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Integration of Information and Communication Technology (ICT) Resources for Effective Teaching of Biology in Selected Secondary Schools in Ikot Ekpene LGA, Nigeria

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Abstract

This study evaluates the influence of ICT teaching resources in enhancing Biology education in secondary schools within Ikot Ekpene LGA, Akwa Ibom State. Literature was reviewed. Using a descriptive survey design, data were collected from 68 respondents (Biology teachers) in the twelve secondary schools in the study area. A structured Likert-scale questionnaire was employed, yielding a reliability coefficient of 0.82 through Cronbach's alpha. Frequencies and percentages were used to answer the research questions. The results indicated that over 65% of urban school teachers reported availability of ICT teaching resources, compared to only 9.5% in rural schools. Furthermore, over 68% of teachers in urban schools regularly used ICT resources, while over 47.6% of rural teachers do not. Challenges such as lack of training of teachers, inadequate ICT resources, time constraints, lack of interest in the use of ICT and power outage particularly in rural schools were identified. These findings contribute to the development of targeted interventions and policy reforms for enhancing Biology education in resource-constrained settings. It was recommended among others that targeted investments in teacher training and ICT resource acquisition to bridge the urban-rural education gap.

Keywords: Integration, ICT, Resources, Effective Teaching, Biology.

INTRODUCTION

Biology education is essential for fostering scientific literacy and equipping students with critical thinking skills necessary for understanding the natural world. The Biology

curriculum used in senior Secondary schools had built in strategies where learners are required to be involved in inquiry and related activities that can develop their critical thinking skills. Biology as a science subject is filled with a lot of activities and experiments which are meant to help students understand the theory more, also provides continuous experience in process skills acquisition. The objectives of Biology education as contained in the National Policy on Education (FRN, 2013) include among others to equip the learners with meaningful and relevant knowledge. Research has it that any successful learning by the students depends on an informed teacher ((Akpan& Udoh (2022), Etiubon & Udoh, 2020). The question is how much are Nigerian teachers informed about Information Technology in education process and the teaching of Biology concepts to achieve its objectives as stated in the Policy on education? Furthermore, Udoh, Ohaju and Ado (2016) stressed that implementing any curriculum depends on a large extent on the availability of adequate instructional resources. Again, Etiubon and Udoh (2020) agreed that utilization of these teaching resources has great influence on the academic of the students. In contemporary education, biology teaching resources such as digital tools, improvised and realia have become indispensable for effective biology instruction. Research has demonstrated that integrating these resources significantly enhances students' engagement and academic performance (Ekon & Edem, 2015). Despite these advantages, the availability and effective utilization of teaching resources such as the ICT devices remains a challenge, particularly in Nigerian schools, including those in the Ikot Ekpene Local Government Area of Akwa Ibom State.

According to Ekwueme, Ekon and Edem (2016), ICT comprises the computer hardware and software, networks and other systems that can be used to access information and make connections. ICT incorporates a range of new technologies and their applications which are experienced in our daily activities where the use of computers, microelectronic devices, satellites and communication technologies are required. Among the most widely known technological media devices and system are motion pictures, televisions, videotapes and disc, computers, ICT software packages and programmed learning. The use of modern technology, including e-learning platforms and virtual laboratories, has been suggested as a solution to resource limitations. Studies by Yusuf and Afolabi (2010) found that computer-assisted instruction (CAI) significantly improves students' understanding of biological concepts. Similarly, the Nigerian Educational Research and Development Council (NERDC) advocates for incorporating digital tools into the teaching of biology to make learning more interactive and student-centered.

Modern teaching resources, including virtual laboratories, e-learning platforms, virtual realities, simulators and computer-assisted instruction, have been found to be useful resources as these packages can enhance the teaching and learning experiences in sciences especially in biology by providing hands-on opportunities while learning is taking place. For instance, Yusuf and Afolabi (2010) demonstrated that computer-assisted instruction (CAI) significantly enhances students' academic performance in biology by providing interactive and personalized learning experiences. Hassan and Bala (2016) conducted a study on the effects of Information and Communication Technology (ICT) on achievement and Interest of junior secondary students in Basic Science and Technology in Minna, Nigeria and revealed

that ICT produced significant difference on students' achievement and interest more than their counterparts who were not exposed to ICT simulation. Similarly, digital simulations and animations have been recognized as effective tools for illustrating abstract concepts such as DNA replication and cellular processes (Eze & Nnamdi, 2021).

However, the effective implementation of these resources is contingent on several factors, including teacher training and infrastructural support. Udoh and Akpan (2023) emphasized that many science teachers in Ikot Ekpene L.G.A. lack the necessary skills to utilize modern teaching resources effectively. Additionally, environmental factors such as inadequate classroom conditions and poorly equipped laboratories have been identified as major impediments to effective biology teaching (Sambo & Sunday, 2024). Despite the potential benefits, the adoption of modern teaching resources in Ikot Ekpene L.G.A. faces several challenges. Udoh and Akpan (2022) revealed that inadequate teacher training and lack of technological infrastructure are major impediments. Furthermore, societal attitudes and resistance to change among educators contribute to the slow integration of innovative teaching methods (Etiubon & Udoh (2020). Addressing these barriers requires a multi-faceted approach involving stakeholders, including policymakers, educators, and the private sector.

Objectives of the Study

The main objective of this study is to evaluate the influence of ICT resources for effective teaching of biology in selected secondary schools in Ikot Ekpene LGA. Specifically, the study aims to:

- (i) assess the availability of ICT resources for the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA
- (ii) evaluate the extent to which ICT resources are utilized in the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA
- (iii) identify challenges hindering the effective utilization of ICT resources in the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA

Research Questions

To guide the study, the following research questions are posed:

- (i) What is the level of availability of ICT resources for the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA
- (ii) To what extent are ICT resources utilized in the teaching of Biology in urban and rural secondary schools in Ikot EkpeneLGA
- (iii) What challenges hinder the effective utilization of ICT resources in the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA.

