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Full Length Research Paper

The prevalence of respiratory tract infections in the Ghaem Hospital of Mashhad

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Respiratory tract infection is a serious concern for public health worldwide, and imposes a lot of pressure on health facilities, specifically in developing countries along with economic restrictions. This study evaluated the prevalence of bacterial pathogens and their antibiotic sensitivity pattern among patients with respiratory tract infection in Ghaem Hospital, Mashhad, east of Iran during the 3 years period. All clinical isolates were identified by conventional biochemical tests. Antibacterial susceptibility testing was performed by disc diffusion method following clinical and laboratory standards institute (CLSI) guidelines. Among 4897 clinical respiratory samples, 3748 samples were positive. Out of 3748 culture positive, 42% were related to females and 58% to males. The prevalence of respiratory infections in our study reported 27.5%. Most isolates were obtained from the age group of 60-80 years old. The most common isolated were Acinetobacter spp. 37% and Klebsiella pneumonia 21%. Antimicrobial profile of Acinetobacter spp. and Klebsiella pneumonia showed maximum resistance to Amikacin 86.8 and 50.3% respectively. According to our study, the duration of hospitalization in the ICU, especially surgery ICU, is associated with an increased risk of respiratory infection. Therefore, infection control plays an important role in the ICUs.

Key words: Respiratory tract infections, Antibacterial susceptibility test, Intensive care unit.

INTRODUCTION

Respiratory tract infections (RTIs) are one of the common diseases which is the leading cause of mortality and account for more than 4 million fatalities annually (Khaltaev, 2017; Richter et al., 2016). Pneumonia accounted for 15% of the deaths in children aged under 5 years in 2015 (Khaltaev, 2017). also It is the second leading cause of untimely death and one of the most common reasons for hospitalization (Srinivasa and Shruthi, 2018).

Respiratory infections caused by a group of pathogens

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#Zohre Kaseb and Sepideh Hassanzadeh contributed equally to this work.

including viruses, bacteria and fungi (Srinivasa and Shruthi, 2018; Tang et al., 2019). The various types of bacteria which are involved in RTIs are *Acinetobacter spp.* , *Klebsiella pneumonia*, Pseudomonas aeruginosa and *Escherichia coli* (Wang et al., 2016). These infections are composed of upper respiratory tract infections (URTIs) and lower respiratory tract infections (LRTIs) (Khan et al., 2015). The causes of respiratory infections are influenced by the age, gender, season and pre-existing medical problems. Costs attributable to respiratory tract infection in patients settings are an important problem on national healthcare funds particularly in low income countries (Srinivasa and Shruthi, 2018; Ghanbari et al., 2018). Cases of RTIs reply to antibiotics treatment though antibiotics misuse since respiratory tract infection is prevalent particularly in developing countries and might lead to resistance (Khan et al., 2015). Therefore, the aim of this study was to consider bacterial pathogens of RTIs and their antibiotic resistance patterns among the patients in Ghaem Hospital settings over a period of 3 years.

This makes surveillance of antibiotic resistance very important for guiding experiential therapy, where health structures and patients must frequently rely on reasonable first-line antibiotics that may have lost their clinical effectiveness. Effective empirical therapy of bacterial diseases needs knowledge on local antimicrobial resistance patterns since respiratory tract infections are usually treated without identification of the causal pathogen or its antibiotics susceptibility profile (Camara et al., 2017).

MATERIALS AND METHODS

This study is a cross-sectional/descriptive study, which was designed during the 3 years period. It was conducted in all wards of the Ghaem Hospital, Mashhad. The Ghaem Hospital is one of the main hospitals in the East of Iran. Clinical tests were done by ward physicians, and during this time, examination for symptoms was conducted by the nurses.

A total of 4897 patients of heterogeneous population of a wide age range with suspected acute respiratory infection of community or hospital origin in Ghaem Hospital, Mashhad were attended in the present study between March 2017 and March 2020.

Specimen culture: The samples were collected from RTI patients. In the central Laboratory of Microbiology, samples were cultured on the enriched and selective media for example blood agar, chocolate agar, eosin methylene blue (EMB).

Identification of isolated organisms: After incubation for 24 hours, necessary examination including gram stain and morphological observation and use of biochemical tests as required to identify the organisms was performed (Khan et al., 2015).

Antibiotic susceptibility testing: Antibacterial susceptibility testing was done by the Kirby-Bauer disc diffusion method on Mueller Hinton agar plates using the following antimicrobial agents to determine resistance pattern for all of the isolated bacteria (Falahi et al., 2017).

RESULTS

In this study, from 4897 suspected patients in different wards of hospital, 3748 cases (76%) were reported of respiratory tract infection. Most of the patients were between 60 and 80 years old; with 58% males and 42% females (male/ female ratio 1.37). The age frequency is shown in Figure 1. Among the total 3748 bacterial isolates, the most frequency isolated Gram-negative organisms causing RTIs were including *Acinetobacter spp.* (1370; 37%), *Klebsiella pneumonia* (774; 21%), *Pseudomonas aeruginosa* (312; 8%), *Escherichia coli* (298; 8%), respectively. In addition, among the isolated Gram-positive organisms, Staphylococcus aureus (138; 4%) was the main pathogen (Table 1). The resistance pattern of bacteria isolated is shown in Table 2. The highly resistant in *Acinetobacter spp.* was observed to Amikacin (R=86.8%), Meropenem (R=88.1%), Cefepime (R=93.5%). Also, *Klebsiella pneumonia* showed high resistance to Amikacin (R=50.3%) and Ceftazidime (R=85.1%).

DISCUSSION

Respiratory infections are considered as one of the main causes of annual mortality in over 4 million people worldwide and as well as the main death factor in developing countries. The infections caused by these infections are responsible for 15 % of the deaths in children under age 5. Respiratory infections are also the second major cause of the deaths during the last years of life (Khaltaev, 2017). Studies of Asian countries showed that a total of 12 million deaths was a quarter of it related to the respiratory causes, which the respiratory infections accounted for about a third of it (Jamrozik and Musk, 2011).

According to the results of the present study, respiratory infections accounted for 27.5% of the Ghaem Hospital infections, which are considered the second most common infection after the urinary infection. The prevalence of respiratory infections in the study of Zahraei et al*.,* in Tehran showed 24.6% (Zahraei et al., 2012). Another study done by Malhotra et al. (2014) showed the prevalence of respiratory infections by 23.3%. The results of these studies are in agreement with the present study. While in other studies including the study of Ho et al. (2018) in Vietnam, Ghafouri et al. (2015), Hasanzade et al. (2009), Falahi et al. (2017), Farzanpour et al. (2013) in Iran, the prevalence of infection was reported 67.6, 65.2, 47.7, and 44%, respectively (9, 13-16). Furthermore, the study of Akhtar N in Pakistan reported an incidence of respiratory infections of 47.9% (Akhtar, 2010). The study of Rachid Razine et al*.,* in Morocco showed a lower prevalence of respiratory infections (10.6%) in the region (Razine et al., 2012). In the present study, the total of 3748 positive samples was 1580 samples (42%) related to females and 2168 samples (58%) related to males, that are similar to the results of Salman Khan et al. (2015).

