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Sanitation-Driven Solutions for Child Health: Strengthening the Health System to Combat Diarrhoea and Malnutrition in Gulu, Uganda

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Abstract

Background: Basic sanitation is lacking in African countries like Uganda, posing a major public health concern that hinders progress and leads to preventable deaths from diarrhoea and malnutrition in children under five**.** This context demands robust sanitation interventions to enhance health outcomes. This study looks at how well the district's health system handles sanitation issues and how these practices impact children's health. This guide gives actionable steps to reduce health dangers from poor sanitation for vulnerable groups.

Methods: The study used a convergent parallel design. It collected implicit, simultaneous data at one time. The diffusion of innovations model was used. This model examined how quickly new ideas spread. It also looked at the equal importance of both aspects. Data came from 10 health centres. Data also came from 317 households. Targeted and random sampling were used. The sampling matched the village population sizes. SPSS and Jamovi analysed quantitative data. These included factor analysis, structural equation modelling, and multivariate analysis. DQA minor lite software analysed qualitative data. This used thematic analysis.

Results: The research findings show a critical open defecation rate of 24.9%, which disproportionately impacts low-socioeconomic households (56%). Furthermore, 28.7% of children suffer from stunting, and 62.7% experience diarrhoea. Multivariate logistic regression analysis shows significant associations between effective emergency sanitation planning, community participation, educational programs, and improved child health outcomes. Providing information had an AOR of 0.17 (95 % CI: 0.034, 0.823, $p<0.05$) among 61% who agreed with the relative risk showing 83% protection against diarrhoea. Health workers' consistent education provided protection against malnutrition, with 58% of participants mentioning sometimes' with an AOR of 0.28 (95% CI: 0.087, 0.0926, $p<0.05$).policy and guidelines on child excreta and diaper disposal in 63% agreed offered 9% protection on child outcomes with AOR of 0.91(95%CI:0.425, 1.969, $p<0.05$). Facilities with robust emergency sanitation plans designed to lower child mortality showed a significant 6.46-fold increase in the odds of achieving this outcome (AOR = 6.46, 95% CI: 3.21-13.01). It's important to note that exposure represents a successful response strategy, with outcomes being the successful control of disease, as shown by odds ratios. To decrease child mortality and illness, the district plans to provide health worker training, improve sanitation infrastructure, and implement new policies.

Keywords: sanitation, child health, health system response, emergency plans, community engagement, Gulu, Uganda

Clinical Trial-Not Applicable as of 24th February 2025

BACKGROUND

Maintaining proper sanitation is a critical determinant of public health outcomes in Africa. Adequate healthcare systems are critical for sanitary advancements, leading to reduced disease transmission, fostering communities to thrive, and ensuring hygienic practices are both safe and respectful. Open defecation remains prevalent in Sub-Saharan Africa, with East Africa being a key area, and ongoing initiatives aim at its eradication (Azevedo, 2017).

In Uganda, poor sanitation puts 20.5% of children under five at risk. According to the Uganda Bureau of Statistics and ICF International (2022), diarrhoea affects 14.4% of these children, and 26% experience stunting. These health impacts extend beyond individual suffering, as two billion people worldwide lack basic sanitation facilities. Therefore, addressing these interconnected problems is crucial for improving global health, securing children's futures, and building resilient communities.

Gulu District serves as a relevant case study because of its limited resources and high population density. Health risks are amplified because 28% of households practice open defecation and have ineffective diaper disposal methods. Contaminated water leads to children having diarrhoea, cholera, and respiratory illnesses.

The aim of this study is to assess how sanitation initiatives in Gulu District's health system impact the health of children. Sclar et al. (2022), Biran et al. (2022), and Bauza & Werth (2017) have shown that community engagement, readiness, governmental policies, and local statutes contribute to enhanced sanitation and health outcomes. The study uses a null hypothesis to guide its analysis. The district's sanitation efforts do not affect children's health, such as diarrhoea or stunting. This brings us to the main research question: How do district health systems' sanitation efforts affect child

health in Gulu District? Gulu District officials ought to recognise the importance of sanitation for children's well-being. Better child health and strong communities depend on sanitation, community action, and healthcare.

Literature Review

Research explores the efficacy of current sanitation and child health programs (Soboksa et al., 2024; Terfa et al.,2021; Santos et al., 2019). Studies highlight that strong infrastructure and skilled staff are vital for better sanitation (Mohammadi et al., 2018). Smith et al. (2014) argue that without these foundational elements, public health initiatives will struggle to succeed. Bose et al. (2024) highlight the importance of innovative educational programs in raising hygiene awareness.

Researchers question the effectiveness of governmental child-friendly initiatives in improving sanitation. Sanitation projects for children in poor African areas failed because of ongoing structural problems, as reported by Saleem et al. (2019) and Kar and Chambers (2019). This inconsistency shows the need to better include children's sanitation needs in health policies.