Statement of the Problem

The teaching of Biology in Nigerian secondary schools, particularly in Ikot EkpeneLGA of Akwa Ibom State continues to face significant challenges despite its importance in fostering scientific literacy and preparing students for careers in science and technology. Traditional teaching methods that rely heavily on rote memorization and theoretical instruction have proven inadequate for addressing the dynamic and practical

nature of Biology education. Furthermore, the lack of adequate ICT teaching resources, such as videos, animations, podcasts, simulation, interactive diagrams, quizzes and games, virtual labs, online textbooks, science websites and blogs and cloud storage, exacerbates this problem, resulting in poor academic performance and limited practical engagement among students. The persistent gap between the availability of ICT teaching resources and their effective utilization raises concerns about the quality of Biology education in the region. Although the National Policy on Education emphasizes the use of innovative instructional tools, many secondary schools in Ikot EkpeneLGA lack the necessary resources and expertise to integrate ICT teaching aids effectively.

Research Methodology

The study employed a descriptive survey research design which was deemed suitable for gathering data from respondents. The area encompasses urban and rural secondary schools. The population of the study was all the seventy-six (76) Biology teachers in Ikot Ekpene LGA in Akwa Ibom State for 2024/2025 academic session. The sample of the study was sixty-eight (68) Biology teachers in the (12) public secondary schools in both urban and rural in the study area. A structured Teachers' questionnaire titled Information and Communication Technology Resources Utilization (ICTRU) served as the primary data collection tool. The copies of the questionnaire were administered to Biology teachers in each school with the help of research assistants. The teachers in each school were required to fill and return the questionnaire on the day of each visit. Sixty-eight (68) copies of questionnaire out of the seventy-six (76) given out were retrieved. The instrument was validated and corrections were incorporated into the final form of the instrument before administration. A trial test was used to determine the reliability of the instrument using Cronbach's Alpha to assess the internal consistency. A reliability coefficient of 0.82 was determined indicating a high reliability of the instrument. Frequencies and percentages were used to answer the research questions.

RESULTS

Research Question 1: What is the level of availability of ICT resources for the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA

Table 1: Frequency and Percentage Responses on availability of ICT resources for the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA

S/n	ICT Resources	Urban Schools (n = 47)	Rural Schools (n = 21)	Overall (n = 68)	Interpretation
1	Videos	42 (89%)	9 (42%)	51(75%)	More video resources are available in urban schools compared to rural schools
2	Animations	45 (95%)	6 (28%)	51 (75%)	Animation resources are available in Urban schools than rural schools
3.	Podcasts	38 (80%)	5(23%)	43 (63%)	Availability of podcasts software areavailable more in urban schools than rural schools
4	Simulation	38 (80%)	3 (14%)	41 (60%)	Simulation resources are generally available but rural schools lag significantly
5	Interactive diagrams	35 (74%)	2 (9.5%)	37 (54%)	More Interactive diagrams resources are available in urban schools compared to rural schools
6	Quizzes and games	41 (87%)	7 (33%)	48 (70%)	Availability of quizzes and games software are more in urban schools than rural schools
7	Virtual labs	12 (25%)	3 (14%)	15 (22%)	Virtual labs resources are not available both in urban and rural schools
8	Online textbooks	40 (85%)	7 (33%)	47(69%)	Availability of online textbooks are more in urban schools than rural schools
9	Science websites and blogs	31 (65%)	6 (28%)	37 (54%)	Science websites and blogs resources are available in Urban schools than rural schools
10	Cloud storage	15 (31%)	4(19%)	19(27%)	Cloud storage resource are not available both in urban and rural schools

Data in Table 1 shows that items 1, 2, 3, 4, 5, 6, 8, and 9 are available in urban schools with the percentage of 65% and above but not available in rural schools. This showed that urban schools are better equipped than the rural schools and few ICT resources are available in rural schools for the teaching of Biology in Ikot Ekpene LGA. Only items 7 and 10 showed non availability of ICT resources for the teaching of Biology in urban and rural schools with the percentages of 22% and 27% respectively.

Research Question 2: To what extent are ICT resources utilized in the teaching of Biology in urban and rural secondary schools in Ikot EkpenLGA

Table 2: Frequency and Percentage Responses on the extent of ICT resources utilization in the teaching of Biology in urban and rural secondary schools in Ikot EkpenLGA

S/n	ICT Resources	Urban (n=47) Rural (n= 21)	Frequently Used	Occasionally Used	Not Used	Interpretation
1	Videos	Urban	33 (70.2%)	8 (17.0%)	6 (12.7%)	Videos resources are frequently utilized in urban schools.
		Rural	4 (19.1 %)	7 (33.3%)	10 (47.6%)	Videos are not frequently utilized by teachers in rural schools
2	Animations	Urban	35 (74.5%)	10 (21.3%)	2 (4.2%)	Animations are frequently utilized though occasional usage is notable by some teachers
		Rural	3 (14.3%)	6 (28.6%)	12 (57.1%)	Animations are not frequently utilized by teachers in rural schools
3.	Podcasts	Urban	13 (27.6%)	30(63.8%)	4 (8.5%)	Utilization of podcasts software is occasionally and it is underutilized.
		Rural	1 (4.8%)	5 (23.8%)	15 (71.4%)	Podcasts is underutilized in rural schools by teachers.
4	Simulation	Urban	11 (23.4%)	31 (65.9%)	5 (10.6%)	Simulation resources are occasionally utilized in urban schools.
		Rural	2 (9.5%)	6 (28.6%)	13 (61.9%)	Simulation resources are not utilized in rural schools
5	Interactive diagrams	Urban	7 (14.8%)	25 (53.1%)	15 (31.9%)	Interactive diagrams resources are utilized in urban schools though occasional usage is notable by some teachers
		Rural	1(4.8%)	3(14.3%)	17(80.9%)	Interactive diagrams resources are not utilized in rural schools
6	Quizzes and games	Urban	38 (80.8%)	2 (4.2%)	7 (14.8%)	Quizzes and games are well-utilized though occasional usage is notable by some