The prevalence of respiratory infections was higher in people over 50 years of age, which emphasizes the direct

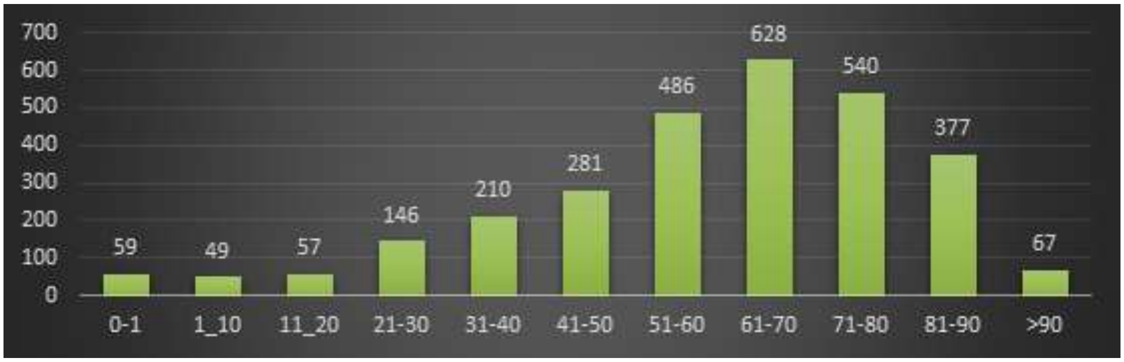

Figure 1. Age distribution analysis of patients with respiratory tract infections at Ghaem Hospital.
Source: Authors.

Table 1. Gender-based prevalence of respiratory tract infection pathogens at Ghaem Hospital.

Bacterial species	Number of isolates	Percentage	Number of patients	Female	Male
Acinetobacter sp.	1370	37	1119	520	599
Klebsiella pneumoniae	774	21	695	263	432
Pseudomonas aeruginosa	312	8	284	126	158
Escherichia coli	298	8	279	100	179
Staphylococcus aureus	138	4	137	51	86
Enterobacter sp.	113	3	124	53	71
Pseudomonas sp.	127	3	110	38	72
Staphylococcus epidermidis	106	3	104	51	53

Source: Authors.

Table 2. Antibiotic resistance patterns of bacterial species isolated at Ghaem Hospital.

Antibiotics	Bacterial species			
	Acinetobacter sp.	Klebsiella pneumonia	Pseudomonas aeruginosa	Escherichia coli
Amikacin	86.8	50.3	55.5	19.2
Meropenem	88.1	64.3	64.5	14.2
Cefepime	93.5	82.9	73.3	72.9
Imipenem	86.4	54.7	58.9	33
Gentamicin	86.2	67	53.4	41.1
Ceftazidime	96.2	85.1	53.5	64.5
cefazolin	98.7	92	96	89.1
Ciprofloxacin	93	69.4	61.1	71.8
Ceftriaxone	96.1	91.2	77.2	77.6
Cefotaxime	97.1	88.8	80.9	75.4

Source: Authors.

relevance between the incidence of respiratory infections with increasing age and repelling the immune system. In the study of Ghafouri et al. (2015) in Imam Reza Hospital in Bojnourd, the average age of these patients (54.3)was almost identical to the average age of study patients.

There are definite risk factors related with respiratory tract infection like length of stay in the hospital, underlying immunocompromised illnesses, age of over 50 years the patient (Malhotra et al., 2014). The study of Nadi et al. in Hamedan Educational hospitals showed 28% of those infected with pneumonia in the age range over 65 (Nadi et al., 2011). In addition, Ismaili et al. (2007) studies at the Baqiyatallah Hospital, Jafari et al. (2006) in Tehran, Larypoor and Frsad (2011) in the Ghom are aligned with the results of the Nadi and present study (Esmaeili et al., 2007; Jafari et al., 2006; Larypoor and Frsad, 2011); whereas in some other studies, younger age groups were affected. The study of Salman Khan et al. (2015) in Nepal, included about 33% of the patients with respiratory infections in the age group of 1-10 years (Khan et al., 2015). In the study Li - min, Wang et al. have also been identified as 51% bacterial isolate related to the age group of 5-25 (age of school and university) (Wang et al., 2016). Also in the study of Srinivasa S was done in India for one month to five years, 48% of the cases were 6 months to 2 years (Srinivasa and Shruthi, 2018).

According to the results of this study, *Acinetobacter spp*. (35%) and second *klebsiella pneumonia* (20%) are the most common bacterial pathogens isolated from respiratory samples of Ghaem Hospital. Also, in a study conducted in the same center in the 83 and 84 years (Ghazvini et al., 2006), the same bacterial frequency was reported.

The result of Pradhan et al. (2014) study in India reported *Acinetobacter* as the most common pathogens isolated in respiratory infection. While in the studies of Sadeghi et al., in Yahyanejad hospital (Sadeghi et al., 2009) and Nadi et al. (2011) in Hamedan (Nadi et al., 2011) *Enterobacter* is the most common bacterial pathogens isolated from respiratory samples. It is also the most common pathogens in the study of Li– min wang et al. in china Haemophilus influenzae and Staphylococcus aureus (Wang et al., 2016) and in the study of Salman Khan et al. (2015), which were consistent with the results of our study.

The results obtained from the pattern of antibiotic resistance in this study indicate that Acinetobacter spp. have the highest resistance to Amikacin, Meropenem and Cefepime. Also, *Klebsiella pneumonia* showed maximum resistance to Amikacin and Ceftazidime. In other studies, different patterns of antibiotic resistance have been reported. In a study conducted by Ghafouri et al. (2015) in Imam Reza hospital at Bojnurd, the highest resistance rate was observed in Acinetobacter, which 100% of the cases were resistant to Amikacin, Ciprofloxacin, Gentamicin.

In the study Imani et al. (2015) at the Baqiyatallah hospital, 100% of isolated *klebsiella* species, showed resistance to the Amikacin and Amoxicillin. Whereas, according to the results of Golam Sarower Bhuyan, 100% of *klebsiella pneumonia* species had resistance to the Azithromycin (Bhuyan et al., 2017). According to the studies, antibiotic resistance in different regions of Iran and the world is different due to the genetic variation of pathogens and the difference in antibiotic use.

To prevent the rise of bacterial resistance, the determination of the resistance pattern and sensitivity by antibiogram method for bacterial pathogens is necessary and should be taken from the experimental or unnecessary prescription of antibiotics and treat the patient at the right time. This research has the highest prevalence of infection in the intensive care unit, especially the surgical ICU and stroke ICU. The intensive care unit (ICU) is one of the high - risk areas for respiratory infections because of the severity of the disease and increased hospitalization (Kayaaslan, 2016). So, it is very important to identify the underlying factors of infection in the ICU and control and prevent them, and Ventilation.

Conclusion

We found that RTIs accounted for 27.5% of total hospital infection. Due to the high prevalence of respiratory infections, especially in the special care unit and the importance of control, prevention and treatment of appropriate antibiotics in order to reduce the costs of hospital and death in these infections is essential in this study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Challenges and opportunities in advancing microbiology research in Africa: A review

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The need for efficient microbiology technologies in Africa has been a significant challenge to advancing microbiology research and study. This review examines the impact of this challenge and identifies the opportunities that exist to address them. These include the slow pace of research and development, the limited ability to identify and manage infectious diseases, and the challenge of monitoring and controlling food and water quality. The impact of the slow pace of research and development on microbiology is particularly concerning, as it limits the ability of African researchers to carry out complex microbiology experiments. This, in turn, limits the amount of knowledge that can be generated about various aspects of life, including human health, agriculture, and environmental science. Despite these challenges, this article identifies opportunities for addressing Africa's lack of efficient microbiology technologies. One opportunity is the development of specialised research facilities that can support microbiology research in the continent. Another opportunity is training researchers and technicians to ensure they are equipped with the necessary skills and knowledge to carry out microbiology research. The need for efficient microbiology technologies in Africa has significantly impacted microbiology research and study on the continent. By investing in specialised research facilities, providing training for researchers and technicians, and increasing access to funding for research and development, it is possible to improve the pace of microbiology research and generate new knowledge about various aspects of life in Africa.

