STI Focus

SCIENCE, TECHNOLOGY AND INNOVATION

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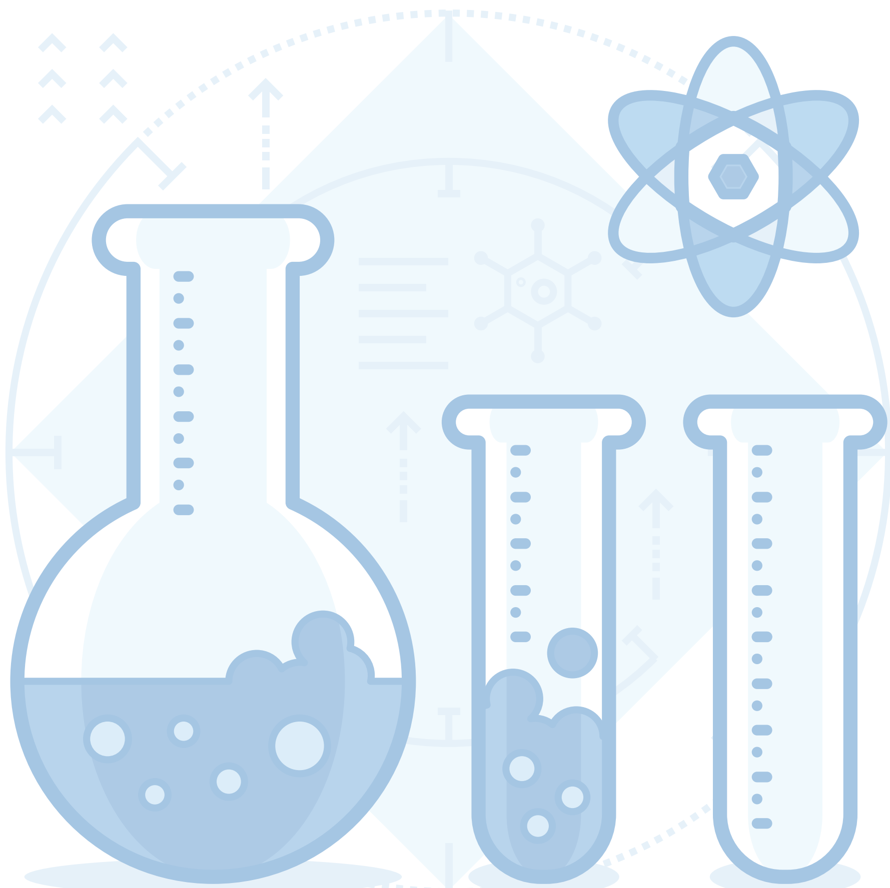

Ministry of Industry, Science, Technology & Innovation

National Institute of Science, Technology and Innovation

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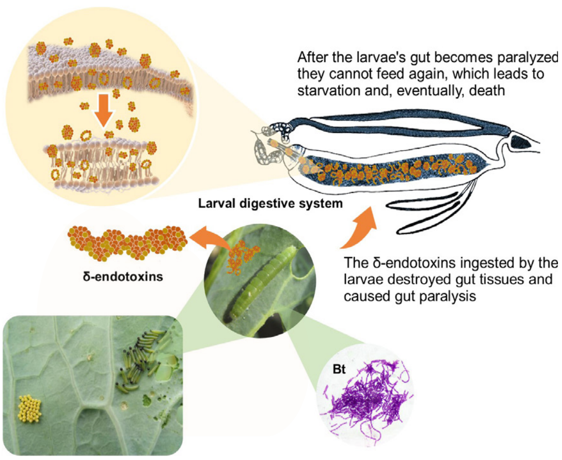

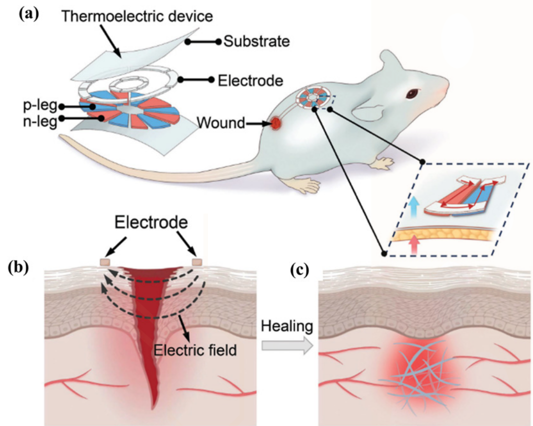

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MANAGED BY

Department of Science, Technology and Innovation Promotion and Development
National Institute of Science, Technology and Innovation (NISTI)
Ministry of Industry, Science, Technology & Innovation (MISTI)

ADDRESS OF NISTI

National Road No2, Sangkat Chak AngRe Leu, Khan Mean Chey, Phnom Penh, Cambodia

FOREWORD

Providing technological solutions to support SMEs and connecting the public to the advancement of Science, Technology, and Innovation (STI) for the growth of the economy and national prosperity are the missions of the National Institute of Science, Technology, and Innovation (NISTI). As STI is important to society and appears to have limited public access, establishing scientists' communication channels such as STI Focus publication for sharing, disseminating, and publishing the findings is necessary. The most recent issue of STI Focus, which encompasses a section on new scientific findings and technical trends, and provides insight into recent trends in scientific research and the advancement of technology related to life science, environment, health, and electronic and robotic automation, is greatly welcomed. The manuscripts have been written by Cambodians who hold degrees from respectable foreign universities as well as from within the country.

My congratulations go to all of the authors who contributed their best expertise to publish their manuscripts on this issue of STI Focus, which I read with great enthusiasm and thought to be very beneficial. These manuscripts undoubtedly increase public knowledge of science and its potential for bettering our everyday lives. I would like also to take this opportunity to express my sincere thanks to NISTI and all individual members involved in initiating and creating this STI Focus publication. I sincerely hope that the STI Focus could engage more scientists and could help boost the promotion of STI as well as STEM education and careers in Cambodia.

Phnom Penh, 27 December 2024

Minister

HEM Vanndy

EDITORIAL NOTE

The latest edition of STI Focus wraps up 2024 with a steadfast commitment to advancing Science, Technology, and Innovation (STI) through impactful research and insightful thought leadership. This issue is organized into two central sections: Scientific Findings, and Technology Trends, each offering an in-depth perspective on current innovations and future opportunities. In Scientific Findings, we delve into research on Utilizing the Entomopathogenic Bacterium *Bacillus thuringiensis (Bt)* as a Microbial Biopesticide, Overview of Antimicrobial Resistance and Use in Cambodia, Exploring Demographic and Behavioral Factors Influencing Knowledge and Participation in Health Check-Ups Among University Students, and Leveraging AI-integrated IoT Solutions for Efficient Public Waste Management in Cambodia.

The Technology Trends section features pioneering research on the Using Phytoremediation to Remove Indoor Air Pollution: A Sustainable Approach for Green Environment, Health, and Well-Being, Development of Human Tissue/ Organ from Your Home Meal, Thermoelectric Device for Waste Heat Recovery, Electronics Thermal Management, and Bioelectronics Applications, Exploring Advancements in Robotic Automation and Their Impact on Manufacturing Processes, Alternative Substrates for Sustainable Oyster Mushroom Production in Cambodia, and Reimagining Domestic Life: The Potential of IoT in Cambodia's Connected Homes. Each article in this issue has undergone rigorous peer review to maintain high standards of scholarly excellence. We extend our heartfelt appreciation to the authors, reviewers, and officers at the National Institute of Science, Technology and Innovation (NISTI) for their unwavering commitment to advancing STI.

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SCIENTIFIC FINDINGS

Utilizing the Entomopathogenic Bacterium *Bacillus thuringiensis* (*Bt*) as a Microbial Biopesticide

Chem Chanchao
Master's Degree, Biochemical Technology
King Mongkut's University of Technology Thonburi
Thailand

Ourn Eneang
Master's Degree
Agro-Industrial Engineering
Institute Technology of Cambodia, Cambodia

Highlight

- Leaf-spraying and leaf-dipping methods are used to assess the effectiveness of *Bacillus thuringiensis* (*Bt*).
- Bt produces Cry and Cyt proteins that target insect pests, providing a practical and eco-friendly alternative to chemical pesticides.
- It is utilized in agriculture to manage pests such as Lepidoptera and Coleoptera, thus protecting crops.
- Bt's specificity minimizes its impact on non-target organisms, making it a sustainable option in integrated pest management (IPM).

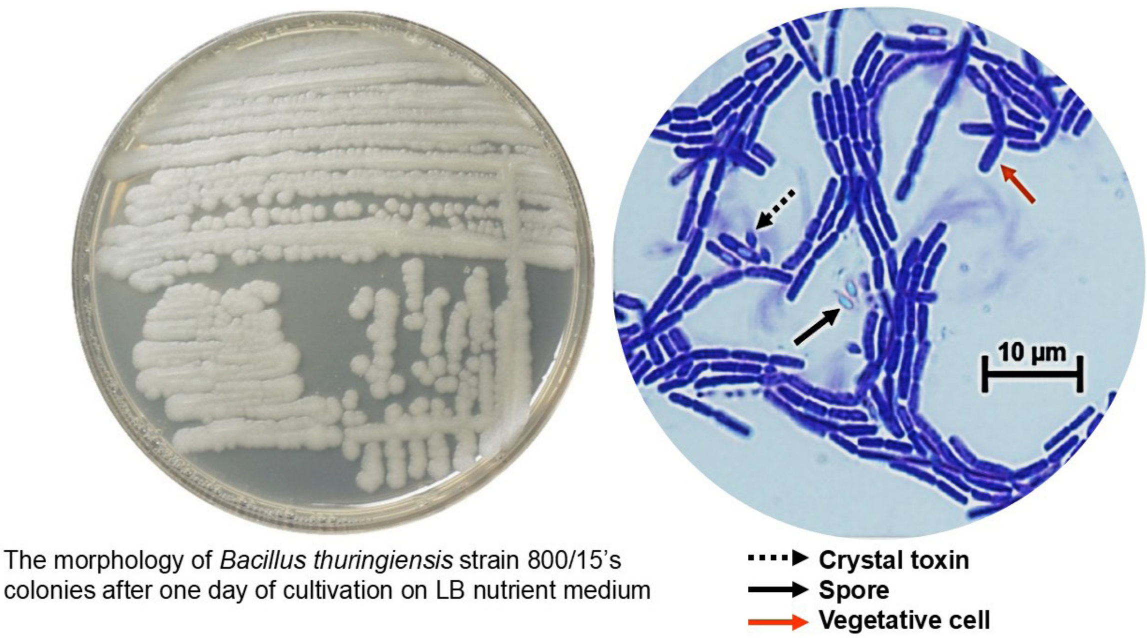

Figure 1. *Bacillus thuringiensis (Bt)* is a Gram-positive, spore-forming bacterium that produces parasporal crystalline inclusions containing Cry and Cyt proteins (Shikov et al., 2024).

I. Introduction

Biopesticides based on the entomopathogenic bacteria *Bacillus thuringiensis* (*Bt*) are used worldwide on broad extensions of different crops and vegetables, mainly against lepidopteran and coleopteran pests (do Nascimento et al., 2022). *Bt* is a gram-positive, spore-forming bacteria known for its ability to produce crystal proteins that are toxic to many insects (**Figure 1**) (Shikov et al., 2024; Kumar et al., 2021). It is a highly successful microbial insecticide used in agriculture to control various insect pests. It contains insecticidal proteins that make it an effective and environmentally friendly biopesticide. It was first commercialized in France in the late 1930s and has been applied to crops for over 40 years as an insecticidal spray, which is a mixture of spores and the associated protein crystals (Kumar et al., 2021; Nester et al., 2002).

The first commercial *Bt* biopesticide was developed almost 100 years ago, marking a long history of safe and effective use. This history is backed by numerous scientific studies and field trials that have consistently demonstrated the safety and efficacy of *Bt* biopesticides. It is considered safe for humans and animals (Ibrahim et al., 2010). These insect pathogens rely on insecticidal pore-forming protein toxins to kill insect larval hosts (Bravo et al., 2011). *Bt* produces two types of toxins: crystal proteins (Cry) and cytolytic proteins (Cyt), also known as δ-endotoxins. Cry proteins are large and crystalline proteins that typically form parasporal crystals during sporulation. Cyt proteins are smaller, hemolytic toxins that also form crystalline inclusions, although their structure differs from Cry proteins.

Cry proteins are known for their ability to form pores in cell membranes. They are produced as parasporal crystalline inclusions, which get activated by the proteolytic action inside the insect's gut after ingestion (Kumar et al., 2021). When the insect larvae ingest the proteinaceous crystal, the digestive enzymes present in the gut activate the toxin, resulting in pore formation in the cell membrane of the gut, followed by paralysis of the gut and eventually causing the death of the larvae (Vachon et al., 2012). Cry proteins target a diverse range of insect species, primarily of the order Lepidoptera (butterflies and moths), Coleoptera (beetles and weevils), and Diptera (flies and mosquitoes) (Domínguez-Arrizabalaga et al., 2020). Besides the δ-endotoxins, *Bt* also synthesizes Vegetative Insecticidal Protein (Vip) and Secreted Insecticidal Protein (Sip), which are biodegradable and affect specific targets, especially species of Coleoptera and Lepidoptera (Chakroun et al., 2016).

However, it is essential to note that *Bt* biopesticides are not without their challenges. For instance, the development of resistance in target pests and the potential impact on non-target organisms are areas of concern. Nevertheless, when used as part of an integrated pest management (IPM) strategy, *Bt* biopesticides play a crucial role in sustainable agriculture. The previous study reported that it would take approximately more than ten years to develop novel chemical pesticides that could be suitable for pest control, with an investment of over 280 million USD. In contrast, only 3-7 million USD for *Bt* biopesticides is needed less than four years to get to a commercial launch (Marrone, 2019).

Since using chemical pesticides results in the development of resistance by insects and is harmful to both humans and the environment, *Bt* served as the best alternative to overcome the above issue. Biopesticides based on the insecticidal toxins produced by *Bt* are essential for IPM practices (Ortiz & Sansinenea, 2022). The use of *Bt* as a biopesticide is as efficient as chemical pesticides; hence, it forms part of the IPM strategy that prefers non-chemical pesticides for pest control. Therefore, this article aimed to isolate the entomopathogenic bacterium *Bacillus thuringiensis* (*Bt*) as a microbial biopesticide against cabbageworm larvae (*Pieris rapae*), which are highly destructive pests in subtropical and tropical regions.

II. Materials and Methods

2.1 Isolation, Identification, and Characterization of *Bt*

Soil samples were incubated at 75 °C for 20 min to eliminate the non-spore-forming cells. Afterwards, soil samples were suspended in saline 0.85% solution (1 g soil in 9 mL saline solution) and shaken at 250 rpm for 1 hour. Suspended soil samples were subjected to aseptic dilution individually using the serial dilution method. Approximately 200 µL of each soil suspension spread on the surface of nutrient agar (NA) medium (per litre: 1.0 g beef extract, 5.0 g peptone, 2.0 g yeast extract, and 5.0 g NaCl [pH 7.0] and incubation time was 24 h at 30 °C. Bacterial colonies exhibiting Bt-like phenotype flat, matte white color, dry, and uneven borders were picked up carefully and subcultured on nutrient agar medium for single-colony isolation.

The selected colonies were grown on T3 agar medium (per litre: 3.0 g tryptone, 2.0 g tryptose, 1.5 g yeast extract, 0.05 M sodium phosphate [pH 7.0], and 0.005 g MnCl and incubated at 30 °C for 72 hours. 1 mL of each incubated broth suspension was centrifuged (4500 rpm) for 10 min. The supernatant was discarded, and the pellet was suspended in 1 ml of sterile normal saline. A suspended bacterial suspension loop was used to form bacterial film and heat fixing. The film was subjected to spore stain procedures and then examined by an oil immersion lens of the light microscope.

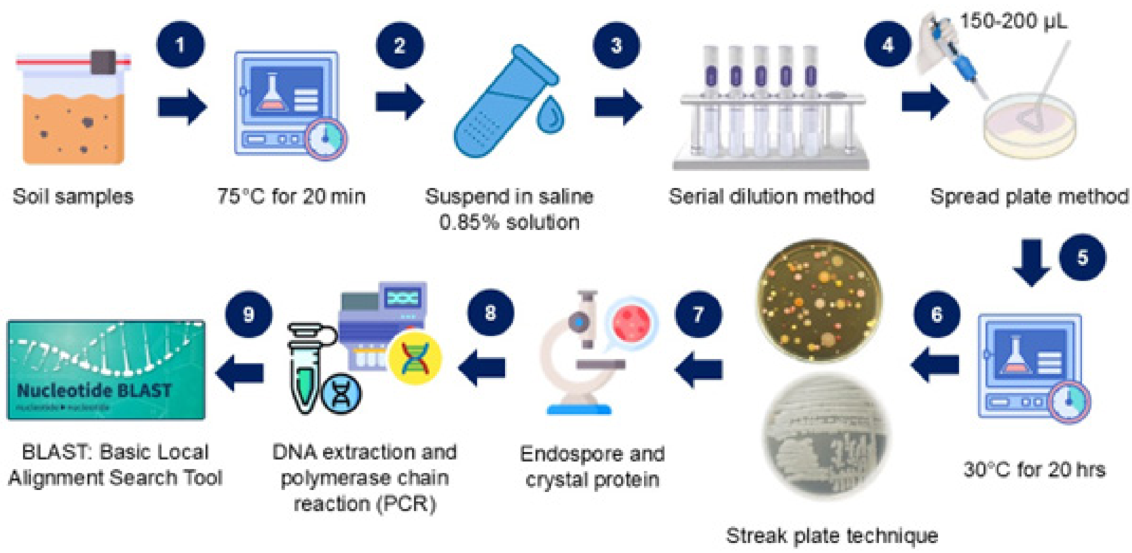

Figure 2. The process involves isolating, identifying, and characterizing *Bt* strains.