Recognise the socio-economic determinants that impede sanitation access. Research conducted by Islam et al. (2020) established a correlation between open defecation and adverse effects on child health, with the practice contributing to 38% of diarrhoea incidents and exacerbating health inequalities in disadvantaged countries. In agreement with Contreras et al. (2022), this literature also posits the imperative for creative interventions to surmount these shortcomings.

A major knowledge gap about essential skills for effective community engagement persists, according to Shrestha et al. (2022), even though sanitation has improved. To fix the varied health outcomes caused by unequal resource distribution, health systems need a complete review. Kar and Chambers (2019) highlight how important community involvement is for sanitation projects.

However, getting marginalised groups involved is still difficult, showing we need new approaches (Busienei et al. 2019).

In conclusion, despite widespread agreement regarding the significance of sanitation for child well-being, deficiencies persist in policy efficacy, community involvement, and the assessment of interventions, showing avenues for subsequent investigation and initiatives (Terfa et al., 2021). A major deficiency exists in research concerning the expansion of hygiene education within healthcare systems where cultural considerations play a prominent role. Under-funded healthcare systems compromise health, vital for disease prevention. The resolution of socio-cultural impediments is fundamental to the formulation of interventions aimed at achieving lasting improvements in sanitation.

Rogers' 2003 Diffusion of Innovations model omits the social and cultural dimensions of community engagement. Advocates believe the model retains its utility in explaining sanitation technology adoption. To foster community engagement and guarantee successful implementation, diverse communication strategies and targeted actions are requisite.

Researchers debate mixed-methods research's necessity for evaluating governance and policies for improved sanitation programs. The existing literature shows that a lack of sufficient funding, ineffective implementation strategies, and poor coordination hinder advancements. Therefore, future research must consider these interconnected factors.

MATERIALS AND METHODS

Study Design

The research utilised a convergent parallel design, integrating quantitative and qualitative methodologies in equal measure, with data acquisition occurring concurrently. The researchers

concluded that the clinical trial was not applicable. The aim was to evaluate the impact of sanitation within district health systems on child well-being. Researchers adopted a pragmatic mixed-methods paradigm as the foundation for this study. The acquisition of knowledge regarding this subject proved intricate, causing the integration of quantitative data and qualitative observations (Morgan, 2007).

The Study sites

This investigation was conducted within the Awach and Owoo sub-counties of Gulu District, Uganda. The selection of these locations was influenced by a variety of geographical and demographic factors. The study examined sanitation and child health challenges, such as diarrhoea and inadequate nutrition, within the district health systems of the specified tropical region, with a population of 26,508 individuals across 4,418 varied households. The study was made possible by the participation of parents of young children, health experts, and local leaders, who were enlisted by Awach and Owoo. Awach sub-county comprises 6,371 males and 6,631 females, accounting for 2,167 households. Owoo sub-county's demographic profile shows 6,618 males and 6,888 females, comprising 2,251 households. 3399 households, health practitioners, and community leaders were targeted. Eligibility for this study required participants to be at least 18 years of age, live within the designated sub-counties, and possess the capacity to provide informed consent.

Child health outcomes, such as diarrhoea and malnutrition, were the dependent variables. Researchers using designed tools gathered data on income, sanitation, and the health system. Quantitative surveys were used to collect data; qualitative data came from focus groups and interviews. Researchers assigned equal importance to both data types.

Recruitment and Participant Selection

Researchers recruited participants for the study using a multistage sampling approach, which included three steps. The study aimed to recruit 360 participants, caregivers aged 18 or older with

children under 5 years old, through a combination of sampling methods. The study used random sampling for households from a total population of 26,508 and purposive sampling for caregivers who met set criteria. The researchers also used a method to include different people, considering things like their age, gender, and how much money they have. We employed expert sampling to find key informants with relevant qualifications and abilities.

Fisher's formula, represented as $n = z^2p(1-p)/d^2$, was applied by the researchers for the calculation of the quantitative sample size. A sample size of 317 households was determined, utilising a 95% confidence level and a 0.05 margin of error. A standard deviation of 1.96 and a 29.1% prevalence of diarrhoea served as the basis for this determination (Omona et al. 2017). The research involved ten healthcare professionals and utilised four group discussions, each comprising six to eight participants, to collect sufficient data. Researchers stratified the participant pool by urban-rural status to ensure comprehensive representation. Simple random sampling in proportion to their size allowed for the choice of villages and households. To ensure diverse perspectives, community caregivers, and sanitation committee members were included. Interviews were conducted with key stakeholders, including health assistants, inspectors, educators, and health officials. Expert sampling served as the selection criterion for the participants. Data was gathered from a varied demographic through a structured method.

Data Collection and Ethical Considerations

Data collection began on 21st October 2024 and ended on 15th December 2024. Structured questionnaires, designed by the researcher and the WHO, were used to gather quantitative data. The questionnaires collected information on demographics, sanitation, health actions, and child diarrhoea/malnutrition. Trained assistants surveyed 317 households with children under five and saw sanitation. The Local Council guided the study by providing household lists and village maps for

sampling. Each survey lasted 60 minutes per household, based on pre-tests conducted in similar settings.