Key words: Technologies, Laboratory techniques, Diagnostic methods, Capacity building, Education.

INTRODUCTION

Microbiology's development as a science confounds the history of biotechnological techniques in humanity. Microbiological technologies refer to a wide range of tools and techniques used to study microorganisms, including bacteria, viruses, fungi, and protozoa. These technologies have revolutionised our understanding of microbiology and have enabled scientists to explore the diversity and complexity of microbial life (Tortora et al., 2016; Madigan et al., 2018). Some common microbiological technologies include: Microscopy (Figure 1) uses microscopes to

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Figure 1. Some common microbiological technology devices (Some images of various microscopes types) used. A microscope is an instrument that is used to magnify small objects. Microscopes opened a window into the invisible world of microorganisms. Some microscopes can even be used to observe an object at the cellular level, allowing scientists to see the shape of a cell, its nucleus, mitochondria, and other organelles.
Source: https://thebiologynotes.com/types-of-microscopes/#2-compound-microscope

visualize and study microorganisms. Different types of microscopes, such as light, electron, and fluorescence, can reveal different aspects of microbial morphology, structure, and behavior. Culture techniques (Figure 2) involve the cultivation of microorganisms in the laboratory using nutrient-rich media. These techniques are used to isolate and identify microbial species, study their growth characteristics, and test their susceptibility to different antimicrobial agents. Polymerase chain reaction (PCR) (Figure 3) is a technique that amplifies small amounts of DNA or RNA from microorganisms, allowing their detection and identification. PCR has become an important tool in microbial diagnostics and research. Next-generation sequencing (NGS) (Figure 4) technologies allow the rapid and high-throughput sequencing of microbial genomes, enabling the study of microbial diversity, evolution, and function. Examples of NGS platforms include Illumina, PacBio, and Oxford Nanopore. Bioinformatics (Figure 5) uses computational tools and databases to analyse and interpret large-scale microbial data. Bioinformatics is crucial in analysing NGS data and integrating diverse microbiological data sets (Tortora et al., 2016; Madigan et al., 2018).

Molecular evidence from the Neolithic village of Jiahu in China dates to 7000 BC and shows the first use of microorganisms to ferment cereal grain to produce an alcoholic beverage (McGovern et al., 2004; Vitorino and Bessa, 2017). In northern Mesopotamia, evidence for similar dating dates back to 5400–5000 BC and was discovered in the Zagros Mountains (McGovern et al., 1996). An old jar at the Neolithic site of Tepe in Mesopotamia that was also dated to 5400–5000 BC, which contains tartaric acid, is the first indication that wine was produced (McGovern et al., 1996), while grape juice residues found in Dikili Tash, Greece, have also been dated to 5000 BC (Valamoti et al., 2007; Vitorino and Bessa, 2017). This evidence suggests that these civilisations began producing wine on a large scale in 5000 BC, based on their technological process (Borneman et al., 2013). As a result of the empirical domestication of yeasts (Sicard and Legras, 2011), fermentation practices developed and spread throughout

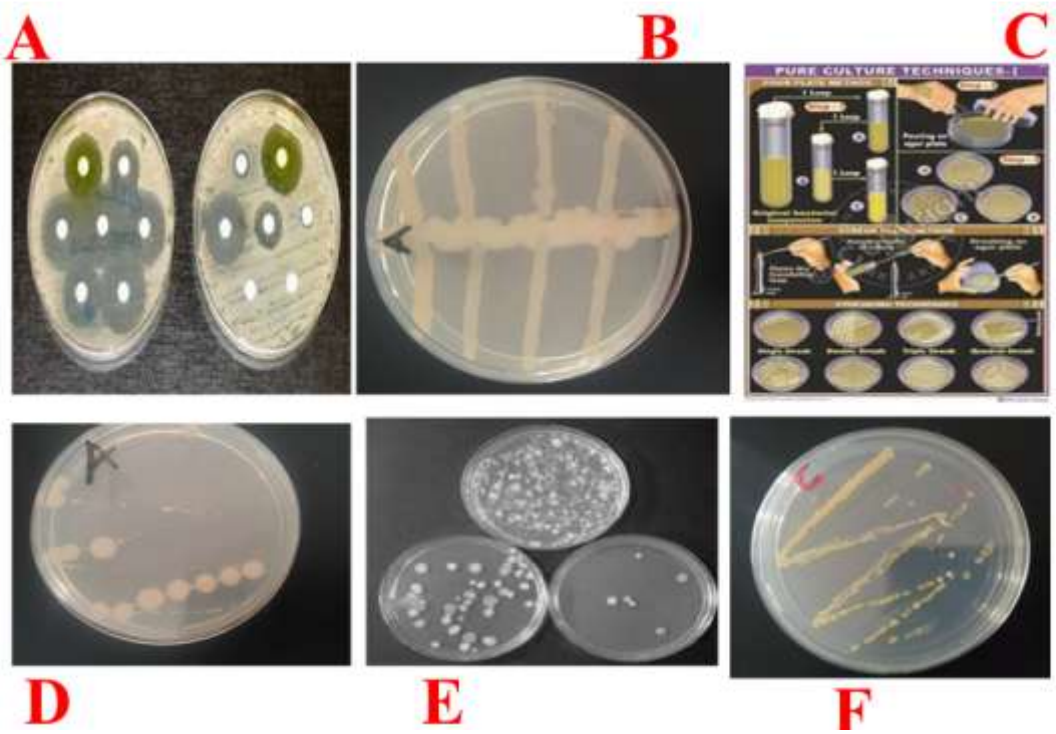

Figure 2. Showing the culture techniques. Culture methods involve taking samples from the field and detecting the presence of microbe by culturing them. From the amount of microbial species their influence on corrosion is estimated. Culture media to grow different microbes have been established. Note: A shows the antagonize effects of a bacteria on an antibiotics; B shows the compatibility of two different bacteria; C shows the different forms of culture methods; D, E and F shows the growth of a bacteria on culture plate through spread and strike methods.
Source: https://www.cdc.gov/microbes/bacteria.html

Figure 3. Showing various types of Polymerase chain reaction (PCR). Polymerase chain reaction PCR method. PCR is a very sensitive technique that allows rapid amplification of a specific segment of DNA. PCR makes billions of copies of a specific DNA fragment or gene, which allows detection and identification of gene sequences using visual techniques based on size and charge.
Source: https://www.thermofisher.com/us/en/home/life-science/cloning/pcr-amplification/pcr-basics/what-is-pcr.html

Figure 4. Showing various forms of Next-generation sequencing (NGS). Next-generation sequencing (NGS) is a massively parallel sequencing technology that offers ultra-high throughput, scalability, and speed. The technology is used to determine the order of nucleotides in entire genomes or targeted regions of DNA or RNA.
Source: https://www.illumina.com/techniques/sequencing/ngs.html