The genomic DNA of the pure isolates was extracted using the GenElute Bacterial Genomic Miniprep Kit (Sigma-Aldrich, USA) according to the manufacturer's instructions. The 16S rRNA genes were amplified by PCR (Bio-Red, T100 Thermal Cycler) using the universal bacteria-specific primers forward primer 8F 5′AGTTGATCCTGGCTCAG3′ and reverse primer 1492R5′TACCTTGTTACGACTT3′. The PCR procedure was performed with standard conditions according to the manufacturer's instructions. The PCR amplification steps were carried out as follows: a single cycle runs at 94 °C for 5 min, then 30 cycles composed of denaturation at 94 °C for 1 min, a single step of annealing at 55 °C for 1 min, next single step of synthesis at 72 °C for 2 min, followed by one step of extension at 72 °C for 7 min, and a final 4 °C infinitive. The 16S rRNA sequences of the selected Bt isolates are then meticulously analyzed using the Basic Local Alignment Search Tool (BLASTn). **Figure 2** illustrates the isolation, identification, and characterization of Bt strains (El-Ghiet et al., 2023; Hassan et al., 2021).

2.2 Insecticide larvae bioassay

Two different methods, leaf-spraying and leaf-dipping (Shotaro et al., 2014), were used to test the effect of Bt bacterial suspension (10^7 CFUs/mL) on one-week-old cabbageworm larvae (*P. rapae*). Cabbageworm larvae are highly destructive pests in subtropical and tropical regions, feeding on cabbages and other cole crops such as broccoli, cauliflower, Brussels sprouts, collards, kale, mustard greens, turnip greens, radishes, turnips, rutabagas, and kohlrabi. In the leaf-spraying method, 1 ml of the Bt suspension was sprayed on fresh, clean Napa cabbage (*Brassica rapa subsp. pekinensis)* leaves, and ten *P. rapae* larvae were immediately introduced on Napa cabbage leaves. In the leaf-dipping method, fresh, clean Napa cabbage leaves were dipped for 30 seconds in the Bt suspension and then fed to ten *P. rapae* larvae. The experiments were conducted at room temperature, and the mortality rates were observed at 0, 6, 12, 24, and 48 hours. Distilled water instead of Bt bacterial suspension was used as a control. The experiments were performed in triplicate (N=3).

III. Results and Discussion

3.1 Insecticidal Activity of Bt and Mode of Action

In this article, we conducted a study to assess the insecticidal activity of the Bt strain on cabbageworm larvae, which are highly destructive pests. The study involved two methods to evaluate the effectiveness of Bt at 0, 6, 12, 24, and 48 hours, respectively. Insecticide larvae bioassays were carried out using leaf-spraying and leaf-dipping techniques to determine the impact of Bt on larvae by observing mortality rates,

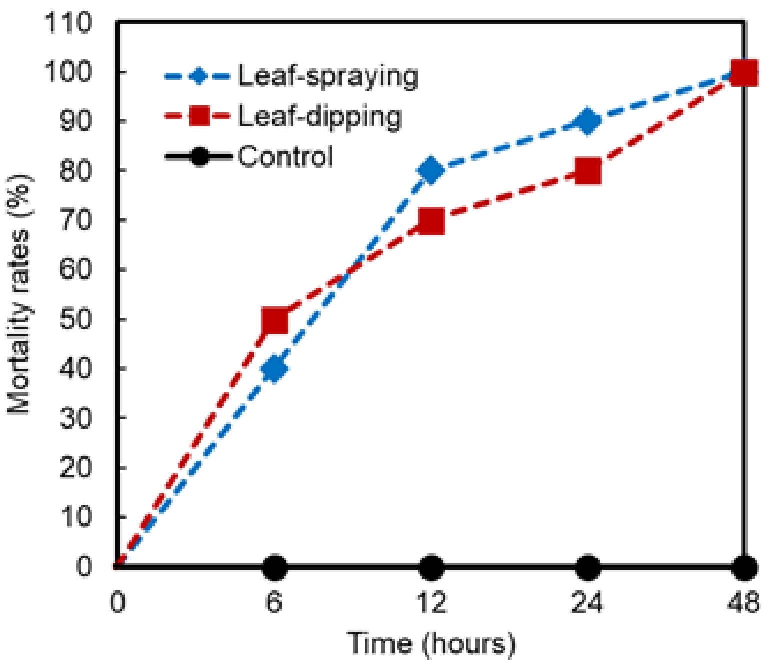

Figure 3. The mortality of cabbageworm larvae using leaf-spraying and leaf-dipping

larval development, and any sub-lethal effects after exposure to Bt.

The results of our study reaffirm the effectiveness of both leaf-spraying and leaf-dipping in assessing Bt's insecticidal activity. The mortality of cabbageworm larvae began within 6 hours of exposure to Bt, reaching 80% to 100% at 24 to 48 hours, respectively (**Figure 3**). From a practical standpoint, leaf spraying necessitates specialized equipment and may be more time-consuming due to the need for setting. In contrast, leaf-dipping is more straightforward and quicker, requiring less equipment but potentially leading to unrealistic Bt amounts on the leaf surface. Regarding field conditions, leaf-spraying better simulates the application of Bt in agricultural settings, while leaf-dipping may not accurately replicate actual field conditions.

The decision between leaf-spraying and leaf-dipping is not arbitrary but rather depends on the specific objectives of the bioassay. Leaf-spraying is the preferred method for studies that aim to mimic field conditions, while leaf-dipping is useful when consistent Bt exposure is required. Therefore, leaf spraying is an effective method for pest control and is commonly used by farmers to protect their crops from insects. Both methods are valuable and should be guided by research goals and the nature of the Bt strain being used.

The use of Bt formulations in the form of sprays or liquid suspensions has been a significant development, reported on a commercial scale (Kumar et al., 2021). According to a previous report by Reyaz et al. (2021), Bt was used as an insecticidal spray in the mid-twentieth century, and since then, numerous Bt-based biopesticides have been marketed. Nowadays, Bt is widely reported as the most commonly used biological insecticide microbial agent, aiming to enhance human well-being and agricultural productivity (Poulin et al., 2022).

As described previously, Cry proteins have a precise mode of action and are affected by binding to specific receptors in the gut epithelial cells of susceptible insects. When larvae insects ingest these proteins, the alkaline pH of their gut solubilizes the Cry proteins, which are then activated by proteolytic cleavage. The active toxins bind to receptors on the gut cells, causing pore formation, cell lysis, and, eventually, larvae insect death (**Figure 4**) (Liu et al., 2018). Cry proteins are specific to certain insect orders, such as Lepidoptera (moths and butterflies), Coleoptera (beetles), and Diptera (flies and mosquitoes) (Domínguez-Arrizabalaga et al., 2020). This specificity is due to the need for specific gut receptors in the target insect species. Different Cry proteins can be used to target different pests, making them highly valuable in IPM strategies. Due to their precision, Cry proteins are considered environmentally friendly as they pose minimal risk to non-target organisms, including beneficial insects, mammals, and humans.

On the other hand, Cyt proteins have a more general effect than Cry proteins. They are directly inserted into cell membranes to form pores, causing cell lysis through a cytolytic effect (Soberón et al., 2013). This mode of action is less dependent on specific receptors and is effective against a broader range of cells, including insect and mammalian cells. Thus, Cyt proteins have a broader range of activity, often acting synergistically with Cry proteins to enhance insecticidal activity. They are particularly effective against Dipteran insects but can also affect non-target organisms due to their less specific mode of action. While Cyt proteins are less commonly used in pest control, they are essential in formulations targeting mosquito larvae (Wu et al., 2021). However, due to their broader spectrum of action, the potential impacts on non-target organisms should be carefully considered.

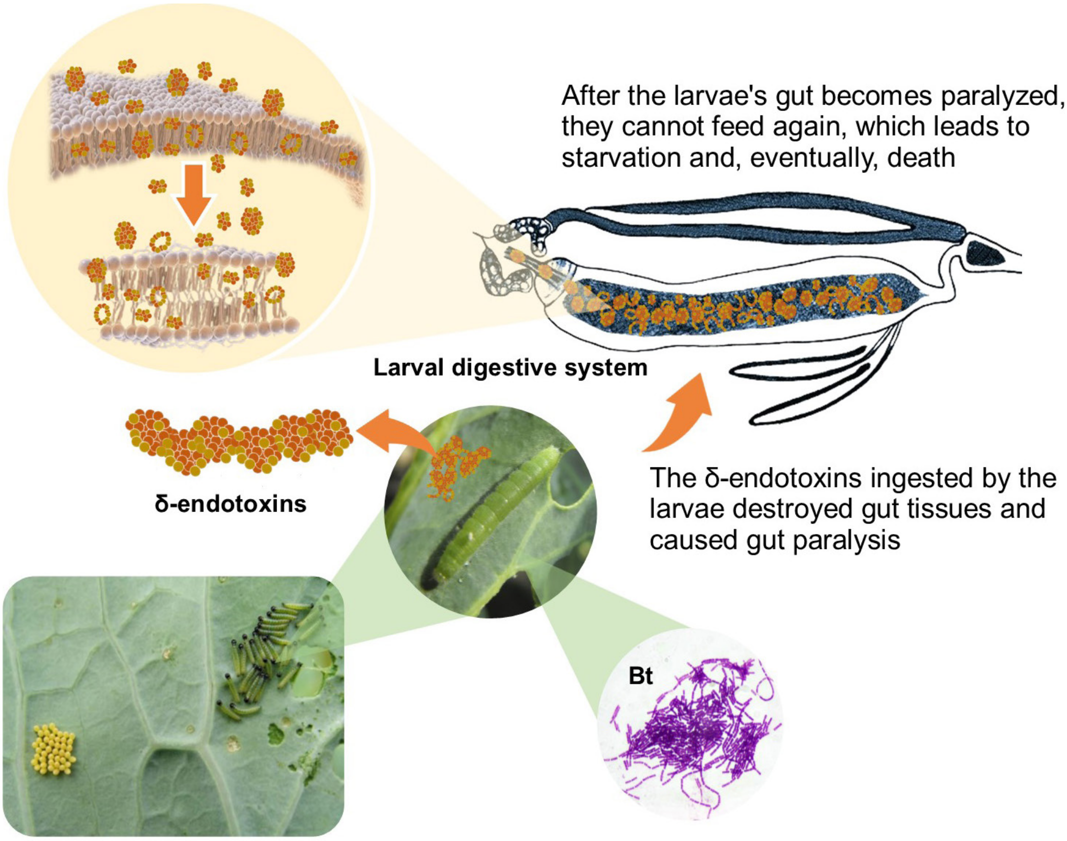

Figure 4. Larvae consume plant material treated with Bt. This treatment contains crystalline proteins known as δ-endotoxins, which are active insecticides. Once inside the larval gut, which is alkaline in nature, the crystalline proteins are solubilized and activated by gut proteases. This process converts the Cry protoxins into active toxins.

Bt's application-based bioinsecticides not only target lepidopteran larvae like cabbageworms, cabbage loopers, hornworms, European corn borers, cutworms, some armyworms, diamondback moths, tent caterpillars, and also Indianmeal moth larvae (Jallouli et al., 2020). In Cambodia, Bt is also one of the applications for farmers to adoption of IPM practices. The use of Bt biopesticides against significant insect pests is listed among 11 practices, including 1) use of a resistant variety; 2) seed treatment with pesticide/biopesticide; 3) use of purchased seeds coated with pesticides; 4) use of seedlings rather than direct sowing; 5) use of finely meshed nets in seedling production to protect seedlings from insects; 6) use of Bt biopesticides against significant insect pests; 7) use of neem extract as oviposition and feeding deterrent against significant insect pests; 8) use of Trichoderma or *Bacillus subtilis* as bio-control agents against plant pathogens; 9) planting barrier crops around the field to limit insect pest incidences in main crop; 10) using colored sticky traps; and 11) removing plant debris from the field as a sanitation practice (Mwambi et al., 2023).

Currently, Cambodia's situation is that although Bt's application was introduced in IPM practices against insect pests, especially lepidopteran caterpillars and flea beetles, farmers are still predominantly relying on the application of chemical pesticides to manage these pests (Ramasamy et al., 2020).

IV. Conclusions and Future Work

Utilizing *Bacillus thuringiensis (Bt)* as a microbial biopesticide offers a sustainable and environmentally friendly approach to pest management. Bt, a well-known bacterium that is pathogenic to insects, has shown significant effectiveness against a wide range of insect pests, particularly larvae, making it an essential tool in integrated pest management (IPM) programs. When conducting bioassays for insecticide larvae, the leaf-spraying and leaf-dipping methods play a crucial role in assessing the efficiency of Bt, providing us with valuable insights into its performance. The specificity of Bt toxins in targeting insect species, along with their minimal impact on non-target organisms and the environment, highlights the potential of Bt as a critical component in reducing reliance on chemical pesticides. However, challenges like developing resistance in targeted insect populations and variability in field performance due to environmental factors require ongoing research and innovation.

Future research should prioritize enhancing the efficiency and stability of Bt formulations under different environmental conditions to improve field performance. This could involve exploring new formulations that increase the persistence of Bt toxins on plant surfaces and in the environment. Advances in genetic engineering also offer opportunities to broaden the spectrum of Bt's activity or enhance its potency against resistant pest populations.

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Sustainable agriculture, a field of increasing global importance, is the focus of Mr. Chem Chanchao's research. His work not only addresses the immediate need for food production but also considers the long-term health of the environment, economic viability, and social equity. His multifaceted approach, which includes concepts that aim to eliminate waste, give new life to discarded items, repurpose materials, and encourage a new generation to consider the environmental impact of consumption decisions, has the potential to significantly impact the needs of current and future generations in a rapidly changing world. He is currently a PhD student awarded by the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT Scholarship) at the Laboratory of Water and Environmental Microbiology in the Department of Environmental Engineering Science at the Graduate School of Science and Technology, Gunma University, Japan.

Be Sokkeang
Master's Degree, Industrial Chemistry
King Mongkut's University of Technology Thonburi
(KMUTT),Thailand

Peung Keanseng
Bachelor's Degree
Science Research, University of Puthisastra,
Cambodia

Highlight

- Antimicrobial Resistance (AMR) in Cambodia poses a significant threat to public health and food safety.
- Many livestock producers misuse antibiotics due to a lack of knowledge, worsening AMR risks.
- The reliance on unlicensed vendors for medications contributes to high AMR levels among the population.

I. Introduction

Antimicrobial resistance (AMR) poses a serious threat to modern medicine and hampers the ability to effectively respond to infectious diseases at risk according to World Health Organization (WHO) (WHO, 2016) As microorganisms develop resistance to medications, treating infections becomes increasingly challenging, leading to higher rates of disease transmission and mortality (WHO, 2023) .According to Food and Agriculture Organization (FAO), in Cambodia, AMR presents significant challenges to improving healthcare quality, safe food production, access to clean and safe water, and a healthy environment (FAO, 2021). Southeast Asia is a very dynamic region with rapid (though unequal) economic growth, and it has been suggested that it is the epicenter of AMR and new infectious illnesses (Zellweger et al., 2017). The impact of AMR poses a severe danger to global health and is anticipated to have a considerable negative impact on both health and the economy, especially in low- and middle-income nations (Gandra et al., 2020).

The spread of AMR can be attributed to several factors, including the overuse and misuse of antibiotics in healthcare and agriculture, and a lack of public awareness regarding proper medication practices (Ahmed., 2024). In 2019, Cambodia reported 13,400 deaths associated with AMR with 3,200 directly linked to it ranking 156th out of 204 countries in term of age-standardized mortality rate related to AMR per 100,000 population (Institute for Health Metrics and Evaluation, n.d.) Controlling antibiotic usage across all stages of food production, including for agricultural production, is essential to reducing the risk of AMR in people (Samtiya et al., 2022). Despite existing literature on AMR, this study aims to fill this gap by providing an overview of both antimicrobial resistance and usage, highlighting the interconnectedness of these issues in the context of Cambodia's healthcare and agricultural sectors.

II. Methods

This review involved a literature search to collect relevant studies on antimicrobial resistance (AMR) and antimicrobial usage in Cambodia, resulting in fifteen papers from databases such as PubMed, Sciencedirect, and Google Scholar. The selection criteria included studies published in the last recent years. The search utilized terms such as “antimicrobial resistance,” “Cambodia,” “antibiotic use,” “hygiene practice,” “antibiotic sale,” and “One Health.” Studies were included in the reported on the prevalence of AMR in Cambodia, factors contributing to its emergence, and initiatives being undertaken to address the issue.