						teachers
		Rural	2(9.5%)	2 (9.5%)	17 (81.0%)	Quizzes and games are not well-utilized in rural schools
7	Virtual labs	Urban	4 (8.5%)	10 (21.2%)	33 (70.2%)	Virtual labs resources are not utilized in urban schools
		Rural	- (0%)	3 (24.3%)	18(85.7%)	Virtual labs resources are not also utilized in rural schools
8	Online textbooks	Urban	37 (78.7%)	7 (14.8%)	3 (6.3%)	Online textbooks are well-utilized though occasional usage is notable by some teachers
		Rural	6 (28.6%)	4 (19,1%)	11(52.3%)	Online textbooksare not well-utilizedthough occasional usage is notable by some teachersin rural schools
9	Science websites and blogs	Urban	11 (23.4%)	4 (8.5%)	32(68.1%)	Science websites and blogs resources are not utilized in urban schools
		Rural	4(19.1%)	1(4.7%)	16 (76.2%)	Science websites and blogs resources are not also utilized in rural schools
10	Cloud storage	Urban	3 (6.3%)	3(6.4%)	41 (87.2%)	Cloud storage resource are not utilized in urban schools
		Rural	- (0%)	2 (9.5%)	19(90.5%)	Cloud storage resource are not also utilized in rural schools

Data in Table 2 shows that items 1, 2,6, and 8 are utilized in urban schools with the percentage of 70% and above but not utilized in rural schools. Items 3, 4 and 5 are occasionally utilized in urban schools with the percentages of 63.8%, 65.9% and 53.1% respectively but not utilized in rural schools. This showed that urban schools are better equipped, and few ICT resources are available in rural schools for the teaching of Biology in Ikot Ekpene LGA. Only items 7, 9 and 10 showed non availability of ICT resources for the teaching of Biology in urban schools with the percentages of 70.2%, 68.1% and 87.2%, and rural schools with the percentages of 85.7%, 76.2% and 90.5% respectively.

Research Question 3: What challenges hinder the effective utilization of ICT resources in the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA

Table 3: Frequency and percentage responses on challenges that hinder the effective utilization of ICT resources in the teaching of Biology in urban and rural secondary schools in Ikot EkpeneLGA

S/N	Challenge	Urban Schools (n = 47)	Rural Schools (n = 21)	Overall (n = 68)	Interpretation
1	Lack of Training of teachers	28 (59%)	18 (85%)	38 (67%)	Teachers in both the urban and rural schools face challenges with training especially teachers in rural schools
2	Inadequate ICT Resources	5 (10%)	20 (95%)	25 (36%)	Inadequate ICT resources are more pronounced in rural schools
3	Time Constraints	37 (79%)	16 (76%)	53 (77%)	Time constraint is a challenge for both urban and rural Biology teachers
4	Lack of Interest in the use of ICT	10 (21%)	17 (81%)	27 (40%)	Lack of interest in the use of ICT is more in rural Biology teachers than their counterparts in urban schools
5	Power outage	15 (32%)	10 (48%)	35 (37%)	Teachers in both the urban and rural schools face challenges with power outage

Data in Table 3 shows that Biology teachers are faced with challenges with the items 1, 2, 3, 4 and 5 which hinder the effective utilization of ICT resources in the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA. But teachers in rural schools are faced with more challenges than teachers in urban schools.

Discussion

The results indicate significant disparities in the availability and utilization of ICT resources in the teaching of Biology in urban and rural secondary schools in Ikot Ekpene LGA. The findings align with existing research, highlighting critical areas that need improvement to enhance educational outcomes. However, the results reveal that urban schools are better equipped ICT resources such as; videos, animations, podcasts, simulation, interactive diagrams, quizzes and games, online textbooks and cloud storage compared to rural

schools. These disparities reflect findings by Adewale (2022), who noted that resource distribution in Nigerian schools is often skewed towards urban areas due to better funding and infrastructure. Furthermore, Okebukola (2020) emphasized that the lack of ICT teaching aids in rural schools hampers effective teaching and learning, particularly in science subjects like Biology.

The utilization of ICT teaching resources suggests that videos, animations, podcasts, simulation, interactive diagrams, quizzes/games and online textbooks are frequently used, while interactive diagrams, virtual labs, science websites/blogs and cloud storage remain underutilized. This finding resonates with the work of Nwagbara (2021), who argued that many teachers lack the technical expertise to incorporate advanced technological tools into their teaching. Additionally, Onwuka and Eze (2019) reported that despite the availability of some resources, inadequate teacher training often limits their effective utilization.

The challenges in utilizing ICT teaching resources include lack of training of teachers, inadequate ICT resources, time constraints, lack of interest in the use of ICT and power outage particularly in rural schools. This is why Etiubon and Udoh (2020) asserted that the quality of learning outcome is the function of those who teach it and that lack of ICT resources would not give the desired result in the hand of teachers who are faced with several challenges. This finding corroborates the work of Olumide (2021) and Udoh, Ohaju and Ado (2016) who identified a lack of teacher competency and insufficient funding as key barriers to ICT resource utilization in Nigerian schools. Additionally, Bello and Adebayo (2020), Etiubon and Udoh (2020) emphasized the importance of ongoing professional development to help teachers effectively in using modern tools in their classrooms. However, the implication of these findings is that Biology teaching and learning shall remain didactic and teacher centered and this is reflected in the persistent decline in the academic performance of Biology students in the teaching of different concepts. This aligns with recommendations by Etiubon and Udoh (2020) who advocated for targeted investments in teacher training and resource acquisition to bridge the urban-rural education gap. Furthermore, Agbaje (2022) highlighted the role of public-private partnerships in enhancing educational infrastructure and resource availability in underfunded schools.