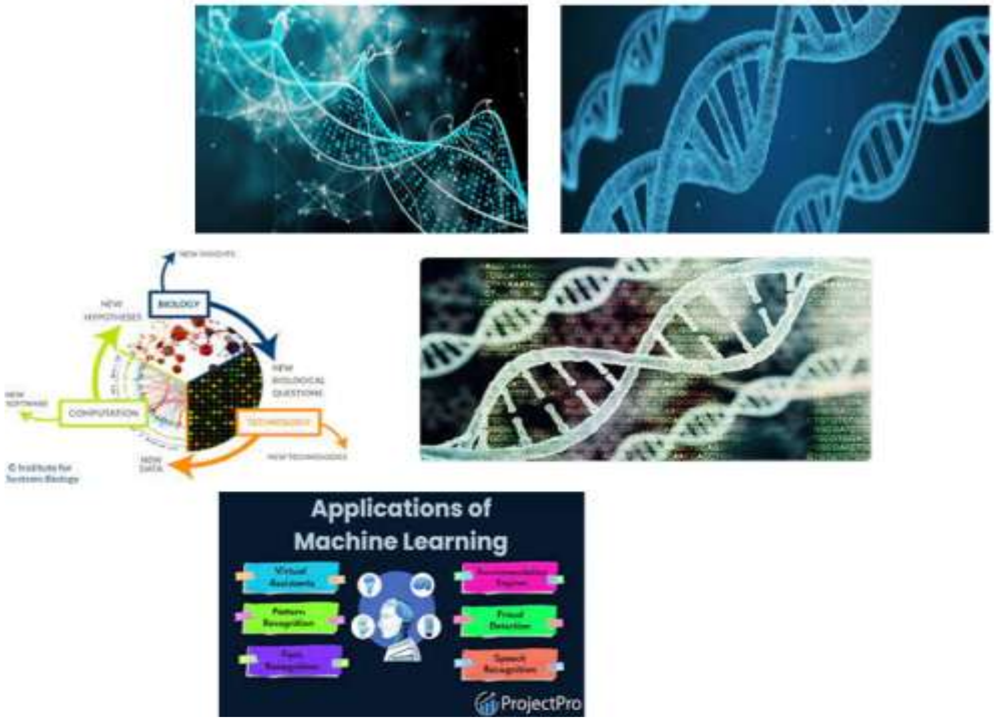

Figure 5. Showing some images of Bioinformatics learning's. Bioinformatics uses biology, chemistry, physics, computer science, computer programming, information engineering, mathematics and statistics to analyse and interpret biological data. The subsequent process of analysing and interpreting data is referred to as computational biology.
Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4010455/

Asia, Mesopotamia, Egypt, and the Old World (Pasteur, 1857; Vitorino and Bessa, 2017). This led Louis Pasteur to explore the true causes of fermentation (Pasteur, 1857). Pasteur was approached in 1856 by an agricultural-industrial region in Lille that was facing production problems with beetroot-based alcohol. As a result, Pasteur began studying the fermentation of lactic acid and alcoholic alcohol (Gal, 2008). His appreciation of the microscopic universe propelled him to propose vaccinations against anthrax (1881) and rabies (1885) that were later used against the disease (Pasteur, 2002; Plotkin and Plotkin, 2011; Vitorino and Bessa, 2017). As a result of Pasteur's work, fermentation-based products were synthesised at an accelerated rate, and improvements were made to techniques that had already been developed. The results of his studies contributed to the formation of microbiology as a science, which initially focused on disease control through sanitary methods.

Technological Microbiology only attracted the market's attention after microbial products started being required on an industrial scale. A good example of this was the use of glycerol during World War I to manufacture explosives (Wang et al., 2001; Vitorino and Bessa, 2017) and the large-scale production of penicillin in the 1940s, thanks to Fleming's discovery (Neushul, 1993). As a result of a United States Supreme Court decision in the 1980s, technological microbiology is considered to have begun in the 1980s. In this case, a *Pseudomonas putida* variant was patented, which was effective in digesting organic compounds found in crude oil spills (Robinson and Medlock, 2005; Vitorino and Bessa, 2017). We learned that our ignorance of microbial diversity was enormous in the 1970s when Carl Woese and colleagues used a universally conserved sequence, the 16S rRNA molecule, as a taxonomic marker. As a result, a new prokaryotic domain, the Archaea, was concealed (Woese and Fox, 1977; Woese et al., 1990; Vitorino and Bessa, 2017). A recent discovery of genomics has revealed that the tree of life is even more complex than before, as two exceptionally complex and poorly studied groups have been identified (Spang and Ettema, 2016). Candidate Phyla Radiation is a bacterial group, while DPANN is a superphylum of Archaea. Based on these studies, we may continue to see the tree of life grow in the future. Further, although many archaea, such as Halobacterium, Pyrococcus, and Thermococcus, have already been recognised as having potential biotechnological applications (Coker, 2016; Waditee-Sirisattha et al., 2016; Vitorino and Bessa, 2017), Technological Microbiology will continue to provide new perspectives on the use of these species in developing new or improved products as new microorganisms with diverse nutritional requirements and metabolic profiles emerge. Classical Microbiology has therefore progressed through discovering new species, selecting and improving known strains, and introducing non-native genes to acquire expressed products or new functional traits (Vitorino and Bessa, 2017).

Africa faces significant challenges with respect to the development and adoption of advanced technologies, particularly in the area of aquaculture. The lack of adequate technological infrastructure has significantly limited the growth and expansion of this sector, hindering the development of microbiological applications in aquaculture. Microbiology is a vital field of study that is crucial for understanding various aspects of life. However, the need for efficient microbiology technologies in Africa has significantly impacted the advancement of microbiology research on the continent. With 54 countries, Africa is the world's second-biggest and most populated continent. Despite its vast natural resources, Africa needs to catch up in technological development. This review discusses the impacts of the lack of efficient microbiology technologies on microbiological research and the opportunities these topics present. The lack of efficient microbiology technologies in Africa has led to a slow pace of research and development in the field. With access to advanced technologies such as high-throughput sequencing, advanced microscopy, and advanced cell culture techniques, African researchers may find it easier to carry out complex microbiology experiments. The lack of efficient microbiology technologies also limits the ability to monitor and control food and water quality, leading to outbreaks of foodborne illnesses and other waterborne diseases. With advanced technologies, researchers can identify pathogens responsible for these diseases and develop effective treatments to prevent their spread. In addition, access to efficient microbiology technologies can help researchers conduct more in-depth studies of microorganisms and their interactions with humans and the environment. This knowledge can lead to the development of new treatments and preventative measures.

Microbiology research plays a crucial role in understanding infectious diseases, improving healthcare, and promoting sustainable development. Despite significant progress in recent years, microbiology research in Africa still faces numerous challenges that hinder its advancement. By conducting a review focused on the challenges and opportunities in this field, valuable insights can be gained, leading to the formulation of effective strategies to overcome these obstacles and maximize the potential for microbiology research in Africa. This study aims to shed light on the current state of microbiology research in Africa, identify the challenges it faces, and explore the opportunities for growth and development in this important scientific discipline. The study take into consideration the following: Technological microbiology in agriculture and aquaculture, technological microbiology in food, technological microbiology in chemical and fuel, science and technological microbiology in the environment, technological microbiology in the medical industry, Technological Microbiology of Materials, the molecular technology of microbiology, and technological microbiology in education.

METHODOLOGY

Literature search

For this study, the search databases covering Web of Science, Google Scholar, and subscribed journals served as Core Collections. Papers published up to 2022 were initially retrieved using amalgamations of several keywords. In addition, the studies found in the preliminary search were distinguished according to the relevance of the information they contained regarding microbiology research. Further classification of these papers was done according to the topics explored: Technological microbiology in agriculture and aquaculture, technological microbiology in food, technological microbiology in chemical and fuel, science and technological microbiology in the environment, technological microbiology in the medical industry, Technological Microbiology of Materials, the molecular technology of microbiology, and technological microbiology in education. In total, 79 publications reporting microbiology research were obtained in full-text format.