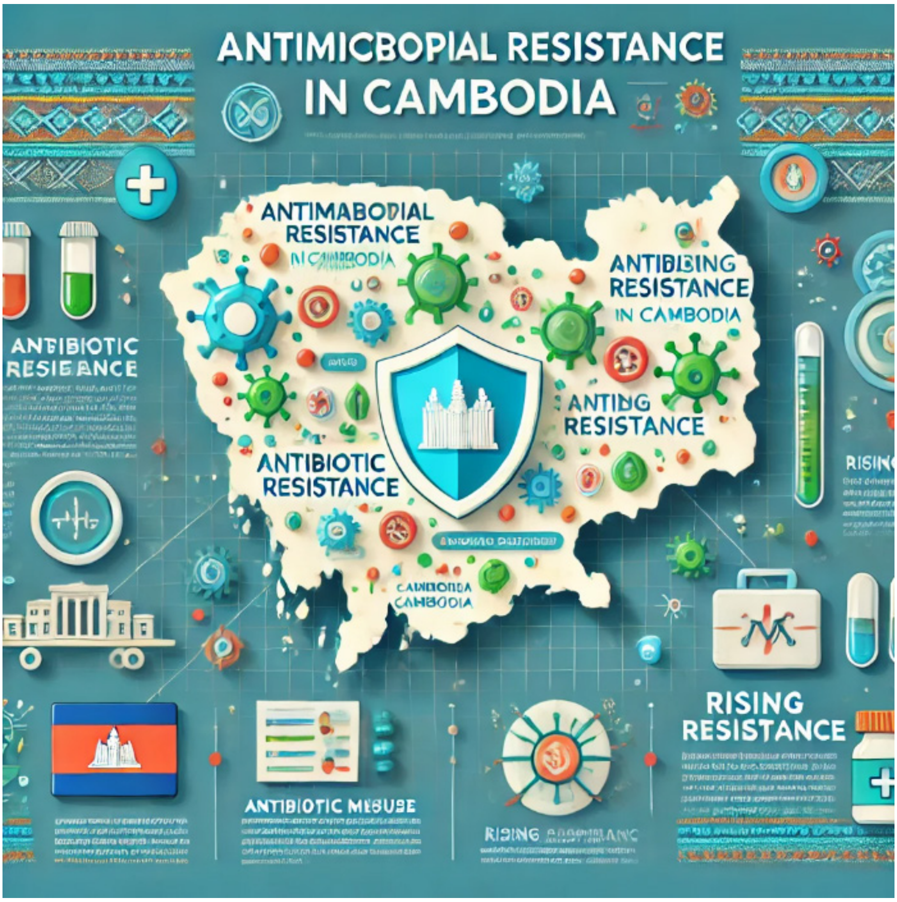

Figure 1. Overview of Anti Microbial Resistance (AMR) in Cambodia

III. Result

3.1 AMR in Cambodia’s Agriculture

Producers had little knowledge of antibiotic drugs and the farmers were mistaken in their understanding that Antibiotic drugs are utilized to relieve inflammation (Chea et al., 2022). A large majority of merchants claimed that AMR indicates that the animal is resistant to antibiotics, and many did not believe that AMR can be transmitted from people to animals (Heyman, 2020). Farmers and veterinarians used antibiotics to enhance animal growth, believing they helped combat diseases like the common cold and diarrhea, which could impact meat production, even though they didn’t explicitly refer to this as “growth promotion” (Om et al. , 2016). A significant proportion of Salmonella and Campylobacter strains obtained from chicken meat vendors in Phnom Penh markets showed resistance to nalidixic acid, amoxicillin, ciprofloxacin, and cephalotin (Lay et al., 2011). In the study, 24 of the 48 isolates (50%), indicating multidrug resistance and raising concerns about antibiotic resistance in the aquaculture system (Peng et al., 2024). The Ministry of Agriculture, Forestry and Fisheries in Cambodia outlines strategies to combat Antimicrobial Resistance (Chea., 2021).

3.2 Cambodian Health Care Habit

There are elevated resistance rates to numerous first-line antibiotics, particularly within the Enterobacteriaceae family (Reed et al., 2019). The study emphasizes a marked rise in the prevalence of extended-spectrum beta-lactamase-producing Enterobacteriaceae which increased from 28.9% in 2012 to 48.2% in 2015 (Caron et al., 2018). The researchers conducted community interviews in seven areas outside of Phnom Penh and discovered that 62% of individuals reported purchasing medicines from unseen vendors (Heyman, 2020). In addition, there is an unknown but likely greater number of unlicensed and untrained private providers (Annear et al., 2015). People's confidence in the effectiveness of drugs is often based on how quickly symptoms are relieved (Suy et al., 2019). The study revealed that out of the 2000 participants, more than half believed that antibiotics are effective for treating wounds (64.3%) and skin ulcers (59.8%), interpreting these conditions as any injuries that disrupt the skin or other body tissues (Lim et al., 2021).Access to antibiotics is unrestricted and supported by various community facilitators (Om et al., 2017).Also, the convenience provided by Invisible Medicine Seller and other unofficial Healthcare Providers, including the provision of medications when other facilities were closed (Suy et al., 2019).

The high levels of AMR among hospitalized children in Cambodia are linked to greater mortality rates and rising healthcare costs, endangering the efficacy of first-line treatments for sepsis (Fox-Lewis et al., 2018). Fatalities from chronic respiratory illnesses, gastrointestinal problems, diabetes, renal disease, maternal and neonatal conditions, and accidental accidents are all less common in Cambodia than fatalities from AMR (Institute for Health Metrics and Evaluation, n.d.).

Table 1. Survey result on 2005 participants about their thoughts on Antibiotic drugs (Lim et al., 2021)

Treatment Effect Believes	Percentage (%)
Wound	64.3
Skin Ulcers	59.8
Pain	28.1
Sore Throat	25.6
Gastric	24.4
Cold	21.7
Fever	12.7

IV. Discussion

Antimicrobial resistance is a significant concern in Cambodia. Many producers in the country's agriculture sector have limited knowledge about antibiotics and their proper use, with only one-fourth of growers accurately identifying the antibiotics they apply on their farms (Chea et al., 2022). Compounding these challenges, many individuals in Cambodia frequently obtain medications from unlicensed and untrained private providers (Annear et al., 2015). Furthermore, a large proportion of participants mistakenly believe that antibiotics are effective for common ailments, such as wound healing and colds (see **Table 1**). To address these issues, the Royal Government of Cambodia has implemented the Multi-Sectoral Action Plan 2019-2023, which aims to combat AMR through a collaborative effort involving the Ministry of Health, the Ministry of Agriculture, Forestry and Fisheries, and the Ministry of Environment (Food and Agriculture Organization, 2021).

V. Conclusion

Antimicrobial resistance poses a significant threat to public health and food safety in Cambodia. Misuse of antibiotics in agriculture and reliance on unlicensed vendors for medications contribute to rising resistance levels. While the Royal Government's Multi-Sectoral Action Plan 2019-2023 is a vital initiative, challenges remain. Effective action requires stricter regulations on antibiotic sales, enhanced public education, and improved monitoring of antibiotic use in both healthcare and agriculture. Collaborative efforts are essential to mitigate AMR and protect the health of the Cambodian population. This work highlights the initial challenges of addressing AMR in Cambodia and underscores the need for further research to fully assess all related issue.

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Mr. Be Sokkeang is currently a program manager and lecturer of Science Research in the Faculty of Health Sciences and Biotechnology at University of Puthisastra (UP). He holds a Master of Science in the field of Industrial Chemistry from King Mongkut's University of Technology Thonburi in Thailand in 2021, and a Bachelor Degree in Biochemistry in Cambodia at RUPP in 2019. His researches focus on Environmental (including soil, drinking water and wastewater) and food safety (Including microbial and heavy metals). He leads several projects focusing on biomass conversion for pollution removal and use it for agriculture purposes. In addition, he is also working on heavy mental and microbial content in food.

Exploring Demographic and Behavioral Factors Influencing Knowledge and Participation in Health Check-Ups Among University Students

Be Sokkeang
Master's Degree, Industrial Chemistry
King Mongkut's University of Technology Thonburi
(KMUTT),Thailand

Lim Chanboramey
Bachelor's Degree
Science Research
University of Puthisastra, Cambodia

Phally Seavmean
Bachelor's Degree
Science Research
University of Puthisastra, Cambodia

Sok Channary
Bachelor's Degree
Science Research
University of Puthisastra, Cambodia

Neang Sreyloeng
Bachelor's Degree
Science Research
University of Puthisastra, Cambodia

Highlight

- Identifying the demographic and behavioral factors that influence health knowledge is crucial for understanding individuals' comprehension of healthcare.
- Health check-ups typically involve discussions about personal and family medical history, physical examinations, screening tests, and living conditions.
- help detect early signs of illness and prevent conditions from worsening.
- It is commonly assumed that university students have a strong understanding of healthcare due to their educational background. This study aims to evaluate whether this assumption is accurate.

I. Introduction

The global population is aging due to increased life expectancy and declining fertility rates (World Bank, 2019). While population aging has been a gradual trend in developed countries, it is occurring more rapidly in many developing nations, including Cambodia. In Cambodia, the elderly population (60 years and older) has been growing at a faster rate than the overall population (National Institute of Statistics, 2019). In 1998, 5.25% of Cambodia's population was aged 60 or older, by 2008, this figure had risen to 6.34%, and by 2019, it had reached 8.86%. This percentage is projected to increase to 23.17% by 2050 (National Institute of Statistics, 2019). Compared to the world's population aging (aged 65 or older), it was 703 million in 2019 and it is expected to double to 1.5 billion by 2050 (UN, 2020). As people age, they often face multiple health issues simultaneously. Although various factors influence health, demographic and personal characteristics such as age, gender, and lifestyle choice are significant determinants (WHO, 2022).

It is crucial to identify risk factors and detect diseases at an early age, while there is still an opportunity to intervene before the disease develops or progresses (Teo, C. H., et al., 2017). One pivotal moment in a student's life is the transition from high school to university. During this period, students are more likely to adopt unhealthy behaviors, such as poor eating habits and lack of exercise, which can negatively impact their health (Deforche et al., 2015). Lifestyle and health behaviors are essential for both maintaining and improving well-being. At university, young adults based on age group between 18-25 must adjust to a new environment, make new friends, and navigate various challenges while striving for academic success. These factors can increase their susceptibility to various health issues (Deforche et al., 2015).

While health examinations are significant for the early detection and prevention of diseases, many individuals, particularly undergraduate, often neglect these essential services. Given the unique medical concerns and pressures faced by this age group, it is important to understand the factors that influence their use of the health services to develop effective solutions. Demographic factors such as age, gender, socioeconomic status, and academic level can significantly affect students' awareness of and access to health examinations. Additionally, behavioral factors including diet, sleep, physical activity, lifestyle choices, attitudes toward health, and past medical experiences can also play a major role in shaping their approach to health check-ups. This research aims to assess the general knowledge of university students regarding health check-ups and to investigate the differences between males and females, and behavioral factors that influence participation in medical check-ups. Additionally, the study seeks to raise awareness about the significance of health check-ups among students and to promote a broader understanding of the importance of regular health examinations.

II. Methodology

Study Design

Exploring approach was selected to thoroughly evaluate the research objective among university students at University of Puthisastra (UP) in Phnom Penh, Cambodia. UP is one of health science private university provide many health science program to the students. This research was conduct at UP to address a gap in knowledge specific to improving program, policies, or practices within the UP. All students enrolled for the 2023-2024 academic year, across all faculties were eligible to participate with no exclusion criteria applied.

Participants and Recruitment

A total of 100 participants from UP were randomly selected and surveyed using both paper-based and Google Form questionnaires through face-to-face interactions. Due to certain limitations, only 97 of these approached volunteered and consented to participate in the study. In addition, no students were excluded from the data analysis.

Ethical Considerations and Consent

This study has been approved by the University of Puthisastra Research Committee (UPRC). All data were kept confidential, and participants' names were not included in the results. Data will be deleted three years after the research is completed. It was stored on a computer and will not be accessible to any third parties. Participants signed a consent form agreeing to take part voluntarily, and they were informed that they could choose not to answer any questions they found uncomfortable and had the right to withdraw from the study at any time.

Study Questionnaire

The study questionnaire consists of six parts. The first part collected general information, including participants' name, age, gender, major, year of study, marital status, current residence, and health insurance status. The second part assessed knowledge about health check-ups, including the frequency of check-ups, sources of information, and understanding of typical medical examinations. The third part focused on participants' experiences with health examinations, including their participation, reasons and past experiences. The fourth part explored personal behaviors such as smoking, alcohol consumption, diet, sleep patterns, overall health, and mental well-being. The fifth section addressed perceptions and attitudes towards medical check-ups, including their importance and preferences for healthcare providers. The final part invited additional comments and suggestions regarding health services. The questionnaires were developed based on a thorough literature review, and before conducting the interviews, they were pre-tested to ensure clarity and effectiveness. Additionally, 5% of the total participants (5 students) were selected for the pre-test, ensuring a mix of demographic backgrounds to capture a range of respondent profiles.

Data Analysis

The descriptive statistic was used to summarize the data. Microsoft Excel was utilized to calculate means and standard deviations, create graphs, and present the data in percentages. To assess the general check-ups knowledge between male s and females, the data in percentages were used to investigate the knowledge. In addition, the high percentages results of behavioral factors were used as key behavioral factors in health check-up.

III. Results

3.1 The Demographic of Participants

Table 1. A total of 100 students participated in this study, with 3 students excluded for non-involvement in this survey. The gender distribution was 73% female and 24% male. The age of participants ranged from 18-20 years (62% by female 47% and male 15%), 21-23 years (32% by female 24% and male 8%), and 24-26 years (3% by female 2% and male 1%). The students were enrolled in various faculties at the University of Puthisastra, with the majority from Dentistry (39%), pharmacy (19%), Medicine (18%), Science Research (15%), and Nursing (6%). Over half of the students (75%) had no health insurance by 59% females and 16% males In addition, only 12% have health insurance (8% females and 4% males).

3.2 Participants in Health Check-up and Personal Behavior

Health Check-Up Frequency: Participants reported attending a health check-up either once a year 26.80% by 22.68% females and 4.12% are males. In addition, there are 24.75% (18.56% females and 6.19% males) and 32.99% (21.65% females and 11.34% males) were check-up more than twice a year and only when not feel well, respectively. However, 15.46% (12.37% females and 3.09% males) were never have a health check-up (**Table 2**). This indicates that while notable portions of individuals are proactive in monitoring their health, nearly an equal proportion do not engage in regular health check-ups (Medicover Hospitals, 2024).

Reasons for Health Check-Ups: Among those who do undergo health checks, the primary reason for sudden

Table 1. The Demographic of participants

Sociodemographic Characteristic	Frequency (N=100)	N (%)		Percentage (%)
		Female	Male	
Gender				
Male	24			24%
Female	73			73%
Missing Data	3			3%
Age group				
18-20	62	47 (47%)	15 (15%)	62%
21-23	32	24 (24%)	8 (8%)	32%
24-26	3	2 (2%)	1 (1%)	3%
Missing Data	3			3%
Major of study				
Dentistry	39	26 (26%)	13 (13%)	39%
Pharmacy	19	18 (18%)	1 (1%)	19%
Nursing	6	5 (5%)	1 (1%)	6%
Medicine	18	13 (13%)	5 (5%)	18%
Science research	15	11 (11%)	4 (4%)	15%
Missing Data	3			3%
Marital Status				
Single	93	69 (69%)	24 (24%)	93%
In Relationship	3	3 (3%)	0 (0%)	3%
Married	1	1 (1%)	0 (0%)	1%
Missing Data	3			3%
Health Insurance				
Yes	12	8 (8%)	4 (4%)	12%
No	75	59 (59%)	16 (16%)	75%
Not Sure	10	6 (6%)	4 (4%)	10%
Missing Data	3			3%

illness is (35.06%) there are 28.87% females and 6.19 males (**Table 2**). This suggests that many individuals seek medical attention only when symptomatic, rather than for preventive care. Followed by the need for follow-up (27.84%) are 19.59% females and 8.25% males. A bigger percentage check their health due to worry there are 25.77% females and 9.27% males, indicating some individuals never check-up is 2.06% (Medicover Hospitals, 2024).

Reasons for Not Checking Health: Among those who rarely or never go for check-ups, the predominant reason is the perception of rarely or never being sick (42.27%) which is 28.87% individuals of female and 13.40% individuals of male, implying that some equate the absence of symptoms with good health. Financial difficulties are another significant barrier (16.49%) include 14.43% individuals of female and 2.06% individuals of male , and some participants simply believe they are healthy (36.08%) in this percentage there are 26.80% individuals of female and 9.28% individuals of male (**Table 2**). The participants that were scared of the result are (5.15%) which participated by 5.15% individuals of female. (Taber et al., 2015).

Table 2. provides a detailed overview of health check-up frequency, reasons for undergoing health checks, and certain lifestyle habits among the participants.

Participated in health check up and personal behavior	Subcategory	N (%)		Total (%)
		Female	Male	
How often the participants go to check-up	Once a year	22 (22.68%)	4 (4.12%)	26.80%
	Rarely / Never	12 (12.37%)	3 (3.09%)	15.46%
	More than twice a year	18 (18.56%)	6 (6.19%)	24.75%
	Only when not feel well	21 (21.65%)	11 (11.34%)	32.99%
The cause of checking health	Feel unwell of all sudden	28 (28.87%)	6 (6.19%)	35.06%
	Need to follow up	19 (19.59%)	8 (8.25%)	27.84%
	Felt worried and want to check up	25 (25.77%)	9 (9.27%)	35.04%
	Never Check up	1 (1.03%)	1 (1.03%)	2.06%
The cause of never checked up	Rarely or never get sick	28 (28.87%)	13 (13.40%)	42.27%
	Financial problem	14 (14.43%)	2 (2.06%)	16.49%
	Think that they are healthy	26 (26.80%)	9 (9.28%)	36.08%
	Scare of result	5 (5.15%)	0 (0.00%)	5.15%
Alcohol consumer	Occasionally	35 (36.08%)	12 (12.37%)	48.45%
	Never	38 (39.18%)	12 (12.37%)	51.55%
Smoking	Yes daily	1 (1.03%)	0 (0.00%)	1.03%
	Occasionally	0 (0.00%)	2 (2.06%)	2.06%
	Never	72 (74.23%)	22 (22.68%)	96.91%
Physical activity (exercise)	Daily	5 (5.15%)	6 (6.19%)	11.34%
	Several times a week	21 (21.65%)	12 (12.37%)	34.02%
	Several time a month	30 (30.93%)	4 (4.12%)	35.05%
	Rarely/Never	17 (17.53%)	2 (2.06%)	19.59%
Eat fruits and vegetables	Daily	33 (34.02%)	15 (15.46%)	49.48%
	A few times a week	35 (36.08%)	8 (8.25%)	44.33%
	A few times a month	4 (4.12%)	0 (0.00%)	4.12%
	Rarely/Never	1 (1.03%)	1 (1.03%)	2.06%

Lifestyle Habits: The table also highlights participants' lifestyle choices. Nearly half occasionally consume alcohol (48.45%) including 36.08% individuals of female and 12.37% individuals of male, which can negatively impact health, including weakening muscles and damaging the lungs, brain, and heart (Nidirect, 2017). In contrast, (51.55%) report never consuming alcohol that consists of 39.18% females and 12.37% individuals of male. Regarding smoking, the majority (96.91%) have never smoked, a positive health indicator, while a small percentage smoke daily (1.03%) including.