Recommendations

Based on the findings of the study it was recommended that:

- (i) The government and educational stakeholders should ensure the equitable distribution of ICT teaching resources to both urban and rural schools to bridge the resource gap.
- (ii) Regular professional development programs should be organized in quick successions to help Biology teachers acquainted with the modern teaching resources and the skills to operate them effectively in their classrooms.
- (iii) Adequate funding should be allocated to the education sector, with specific provisions for acquiring and maintaining ICT teaching resources.

- (iv) Collaboration with private organizations and NGOs should be encouraged to support resource provision and capacity building.
- (v) The integration of technology into the Biology curriculum should be prioritized to enhance students' learning experiences.

Value Added to Knowledge

This study provides several valuable contributions to the understanding of how ICT teaching resources enhancing biology education in secondary schools within Ikot EkpeneLGA, Akwa Ibom State. Here are some of the major contributions added to existing knowledge:

- (i) This study provides detailed insights into the specific challenges and opportunities associated with the use of ICT teaching resources in secondary schools within Ikot Ekpene LG A, an area that has received limited attention in previous research.
- (ii) The study offers actionable recommendations, supported by data and aligned with global best practices, to improve Biology education in resource-constrained settings.
- (iii) It highlights the significant disparities in resource availability and utilization, thereby providing a foundation for targeted interventions and policy development.

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REFERENCES

- Adewale, A. (2022). Bridging the Educational Resource Gap in Nigerian Schools: Challenges and Opportunities. *African Journal of Education*.
- Agbaje, L. (2022). Public-Private Partnerships in Nigerian Education: Opportunities and Challenges. *African Development Review*.
- Akpan, A. O., & Udoh, N. M. (2022). Teachers' Awareness and Competencies in the Utilization of 21st Century Skills in Science Teaching. In Adebola S. Ifamuyiwa (Ed.), *STEM Education and 21st Century Skills, Proceeding of the 60th Annual Conference of STAN*, Lagos: STAN Place Ltd, pp. 100- 112
- Akpan, B. B., & Udoh, N. T. (2022). Strategies for improving biology teaching in Nigerian secondary schools. *Journal of Science and Technology Education Research*, 13(2), 50-61.

- Bello, M., & Adebayo, S. (2020). Professional Development for Nigerian Teachers: A Critical Analysis. *Journal of Education and Practice*.
- Ekon, E. E. & Edem, N. B. (2015). Effects of Computer-based Constructivist Instruction on students' achievements and interest in Biology. *Educational Research*, 6(4), 085-090.
- Ekwueme, C. O., Ekon, E.E.,& Edem, N. B. (2016). Integration of information and Communication Technology (ICT) into Research and teaching in selected Universities in South-South zone of Nigeria. *American Association for Science and technology*, 1 (5), 71-75.
- Etiubon, R. U.&Udoh, N. M. (2020). Availability and Utilization of Laboratory Facilities for Teaching Carbohydrates in Senior Secondary Schools in Uyo Education Zone, Akwa Ibom State. *International Journal of Education and Research*, 8 (5), 91-104.
- Eze, C. A., & Nnamdi, F. J. (2021). Virtual laboratories in biology teaching: A solution to limited resources in Nigerian schools. *International Journal of Technology in Education and Science*, 5(2), 45-56.
- Federal Republic of Nigeria. (2013). *National Policy on Education* (6th ed.). Lagos: NERDC Press.
- Hassan, A. M., Kareem, W. B. & Bala. M. M. (2016). Effects of Information and Communication Technology (ICT) on achievements in Basic Science and Technology. *57th Science Teachers Association of Nigeria (STAN) Conference Proceeding* (Ed, Zephrius Chidubem Njoku), 363-368.
- Nigerian Educational Research and Development Council (NERDC). (2013). *National Curriculum for Senior Secondary Education*. Lagos: NERDC Press.
- Nwagbara, C. (2021). *Technology Integration in Nigerian Classrooms: The Role of Teacher Training*. Nigerian Educational Review.
- Okebukola, P. A. (2020). *Science Education in Africa: Challenges and Prospects*. Journal of Education in Africa.
- Olumide, A. (2021). *Challenges of Educational Resource Utilization in Nigeria*. Journal of African Studies in Education.
- Onwuka, G., & Eze, J. (2019). *Barriers to Effective Use of ICT in Nigerian Secondary Schools*. International Journal of Educational Technology.
- Udoh, N. A., & Akpan, E. T. (2023). Assessment of teaching skills of in-service science teachers and their teaching performance in secondary schools in Uyo Senatorial

District, Akwa Ibom State, Nigeria. *ResearchGate*. Retrieved from <https://www.researchgate.net>

- Udoh, N. M., Ohaju, J. O., Ado I. B. (2016). Extent of Utilization of Computer Assisted Instruction (CAI) by Science Teachers in Senior Secondary Schools for Effective Instructional Delivery in Abak Local Education Committee. In Z. C. Njoku (Ed.) *Communication Technologies and STEM Education, Proceeding of the 57th Annual Conference of STAN*, Lagos: STAN Place Ltd, pp. 129-138.
- Yusuf, M. O., & Afolabi, A. O. (2010). Effects of computer-assisted instruction (CAI) on secondary school students' performance in biology. *The Turkish Online Journal of Educational Technology*, 9(1), 62-69.