TECHNOLOGICAL MICROBIOLOGY IN AGRICULTURE AND AQUACULTURE

Agricultural/Aquaculture Technological Microbiology refers to the use of microorganisms in the agriculture and aquaculture industry to improve the productivity and quality of crops, livestock, and aquatic animals. Microbes are essential to the agricultural and aquaculture industry as they play critical roles in nutrient cycling, soil health, waste management, and disease control. Some of the applications of agricultural/aquaculture technological microbiology includes Biofertilizers: Microbes such as Rhizobium, Azotobacter, and Azospirillum are used as biofertilisers to enhance the nutrient uptake of plants and improve soil health. Biocontrol agents: Microbes such as *Bacillus thuringiensis*, *Trichoderma* spp., and *Pseudomonas fluorescens* are used as biocontrol agents to control pests and diseases in crops. Aquaculture probiotics: Probiotic bacteria such as Lactobacillus and Bifidobacterium are used in aquaculture to improve the health and growth of fish and shrimp (Amenyogbe et al., 2022a). Bioremediation: Microbes such as *Pseudomonas aeruginosa* and *Bacillus subtilis* are used for bioremediation of soil and water contaminated with pesticides and other pollutants. Fermentation: Microbes such as *Saccharomyces cerevisiae* and *Lactobacillus acidophilus* are used in the fermentation of food products such as yoghurt, cheese, and beer. Agricultural/ Aquaculture technological microbiology is an important field that has the potential to improve the sustainability and efficiency of the agriculture and aquaculture industry while reducing the environmental impact of these industries.

According to Nnaji and Dike (2020), the need for advanced microbiological technologies in Africa has made diagnosing and treating fish diseases difficult, resulting in significant economic losses for fish farmers. Moreover, the need for advanced technologies has also limited the ability of researchers to study microbial communities in fish ponds, which has hindered the development of effective strategies for maintaining optimal water quality in aquaculture systems. The lack of adequate technologies in Africa has hampered the development of advanced microbiological applications in aquaculture in most African countries with the exception of few such as South Africa and Egypt. Microbiological applications such as probiotics, prebiotics, and synbiotics have improved aquaculture species' growth and health, reduced antibiotic use, and enhanced disease resistance (FAO, 2016, 2018a, 2018b, 2019; Goddard, 2018). However, the application of these microbiological products is heavily dependent on the availability of advanced technologies such as bioreactors, sophisticated laboratory equipment, and high-speed internet connectivity for data analysis and transfer. The absence of such technologies in many parts of Africa has significantly limited the application of microbiological solutions in aquaculture, hindering the growth and development of the sector (Naylor et al., 2009; Gallois and Lafont, 2016; Oyebanji et al., 2017).

Several strategies can be employed to address the lack of technologies in Africa and their impact on microbiological use in aquaculture. First, governments and private sector organizations can invest in the development of advanced technological infrastructure, such as bioreactors and laboratory equipment, to support the production and application of microbiological solutions. Second, collaborations between African and international research institutions can be established to facilitate the transfer of knowledge and expertise on microbiological solutions for aquaculture. Third, training and capacity-building programs can be developed to equip local farmers and aquaculture practitioners with the necessary skills and knowledge to adopt and apply microbiological solutions in their operations. Fourth, initiatives such as public-private partnerships and venture capital investments can be encouraged to support the development and adoption of advanced technologies in aquaculture.

TECHNOLOGICAL MICROBIOLOGY IN FOOD

Food Technological Microbiology refers to the study of microorganisms that are involved in food production, preservation, and spoilage. Microbes play a significant role in the food industry, as they can be utilised to improve the quality, safety, and shelf life of food products. Some of the applications of Food Technological Microbiology include Fermentation: Microbes such as *lactic acid* bacteria, yeast, and mould are used in the fermentation of various food products such as bread, cheese, yoghurt, and alcoholic beverages. Food preservation: Microbes such as *lactic acid* bacteria and propionibacteria are used in the production of fermented sausages and cheese, which can be stored for a long time due to the presence of organic acids and low pH. Food safety: Microbes such as *Salmonella*, *Escherichia coli*, and *Listeria monocytogenes* can cause foodborne illnesses, and their detection and control are crucial for ensuring food safety. Probiotics: Microbes such as *Lactobacillus* and *Bifidobacterium* are used as probiotics in functional foods to improve gut health and boost the immune system. Biopreservation: Microbes such as bacteriocin-producing lactic acid bacteria are used in biopreservation to inhibit the growth of spoilage and pathogenic bacteria in food. Food Technological Microbiology is a critical field in the food industry. It provides solutions to improve food quality, safety, and shelf life while reducing food waste and environmental impact.

The lack of technology has hindered the growth and development of food technology microbiology in many countries in Africa, however, this may not be the case in countries such as South Africa, Egypt and Nigeria Food processing, storage, and preservation become challenging without adequate technology, leading to food spoilage and contamination. Furthermore, the lack of technology makes conducting research and development in the food industry difficult, limiting innovation in the food industry. Additionally, the absence of modern technology in Africa has led to using traditional food preservation methods, which are often inefficient and ineffective. For instance, smoking and sun-drying are common traditional food preservation methods in Africa. However, they can lead to the growth of bacteria, fungi, and other microorganisms, leading to food spoilage and contamination (Adebowale et al., 2008; Oyebanji et al., 2017). Moreover, the lack of technology has also limited the adoption of food safety practices, leading to a high incidence of foodborne illnesses. Inadequate monitoring and surveillance of food products have led to the consumption of contaminated food, leading to outbreaks of diseases such as cholera, typhoid, and salmonellosis.

TECHNOLOGICAL MICROBIOLOGY IN CHEMICAL AND FUEL

Chemical and Fuel Technological Microbiology refers to the use of microorganisms to produce chemicals and fuels through biological processes. Microbes can produce a wide range of chemicals and fuels that can replace petroleum-based products and reduce the environmental impact of these industries. Some of the applications of Chemical and Fuel Technological Microbiology include Biofuels: Microbes such as algae and bacteria can be used to produce biofuels such as ethanol, biodiesel, and methane. These biofuels can be produced from renewable resources such as biomass and can reduce greenhouse gas emissions compared to traditional fossil fuels. Bioplastics: Microbes such as *Pseudomonas putida* and *Escherichia coli* can be used to produce biodegradable bioplastics that can replace petroleum-based plastics. Enzyme production: Microbes such as *Aspergillus niger* and *Trichoderma reesei* can be used to produce enzymes such as amylases, cellulases, and proteases, which are used in various industries such as food, paper, and textile. Fine chemicals: Microbes such as Streptomyces and Penicillium can be used to produce fine chemicals such as antibiotics, immunosuppressants, and anti-cancer drugs. Bioremediation: Microbes such as *Pseudomonas aeruginosa* and *Rhodococcus erythropolis* can be used for bioremediation of contaminated soil and water by degrading pollutants such as hydrocarbons and pesticides. Chemical and Fuel Technological Microbiology is an important field that has the potential to provide sustainable solutions for chemical and fuel production while reducing the environmental impact of these industries.

One of the first large-scale industrial fermentation processes to gain global significance was the microbial production of acetone and butanol, which was performed efficiently by the Clostridium genus (Vitorino and Bessa, 2017). The inability to compete with chemical synthesis from petrochemical feedstock also affected the centennial microbial synthesis of glycerol. As a result, glycerol became an important raw material for the production of various chemicals in developing countries, including Africa, when the price of propylene increased due to its decreased availability. The alternative synthesis of glycerol by fermentation became more attractive as a result (Wang et al., 2001; Vitorino and Bessa, 2017).