Physical Activity and Diet: Physical activity varies, with around (34.02%) participants exercising several times a week are 21 (21.65%) females and 12 (12.37%) males, and several times a month (35.05%) are 30 (30.93%) females and 4 (4.12%) males (**Table 2**). In addition, Dietary habits are relatively positive, with many participants consuming fruits and vegetables daily are 34.02% females and 15.46% males and a few times a week are 36.08% females with 8.25% males. However, unhealthy lifestyle choices like poor diet and lack of exercise remain significant risk factors for conditions such as diabetes, cancer, obesity, and cardiovascular diseases (Baumann et al., 2015). However, due to the limitation of sample size of this study, it can restrict the generalizability of the results, making it important to acknowledge this limitation for readers to better understand the context of the finding. With a small sample, there may be insufficient power to detect significant effects. The future research should aim to include a larger sample size to validate these results.

IV. Conclusion

The results highlights the importance that the females are more active in seeking health check-ups, focusing on preventive and health concern. In addition, the females are more likely to attend follow-up visits and respond to sudden changes in their health. On contrast, males response less engagement with healthcare, with only a few reporting annual check-ups. This indicates that men may be more prone to neglect preventive healthcare, potentially missing opportunities for early detection and treatment of health issues. The higher participation of females underscores a clear gender gap in health check-up behaviors, with females showing greater awareness and engagement compared to men. Key behavioral factors such as financial problems and the symptom-free . These factors may contribute to lower engagement in preventive health practices. Addressing these barriers and educating individuals on the importance of regular check-ups, regardless of current health status, could help improve overall health outcomes. However, the sample size and cross-sectional study should use for future work.

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Leveraging AI-integrated IoT Solutions for Efficient Public Waste Management in Cambodia

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Nov Lihour
Ph.D., Integrated IT Engineering
Seoul National University of Science and Technology
Republic of Korea

Va Hongly
Ph.D.
Software Convergence
Soonchunhyang University, Republic of Korea

Nom Vannkinh
Master's Degree
Computer Science
Institute of Technology of Cambodia, Cambodia

Highlight

- Identify potential challenges for waste management in Cambodia.
- Review the impact of AI-integrated IoT solutions for waste management.
- Compare several machine-learning models for solid waste classification.
- Suggest potential model and dataset for tackling waste collection and segregation issues.

I. Introduction

Waste management is a crucial factor for enhancing environmental protection, quality of life, and public safety (Arteaga et al., 2023; Yim et al., 2023). Proper waste monitoring and control methods will prevent the contamination of air, water, and soil from any harmful waste pollutants. Phnom Penh has shown a noticeable raising amount of waste generation, approximately 365,224 tons of municipal waste, due to its rapid economic growth and urbanization over the past few decades (Seng, 2015). The rapid increase in waste generation and limited capacity of waste management systems has resulted in significant issues including overflowing waste bins, improper waste disposal, and environmental pollution. It should be noted that the country's waste management system is currently inefficient due to several combinations of factors such as inadequate infrastructure and lack of public awareness on proper waste disposal practices. **Figure 1** shows an inadequate waste disposal and overflowing dustbins at one public area where various types of waste were thrown together at the dustbin without proper segregation.

The overflowed waste issue is due to the inefficiency of waste collection services which are often irregular and delayed across different areas (Yim et al., 2023). Additionally, it is even more difficult to manage waste effectively since there is no formalized waste segregation system. This allows for all types of waste to be mixed, which reduces waste recycling efficiency or even makes the process impossible. It is worth mentioning that various types of waste are generated daily, and they can be broadly categorized into household waste,

Figure 1. Improper waste disposal in one public area (Singh et al., 2018).

commercial waste, industrial waste, medical waste, and electronic waste (E-waste) (Singh et al., 2018). This diversity in waste types presents significant challenges for the management entity, particularly in terms of segregation, collection, and disposal.

Internet of Things (IoT), which is a technology that allows to connect objects, devices, or sensors to the internet, has been widely used for remote control and monitoring in various applications. It should be noted that the Intelligent IoT (IIoT) is revolutionizing interactions with the environment through Artificial Intelligence (AI) integration, leading to better decision-making and efficiency from industrial applications to individual applications. The data collected from embedded devices on IoT framework creates efficiency for various operations.

By applying intelligent decision-making, it is possible to largely reduce energy consumption, thus contributing to environmental sustainability and improving the quality of life (Gyawali et al., 2020; Risfendra et al., 2024). A significant finding by Rahman et al. (2022) presents an architecture for a waste management system that uses CNNs to classify waste and IoT for real-time data monitoring. The model is designed to sort digestible and indigestible waste, leveraging multiple sensors embedded in a smart trash bin. The system achieves a classification accuracy of 95.31% and a System Usability Scale (SUS) score of 86%, reflecting its effectiveness and usability. Although this implementation is not present locally, it provides valuable insights into the potential of AI and IoT integration in waste management.

In this paper, we present a potential AI-integrated IoT solution to tackle some of the above-mentioned issues, specifically for waste monitoring and segregation task. Our study contributes to more efficiency and environmental soundness for waste management in Cambodia, particularly Phnom Penh city. The solution monitors waste levels in real-time with proper waste disposal guidance to provide a more efficient timely collection process. It also allows for the identification of what type of waste will accumulate most in frequency, making recycling possible, and reducing contamination.

II. AI-Integrated IoT Solutions for Waste Management

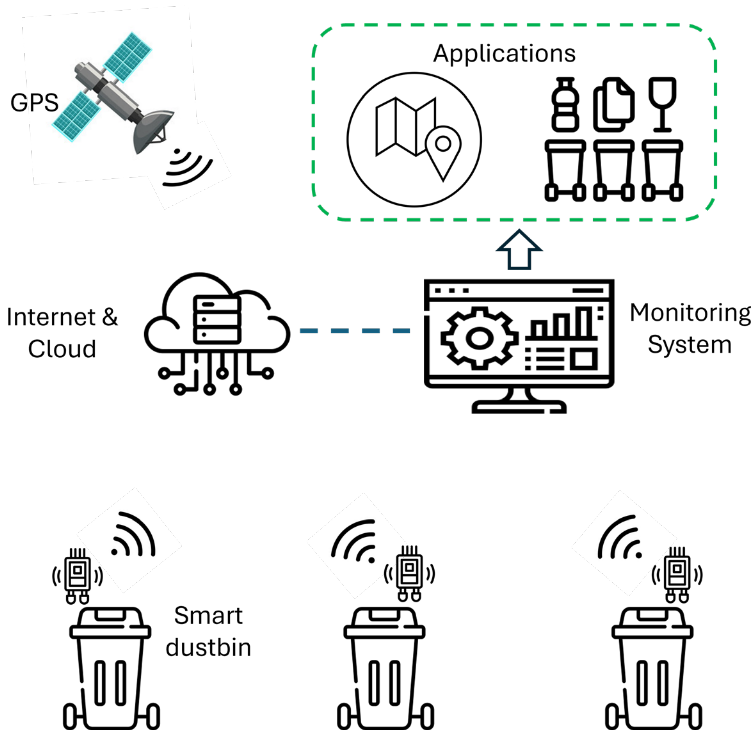

Figure 2. Conceptual design of real-time waste monitoring system using IoT technology.

In waste management, several critical requirement tasks may include prediction of waste generation pattern, classification of different types of wastes, and determination the efficient routes for collection vehicles. **Figure 2** shows the conceptual implementation for waste monitoring and collection-route optimization system using IoT technology. With a more advanced branch of machine learning, known as deep learning (DL), we can achieve high precision in classifying and sorting waste by utilizing Convolutional Neural Networks (CNN).

The convolutional neural network (CNN) model is employed to extract essential features from the input waste images, including texture, shape, color, and pattern that make the system categorize diverse waste types. State-of-the-art (SOTA) algorithms, such as ResNet, DenseNet, EfficientNet, and InceptionNet, are particularly effective in terms of waste type classification due to their complicated neural network layer of the architecture for capturing the patterns of the image data. The model was trained with annotated datasets that integrated data augmentation techniques such as image rotation, flipping, shifting, and scaling to enhance the classification performance with image variations.

Existing literature extensively covers the intricacies of CNN models for image processing as illustrated in **Figure 3.** It summarizes various studies in terms of implemented strategies, the characteristic specificity of these models, the nomenclature of these models, their assessment criteria, and the specific issues these papers address as illustrated in **Table 1**.

Table 1. Performance evaluation of different solid waste classification solutions and applied datasets.

Work	Data source	Number of Images	Number of Classes	Model	Accuracy Performance
Gyawali et al., 2020	Trash Net + In-house data	3102	4 (Paper, Plastic, Metal, Glass)	ResNet18	87.8%
Meng et al., 2020	TrashNet	2527	6 (Cardboard, Glass, Metal, Paper, Plastic, and Trash)	ResNet50	95.35%
	In-house	10108			91.40%
Mao et al., 2021	Trash Net	2527	6 (Cardboard, Glass, Metal, Paper, Plastic, and Trash)	Optimized DenseNet121	94.02%
Poudel et al., 2022	TrashNet+in-house data (organic class)	3242	7 (Cardboard, Glass, Metal, Paper, Plastic, Organic and Trash)	InceptionV3	98.72%
Shi et al., 2021	TrashNet	2527	6 (Cardboard, Glass, Metal, Paper, Plastic, and Trash)	MLH-CNN	92.60%
Risfendra et al., 2024	Klasifikasi Sampah	7014	6 (Cardboard, Glass, Metal, Paper, Plastic, and Residue)	EfficientNet-B0	91.94%
Rahman et al., 2022	TrashNet	2527	6 (Cardboard, Glass, Metal, Paper, Plastic, and Trash)	ResNet-34	95.31%

We observed that Trashnet (Yang, & Thung, 2016) is a primary dataset used in the classification methodologies for waste. It has six common classes including glass, paper, cardboard, plastic, metal, and trash within the dataset, thus covering a wide variety of waste materials. The two best approaches to this state-of-the-art (SOTA) are InceptionV3 and Resnet. Algorithmically, it has been proved that it classifies the type of wastes with very high performance, which shows that the algorithms are effective in using deep learning for environmental purposes. However, there are two major issues that could be highlighted in terms of the quality of images and processing time. Image quality in the dataset can easily influence how well the model learns and therefore classifies waste. Misclassification may come about by bad-quality images. The second issue is that the processing time required for all these advanced deep-learning methods is enormous.

Additionally, it requires a tremendous amount of computational requirements for training and execution for

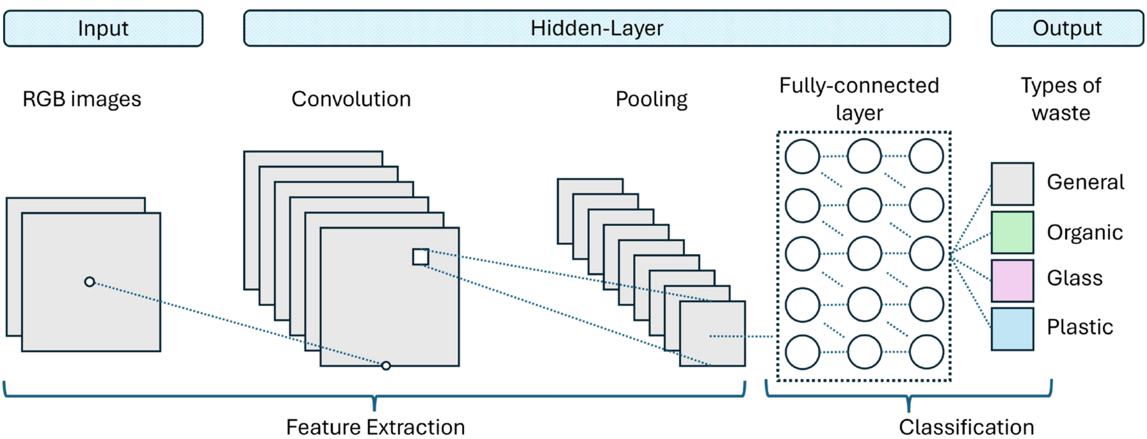

Figure 3. A generic design of CNN model for waste classification.

InceptionV3 and Resnet over large datasets. This can be problematic, especially in cases where processing needs to be ultra-fast and limited in computational resources. Thus, the ones described above on machine learning advances, particularly models like InceptionV3 and Resnet, offer promising pathways to enhance waste classification through the Trashnet dataset. Challenges need to be addressed in image quality and processing time, and it will significantly boost further sustainable waste management quality.

III. Conclusion

The integration of AI algorithms with Internet of Things (IoT) systems for waste management is a great step toward the optimization and automation of most processes involved in the domain. It enables the prediction of waste generation patterns, classify different types of wastes with high accuracy, and determine efficient routes for collection vehicles. It is also lead to substantial savings in time and other resources, hence promoting more sustainable waste management practices that can be applied for Cambodia's waste management system in the future.

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Dr. Nov Lihour is currently a senior lecturer and researcher at Cambodia Academy of Digital Technology (CADT). He obtained master's and doctoral degrees in the Dept. of Integrated IT Engineering from Seoul National University of Science and Technology (SeoulTech), Republic of Korea, in 2020 and 2023, respectively. He was under the Electromagnetic Measurement and Applications (EMMA) laboratory, where his research focuses on dielectric material characterization, RF/Microwave design and measurement. His works got published in several SCIE journals including IEEE Access, IET Science Measurement & Technology, Microwave and Optical Technology Letter, and Sensors and Actuators A: Physical as the main and co-author.

TECHNOLOGY TREND

Using Phytoremediation to Remove Indoor Air Pollution: A Sustainable Approach for Green Environment, Health, and Well-Being

5

Chhon Yanvary
Master's Degree, Biotechnology
King Mongkut's University of Technology Thonburi (KMUTT),Thailand

Sorn Virak
Master's Degree, Biochemical Technology
King Mongkut's University of Technology Thonburi (KMUTT),Thailand

Highlight

- Using phytoremediation to purify indoor air pollutants such as formaldehyde, benzene, and ammonia.
- Phytoremediation uses plant roots, leaves, and associated microorganisms to clean the pollutant.
- Integrating indoor plants offers an eco-friendly and sustainable approach to creating healthy spaces for living.

I. Introduction

The rapid economic development and population growth have led to increase the demand for resources (e.g., energy, water, and food), resulting in pollution. Air pollution is a major concern globally due to its widespread nature, environmental damage, and potential health risks. Despite concerns about anthropogenic emissions, our reliance on fossil fuels for electricity generation, transportation, industrial and domestic heating, and so on has led to deteriorating air quality, especially in developing countries (Leung, 2015). This issue has become a public concern in modern metropolises, especially for public health issues causing respiratory illnesses and cardiovascular problems (WHO, 2023). Of course, people are attracted to indoor air pollution due to spending a long time in an indoor space like home, school, office, and closing space (Mannan & Al-Ghamdi, 2021). At the same time, good air quality can protect occupants' health and increase worker productivity, despite variations in indoor time and health conditions.

Indoor air pollution poses a critical health risk to human health. Meanwhile, more than two-thirds of the literature's combined indoor and outdoor air quality studies have revealed that indoor air pollutant concentrations are higher than outdoor (Leung, 2015). However, the sources of indoor air pollution include household products, building paint, kitchen and smoking (Tran et al., 2020). These pollutants include volatile organic compounds (VOCs), carbon dioxide (CO_2), carbon monoxide (CO), particulate matter (PM), and biological contaminants such as mold and bacteria (Kumar, 2013) (**Figure 1**).

The effects of indoor air pollution, causing irritations of eyes, skin, and respiratory system to long-term ones like cancer, cardiovascular disorders, and respiratory diseases (Manisalidis et al., 2020; WHO, 2023) (**Figure 2**). The indoor air pollutants include VOCs, benzene, formaldehyde, and CO, which caused several health

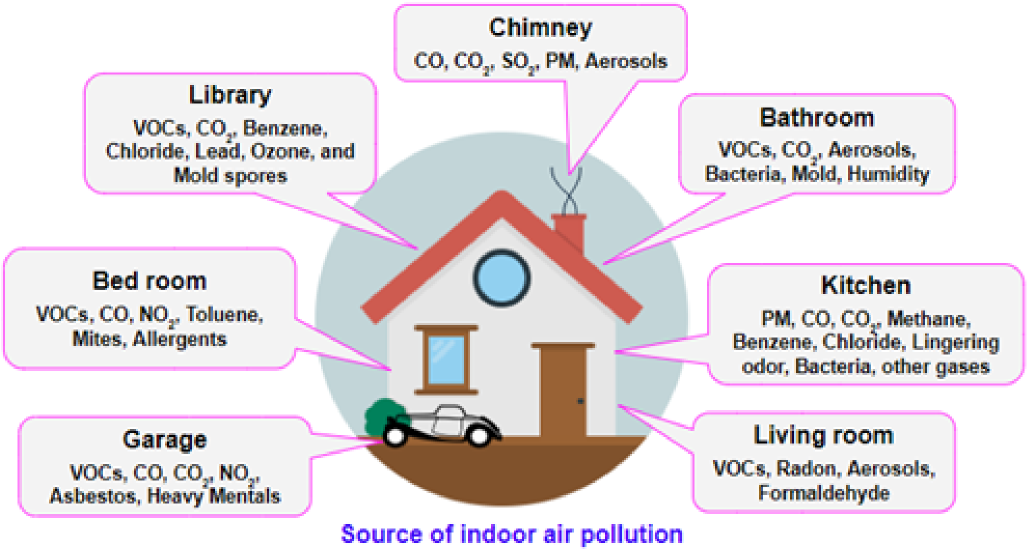

Figure 1. The sources and types of different indoor air pollutants.