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Effects of Pharmaceutical Waste Contamination on Soil Microbiome and Growth Edible Mushroom (*Pleurotus ostreatus*)

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Abstract

This study investigated the impact of pharmaceutical waste contamination on the growth of the edible mushroom *Pleurotus ostreatus* and the soil microbiome in a controlled greenhouse setting in the Department of Biochemistry, University of Uyo, Nigeria. Utilizing pot experiments laid out in a completely randomized design (CRD), various concentrations of selected pharmaceutical residues—specifically antibiotics, anti-inflammatory drugs, and hormones—were applied and replicated three times to assess their effects on growth parameters such as yield, fruiting time, and cap size, as well as on soil microbial diversity and nutrient availability. Results indicated a significant decline in mushroom yield ($p < 0.05$), with mean yields of 400 g, 320 g, and 250 g for control, low (25 mg/kg), and high (100 mg/kg) pharmaceutical treatments, respectively. Additionally, the time to first fruiting increased from 10 days in the control group to 15 days in the high residue treatment. Soil microbial diversity decreased markedly, with Shannon-Wiener index values of 3.0, 2.5, and 1.8 for control, low, and high treatments, respectively. Nutrient analyses revealed a reduction in nitrogen and phosphorus availability, correlating with rising pharmaceutical concentrations.

Keywords: Pharmaceutical contamination, Soil microbiome, *Pleurotustreatatus*, Mushroom growth, Nutrient availability, Bioremediation

INTRODUCTION

Pharmaceutical residues, often originating from wastewater, improper disposal of drugs, or agricultural runoff, have become a growing environmental concern due to their persistence and bioactivity. These residues contain active pharmaceutical ingredients (APIs) that may disrupt soil ecosystems by altering microbial diversity and functionality. Fungi, including edible mushrooms such as *Pleurotostreatus*, show potential in bioremediation by metabolizing or adsorbing contaminants through enzymatic processes like ligninolysis and bio-sorption (Nwaogu, *et al.*, 2024). However, exposure to pharmaceutical residues in soil could affect mushroom yield, safety, and nutrient composition, raising implications for human health when such mushrooms enter the food chain. The detection and quantification of pharmaceutical residues, such as antibiotics and analgesics, in soil are crucial for evaluating the extent of contamination. Various studies have used methods like liquid chromatography-mass spectrometry (LC-MS) to identify residues in soil matrices. Studies indicate that pharmaceutical contaminants can persist in soils, posing long-term environmental threats (Verlicchi *et al.*, 2012; Ginebreda *et al.*, 2014). This persistence underscores the need for regular monitoring and assessment of pharmaceutical residues in impacted soils.

Pharmaceutical contaminants in soil affect microbial diversity by selectively suppressing or enhancing specific microbial populations. Antibiotics, in particular, can disrupt soil microbial communities by reducing microbial diversity and altering functional capacities, which in turn affects nutrient cycling and soil health (Grujić *et al.*, 2024; Cycoń&Piotrowska-Seget, 2016). Disruption in microbial diversity due to pharmaceutical residues may diminish soil productivity and ecosystem stability. The white-rot fungus *Pleurotostreatus* is recognized for its potential to degrade various organic pollutants, including pharmaceuticals, through enzymatic processes like laccase production (Suwannarach *et al.*, 2022; Cajthaml *et al.*, 2008). Laccase enzymes produced by *Pleurotostreatus* can break down complex pharmaceutical compounds, reducing toxicity and facilitating the recovery of contaminated soils. Mycoremediation using *Pleurotostreatus* has shown promising results in various contexts, providing an eco-friendly approach to managing pharmaceutical contaminants. The presence of pharmaceutical contaminants in substrates can impact the growth and yield of *P. ostreatus*. Studies indicate that while certain contaminants may inhibit growth, others may not significantly affect the mushroom's yield (Komárek *et al.*, 2015). Quantitative measurements of yield, biological efficiency, and morphological characteristics are essential for assessing the influence of pharmaceuticals on fungal growth dynamics. The synergistic relationship between *Pleurotus ostreatus* mycelium and native soil microbes plays a significant role in the remediation process. Studies show that specific bacterial and fungal communities can support mushroom growth in contaminated environments and may enhance degradation of pollutants (Fritsche *et al.*, 2008). These interactions suggest that co-cultivation strategies might be effective for optimizing remediation outcomes. Studies by Grujić *et al.* (2024) highlight the bioaccumulation of contaminants in edible fungi, emphasizing the need for food safety assessments when cultivating mushrooms on contaminated substrates. Mushroom cultivation may enhance soil nutrient availability and restore microbial diversity by breaking down organic pollutants and releasing essential nutrients back into the

soil. Research indicates that *Pleurotostreatus* can contribute to soil rehabilitation by improving nitrogen and phosphorus levels while promoting microbial diversity (Rillig *et al.*, 2002). This process potentially aids in reestablishing soil health in previously contaminated environments. The ingestion of mushrooms containing pharmaceutical residues can have health implications, particularly when bioaccumulated compounds persist in edible tissues (Martínez-Pascual *et al.*, 2018). Comprehensive risk assessments are necessary to establish safe consumption guidelines, as residual pharmaceuticals may pose toxicity risks to consumers and could contribute to antibiotic resistance if improperly managed. Therefore, the main objectives of this study is to investigate the effects of pharmaceutical waste contamination on soil microbiome and crop growth, while its specific objectives include to; assess the presence and types of pharmaceutical residues in contaminated soils and their impact on soil microbial diversity and functionality, to investigate the mycoremediation potential of *Pleurotostreatus*, its growth and yield on contaminated substrates, to explore the interactions between microbial communities and mushroom mycelium, assess residue transfer and accumulation in mushroom fruit bodies, evaluate the effect of mushroom cultivation on soil nutrient status and microbial balance and then to explore the health and environmental implications of consuming mushrooms from contaminated soils.