As a means of reducing fossil fuel dependence, the synthesis of chemicals through metabolic processes in microbes is urgently needed. A biorefinery converts renewable resources into substrates that are susceptible to microbial action using biomass or waste products in modern research (Sauer, 2016), which has prompted the industry to move from fossil fuel usage to renewable raw materials as a result of climate change and environmental problems (Moon et al., 2016). A new generation of biofuels may also be produced by microorganisms (Liao et al., 2016; Vitorino and Bessa, 2017). Tolerating acetic acid is another challenge facing second-generation ethanol production. This acid inhibits lignocellulose hydrolysate. Currently, it is not known what polygenic basis exists in some strains of *S. cerevisiae* that lead to high acetic acid tolerance. However, its identification may allow strains to be improved acetic acid tolerated more effectively without adversely affecting other yeast properties that are important to industry (Meijnen et al., 2016). Furthermore, the development of pre-treatment techniques for cellulose sources such as forestry, crop residues (eucalyptus bark, corn, and rice husks), and yeast genetic improvement (McIntosh et al., 2016; Vitorino and Bessa, 2017) are capable of boosting second-generation ethanol production.

Microbial conversion of biomass can also produce biogas and other energy molecules besides bioethanol. However, AD's performance for biogas production is not only influenced by the maintenance of a high density of these bioconversion microorganisms but also by several ion-specific transporters and enzyme systems not yet well-known, so the knowledge of genes that control these systems efficiently will be an important part of future production challenges (Goswami et al., 2016; Vitorino and Bessa, 2017).

Without adequate technology, conducting research and development in this field is difficult, which limits innovation in the sector. Furthermore, the lack of technology has led to using traditional methods for producing chemicals and fuels, which are often inefficient, costly, and environmentally harmful. In addition, the lack of technology has also limited the adoption of sustainable practices, such as renewable energy, in chemical and fuel production. Africa is rich in renewable energy resources such as solar, wind, and hydropower, but the lack of technology has made it difficult to harness these resources for energy production (Agbogidi et al., 2016; World Bank, 2018). Moreover, the absence of technology has led to out-dated and harmful chemical processes, such as leaded gasoline, which is still used in some African countries. Leaded gasoline has adverse health effects, including damage to the nervous system and cognitive impairment. The lack of technology has also led to poor waste management practices, which have led to pollution of the environment, including air, water, and soil.

SCIENCE AND TECHNOLOGICAL MICROBIOLOGY IN THE ENVIRONMENT

Environmental Technological Microbiology refers to the use of microorganisms to address environmental issues such as pollution, waste management, and soil and water quality. Microbes play a critical role in maintaining the balance of ecosystems and can be utilised to improve environmental sustainability. Some of the applications of Environmental Technological Microbiology include Bioremediation: Microbes such as bacteria, fungi, and algae can be used to remediate contaminated soil and water by breaking down pollutants and converting them into less harmful substances. Composting: Microbes such as bacteria and fungi can be used in the composting process to break down organic waste and convert it into nutrient-rich compost, which can be used to improve soil health. Wastewater treatment: Microbes such as bacteria and protozoa can be used in wastewater treatment plants to break down organic matter and remove pollutants from wastewater. Carbon sequestration: Microbes such as cyanobacteria and algae can be used for carbon sequestration by converting carbon dioxide into biomass through photosynthesis. Biogas production: Microbes such as methanogenic bacteria can be used to produce biogas from organic waste such as agricultural waste and sewage sludge.

In treating effluents, especially industrial effluents, microbial enzymes have been used directly because of their faster action, eliminating the need for fermentation (Vitorino and Bessa, 2017). Among the wastewater treatment methods used are lipases, which remove triglycerides by converting them to fatty acids (Jamie et al., 2016). As the fat layers form on the surface of aerated tanks, these enzymes are critical in removing these layers continuously to allow oxygen to be transported (Hasan et al., 2006). Researchers are currently investigating integrating solid waste treatment or even wastewater treatment using microbial fuel cells (MFC), that is, microbial cells that use electrons donated by the waste as a source of energy (Xu et al., 2016; Vitorino and Bessa, 2017). In addition to treating effluent and generating electricity, this alternative technology can be conducted using mixed MFC cultures that can be adapted to various substrates (Pendyala et al., 2016). Improve purification of drinking water has also been the focus of research. Enzymatic waste treatment is usually less expensive but involves using biodegradable enzymes. The development of thermostable or pH-resilient microbial enzymes requires further research.

Additionally, the use of enzymes in waste treatment has been hindered by a lack of knowledge about the enzyme-producing species that may be applicable since only about 2% of all microorganisms have been tested for their enzyme potential (Hasan et al., 2006; Vitorino and Bessa, 2017). Environmental Technological Microbiology is an essential field providing sustainable solutions to environmental challenges. By harnessing the power of microorganisms, we can create more efficient and sustainable ways of managing waste, remediating contaminated sites, and improving soil and water quality.

Environmental technological microbiology plays a critical role in sustainable development and environmental protection. Unfortunately, this field is not well developed in many countries in Africa. The lack of environmental technological microbiology in most African countries has several impacts: The research on microorganisms in the environment is limited, leading to an incomplete understanding of the complex environmental processes in the continent. This hinders the development and implementation of effective environmental policies and management plans. The knowledge gap in environmental technological microbiology limits the ability to manage environmental challenges such as soil degradation, water pollution, and waste management (Adeyemo et al., 2017). This jeopardizes public health and the sustainability of natural resources. The absence of environmental technological microbiology also affects economic growth. Africa's rich biodiversity could be harnessed through biotechnological solutions for environmental protection, agriculture, and medicine. However, this potential remains untapped due to a lack of knowledge and skills. In conclusion, Africa's lack of environmental technological microbiology has far-reaching impacts on the environment, public health, and economic development. It is, therefore, vital for the continent to invest in this field to address current and future environmental challenges.

TECHNOLOGICAL MICROBIOLOGY IN THE MEDICAL INDUSTRY

Medical Technological Microbiology is the study of microorganisms involved in human health and disease. Microbes play a significant role in both causing and preventing diseases, and Medical Technological Microbiology involves using microorganisms and microbial products to diagnose, treat, and prevent diseases. Some of the applications of Medical Technological Microbiology include infectious disease diagnosis: Microbes such as bacteria, viruses, and fungi can be identified using various diagnostic techniques such as culture, PCR, and serological tests. Antibiotic production: Microbes such as Streptomyces and Penicillium are used to produce antibiotics such as penicillin, streptomycin, and tetracycline. Vaccines: Microbes such as bacteria and viruses can be used to develop vaccines for various infectious diseases. Probiotics: Microbes such as Lactobacillus and Bifidobacterium are used as probiotics to promote gut health and prevent or treat diseases such as diarrhea and irritable bowel syndrome. Microbial therapy: Microbes such as bacteriophages and engineered bacteria can be used to treat bacterial infections that are resistant to antibiotics. Medical Technological Microbiology is an essential field that provides solutions for diagnosing, treating, and preventing infectious diseases. By studying microorganisms and their interactions with the human body, we can develop new and more effective ways to improve human health and reduce the burden of disease.