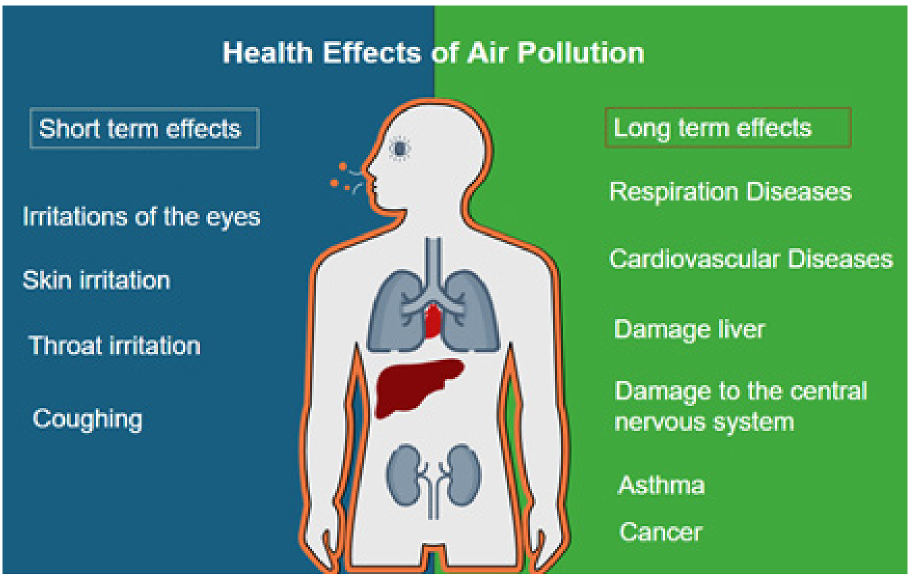

Figure 2. Effects of air pollution on health.

effects, even up to 100 times more harmful than outdoor (Tran et al., 2020; Leung, 2015). The World Health Organization (WHO) has defined a combined group of symptoms as the sick building syndrome (SBS), which include headache, nausea, dizziness, irritation of eyes, mucous membranes, and the respiratory system, as well as drowsiness, fatigue, and general malaise (WHO, 2023). Many people die in the US between 65,000 and 150,000 people per year, especially people who work in industry; they spend an average of 80–90% of their time indoors (WHO, 2023).

Environmental pollution is a global problem, and the development of inventive remediation technologies for the decontamination of impacted sites is therefore of paramount importance. Physical, chemical, and biological methods can be used for the remediation of contaminated sites (EPA, 2024a). Poor air quality can lead to "sick building syndrome," where individuals experience acute health effects linked to time spent in a building without a specific illness or cause identified (Joshi, 2008). Long-term exposure to indoor air pollution can result in more serious health issues like cancer and heart disease, and chronic exposure can aggravate conditions like allergies and asthma (Jiang et al., 2016).

Nowadays, there are many techniques used for air remediation to remove VOCs, such as combinations of air filtration, mechanical ventilation, phytoremediation, ionization technology (OC IMP KLIMA, 2020), and activated carbon filters (Janesky, 2021). Ultraviolet light can also be used to activate a catalyst that breaks down pollutants. Ionizers work by releasing ions that attach to airborne particles, causing them to settle out of the air. Lastly, ventilation involves introducing outdoor air into indoor spaces to dilute indoor pollutants (He et al., 2021). While these methods can be effective, they often come with limitations such as high energy consumption, maintenance requirements, and limited effectiveness against certain types of pollutants.
Phytoremediation, the use of plants to remove, degrade, or contain environmental contaminants, offers a promising, low-cost, and sustainable alternative for improving indoor air quality (Kafle et al., 2022). This natural method leverages the inherent abilities of plants to absorb and metabolize pollutants through their leaves, roots, and associated microorganisms (Zhakypbek et al., 2024). The concept, originally applied to soil and water remediation, has garnered increasing attention for its potential in indoor environments. In this review paper, we have summarized the different studies on the potential of phytoremediation in mitigating indoor air pollution. To provide a scientific basis for the incorporation of plants into indoor air quality management strategies, this review also identifies specific plant species that have the ability to remove common indoor pollutants and understands the underlying mechanisms.

II. Sources, Types, and Health Impacts of Indoor Air Pollutants

Indoor air pollutants are substances found in indoor environments that can adversely affect health and comfort. Unlike outdoor pollutants, which are often well-regulated and monitored, indoor pollutants can vary significantly depending on the building's design, usage, and maintenance (Tran et al., 2020). Understanding these pollutants, their sources, and their health impacts is crucial for developing effective mitigation strategies, including phytoremediation (Nedjimi, 2021). There are several types of indoor air pollutants, such as volatile organic compounds (VOCs), carbon monoxide (CO), carbon dioxide (CO2), ozone (O3), nitrogen oxides (NO2), and sulfur dioxide (SO2), etc. (Tran et al., 2020; Liu et al., 2019) (**Figure 1**). VOCs are organic chemicals that can easily evaporate into the air. They are commonly found in household products and building materials. Common VOCs, including formaldehyde, were found in adhesives, particleboard, and some cleaning products (David and Niculescu, 2021; Tran et al., 2020). Benzene is emitted from fuels, tobacco smoke, and some industrial products (David and Niculescu, 2021). VOCs affecting health in the short term can cause headaches, dizziness, and eye irritation (David and Niculescu, 2021; EPA, 2023). Long-term exposure is linked to respiratory problems, liver damage, and an increased risk of cancer (EPA, 2023). Particulate matter consists of tiny particles or droplets suspended in the air.

They are classified based on size, such as PM2.5 (particles with a diameter of 2.5 micrometers or smaller) and PM10 (particles with a diameter of 10 micrometers or smaller) (EPA, 2024b). Those particulate matter sources are dust, pet dander, mold spores, and smoke from cooking or burning materials. Can lead to respiratory and cardiovascular issues, exacerbate asthma, and contribute to other serious health conditions

(**Table 1)** (EPA, 2023; Vathesatogkit, 2024). Other biological contaminants such as mold, bacteria, viruses, and pollen can cause allergic reactions, respiratory infections, and exacerbate asthma (Kumar et al., 2021).

III. Phytoremediation: Principles and Mechanisms

Table 1. Lists the most common indoor air pollutants along with their causes and health effects.

Pollutant	Sources	Health Effects	References
VOCs	Paints, cleaning supplies, pesticides, building materials, and furnishings	Eye, nose, and throat irritation. Damage to the liver, kidneys, and central nervous system	EPA, 2023; WHO, 2010
Particulate Matter (PM)	Combustion processes, industrial processes, dust, pollen, and mold spores	Respiratory and cardiovascular	EPA, 2023; WHO, 2022
Black Carbon	Combustion processes, tobacco smoke, vehicle emissions, and certain heating appliances	Respiratory and cardiovascular problems, asthma, and cancer	EPA, 2024c

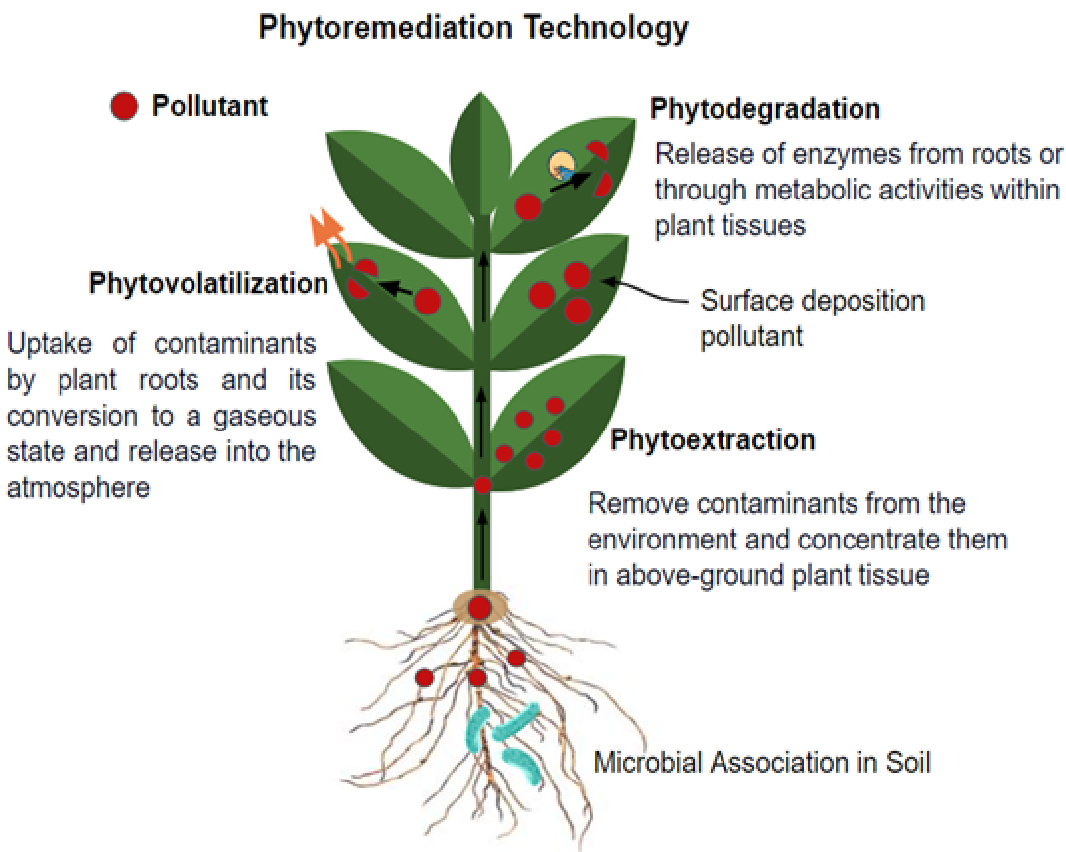

Figure 3. Mechanisms of phytoremediation/plant-based approach for mitigation of indoor air pollution.

An innovative technique called phytoremediation uses plants to absorb toxins from the air, resulting in improving indoor air quality. Its potential for encouraging the biodegradation of organic contaminants requires further research, although it may be a promising area for the future (Kafle et al., 2022). This bioremediation technique leverages the natural abilities of plants to absorb, accumulate, and transform pollutants from air, soil, and water. Originally developed for soil and water purification, phytoremediation has been adapted for indoor environments to address air pollutants. Some plants use leaves to absorb airborne pollution like VOCs such as formaldehyde and benzene from the air through their stoma (Han et al., 2022). Pollutants can also be absorbed through the roots from the soil or growing medium. Once taken up, pollutants can be transported to other parts of the plant for further processing. Plants can metabolize pollutants into less harmful substances. For instance, formaldehyde can be broken down into carbon dioxide and water through enzymatic processes within the plant through the degradation process (Naz et al., 2022).

Some plants can convert harmful pollutants into less toxic compounds. For example, certain species can transform benzene into other substances that are less harmful. Phytoremediation offers a natural and sustainable approach to improving indoor air quality by harnessing the abilities of plants to absorb, transform, and stabilize pollutants (Kumar et al., 2023; Mocek-Płóciniak et al., 2023). Understanding the underlying mechanisms and key factors influencing its effectiveness can help in selecting appropriate plant species and optimizing their use in indoor environments. This approach not only enhances air quality but also provides an aesthetic and eco-friendly solution to air pollution (Han et al., 2022; Kumar et al., 2023) (**Figure 3**).

IV. Plant Species for Indoor Air Purification

Certain plant species have been found to be especially good at eliminating indoor air pollutants in numerous studies. *Dracaena sanderiana* eliminates harmful VOCs known as BTEX (benzene, toluene, ethylbenzene, and xylem), and *Zamioculcas zamiifolia* potentially reduced the amount of BTEX in polluted indoor air (Ravindra & Mor, 2022). *Dieffenbachia compacta* and *Epipremnum aureum* growing in growstone were then tested for their ability to remove formaldehyde (Kumar et al., 2023). The removal capacity of the aerial plant parts, the root zone, and the entire plant growing in growstone were determined by exposing the relevant parts to gaseous formaldehyde in a closed chamber over a 24-h period (Yujin et al., 2019). The removal efficiency was varied between 60 and 95%, which depends on plant species and its parts; however, the removal for formaldehyde concentration reduction was estimated at least 2/3, respectively (Aydogan & Montoya, 2011).

The formaldehyde removal by the root zone was found to be more rapid than the removal by the aerial plant parts. **Table 2** provides an overview of some of the best plants for purifying air by absorbing harmful pollutants such as VOCs (e.g., benzene, formaldehyde) and particulate matter (PM). They do this through various mechanisms, including absorption via leaves, microbial degradation in soil, and capturing particles on waxy surfaces. S*ansevieria trifasciata, Euphorbia milii, Chlorophytum comosum*, and *Spathiphyllum spp.* are particularly effective in removing pollutants and improving air quality, making them ideal for indoor environments. These plants have been evaluated for their ability to absorb and degrade various harmful substances, making them ideal candidates for indoor phytoremediation (**Figure 4**). Phytoremediation is a sustainable approach to improve air quality, contributing to overall well-being; therefore, those plants are recommended to be put in the office, school, hospital, house, etc. in order to purify indoor air, especially in the city or closing space.

Table 2. The effective plants for indoor air purification.

Pollutant	Mechanism	Plant Species	References
Benzene, formaldehyde, xylene, toluene, and trichloroethylene	Absorb VOCs through the leaves and facilitate microbial degradation in the soil	*Sansevieria trifasciata*	Kumar et al., 2023; Yuan et al., 2024
Formaldehyde, trimethylamine, and benzene	Absorb VOCs through the leaves and stem	*Euphorbia milii*	Siswanto, 2017
CO, CO_2, and VOCs	Shoots, roots, and microbial degradation in the soil	*Aglaonema modestum*	Tarran et al., 2007
Formaldehyde and xylene	Break down the pollutants in the root's system	*Chamaedorea elegans*	Siswanto, 2017
PM	Waxes of spider plant leaves	*Chlorophytum comosum*	Kumar et al., 2023
VOCs	Shoots, roots, and microbial degradation in the soil	*Nephrolepis exaltata*	Kumar et al., 2023
Benzene	Wax and stomata	*Dracaena sanderiana*	Treesubsuntorn, & Thiravetyan, 2012
CO, CO_2, and VOCs	Shoots, roots, and microbial degradation in the soil	*Zamioculcas zamiifolia*	Tarran et al., 2007
Formaldehyde and benzene	Leaves can trap airborne particulate matter, including dust and pollen	*Aloe barbadensis*	Kumar et al., 2023
Formaldehyde, toluene, and xylene	Synergism effects of plants and microorganisms in growing water	*Epipremnum aureum*	Kumar et al., 2023
PM, reducing toxic VOCs (like ammonia)	Leaves capture articulate matter	*Spathiphyllum spp.*	Oh et al., 2011
PM, dust, and pollen	Leaves can trap airborne particulate matter, including dust and pollen	*Codiaeum variegatum*	Wu et al., 2021

Figure 4. List of recommended plant species for indoor air pollutants (VOCs and other pollutants) removal.

V. Conclusion

Phytoremediation presents a compelling and sustainable approach to improving indoor air quality by utilizing the natural abilities of plants to absorb, transform, and stabilize pollutants. The extensive research and case studies reviewed in this article highlight the effectiveness of various plant species in mitigating common indoor air pollutants such as formaldehyde, benzene, trichloroethylene, xylene, and ammonia. Phytoremediation not only improves air quality but also offers aesthetic and psychological benefits, contributing to overall well-being. The integration of plants into indoor environments represents a holistic and eco-friendly solution to the challenges of indoor air pollution. By leveraging the power of nature, we can create healthier, more sustainable indoor spaces for living, working, and learning.

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Mrs. Chhon Yanvary is currently a Health and Science Lecturer and researcher at the Foundation Year Department, Faculty of Health Science and Biotechnology, University of Puthisastra (UP). She completed an MSc in Biotechnology from King Mongkut's University of Technology Thonburi, Thailand, in 2014 and holds a BSc. in Biology from the Royal University of Phnom Penh, Cambodia, in 2012. Her research focuses on phytoremediation plants, bacteria association and agricultural residues, and plant tissue culture, as well as science and health science education.

Say Sreypich
Ph.D.
Biomedical Sciences and Engineering
Tokyo Medical and Dental University, Japan

Highlight

- Malfunction of your body parts requires intensive care and much money.
- Your meal such as heart, liver, kidney, skin, and intestine, saves your life.
- Decellularization technology produces tissue/organs at affordable prices for medical applications.