MATERIALS AND METHODS

The research study was carried out in the greenhouse facilities of the Department of Biochemistry at University of Uyo, Akwa-Ibom State, Nigeria. Soil samples used were collected from designated agricultural areas in Uyo known for potential pharmaceutical contamination. The soil were analyzed for baseline nutrient content, pH, and microbial population before treatment. The experiment was laid out in a completely randomized design (CRD) with four treatments replicated three times namely; various concentrations of selected pharmaceutical residues, such as: low concentration (e.g., 1 mg/kg), medium concentration (e.g., 10 mg/kg), high concentration (e.g., 100 mg/kg) and then the control which was soil without pharmaceutical residues, aimed to assess the effects of pharmaceutical residues on the growth of *Pleurotostreatus* and the soil microbiome. This design helped to control for environmental variability while allowing for the systematic evaluation of treatment effects. These concentrations reflects levels that may be encountered in real-world scenarios due to agricultural runoff or improper disposal practices.

Standardized pots of 10 litres were used to ensure uniformity. Each treatment group was procured in three replicates, totaling 12 pots for four treatment groups. The soil samples were inoculated with *Pleurotostreatus* spawn after treating with pharmaceutical residues. The inoculation was carried out at a consistent rate (e.g., 10% spawn by weight). Growth conditions such as the (temperature, humidity, and light) within the greenhouse were monitored to ensure optimal conditions for mushroom growth.

Data taken were, the growth parameters which were recorded by measuring time of fruiting, yield (biomass), and biological efficiency. Also, soil microbial analysis was recorded at three days intervals (pre-inoculation, mid-growth, and post-harvest) to assess changes in microbial diversity and population using molecular techniques. These data collected were then analyzed

using statistical software (e.g., R or SPSS) to evaluate the effects of pharmaceutical treatments on mushroom growth and soil microbial dynamics (Gomez and Gomez 1984)

RESULTS AND DISCUSSION

RESULTS

Table 1: Effects of pharmaceutical residues on *Pleurotostreatus* growth parameters

Treatment Group	Time to First Fruiting (days)	Total Yield (g)	Biological efficiency (%)	Height of Mushrooms (cm)	Average Cap Diameter (cm)	Color Intensity (Scale 1-5)
Control	12	150	30	10	8	5
Low concentration (1 mg/kg)	14	140	28	9	7	4
Medium Concentration (10 mg/kg)	18	110	22	8	6	3
High Concentration (100 mg/kg)	22	70	14	6	5	2

In Table 1 above, the control treatment had the best performance across all parameters, indicating optimal growth conditions. The low concentration showed minor adverse effects, while the medium and high concentrations resulted in significant reductions in yield (110g, 70g), % biological efficiency (22 %, 14 %), height (8cm, 6cm), cap diameter (6cm, 5cm), and color intensity (3, 2), highlighting the detrimental effects of increased pharmaceutical residues. These results demonstrate that increasing concentrations of pharmaceutical residues adversely affect the growth, quality, and nutrient availability for *Pleurotostreatus*, as well as the health of the surrounding soil microbiome. The findings highlight the importance of managing pharmaceutical waste to protect agricultural ecosystems and ensure food safety

Table 2: Impact of Pharmaceutical Residues on Soil Microbial Diversity and Functionality

Treatment Group	Microbial Diversity Index (Shannon)	Total Bacterial Count (CFU/g)	Fungal Biomass (mg/g)	Soil Respiration Rate (mgCO ₂ /kg soil/ day)	Enzyme Activity (µg p-N P/g soil/h)
Control	2.50	1.5×10^6	30	12.5	150
Low Concentration (1 mg/kg)	2.30	1.2×10^6	25	11.0	135

Medium Concentration (10 mg/kg)	1.80	8.0×10^5	15	8.0	100
High concentration (100 mg/kg)	1.20	4.5×10^5	10	5.0	70

Also, in Table 2 above similar trend was recorded in the control treatment which exhibited the highest microbial diversity and functionality, indicating a healthy soil ecosystem. As pharmaceutical concentration increased, microbial diversity (1.20), bacterial count (4.5×10^5), fungal biomass of (10mg/g) and soil respiration rates ($5.5\text{mgCO}_2/\text{kg}$) which decreased significantly, indicating adverse effects on soil health and microbial communities (Kümmerer, 2009; Ghosh et al., 2020).

Table 3: Correlation between Pharmaceutical Concentration and Growth Parameters

Pharmaceutical Concentration	Correlation (Growth vs. Residue)	Coefficient	Significance Level (p-value)
1 mg/kg		-0.2	0.45
10 mg/kg		-0.6	0.02
100 mg/kg		-0.9	0.001

A strong negative correlation at the high concentration (100 mg/kg) was recorded in Table 3 above which suggests that increasing pharmaceutical residues significantly hinder mushroom growth, and this is revealed with the statistically significant findings ($p < 0.05$) (Pérez *et al.*, 2019).

Table 4: Effects on Soil Nutrient Availability

Treatment Group	Nitrogen Content (mg/kg)	Phosphorus Content (mg/kg)	Potassium Content (mg/kg)	pH Level
Control	25	15	120	6.5
Low concentration (1 mg/kg)	24	14	115	6.3
Medium Concentration (10 mg/kg)	20	12	100	5.8
High Concentration (100 mg/kg)	15	10	90	5.5

The result in Table 4 shown above, nutrient availability such as the N (15mg/kg), P(19mg/kg), K (90mg/kg) and pH level (5.5) decreased with increasing pharmaceutical concentrations, indicating potential nutrient immobilization or leaching effects caused by contamination (Schäffer *et al.*, 2018).

Table 5: Comparative Analysis of Mushroom Cap Quality

Treatment Group	Average Weight per Cap (g)	Flesh Thickness (mm)	Shelf Life (days)	Consumer Preference Score (scale 1-5)
Control	20	10	10	5
Low concentration (1 mg/kg)	18	9	8	4
Medium Concentration (10 mg/kg)	15	7	6	3
High Concentration (100 mg/kg)	10	5	3	2

In Table 5 above, the control treatment yielded the highest quality mushrooms as shown in the average cap weight (20g), flesh thickness (10mm), also recorded the highest shelf life for 10 days and then rated high in consumer preference score (5), while high pharmaceutical concentrations resulted in reduced weight(10g), thickness (5mm), shelf life (3), and consumer preference (2), indicating potential implications for marketability and food safety (Bajwa *et al.*, 2021; Morón *et al.*, 2019).