There are four distinct aspects of microorganism participation in the production of medical products or services: biocontrol of diseases, vaccines, antibiotics, and biotherapeutics (hormones, biomaterials, and others) (Vitorino and Bessa, 2017). Parasitic vectors such as the mosquitoes of the genera Aedes and Anopheles spread easily in developing countries because of the difficulty of implementing public policies to control their spread. Recently, outbreaks of emerging and reemerging diseases have prompted the development of biotechnological techniques that assist in diagnosis and prevention. One example is the potential offered by introducing the bacterium *Wolbachia* into the mosquito *Aedes aegypti*, which transmits diseases including dengue fever, yellow fever, chikungunya, and the newly detected Zika virus (Walker et al., 2011). Instead of focusing on mosquito abundance, this approach aims to reduce mosquito longevity. Since only adult female mosquitoes can transmit the disease, bacteria reduce their life span and reduce their ability to transmit the dengue virus (Cook et al., 2008; Turley et al., 2009; Bian et al., 2010; Vitorino and Bessa, 2017).

Despite having a significant burden of disease, most African countries still needs to catch up in the development and adoption of medical technology. The lack of Technology on Medical Technological Microbiology in many African countries including Ghana has hindered its growth and development. The situation was obvious when Covid-19 strike in most African countries. Without adequate technology, conducting research and development in this field is challenging, which limits innovation in the Medical Technological Microbiology field (Daramola et al., 2019; Mboya et al., 2019). Furthermore, the lack of technology has made diagnosing and treating infectious diseases in most African countries difficult, leading to high morbidity and mortality rates (Adebisi et al., 2020). Moreover, the absence of technology has led to poor infection control practices, contributing to the spread of infectious diseases in healthcare settings (Gebreyohannes and Bhagavathula, 2019; Mugisa et al., 2019). The lack of technology has also limited the availability of sterile equipment and supplies, making it challenging to perform invasive procedures safely. Additionally, the need for more technology has hindered the production of vaccines and other essential medical supplies in Africa, leading to a dependence on imports. Covid-19 exposes this situation in recent outbreaks. This dependence on imports has made it difficult for African countries to respond adequately to disease outbreaks and other health emergencies.

TECHNOLOGICAL MICROBIOLOGY OF MATERIALS

Materials Technological Microbiology refers to the use of microorganisms to produce, modify, or degrade materials. Microbes can be used to synthesise a wide range of materials, including biodegradable plastics, biofuels, and electronic components. Some of the applications of Materials Technological Microbiology include Biodegradable Plastics: Microbes such as bacteria and fungi can be used to produce biodegradable and sustainable bioplastics. Biofuels: Microbes such as algae and bacteria can be used to produce biofuels such as biodiesel and bioethanol. Electronic components: Microbes such as *Geobacter sulfurreducens* can be used to produce electrically conductive nanowires that can be used in electronic components. Textile production: Microbes such as bacteria and fungi can be used to produce textile materials such as cellulose and chitin. Biomineralisation: Microbes such as bacteria can be used to mineralise materials such as metals and ceramics, which can be used in various industrial applications. Materials Technological Microbiology provides a sustainable and eco-friendly alternative to traditional materials production methods. By harnessing the power of microorganisms, we can create new materials that are biodegradable, renewable, and have a lower environmental impact. This field could revolutionise various industries and pave the way for a more sustainable future.

Additionally, microbiology has been able to develop a great variety of biomaterials and biosensors through the application of biotechnological techniques. Biomaterials refer to natural or synthetic products that are synthesized by microorganisms in different environmental conditions and can act on biological structures (organs or tissues) (Vitorino and Bessa, 2017). The use of biosensors allows rapid and accurate detection of analysis targets in diverse fields, such as medicine, environmental monitoring, food processing, and others, by integrating microorganisms with physical transducers to generate a signal proportional to the concentration of analytes (D'Souza, 2001; Paitan et al., 2003; Lei et al., 2006; Su et al., 2011; Vitorino and Bessa, 2017).

Bioplastics are a family of important biomaterials. A bioplastic is polyester that accumulates intracellularly in microorganisms as storage granules and has a similar physicochemical property to petrochemical plastics. It is also important to note that these properties, as well as the monomeric composition, can be altered depending on the microorganism from which the bioplastic originates and that the primary interest in these polymers lies in their biodegradability and biocompatibility (Luengo et al., 2003; Vitorino and Bessa, 2017). In addition to acidogenic fermentation or pyrolysis of lignocellulosic biomass, bioplastic can also be manufactured via the bioprocessing of solid and liquid waste (Ivanov and Stabnikov, 2016).

Bioplastics are being used to manufacture high-value-added medical materials, such as films that function as vehicles for drug delivery (Awadhiya et al., 2016). A bioceramic and/or bioactive glass can enhance the biomechanical and bioactivity of PHAs as medical materials (Radecka et al., 2016). Seed coating of agronomic species with bioplastic formulations was recently tested. Future agricultural pest control may be improved using these coatings, which contain spores of growth promoters like *Trichoderma harzianum* (Accinelli et al., 2016; Vitorino and Bessa, 2017). In civil construction, bioplastics may also contribute to the rise of low energy-absorbed materials, which will contribute to energy conservation (Ivanov and Stabnikov, 2016).

Africa is a continent rich in natural resources, but the need for more technology has hindered the development of materials technology microbiology. Firstly, it has limited the ability to explore and exploit the vast natural resources in the continent, which could be used to develop new materials with a wide range of applications (Ogbonna and Nwokonko, 2018; World Bank, 2018; Monyatsi et al., 2019). The extraction and processing of these materials are challenging without appropriate technology, which limits innovation opportunities (Agbogidi et al., 2016; World Bank, 2018). Secondly, the lack of technology has made it difficult to develop and test new materials that could be used in various fields such as construction, electronics, and manufacturing in most countries in Africa. This lack of technology has also hindered research into new biomaterials that could be used in medical applications, such as implants and prosthetics several countries in the continent.

Moreover, the absence of technology has limited the ability to detect and prevent microbial contamination in materials, leading to product failures and health risks (Mugisa and Abwooli, 2019). This is particularly important in the food and beverage industry, where microbial contamination can lead to foodborne illnesses and even deaths. Additionally, the need for more technology has limited the capacity for quality control in the manufacturing industry, leading to the production of substandard and unsafe materials. This has contributed to a lack of consumer confidence in locally manufactured products, leading to dependence on imported materials.

MOLECULAR TECHNOLOGY OF MICROBIOLOGY

Molecular Technological Microbiology is a field of study that focuses on applying molecular biology techniques in studying microorganisms. This field involves the use of advanced molecular techniques such as DNA sequencing, gene expression analysis, and protein analysis to understand the structure, function, and interactions of microorganisms. Some of the key applications of molecular technological microbiology include the study of microbial diversity and evolution, identifying and characterising microbial pathogens, developing new antibiotics and vaccines, and studying microbial metabolic pathways. Molecular technological microbiology also plays a crucial role in biotechnology and the development of new products and processes, such as the production of biofuels and the bioremediation of environmental contaminants.