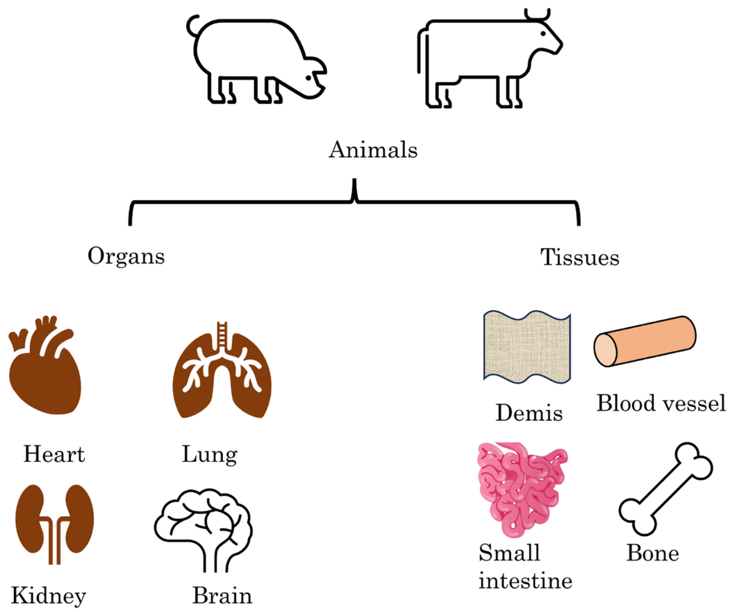

Figure 1. Examples of animal tissues and organs

I. Introduction

Human tissues/organs are damaged by diseases, surgery, age, infections, and everyday activity. Some damage could be treated by medicine or surgery but in some cases (e.g., end-stage kidney diseases, coronary artery disease, and cystic Fibrosis) requires tissue/organ replacement. Patients could use their tissue to make a replacement or receive it from another human. The limitation of human donors requires us to find other alternative solutions such as using other species donors (cow or pig). This manuscript highlighted the technologiesof using animal tissues and organs that we eat every day to prepare unlimited biomedical supplies for medical treatment and also reduce medical fees.

II. Technologies of Preparation of Human Tissue/ Organ from Home Meal

In Cambodia, we consume almost all parts of the pig and cow body, for example, kidney, liver, lung, small intestine, skin, bone/bone marrow, tung, and tendon (**Figure 1**). Those tissues are very important to produce replaceable tissues/organs for humans. Direct using tissues/organs from animals to humans causes immune rejection, inflammation, and transmittance decrease (Platt et al., 2018). The animal tissue/organ is composed of two major components extracellular matrix (ECM) and cells. ECM is a complex network for holding the cells. Cells contain the animal DNA leading to an immune response. Removing cells and leaving only the ECM is the primary work to avoid the rejection of the implant.

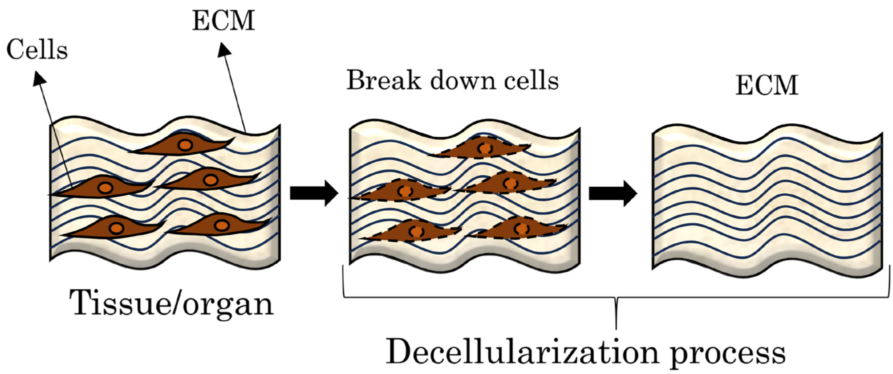

Figure 2. Principle of decellularization process of tissue and organ

Current technology is a decellularization process to remove cellular components leaving only ECM structure (**Figure 2**). It has been reported as a low immune response, low inflammation, and biocompatibility (Nakamura et al., 2017; Say et al., 2024a, 2024b). Physical, chemical, and enzymatic methods are common methods used to prepare decellularized tissue/organ (Gilbert et al., 2006). A single or combination of these methods is used in intensive studies to prepare different types of tissues/organs. The optimum condition of each method respecting the tissue/organ should be optimized to avoid damage to the ECM components (Crapo et al., 2011). A summary of the decellularization methods is listed in **Table 2.1** below.

After decellularization, the decellularized tissue could be implanted directly into the human body (Say et al., 2024b, 2024a). The host cells inside the human body infiltrate into the tissue and then regenerate it to be complete tissue.

For an organ with complex structures and multiple types of cells, reseeding cells in the laboratory (recellularization) prioritized the implantation to humans may be required (**Figure 3**). The details of recellularization can be read in the previous publication (Scarritt et al., 2015; Toprakhisar et al., 2023).

III. Commercial Products

There are some commercial decellularized tissues available on the market. The company produces those materials located in developed countries. Therefore, we need to spend a lot of money to obtain them. Some commercial products are listed in **Table 3.1** below.

Table 2.1 Summary method to prepare the decellularized tissues/organs.

Method	Reagents/ detergent	Description	References
Chemical	Ionic: Sodium dodecyl sulfate, Sodium deoxycholate,	- Solubilize phospholipid membrane, disrupts nucleic acid, - Damage to ultrastructure and ECM components, cytotoxic	(Laker et al., 2020; Moffat et al., 2022)
	Nonionic: Triton X-100	- Disrupt DNA protein. - Less damaged and less effective in removing the ECM structure and components compared to ionic detergent.	(Laker et al., 2020)
	Zwitterionic: CHAPS	- Have both ionic and non-ionic detergents, with minimal disruption to the ECM structure. - Mild disrupt to the thin tissue.	(Petersen et al., 2012)
	Acids: Peracetic acid Base: Sodium hydroxide	- Denature proteins, solubilize cell membranes, and degrade the genetic material. - Increase stiffness of ECM	
Physical	Freeze-thaw	- Disrupt cell membranes by ice crystal formation. - Damage to ECM structure	(Shaw et al., 2012; Watanabe et al., 2019)
	Sonication	- Disrupt cell membrane. - Damage to ECM structure	(Say et al., 2019)
	High hydrostatic pressure (HHP)	- Disrupt the cell membrane and sterilize the tissue at the same time. - Need to optimize the condition to about the damage to ECM structure and its components.	(Funamoto et al., 2010; Hashimoto et al., 2010; Say et al., 2024a, 2024b)
Enzyme	Deoxyribonuclease (DNase), Ribonuclease (RNase)	- Hydrolyze of DNA and RNA fragments - Insufficient to remove cells	(Funamoto et al., 2010; Grauss et al., 2005; Hashimoto et al., 2010)
	Trypsin	- Digest proteins and disrupt cells. - Ineffective to remove cells and require long treatment time.	(Vavken et al., 2009)

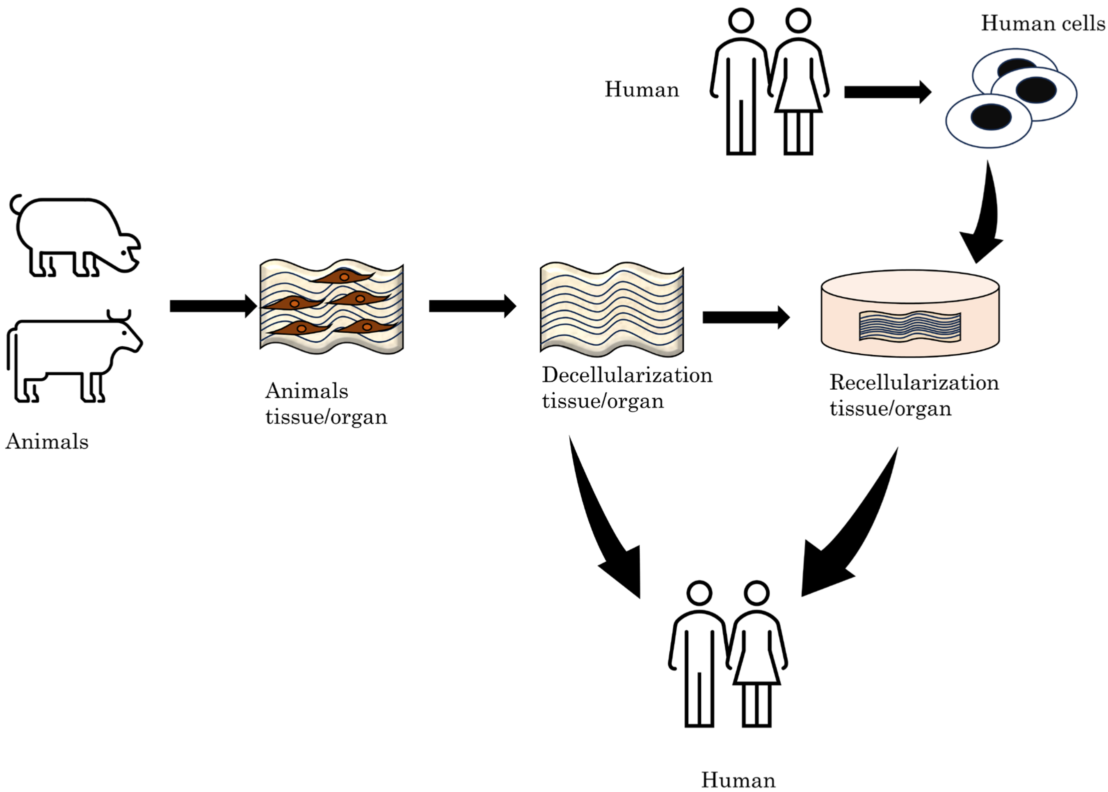

Figure 3. Schematic illustration from animal tissue/organ (home meal) to human

Table 3.1 Summary of commercial products derived from decellularized tissues (Nakamura et al., 2017).

Tissue source	Products	Company	Application
Human pericardium	IOPatch	IOP Inc.	Ophthalmology
Bovine pericardium	CopiOs	Zimmer Dental Inc	Dentistry
Bovine pericardium	Veritas	Baxter	Soft tissue
Human heart valve	CryoValve SG	CryoLife Inc.	Valve replacement
Porcine heart valve	Epic, SJM Biocor, Trifecta	St. Jude Medical Inc.	Valve replacement
Porcine heart valve	Freestyle, Hancock II, Mosaic	Medtronic Inc.	Valve replacement
Porcine heart valve	Matrix P plus N	Autotissue	Valve replacement
Porcine dermis	Fortiva	RTI Surgical	Soft tissue
Porcine dermis	Strattice	LifeCell Corp.	Soft tissue
Bovine dermis	SurgiMend	TEI Biosciences	Soft tissue
Bovine dermis	TissueMend	TEI Biosciences, Stryker Corp.	Soft tissue
Human bone/ cartilage	Chondrofix Osteochondral Allograft	Zimmer Inc.	Knee joint
Human bone	BioAdapt, map3	RTI Surgical	Bone

IV. Future Perspective in Cambodia

Decellularization technology is a simple technology to learn and follow. The raw materials are also easy to access in Cambodia even in the local market. Therefore, if we could produce our tissue/organ, we could reduce medical expenses for our patients. Since the organ is more complicated than tissue, we can start to study tissue. The tissue is also useful in surgery for example: heart valve, skin, blood vessel, corneal, tendon, cartilage bladder, join and colon.   Those are the surgeries that require intensive care.

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Dr. Say Sreypich is currently a Postdoctoral researcher in the School of Medicine, Keio University, Japan. She holds a Doctoral of Philosophy in Engineering in Biomedical Science and Engineering from Tokyo Medical and Dental University in Japan in 2024, a Master's degree in Chemical Engineering from De La Salle University in the Phillippines in 2018, and an Engineering Degree in Chemical Engineering and Food Science from the Institute of Technology of Cambodia in Cambodia in 2011. Her research focuses on developing biomedical material from animal tissue/organs for medical application.

Thermoelectric Device for Waste Heat Recovery, Electronics Thermal Management, and Bioelectronics Applications

Sam Sopheap
Ph.D.
Materials Science Frontier
Yokohama National University, Japan

Highlight

- Thermoelectric device for waste heat recovery.
- Thermoelectric device for electronics thermal management.
- Thermoelectric device for bioelectronics.

I. Introduction

As a solid-state device, a thermoelectric generator could directly convert heat into electricity without any moving part and no mechanical or chemical pollution to the environment (Jouhara et al., 2018; Sam, et al., 2024; Zheng et al., 2014). The working principle of the thermoelectric device is illustrated in **Fig. 1**. Thermoelectric device is basically composed of some main components such as ceramic substrates, metal conductors, thermoelectric elements (p-type and n-type semiconductors), etc. When the heat is applied on the hot side, the electric voltage is then generated due to the Seebeck effect, where electrons of n-type material move in the opposite with electrical current, but the holes of p-type materials move in the same direction. Vice versa, when the electrical current is applied to the device, the electrons and holes are diffused, generating the cold and hot sides. This phenomenon is usually called the Peltier effect, which is useful in cooling/refrigeration applications. In this paper, we discuss the insights of thermoelectric devices in waste heat recovery, electronic thermal management, and bioelectronics applications.

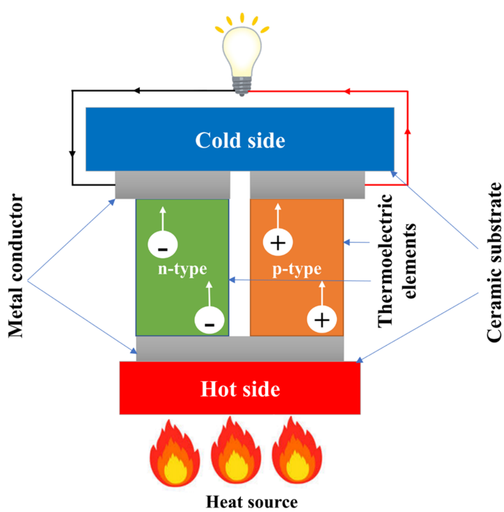

Figure 1. Schematic of the working principle of thermoelectric device.

II. Thermoelectric Device for Waste Heat Recovery

The energy demand remarkably increases every day due to the rise of the population. Moreover, it was reported that more than 60% of the primary energy consumed by industries such as power plants, automotive factories, and other industrial plants, is lost in form of waste heat, while around only 30% is useful energy (Fitriani et al., 2016) (**Fig. 2**). Therefore, optimizing energy consumption by harvesting thermal waste heat is one of the main solutions to sustaining the future energy demand. Heat is energy that can be converted into electricity; therefore, the waste heat or energy loss can possibly be recovered by various solutions such as heat recovery steam generators, heat exchangers, economizers, thermoelectric generators, and other recovery technologies (Jouhara et al., 2018). Among these solutions, the solid-state thermoelectric device is classified as an eco-friendly promising technique to recover industries waste heat into electricity without any moving parts, no chemical, and no mechanical pollution to the environment. Moreover, for automobiles, thermoelectric devices have also been applied to capture the waste heat at the exhaust system and convert it into electricity and supply it back to the vehicles (Sok & Kusaka, 2023a, 2023b; Yang & Stabler, 2009). Hence, the thermoelectric device plays an important role in recovering industries and automotive waste heat .

III. Thermoelectric Device for Electronics Thermal Management

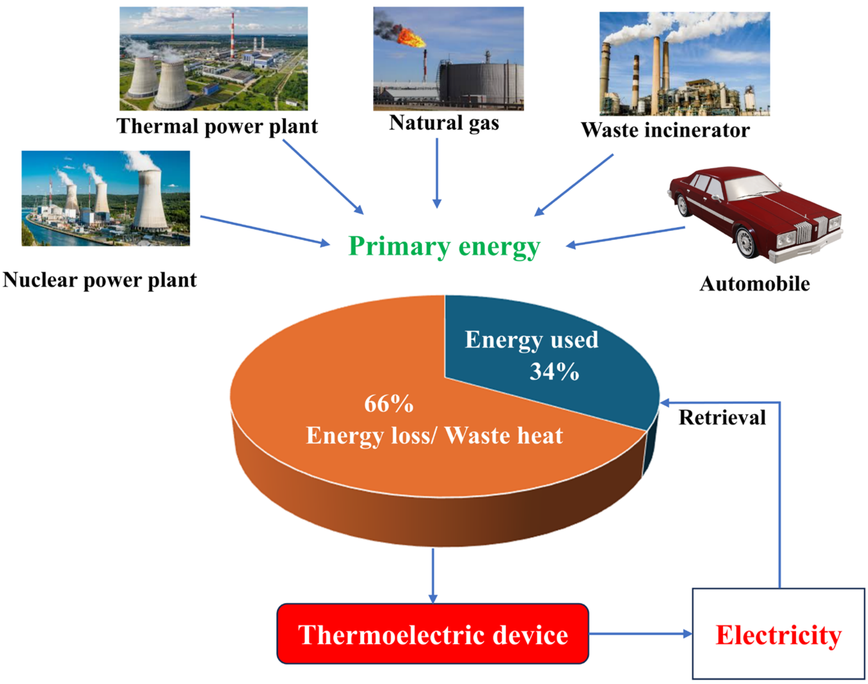

Figure 2. Illustration of the energy loss/waste heat and energy used from various industries. The thermoelectric device can be used to recover the waste heat and convert it into electricity (Fitriani et al., 2016).

With the development of technology, the size of the electronic device become smaller, and the processing speed is required to be faster, resulting in the generation of high temperatures in the system. Therefore, thermal management in electronic components are necessary. In this context, a thermoelectric device could work as a cooler because its function is to cool down the temperature of electronic components. Thermoelectric cooler plays an important role to cool down the temperature rise in electronic system (Nozariasbmarz et al., 2022; Sam, Farooq, Oshita, et al., 2024; Zhu et al., 2023). For example, as illustrated in **Fig. 3**, it was reported the performance of the central processing unit (CPU) system was remarkably improved by integrating with thermoelectric coolers compared to that integrated with a traditional sink and water-cooling system (Tan & Demirel, 2015). They found that the average temperature of CPU integrated with thermoelectric cooler (33.5 °C) is lower than that with a heat sink (41.9 °C) and water-cooling system (38.9℃). In addition, by placing the cold side of thermoelectric coolers to other electronic systems such as laser diodes and microprocessors, the temperature rise in the system can be controlled, leading to expanding their lifespans and improving performances.

