it a valuable tool for sustainable agriculture (Goyal & Dhull, 2017). Other research has focused on the environmental benefits of composting, such as its ability to reduce water pollution and support biodiversity (Tambone et al., 2010). For example, a study published in the Journal of Applied Ecology found that composting can increase the diversity and abundance of soil organisms, which in turn can help to support healthy ecosystems (Macdonald & Farrel, 2019). It can be learned that Composting process is an environmentally friendly and cost-effective way to manage organic waste, and it can also reduce the amount of waste that goes to landfills. However, there are several challenges involved in composting that can make the process difficult. One of the challenges was the difficulty in maintaining the right balance of carbon and nitrogen in the compost pile (United et al. Agency, 2021). Carbon-rich materials, such as leaves and wood chips, are necessary to structure the pile. In contrast, nitrogen-rich materials, such as food waste and grass clippings, are necessary for providing the microorganisms that break down the materials. If the balance is off, the compost may take longer to break down or produce an unpleasant odor.

Another challenge is managing the moisture content of the compost pile (Macdonald & Farrell, 2019). Compost must be moist but not too wet, as excess moisture can lead to anaerobic conditions that produce a foul odor. On the other hand, if the compost is too dry, it will not break down as quickly. Temperature control is also important in composting. The pile needs to reach a certain temperature in order for the microorganisms to break down the materials effectively. However, if the temperature gets too high, it can kill beneficial microorganisms and slow down the composting process. According to Composting Council Research and Education Foundation. (n.d.), Composting can attract pests, such as rodents and flies, which can be a nuisance and a health hazard. Proper management of the compost pile, including regular turning and covering, can help deter pests.

One of the challenges in implementing a successful composting program in school is educating students and staff about the composting process and how to properly manage the compost (United et al. Agency, 2018). This includes teaching them about what can and cannot be composted, how to maintain the right balance of nitrogen and carbon, and how to properly turn and aerate the compost pile. Another challenge is finding a suitable location for the composting program (NYC et al., 2016). The composting area should be easily accessible yet far enough away from buildings and high-traffic areas to avoid unpleasant odors and attract pests. Maintaining a consistent supply of organic waste can also be a challenge, especially during school breaks and holidays when there are fewer people on campus (Stop Waste, 2014). However, this can be addressed by encouraging students and staff to bring in their own food scraps and yard waste from home, as well as partnering with local businesses or community gardens to receive organic waste. Finally, managing the composting program requires ongoing maintenance and monitoring. This includes regularly turning and aerating the compost, monitoring the moisture levels, and addressing any issues with pests or odors.

CONCLUSION

This study introduces an innovative approach to address solid waste management in school environments through the practice of composting. Built upon the principles of Reduce, Reuse, and Recycle (3R), the researchers developed a concept that not only improves sanitation but also fosters environmental consciousness among students. By delving into the depths of composting, students can gain profound knowledge and understanding, which in turn contributes to the reduction of solid waste in educational settings. This composting initiative offers a win-win solution, effectively tackling waste management challenges while simultaneously instilling a sense of environmental responsibility.

Schools adopting composting practices become exemplars of sustainability, serving as role models for the wider community. Their efforts not only manage solid waste effectively but also contribute to building a greener, more environmentally conscious future. This composting approach enables future leaders, the learners themselves, to comprehend the vast scope and impact of human activities on the environment. By empowering students to champion waste reduction and recycling, they become active participants in the fight against improper waste disposal.

Implementing a composting approach for solid waste management in schools proves to be highly effective and sustainable, offering a multitude of benefits. The advantages extend beyond the school community and encompass the environment as a whole. However, the successful implementation of such a program necessitates careful planning and ongoing maintenance. Adequate infrastructure, including compost bins and designated collection areas, must be provided, accompanied by clear guidelines for waste segregation. Furthermore, regular monitoring and comprehensive training for staff and students are crucial to ensure the program's long-term success and sustainability.

Recommendations from the results of this study are as follows.

1) Waste bins should be provided in schools with different labels to help collect and separate waste material according to its respective forms like; plastic, glass, paper, liquid, and metal. For the sake of the metal, screening magnets can be used to automatically separate the mixed material.
2) Schools should be provided with the necessary machines and equipment to facilitate composting process. For example, machines and equipment such as

pellet mills and silos are required in schools for grinding, sieving, and de-stoning during composting.

3) Sensitization programs should be organized periodically in schools to educate staff and learners about waste management. In such programs, learners will be educated about sanitation and how to maintain it for healthy living.
4) When developing a school curriculum, solid waste management should be incorporated, and be given a practical lesson. In this way, both the teachers and the learners will handle it with extra energy to achieve the intended goal.
5) There is a need for management to build a strong school-community relationship for the exchange of resources. Most of the communities have resources, either human or material, needed for composting in schools. By establishing such a healthy relationship with the communities, their support could be sought.
6) School management should encourage the use of composted material for gardening and other school projects, which can serve as a hands-on learning opportunity for students.

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