Because of the expansion of aquatic microbial populations and the increased impacts of anthropogenic activities and environmental change, surface water sources need to be protected more effectively (Amin et al., 2019). Anthropogenic activities have a variety of impacts on aquatic microbial communities, some of which are undefined. However, advanced next-generation sequencing and novel model approaches have begun to shed some light on this significant issue (Labbate et al., 2016). Applying molecular techniques has gained a new understanding of aquatic microbial diversity. The equipment and techniques used in the molecular analysis are called molecular tools. For the purpose of analysing the structure and diversity of microbial communities, clone libraries, FISH, denaturing gradient gel electrophoresis (DGGE), terminal restriction fragment length polymorphisms, single-strand conformation polymorphisms, amplified ribosomal DNA restriction analysis, and ribosomal intergenic spacer analysis (RISA) are the most commonly used molecular techniques in microbiology (Giulietti et al., 2001; Bartlett and Stirling, 2003; Gill and Ghaemi, 2008; Joshi and Deshpande, 2010; Kalle et al., 2014; Blackburn et al., 2015; Yang and Kim, 2015; Blaser et al., 2016; Quideau et al., 2016). In recent decades, however, new technologies have made it possible for aquatic systems to be monitored in real-time. DNA microarrays and PCR-based methods are some of the most promising advances in detecting microbial indicators in water samples in near real-time and quantitatively. Anthropogenic influences on aquatic systems can be assessed more effectively with these methods developed and applied. New technologies have made it possible to assess aquatic systems in real time in recent years. Various molecular approaches show promise in monitoring microbial water quality, including microarrays, real-time sequencing, and Droplet Digital Polymerase Chain Reactions (ddPCR). Microarrays have the advantage of allowing researchers to detect hundreds of different genes at once instead of detecting only one or a few genes at a time with older techniques (like PCR) (Amin et al., 2019). The use of microarrays in detecting multiple types of FIBs/pathogens from common water samples represents a potentially significant technological advance. Using the nanopore MinION device, real-time portable sequencing has been developed recently (Cortés-Hinojosa et al., 2017; Amin et al., 2019) offers several advantages over qPCR. The MinION device allows rapid and targeted treatment of metagenomic sequences in real-time; By using long sequence reads, divergent viral sequences can be accurately identified, and novel viruses can be discovered. Another advanced third-generation technology, ddPCR, provides fast, specific, and sensitive results in quantifying viruses without using standard curves to overcome the challenge associated with slow turnaround (Cortés-Hinojosa et al., 2017; Amin et al., 2019). These new molecular techniques allow viral pathogens to be detected unbiased, rapidly, and accurately in water environments. Molecular technological microbiology is a rapidly evolving field that has significant potential to advance our understanding of microorganisms and their role in various processes, from disease to environmental sustainability.

Molecular technological microbiology is an essential tool used to diagnose, treat, and prevent infectious diseases caused by microorganisms. However, the lack of access to adequate molecular diagnostic facilities and trained personnel in most countries in Africa with the exception of few such as South Africa has hindered the diagnosis and control of infectious diseases, significantly impacting public health. One of the major impacts of this lack of technological advancement in microbiology is the inability to detect and control outbreaks of infectious diseases such as Ebola, cholera, and tuberculosis. This has resulted in high mortality rates, particularly in rural areas with limited access to health facilities. Additionally, the lack of molecular technological microbiology in Africa has stymied the development of new vaccines and research into the genetics and evolution of microorganisms and this was evident when Covid-19 strikes and until now not sure if the continent have its own vaccine for it. This has impeded efforts to control the spread of diseases and the development of new antibiotics.

Furthermore, the absence of molecular diagnostic facilities has a significant economic impact. By delaying disease diagnosis and resolution, infectious disease outbreaks can lead to a loss in productivity and income, particularly in rural areas where agriculture and aquaculture are the primary sources of income. In conclusion, the lack of adequate molecular technological microbiology facilities in majority of countries in Africa significantly impacts public health, economic development, and research. Addressing this issue through investments in infrastructure and education is critical for supporting the growth and well-being of African countries.

TECHNOLOGICAL MICROBIOLOGY IN EDUCATION

The lack of efficient technological microbiology in education has significant impacts on African education, particularly in the areas of healthcare and agriculture. Technological microbiology refers to the application of technology in the study of microorganisms, their genetic makeup, and their interactions with the environment. It plays a critical role in understanding and improving human and animal health and crop and livestock production.

One of the major effects of the lack of efficient technological microbiology in education is the limited access to modern and advanced laboratory facilities and equipment. This led to a lack of practical experience in microbiology in many countries in Africa including Ghana, which is essential for students to understand the concepts and principles of microbiology. As a result, students are not able to develop the necessary skills and competencies required in the field of microbiology. According to a study by UNESCO, the shortage of qualified teachers in Africa is a major challenge in providing quality education in science, technology, engineering, and mathematics (STEM) fields, including microbiology (UNESCO, 2019).

In Africa, the lack of access to technological microbiology education could lead to a shortage of skilled microbiologists, hindering the development of the healthcare and agricultural sectors. According to a report by the African Union, the continent has a shortage of 1 million health workers, including microbiologists, leading to inadequate disease surveillance and management (African Union, 2017). In addition, the lack of trained microbiologists has led to challenges in identifying and controlling infectious diseases, such as tuberculosis, malaria, and HIV/AIDS, which are prevalent in Africa (Nkengasong et al., 2017). Technological microbiology is crucial for increasing crop yields, improving soil health, and preventing plant diseases in the agricultural sector. However, the lack of access to education in this area has led to low adoption of modern agricultural practices, limiting food security and contributing to poverty and malnutrition in many African countries (Makinde et al., 2021). In conclusion, the lack of efficient technological microbiology education in many African countries has significant impacts on the development of the healthcare and agricultural sectors. Addressing this challenge through investments in education and research could help improve disease surveillance and management, increase food security, and contribute to the continent's overall development.

CONCLUSION

The lack of efficient microbiological technologies in Africa significantly impacts the advancement of microbiology research. Some key challenges many African researchers face include limited access to state-of-the-art equipment, inadequate funding, and limited research infrastructure. These challenges hinder the development and application of microbial technologies in various fields, such as agriculture, medicine, and environmental sustainability. Without access to the latest technologies, African researchers may not be able to explore the potential of microorganisms and their products fully. They may miss out on important discoveries that could benefit their communities and the world at large.

Moreover, Africa's lack of efficient microbiology technologies can also contribute to the brain drain phenomenon, where talented and experienced researchers leave the continent searching for better opportunities and resources. This can further impede the progress of microbiology research in Africa and widen the gap between African and developed countries. Investing in research infrastructure, training, and capacity building in microbiology and related fields in Africa is essential to address the challenges mentioned. Although, Governments, funding agencies, and international organisations supports research and development by providing funding and resources for capacity building and equipping laboratories, these supports in most cases are inadequate. By investing in microbiology research and technology, most African countries can tap into the potential of microorganisms to develop sustainable solutions to pressing challenges such as food security, public health, and environmental sustainability. Investing in microbiology research and technology in Africa presents various opportunities. For instance, developing specialised research facilities can help attract international collaborations and researchers. Training programs for researchers and technicians can also enhance their skills, improve the quality of research, and lead to better outcomes. Increased access to funding for research and development can also lead to the development of innovative technologies, which can help solve Africa's challenges. The lack of efficient microbiological technologies in most countries in Africa has significantly impacted the advancement of microbiology research on the continent. The lack of efficient technological microbiology in education significantly impacts most African countries including Ghana’s education. It limits access to advanced laboratory facilities and equipment, leads to a shortage of qualified teachers and instructors, and hinders research and innovation in microbiology. However, investing in microbiology research and technology presents various opportunities that can help improve the pace of research and the quality of outcomes. It is however be noted that some countries such as South Africa, Egypt and some few other countries are doing well in providing such technologies. By addressing these challenges, it is possible to develop new solutions for the challenges facing Africa, particularly in the areas of infectious diseases and food and water safety. The present study provides vital information and opens opportunities for technological inventors and businesses interested in the sector to invest in Africa. This will help advance microbiology research in Africa.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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