IV. Thermoelectric Device for Bioelectronics Application

Due to the ability to convert the heat of the human body into electricity, thermoelectric devices are also compatible with bioelectronics applications. It has been recently reported that a flexible self-power thermoelectric device can power the wireless wearable bioelectronics device for monitoring electrophysiological signals on the skin continuously for stability of 7 days without recharging batteries (Sattar et al., 2024). In addition, as shown in **Fig. 4**, a recent study has found that the electric field generated by a thermoelectric device helps to accelerate the wound healing process 4 days faster than the natural healing process (Zhang et al., 2024). This opens new insights into the applicability of thermoelectric devices in wearable bioelectronics for monitoring bio-signals, diagnosing, and treating disease by using heat on the human skin.

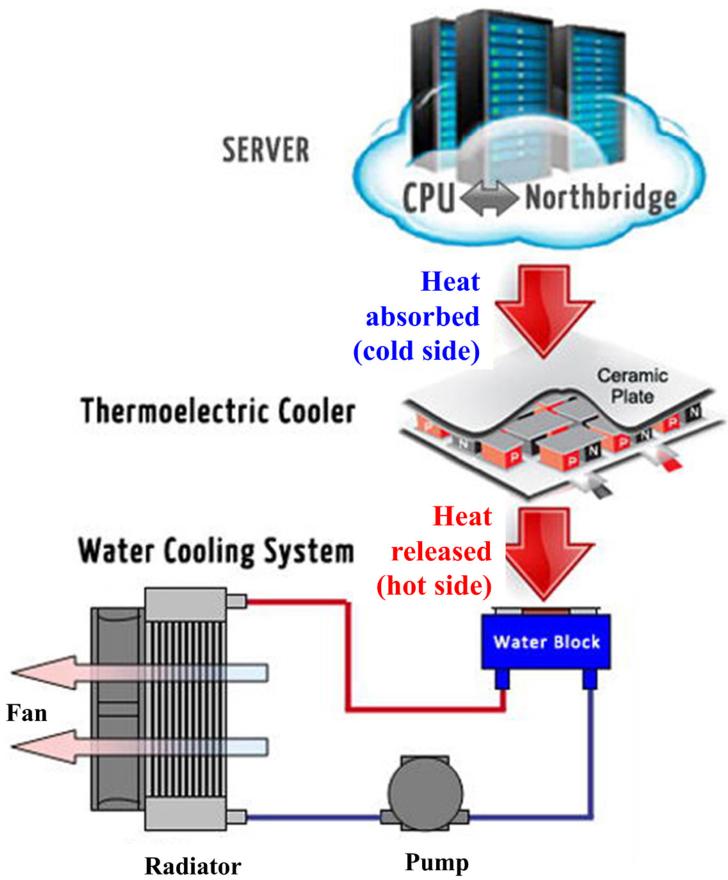

Figure 3. Illustration of integration of thermoelectric cooler for thermal management in the CPU (Tan & Demirel, 2015).

V. Summary

Thermoelectric devices have been widely used in waste heat recovery, electronic thermal management, and bioelectronics. However, the performance of current thermoelectric devices is still limited, where its efficiency is mainly proportional to the performance of thermoelectric materials i.e. n-type and p-type elements.

The current materials that have acceptable performance such as PbTe and Bi_2Te_3 compounds are high-cost and toxic to the environment. Therefore, the current challenge is to find new materials or to improve the performance of existing low-cost and non-toxic materials such as silicides, oxides, and Heusler alloys. When the performance of abundant and eco-friendly materials improves, the potential for thermoelectric device applications will further greatly expand.

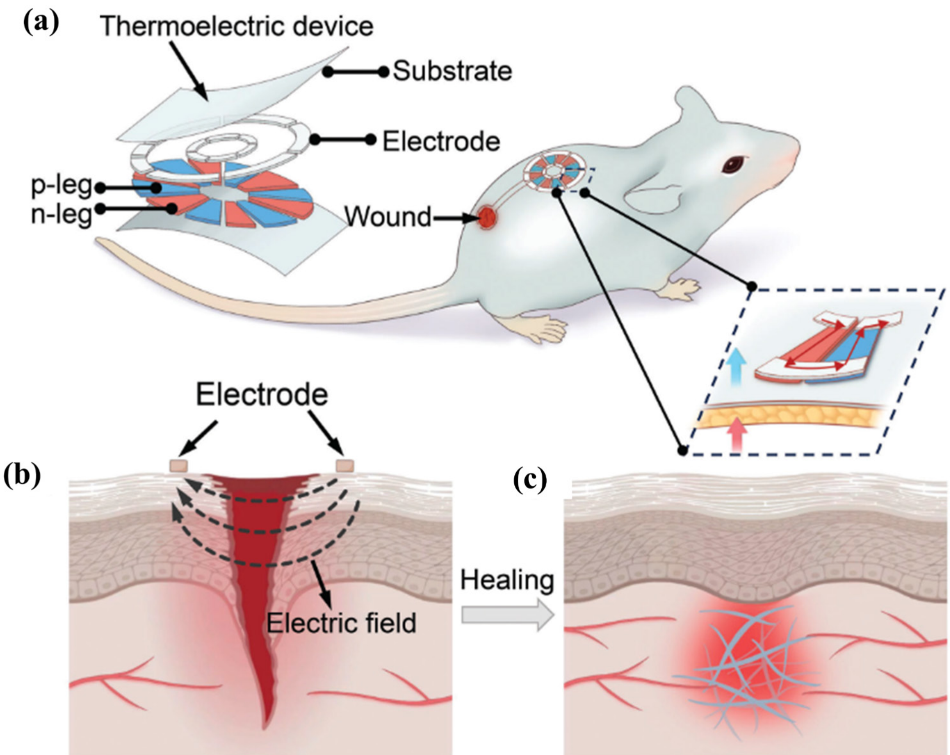

Figure 4. Illustration of a thermoelectric device for wound healing, where the heat source is generated from the rat body (Zhang et al., 2024). (a) A flexible thermoelectric device is attached to the skin, and it is connected by two electrodes made of copper wire from the skin toward the wound. (b) Cross-section view of positioning the electrode on the wound and induced electric field by a thermoelectric device. (c) Acceleration of wound healing is due to the electric field being induced by the thermoelectric device.

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Dr. Sam Sopheap is currently a postdoctoral researcher at National Institute for Materials Science, Japan. He obtained Ph.D. in Materials Science Frontier from Yokohama National University in Japan in 2023, a Master of Science in Mechanical Engineering from De La Salle University in Philippines in 2018, and an Engineering Degree in Industrial and Mechanical Engineering from Institute of Technology of Cambodia in 2016. His research interests are thermoelectric materials and thermal management for electronics.

Exploring Advancements in Robotic Automation and Their Impact on Manufacturing Processes

8

Long Pakrigna
PhD Candidate
Electrical and Electronic Engineering
Universiti Kuala Lumpur, Malaysia

Samok Ponloeu
Master of Science
Computer Science
University of East London, United Kingdom

REACH Makara
Master of Science
Information Technology
SETEC Institute, Cambodia

Chhit Helen
Bachelor of Science
Business Information Technology
ACLEDA University of Business, Cambodia

Toch Ensophea
Dual Major: Bachelor of Science
Computer Science & Data Science,
ACLEDA University of Business & TUX Global
Institute, Cambodia

Highlight

- The trends in robotic automation technologies, and what they do to the manufacturing society.
- The evaluation of the degree of shifts in the usage of robotic automation over time,
- The different benefits derivable from the usage of robotic automation, the challenges experienced in the usage of robotic automation, and the potential outcomes resulting from the future uses of robotic automation.
- Reshaping manufacturing strives to devalue the topic and make recommendations on how to apply automation for manufacturing development and prosperity.

I. Introduction

Automation by means of robots is now an essential criterion for change in manufacturing systems and processes in the manufacturing industrial revolution. By realizing the integration of robotics in manufacturing systems, the level of productivity, precision, and rates of production have enhanced global industries, creating new opportunities and some risks. This research will try to establish the evolution of robotic technologies and realize how industries have adopted them in changing manufacturing processes.

II. Literature Review

A Short History of Robotic Automation in Assembly Lines: Robotic automation in manufacturing has evolved significantly since the 1960s, when early industrial robots were first introduced to handle repetitive tasks. Over time, these systems have become more advanced, with modern robots capable of performing highly

Figure 1.What Manufacturing Look Like in the Digital Era

complex tasks with precision. The integration of "smart" capabilities has further transformed robotics, allowing for adaptive and autonomous decision-making, ultimately enhancing productivity and product quality on assembly lines.

Different Robot Classifications and Their Uses: Various types of robots serve specific roles in manufacturing. Industrial robots are typically used for repetitive processes like assembly, while collaborative robots (cobots) work safely alongside humans. Autonomous mobile robots (AMRs) navigate factory floors independently to transport materials. These robots are widely applied in industries such as automotive, electronics, and pharmaceuticals, where they perform tasks like welding, inspection, and assembly.

Benefits of Robotic Automation: Robotic automation offers numerous advantages, including lower operating costs, improved product quality, and enhanced production flexibility. Research shows that robots reduce human error, improve efficiency, and help businesses adapt more quickly to changing market demands, making them invaluable in modern manufacturing.

III. Application of Technology to Robotics for Automation

Collaborative robots, or cobots, represent an advanced evolution of earlier robotic models and are specifically designed to work alongside human workers. Equipped with complex safety features, cobots ensure seamless human-robot interaction, making them easy to use in tasks like factory assembly and packing. Their ability to collaborate safely with humans has been demonstrated in various workplace applications, enhancing efficiency and productivity.

The integration of artificial intelligence (AI) and machine learning has further advanced robotic systems by enabling them to learn from experience and predict when maintenance is needed. With AI, robots can optimize time management, reduce downtime, and improve decision-making in manufacturing processes. This technological progress has made modern robots much smarter and more efficient compared to earlier models, significantly enhancing overall productivity.

IV. Robots and Its Consequences on Manufacturing Operations

Productivity and Efficiency: It has also been applied in manufacturing, where it has improved the rate of production and processing of products. Higher OEE, results from decreased RTs and cycle time caused by the application of robots, which have no tiredness effect. Live cases will demonstrate how different organizations have benefited enormously from robotic automation, enabling them to achieve massive productivity increases in the production process.

Quality and Precision: Because robots convey a true sense of internal capabilities and task aptitude, robotics has raised the bar on product quality. Since actions can be closely mimicked in the model, it has resulted in a decrease in defects and waste as well as increased product reliability. In support of incorporating robots, the functional-organizational elements contain these considerations to seek the following outcomes.

Workforce Dynamics and Skills: These effects are attributed to the latest manufacturing technology and automation, in relation to the manufacturing workforce. It is true that the application of mechanization in working activities and the robot application in industries makes it develop that the worker is needed for the complicated and creative techniques in a job. This shift call for factors of training and developing methods that would enable the employees to work hand in hand with robots as highlighted by. [A9]

V. Challenges and Considerations

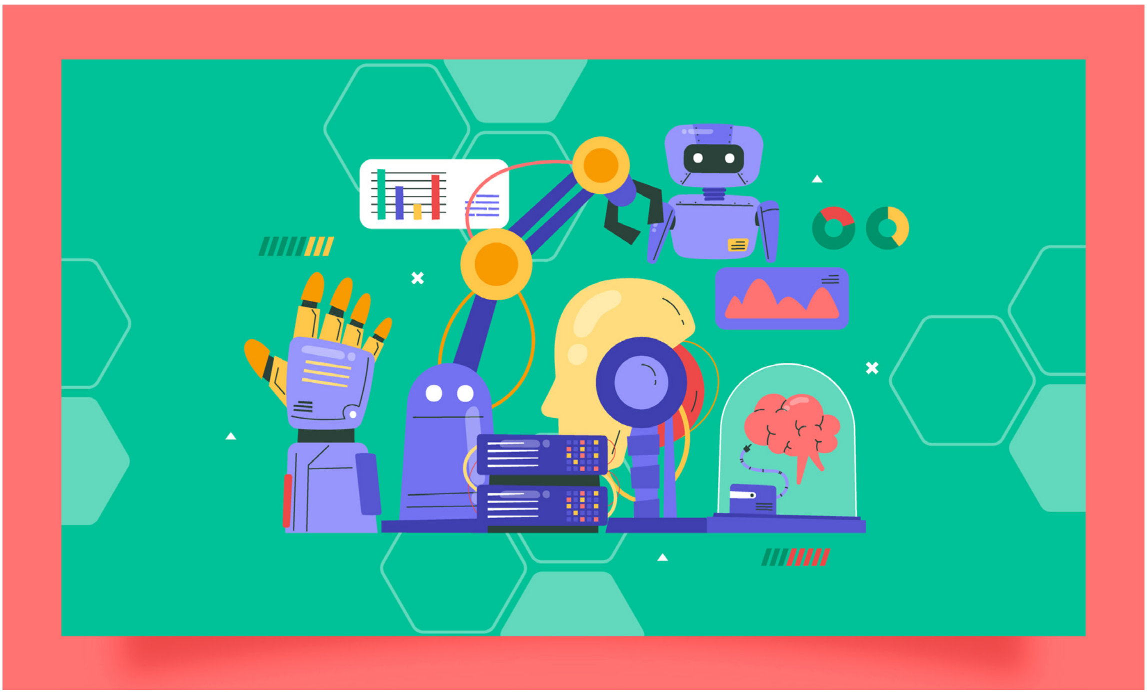

Figure 2. The Integration of Machine Learning and Robotics for Process Automation

The cost and return on investment (ROI) of robotic automation is often a key concern, particularly due to the high initial capital investment required. This leads to debates over the economic feasibility, especially for small and medium enterprises (SMEs). However, the long-term social benefits, such as reduced labor costs, increased productivity, and improved product quality, may ultimately outweigh the upfront costs. Now is the ideal time to assess the potential returns from automation to inform future decision-making.

In terms of safety and regulations, it is critical that standards are met to ensure the safe integration of robots in manufacturing processes. As robots become more prevalent, particularly in environments where humans work alongside them, safety concerns must be addressed through measures such as advanced sensors, safety protocols, and control systems. Ensuring these are in place will help guarantee both the efficiency of robotic operations and the safety of workers in these environments.

VI. Examples of Cases of the Theories in this Book [A10]

The automotive industry has been a leading adopter of robotic automation, with highly advanced robotized production lines now commonplace. These robots perform tasks such as welding, painting, and assembly with speed and precision, significantly enhancing both productivity and product quality. Robotics in this sector

© Freepik **Figure** 3. Robotic Process Automation

has streamlined operations, allowing for consistent output and greater efficiency. Similarly, the electronics manufacturing industry has also greatly benefited from automation, particularly through the use of automated inspection systems. These systems ensure that products meet strict quality standards by detecting deviations at any stage of the manufacturing process, thus maintaining high levels of consistency and reducing errors.

VII. Future Trends and Implications

The Industry is on the verge of going through the fourth industrial Revolution also known as the Industry 4. No such initiatives can be noted as aimed at including even more digital technology into the process of manufacturing. Robotics cannot be halted unto the future and with new technologies being built in AI-ML-IoT[A11] , there will surely be complex systems in the future. They will change the production process and also, management is expected to introduce changes at the level of a social system that impacts the labour market and promotes the economy's growth.

VIII. Conclusion

Robotic automation as a technique is becoming more popular on the manufacturing floor due to more benefits than before in issues to do with productivity, quality and flexibility. If these technologies are to be implemented by industries then there are number of challenges which are going to be faced such as cost factors, safety and concerns to do with the manpower. With all these advancements in technology, organizations is has been noted can benefit in the ever growing digital world through, trying to take advantage of every aspect of robots in an effort to transform the business world and come up with new inventions that will make them more competitive in the market.

IX. Recommendations

Strategic planning is crucial for industries to fully harness the potential of robotic automation. Establishing a robotic implementation plan in cycles allows organizations to tailor strategies based on their specific needs and capacities, ensuring that business targets are met effectively. Skill development is another essential component, as training programs must be introduced to equip workers with the necessary abilities to adapt to the evolving job market in a digital manufacturing environment. Enhancing workforce skills will enable employees to work alongside robots, thereby improving the overall efficiency of automation. Continuous improvement is equally important, as fostering a culture of progress ensures that automated processes are regularly evaluated and optimized. This approach helps companies remain competitive and responsive to changing market demands.

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Mr. Long Parkrigna, a dedicated PhD candidate in Electrical and Electronic Engineering at Universiti Kuala Lumpur, Malaysia, is committed to advancing knowledge in his field. With a Master's degree in Computing in Engineering Systems from King Mongkut's Institute of Technology Ladkrabang and dual Bachelor's degree in Informatics Engineering from IKMI Cirebon, Indonesia and Bachelor of Technology (B.Tech.), Computer Science from National Polytechnic Institute of Cambodia/National Polytechnic Institute of Cambodia, he has a strong academic foundation.

His research focuses on cutting-edge developments in electrical and electronic engineering, aiming to push boundaries and find practical solutions to complex problems. Engaged in rigorous research activities, he is driven by a passion for discovery and a desire to make meaningful contributions to his field.His research focuses on cutting-edge developments in electrical and electronic engineering, aiming to push boundaries and find practical solutions to complex problems. Engaged in rigorous research activities, he is driven by a passion for discovery and a desire to make meaningful contributions to

Reimagining Domestic Life: The Potential of IoT in Cambodia's Connected Homes

Long Pakrigna
PhD Candidate
Electrical and Electronic Engineering
Universiti Kuala Lumpur, Malaysia

Samok Ponloeu
Master of Science
Computer Science
University of East London, United Kingdom

Toch Ensophea
Dual Major: Bachelor of Science
Computer Science & Data Science,
ACLEDA Institute of Business & TUX Global Institute,
Cambodia

Highlight

- The way we live at home is changing thanks to smart home technology. Imagine your home is like a super-smart assistant.
- Smart home technology uses devices you control with your phone or even your voice to make your life easier and more comfortable. For example, you could turn on lights before you arrive home or adjust the thermostat from your phone.
- These devices are called smart home devices, and they connect to the internet to allow remote control and automation. This document explores how these smart homes are changing life in Cambodia, the challenges and opportunities they present, and what the future holds.