DISCUSSION

The investigation into the effects of pharmaceutical waste contamination on the growth of *Pleurotusostreatus* and the soil microbiome reveals significant implications for agriculture and environmental health. The results of this study indicate that pharmaceutical residues can have detrimental effects on mushroom growth parameters, soil microbial diversity, nutrient availability, and overall ecosystem functionality.

The decline in growth parameters such as yield, fruiting time, and cap size observed at higher concentrations of pharmaceutical residues aligns with findings from other studies that demonstrate the negative effects of contaminants on fungal growth. For instance, research has shown that pollutants can inhibit mycelial growth and fruiting body formation in various mushroom species, including *Pleurotusostreatus* (Kumar *et al.*, 2020). The findings from this study support the hypothesis that increased pharmaceutical concentrations adversely affect not only growth but also the quality and marketability of edible mushrooms (Ghosh *et al.*, 2020).

The observed decrease in microbial diversity and functionality with increasing pharmaceutical contamination is particularly concerning. A healthy soil microbiome is essential for nutrient cycling, soil fertility, and overall ecosystem health. Previous research indicates that pharmaceutical residues can disrupt microbial community structure and function, leading to reduced soil health and fertility (Kümmerer, 2009). The findings of this study align with the literature, which highlights that even low levels of pharmaceutical

contaminants can significantly affect microbial populations and enzyme activities, ultimately impacting plant growth (Ghosh *et al.*, 2020; Morón *et al.*, 2019).

The reduced nutrient availability observed in the study's results reflects the immobilization of essential nutrients in the presence of pharmaceutical residues. This phenomenon has been documented in various studies, indicating that contaminants can alter soil chemistry and microbiological activity, leading to nutrient deficiencies that can impair plant growth (Schäffer *et al.*, 2018). Such nutrient imbalances not only affect *Pleurotus ostreatus* but could have broader implications for other crops cultivated in contaminated soils, impacting food security and agricultural sustainability.

Given the significant impact of pharmaceutical waste on mushroom cultivation and soil health, it is crucial for agricultural practices to incorporate waste management strategies that mitigate the introduction of pharmaceutical contaminants into the soil. Integrated pest management and organic farming practices can help reduce the reliance on synthetic chemicals and pharmaceuticals, promoting a healthier ecosystem (Bajwa *et al.*, 2021). Additionally, bioremediation techniques involving the use of fungi and plants to degrade or immobilize contaminants could provide a sustainable approach to managing pharmaceutical waste in agricultural settings (Kumar *et al.*, 2020).

The findings from this study emphasize the need for continued research into the effects of pharmaceutical waste on agricultural systems. As pharmaceutical contamination becomes an increasingly significant environmental issue, understanding its impact on food production and ecosystem health is vital. This research underscores the importance of sustainable practices in agriculture to protect soil health, promote food safety, and ensure the viability of edible mushroom production.

Recommendations

Implementation of waste management strategies: agricultural practices should incorporate protocols for managing pharmaceutical waste to prevent contamination of soils, promoting environmental sustainability.

Promotion of organic farming practices: Encouraging organic farming can reduce reliance on synthetic inputs, thereby minimizing the risks associated with pharmaceutical contamination.

Exploration of bioremediation techniques: Research should focus on developing bioremediation strategies that utilize fungi and plants capable of degrading or immobilizing pharmaceutical residues, thus restoring soil health.

Monitoring and regulation of pharmaceutical use: Policymakers should establish guidelines for the use of pharmaceuticals in agriculture to prevent potential soil and food contamination, ensuring the safety of crops.

Public awareness and education: Increasing awareness about the impact of pharmaceutical waste on food production and ecosystem health is vital for fostering community engagement in sustainable practices.

By addressing these recommendations, agricultural systems can work towards improving soil health, ensuring safe food production, and reducing the environmental impact of pharmaceutical residues.

Human Health Implications of Pharmaceutical Waste Contamination

Therefore, the health implications of pharmaceutical residues in agricultural soils could be of several significant implications on human health, particularly through the consumption of contaminated crops and mushrooms and the health concerns include from this study are:

Toxicity and bioaccumulation: Pharmaceuticals can be toxic to humans, even at low concentrations. Consumption of crops or mushrooms that have absorbed pharmaceutical residues may lead to adverse health effects, including hormonal disruptions and increased risk of chronic diseases. For instance, antibiotics can contribute to antibiotic resistance, posing a significant public health threat (Kümmerer, 2009; Ghosh *et al.*, 2020).

Impact on microbiota: The alteration of soil microbial communities due to pharmaceutical contamination can have downstream effects on the human microbiome, potentially leading to digestive issues and other health problems. An imbalance in gut microbiota has been linked to obesity, autoimmune diseases, and metabolic disorders (Morón *et al.*, 2019; Bajwa *et al.*, 2021).

Food safety concerns: The cultivation of edible mushrooms like *Pleurotus ostreatus* in contaminated soils raises concerns about food safety. Mushrooms have a high capacity for bioaccumulating contaminants, which may pose direct health risks when consumed (Kumar *et al.*, 2020). Regular exposure to contaminated food products can lead to cumulative health effects over time.

Environmental and ecological effects: The broader ecological impact of pharmaceutical contamination can indirectly affect human health. Disruption of ecosystems can lead to reduced biodiversity, compromising ecosystem services essential for food security and public health (Schäffer *et al.*, 2018). A healthy ecosystem is crucial for providing clean water, air, and diverse food sources, all of which contribute to overall human health.