I. Current Landscape of Connected Homes in Cambodia

According to a recent survey conducted by the Ministry of Industry, Science, Technology and Innovation, approximately 25% of urban households in Cambodia have integrated at least one smart home device into their homes. This means that roughly 1 in 4 homes in Cambodian cities have some smart technology. However, rural areas face challenges due to limited access to reliable internet connectivity and electricity. Despite these challenges, the Cambodian market has seen a rise in the number of different smart home devices available, with local companies such as Tech Innovations Ltd. and Smart Solutions Co. emerging as key players by providing affordable and innovative solutions tailored to the needs of

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Cambodian consumers.

II. Challenges and Opportunities

There are some unique challenges to consider when it comes to adopting connected homes in Cambodia, such as affordability, internet access, and electricity stability. Many Cambodian households, particularly in rural areas, struggle with the upfront costs of purchasing smart home devices. They may also lack the technical knowledge for effective installation and maintenance. Intermittent power outages and unreliable internet connectivity can also prevent smart home technology from working smoothly.

However, connected homes offer promising opportunities to address specific needs and challenges in Cambodia. For instance, smart home devices with features like automated power management systems can help people optimize their electricity consumption and reduce utility bills, especially in areas with limited access to affordable energy resources. Smart security systems can enhance safety and provide peace of mind to Cambodian families, particularly in urban areas with rising crime rates.

III. Impact on Domestic Life in Cambodia

The integration of smart devices is reshaping domestic life in Cambodian households, offering benefits such as convenience and energy savings. Families can remotely control home appliances and lighting systems using their smartphones, streamlining daily tasks and reducing energy wastage. IoT-enabled home security systems provide an added layer of protection against theft and intrusions, contributing to a sense of security and well-being.

However, the adoption of connected homes also raises important questions concerning privacy, data security, and potential socioeconomic disparities, which must be addressed. Some Cambodian households may express concerns about privacy and data security, fearing potential misuse of personal information collected by IoT devices. Furthermore, the reliance on technology may exacerbate existing socioeconomic disparities, widening the digital divide between urban and rural communities.

IV. Case Studies and Examples

Several case studies exemplify successful implementations of connected home technology in Cambodia. For instance, the "Smart Villages" project, initiated by the Ministry of Posts and Telecommunications in collaboration with local NGOs, aims to provide rural communities with access to affordable IoT devices and training programs. Through this initiative, participating households have reported significant improvements in energy efficiency, agricultural productivity, and quality of life.

Similarly, the "Safe Homes" program, launched by a coalition of government agencies and private sector partners, focuses on deploying smart security systems in high-crime areas across major cities in Cambodia. As a result, participating households have experienced a reduction in crime rates and an increased sense of safety and security within their communities.

V. Policy and Regulatory Landscape

The Cambodian government recognizes the potential of IoT technology to drive economic growth and improve quality of life for its citizens.

In 2023, the Ministry of Posts and Telecommunications unveiled the National Strategy for IoT Development, outlining key priorities and initiatives to promote innovation and investment in the IoT sector. Additionally, the government has implemented regulatory frameworks to safeguard consumer rights and ensure the responsible use of IoT devices.

However, challenges persist in aligning policy objectives with the evolving needs of the connected home market. Regulatory barriers, such as import tariffs and certification requirements, can hinder the importation and distribution of IoT devices, stifling market growth and innovation. Moreover, limited enforcement capacity and bureaucratic inefficiencies pose additional challenges to effective policy implementation.

VI. Future Outlook and Recommendations

Looking ahead, the future of connected homes in Cambodia holds immense promise for transforming domestic life and driving sustainable development. To realize this potential, stakeholders must prioritize several key recommendations:

- Enhance affordability and accessibility of IoT devices through targeted subsidies and financing schemes.
- Expand internet infrastructure and improve connectivity in rural areas to facilitate widespread adoption of connected home technology.
- Strengthen consumer education and awareness initiatives to build trust and confidence in IoT devices and cybersecurity measures.
- Foster collaboration between government, industry, and civil society to develop comprehensive policies and regulatory frameworks that promote innovation and protect consumer rights. This could involve creating public-private partnerships to develop and implement new technologies, as well as establishing clear guidelines for data privacy and security.

VII. Conclusion

In conclusion, connected homes offer a transformative opportunity to reimagine domestic life in Cambodia, unlocking new possibilities for convenience, efficiency, and security. While challenges remain in terms of affordability, accessibility, and regulatory frameworks, the benefits of IoT technology far outweigh the barriers. By embracing innovation, fostering collaboration, and prioritizing the needs of its citizens, Cambodia can pave the way for a brighter and more connected future for all.

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Alternative Substrates for Sustainable Oyster Mushroom Production in Cambodia

10

Sour Vannak
Master's Degree, Agricultural science (Biocontrol)
King Mongkut's Institute of Technology ladkrabang
Thailand

Bo Chanveasna
Master's Degree, Agriculture in Food Security and Agricultural Development, Kyungpook National University, Republic of Korea

Highlight

- Oyster mushrooms (OM) can grow on various types of cellulose, a substance found in plant cell walls. Typically, growers use para rubber sawdust as the primary substrate.
- Residues from crop cultivation, such as rice straw, mango and cashew sawdust, corn cobs, and oil palm empty fruit bunches (EFB), can be used as alternative substrates to para rubber sawdust.
- Using alternative substrates for OM cultivation can increase farmers' incomes, reduce agricultural waste, and lower production costs, contributing to national food security and sustainable agricultural production.

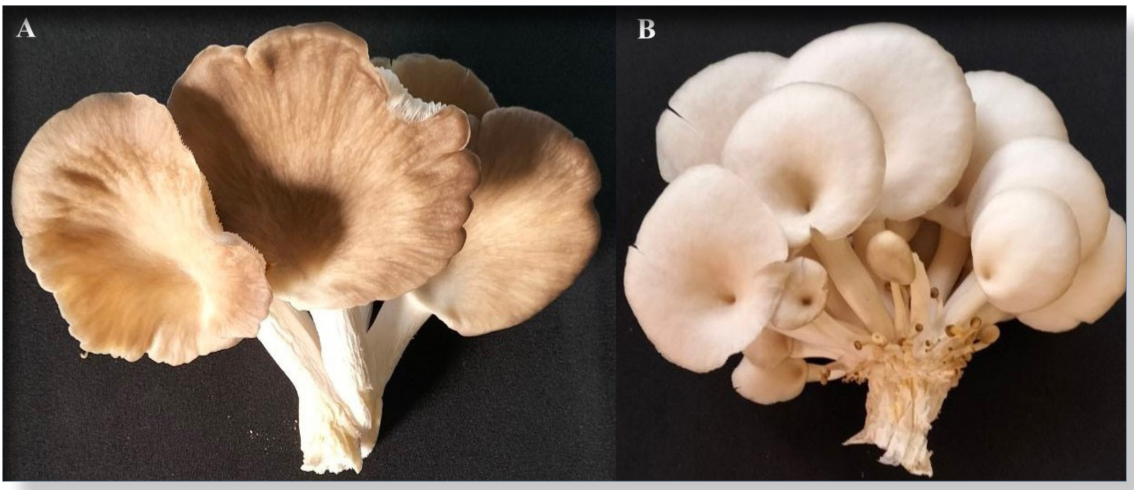

Figure 1. Oyster mushroom most cultivated in Cambodia, cultivar Phuthan (a), cultivar Hongry (b)

I. Introduction

Cambodia experiences a tropical climate characterized by distinct wet and dry seasons. The warm temperatures and high humidity, create ideal conditions for cultivating various types of mushrooms (Nongthombam et al., 2021). Among the numerous mushroom species, the OM (*Pleurotus* spp.) is widely cultivated and utilized in many Cambodian recipes (Srey, 2019). OM are saprophytic fungi that thrive by decomposing lignocellulosic materials, making them highly efficient at growing on various agricultural wastes

(Khan et al., 2011). This adaptability to different substrates, combined with their short lifecycle, makes OM an ideal candidate for sustainable mushroom cultivation, particularly in regions where agricultural by-products are abundant (Sharma et al., 2013).

The cultivation process typically begins with mixing the substrate, which generally consists of sawdust, with mushroom nutrients. This mixture is then sterilized before being inoculated with mushroom spawn. After inoculation, the substrate bag logs are exposed to a nursery environment with high humidity to induce the fruiting bodies (Pathmashini et al., 2009). Generally, growers utilize para rubber sawdust from Kampong Cham and Thbong Khmum province, where there are extensive para rubber plantations and wood processing factories (Hosoishi et al., 2013). The rise in OM cultivation in the country has increased the demand for para rubber, leading to shortages and rising costs. In response to this issue, we successfully demonstrated that cashew sawdust can be used as an alternative to para rubber (Sour et al., 2024). Additionally, other agricultural waste could also be efficiently utilized for OM production. The objective of this review is to mention some alternative substrates in Cambodia that could be used for OM cultivation instead of para rubber sawdust.

II. Alternative substrates for oyster mushroom production

Wood is primarily composed of cellulose and hemicellulose, polysaccharides that provide structural integrity to plant cell walls. These components are ideal for mushroom cultivation, serving as rich sources of carbon and energy for fungi (Mercy et al., 2011). Nevertheless, growers should mix these woody wastes with other mushroom nutrients to enhance their growth rate and yields. The OM substrate pH level should ideally range from 5.5 to 7.5, the substrate should have a nitrogen content of about 1.5% to 3%, promoting robust mycelial growth while preventing excessive competition from contaminants (Khan et al., 2013; Salami et al., 2016).

Cambodia, an agricultural country, produces a variety of economic crops such as rice, cashew, mango, corn, and oil palm, which generate residues including rice straw, cashew or mango sawdust, corn cobs, and EFB (Theng et al., 2022). These crop residues can all be utilized as substrates for OM production (**Table 1**).

Table 1. Some economic crop residues which could use as OM cultivation (MAFF, 2022)

No.	Crop	Cultivation area (hectare)	Most Cultivated Province	Type of residue
1	Rice	3,552,738	Battambang	Rice straw
2	Cashew	405,991	Kampong Thom	Sawdust
3	Mango	152,073	Kampong Speu	Sawdust
4	Corn	33,512	Tbong Khmum	Corn cob/leaves
5	Oil palm	19,490	Sihanouk	Empty fruit bunch

Rice straw could be an optimal substrate for OM cultivation given Cambodia's extensive rice production during both the rainy and dry seasons. Preparing rice straw is quite similar to that of sawdust: first, the straw is wetted and then cut into lengths of 15–20 cm before being mixed with mushroom nutrients, packed into bag logs, and sterilized prior to inoculating with mushroom spawn. However, a drawback of using rice straw is the additional time required for cutting, and it produces fruiting bodies over a relatively short period, approximately one month (Yang, 2013).

Cashew and mango tree have been cultivated in vast area across country. Normally, they produce fruit approximately 3 – 5 years after planting and after that 10 – 15 years, the tree could be old and tall which difficult to take care, so the growers always cutting and then the wood factory would process them and remain a waste as sawdust. The process of utilize cashew and mango to cultivate OM is the same with para rubber sawdust. Nevertheless, using cashew and mango sawdust possibly couldn't reduce substrate cost due to growers have to buy it from wood factory same as para rubber sawdust (Sour et al., 2024; Biswas et al., 2016).

Figure 2. Oyster mushroom cultivation process, substrate mixing (a), OM spawn injection (b), induce OM fruiting body in nursery (c)

Corn cobs and leaves are often left behind after the harvest. Utilizing these residues as substrates for oyster mushroom cultivation has the potential to increase the value of corn and reduce agricultural waste. Corn cobs or leaves need to be ground or cut into small pieces, soaked in water, drained, mixed with mushroom nutrients, packed into mushroom bags, sterilized, and inoculated with mushroom spawn. A potential drawback of using corn residues as substrates is the risk of contamination by *Aspergillus* spp., which can destroy the mushroom spawn. Therefore, careful attention should be given to the sterilization process (Nurudeen et al., 2013).

Table 2. Yields of oyster mushrooms from different substrates

No.	Crop Residues	MC[a]	YD[b]	AW[c]	References
1	Rice	25.00	1.50	257.20	Zhang et al., 2002
2	Para rubber	31.70	3.00	235.67	Sour et al., 2024
3	Cashew	37.50	3.00	224.28	Sour et al., 2024
4	Mango	31.50	3.00	257.75	Khan et al., 2012
5	Corn	41.20	2.00	76.25	Rakib et al., 2020
6	Oil palm	35.00	3.00	257.50	Marlina et al., 2015

a/ Mycelium growth duration to complete bag log (days)

b/ Duration of oyster mushroom produce fruiting body (months)

c/ Average oyster mushroom fresh weight per 1kg bag log (g)

Oil palm crops are extensively planted in Sihanouk Province, primarily by oil processing factories. The remaining empty fruit bunches (EFB) can be used as substrates for cultivating OM. EFBs are cut into small pieces, mixed with mushroom nutrients, packed into polyethylene bags, sterilized, and inoculated with OM spawn. However, a disadvantage of using EFBs is the time-consuming process of cutting them into small pieces, and the limited distribution of planting areas across the country (Marlina et al., 2015).

OM cultivated on these substrates can yield significantly different nutritional profiles and biomass. These substrates offer unique benefits such as being rich in lignin and cellulose, enhancing mushroom yield, or promoting faster colonization (**Table 2**). Most of previous studies focus on mushroom yields and some focus on mushroom's nutrition or medicinal properties (Patel et al., 2012). Overall, these substrates not only support substantial yields but also influence the nutritional value of the mushrooms, which can vary in protein, fiber, and mineral content based on the substrate composition (Khan et al., 2012; Marlina et al., 2015).

Figure 3. Wood processing factory in Tbong Khmum province

III. Conclusion

Being an agrarian country, Cambodia generates a significant amount of agricultural waste or residues that can be utilized for OM cultivation. Rice straw, mango and cashew sawdust, cobs and leaves of corn and oil palm fruit bunches are all suitable alternative substrates for OM production. However, selecting the appropriate substrate should be based on factors such as production costs, resource availability, ease of processing, yield collection duration, and total mushroom yield, all of which contribute to achieving the highest profit for sustainable production.

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Mr. Sour Vannak is a lecturer and researcher at Department of Agronomy of Kampong Speu Institute of Technology. He holds a Master in Agricultural Science from King Mungkut's Institute of Technology Ladkrabang, Thailand in 2016, and a Plant Science degree from Rajamangala University of Technology Tawan-ok Chanthaburi campus in 2013. Currently he pursues a PhD in Agricultural and Environmental Science (International program) in Khon Kaen University, Thailand. His researches focus on Plant Physiology specific in Plant Water Consumption.

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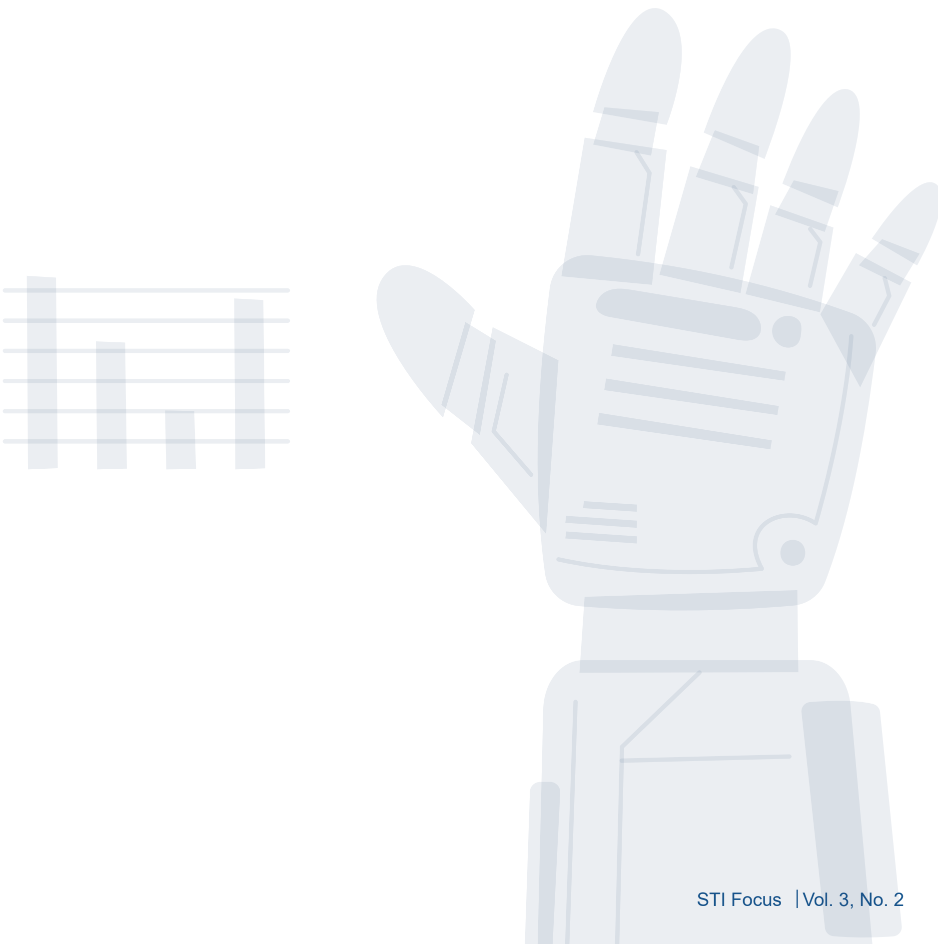

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