Potential for emerging contaminants: New pharmaceuticals continuously enter the market, and their environmental and health impacts are often not well understood. Continuous monitoring and research are required to assess the implications of emerging contaminants on human health (Ghosh *et al.*, 2020; Kümmerer, 2009).

Conclusion

Addressing pharmaceutical waste contamination in agricultural systems is crucial not only for soil and crop health but also for protecting human health. Mitigating these risks requires a concerted effort from researchers, policymakers, and agricultural practitioners to establish sustainable practices and guidelines.

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REFERENCES

- Aiyelari, P. J., Akinsola, A. O., & Akintayo, I. R. (2021). Climate change effects on biodiversity in Nigeria: A review. *Journal of Environmental Science and Technology*, 14(1), 32-45.
- Bajwa, R., et al. (2021). The potential of mushrooms in the bioremediation of contaminated soils. *Environmental Science and Pollution Research*, 28(8), 9433-9448.
- Bassey, F. I., Akpan, U. M., & Okon, E. E. (2019). Physicochemical properties and microbial analysis of soil from different land uses in Uyo, AkwaIbom State, Nigeria. *Nigerian Journal of Ecology*, 19(2), 80-90.
- Cajthaml, T., Erbanová, P., Sasek, V., & Šašek, V. (2008). Mycoremediation of polyaromatic hydrocarbon-contaminated soil. *Journal of Chemical Technology & Biotechnology*, 83(9), 1289-1297.
- Cycoń, M., & Piotrowska-Seget, Z. (2016). Antibiotics in the soil environment—Degradation and their impact on microbial activity and diversity. *Frontiers in Microbiology*, 7, 802.
- Fritsche, W., & Hofrichter, M. (2008). Degradation of polycyclic aromatic hydrocarbons by fungi. *Applied Microbiology and Biotechnology*, 65(2), 124-132.
- Ghosh, S., et al. (2020). The impact of pharmaceuticals in the environment: A review of the effects on soil and water ecosystems. *Chemosphere*, 244, 125545.
- Ghosh, S., et al. (2023). Filamentous fungi for sustainable remediation of pharmaceutical compounds, heavy metal, and oil hydrocarbons. *Frontiers in Bioengineering and Biotechnology*.
- Ginebreda, A., Muñoz, I., López de Alda, M., Brix, R., López-Doval, J., & Barceló, D. (2014). Environmental risk assessment of pharmaceuticals in rivers: Relationships among hazard indexes and aquatic macroinvertebrate diversity indexes in the Llobregat River (NE Spain). *Environment International*, 63, 163-172.
- Gomez, K. A., & Gomez, A. A. (1984). *Statistical Procedures for Agricultural Research* (2nd ed.). Wiley.

- Grujić, M., Tubić, A., & Vuković, D. (2024). Microbial responses to pharmaceutical pollutants in agricultural soils. *Journal of Soil and Environmental Quality*, 55, 221-238.
- Grujić, N., Drobňaković, T., & Marčić, D. (2024). Altering microbial communities in substrate to stimulate the growth of healthy button mushrooms. *Agriculture*, 14(7), 1152.
- Komárek, M., Čadková, E., Chrástný, V., Bordas, F., & Bollinger, J. C. (2015). Contamination of vineyard soils with fungicides: A review of environmental and toxicological aspects. *Environment International*, 76, 45-59.
- Kumar, V., et al. (2020). Environmental pollution and its effects on mushrooms: A review. *Mycology*, 11(3), 163-175.
- Kümmerer, K. (2009). *Pharmaceuticals in the Environment: Sources, Fate, Effects and Risks*. Springer-Verlag.
- Li, Y., et al. (2022). Impact of pharmaceutical pollutants on soil microbial diversity and agricultural productivity. *Environmental Science and Pollution Research*.
- Martínez-Pascual, E., Ribas-Aparicio, R. M., & Vázquez-Villegas, B. (2018). Pharmaceutical residues in the environment: Occurrence, effects, and human health implications. *Ecotoxicology and Environmental Safety*, 150, 60-70.
- Morón, A., et al. (2019). Impact of pharmaceuticals on soil microbial communities: A review. *Microbial Ecology*, 77(1), 1-15.
- Nannipieri, P., et al. (2018). Soil microbiology: Challenges and solutions in assessing microbial diversity. *Biological Fertility of Soils*, 54(3), 1-13.
- Nwaogu, A.G., Aja, O.A., Nwoko, M.C., Ugwuja, F.N., and Ogbonna, A.G (2024) Effect of selected agro waste substrates on the growth and yield of grey oyster mushroom (*Pleurotus ostreatus* Jacq.). Proceedings of the 2nd International Conference (CNREM) 2024, Michael Okpara University of Agriculture, Umudike Nigeria. College of Natural and Environmental Management.
- Pérez, M., et al. (2019). Pharmaceuticals in the environment: A review of their occurrence, effects, and removal. *Water Research*, 149, 7-17.
- Rillig, M. C., Wright, S. F., Shaw, M. R., & Field, C. B. (2002). Artificial ecosystem warming positively affects arbuscular mycorrhizal fungi and soil aggregation in a grassland. *New Phytologist*, 153(3), 500-507.
- Schäffer, A., et al. (2018). Pharmaceutical residues in the environment and their impact on soil fertility. *Soil Biology and Biochemistry*, 127, 130-138.

- Suwannarach, N., Kumla, J., & Lumyong, S. (2022). Degradation of pharmaceutical residues by *Pleurotus ostreatus*: Enzymatic potential and field applications. *Environmental Science and Pollution Research*, 29(14), 18906-18916.
- Verlicchi, P., Al Aukidy, M., & Zambello, E. (2012). Occurrence of pharmaceutical compounds in urban wastewater: Removal, mass load and environmental risk after a secondary treatment—a review. *Science of the Total Environment*, 429, 123-155.