To better grasp the situation, we interviewed caregivers, community leaders, and sanitation officials. We transcribed the recordings of group discussions and interviews word-for-word. Health officials invited 8-10 individuals to a meeting about the health system's plan for childhood diarrhoea and malnutrition, asking them to participate. The lead author, with a translator, interviewed in the local language (Acholi). They recorded and transcribed these interviews into English for comparison.

Household identification, interviews, discussions, and sanitation observations allowed researchers to collect the data. The study adhered to the Declaration of Helsinki, prioritising participant ethics, safety, and welfare. The IRB, UNCST approved the study and local authorities. Ethically, the study ensured consent and kept information confidential using anonymisation. Researchers conducted data collection in a private setting with strict access controls. Following top ethical guidelines, we have inserted place security measures for sensitive data. Focus groups with caregivers and sanitation committee members were led by different research assistants in their respective fields to ensure consistency. The team gathered both types of data and combined them for interpretation.

The researcher checked their data tools with experts and in a test run to make sure they were correct and consistent. The researchers assessed content validity using the content validity index (CVI) for the instruments. Experts reviewed and revised them in response to feedback to ensure coverage of relevant content. The CVI calculation resulted in 0.84, which exceeds the standard threshold of 0.80. Experts checked construct validity using EFA, CFA, and SEM. The EFA results revealed a two-factor solution accounting for 20.35% of the variance, and the CFA showed a good fit. SEM showed significant relationships between district health system responses and childhood

diarrhoea and malnutrition outcomes, with these outcomes influenced by socioeconomic status and access to sanitation. A Cronbach's alpha coefficient of 0.79 confirmed reliability, showing high internal consistency. To ensure quality qualitative data, researchers employed techniques like member checking and peer debriefing.

Data Analysis Procedure

SPSS analysed the data on demographics, sanitation, and measurements given as frequencies and percentages. The team used Jamovi, which interfaces with SPSS, to conduct an Exploratory Factor Analysis (EFA) and find latent factors in the data. This process entailed data preparation, factor extraction, factor rotation, and interpreting the results.

Based on the EFA results, researchers developed a confirmatory factor analysis (CFA) model to test the factor structure. The study used maximum likelihood to build the CFA model and checked its fit with indices like chi-square, CFI, and RMSEA. Then, we interpreted the CFA results to understand the relationships among the factors. Following the CFA, researchers used SEM to study how characteristics relate to outcome variables. Maximum likelihood estimation allowed the researchers to estimate the SEM model, and they used fit indices to evaluate model fit. The researchers then used the SEM model results to study the links between the factors and the outcome variables.

To confirm their theories, applied inferential analysis. Logistic regression was also used to examine the links between factors and the results. Maximum likelihood estimation allowed for the calculation of odds ratios for the significant predictors. To understand the relationship between predictors and outcomes, Analysed the logistic regression results. Thematic analysis of the qualitative data occurred using QDA Miner Lite. We familiarised ourselves with the data, coded

it, and found themes. Then, they interpreted the themes within the context of the research question and the literature.

RESULTS

Demographic characteristics of study participants

The study achieved a 100% response rate. The key findings in Tables 1 and 2 showed that 94% (298/317) of caregivers were female. Among the children, 50.5% were male, and 50.5% were between 24 and 59 months old. The study classified 56.8% of households as having low socioeconomic status. A high proportion of these, 80.5%, lived in the rural area of Owoo sub-county compared to the urban area of Awach sub-county, where only 31.4% fell into this category.

The nutritional status of children showed that 38.5% were malnourished, as measured by a Mid-Upper Arm Circumference (MUAC) reading below 12.5 cm. Researchers classified 7.6% of the children as severely underweight, based on MUAC readings below 11.5 cm. They reported a higher percentage of undernourished children in the urban area of Awach (54.3%) than in the Owoo sub-county (23.8%). According to the World Health Organisation (WHO) standard Z-scores, children's data revealed stunting in 28.7% (HAS <-2 SD), underweight in 16.4% (WAS <-2 SD), and wasting in 13.6% (WHS <-2 SD).

Diarrhoea affected 62.7% (199/317) of households, with no differences seen in the two sub-counties. The finding revealed that 24.9% (79/317) of households lacked access to sanitation facilities, and only 20.5% (65/317) practiced handwashing with soap. However, sharing latrines was common among these households. Half (48.6%) of households lacked child excreta facilities, and 68.1% engaged in unimproved anal cleaning. Among 51.4% with child excreta facilities, 20.8% had

latrine slabs and 30.6% had latrines without slabs. Households normally washed and reused 53.6% of soiled cloth diapers, according to the findings.

Table 1: Socio-demographic characteristics of participants

Variables	Categories	Awach Sub-county		Owoo Sub-county		Gulu District	
		Freq. (n=153)	Percent (%)	Freq (n=164)	Percent (%)	Freq (n=317)	Percent (%)
Caregiver gender	Male	10	6.5	9	5.5	19	6.0
	Female	143	93.5	155	94.5	298	94.0
Child gender	Male	79	51.6	81	49.4	160	50.5
	Female	74	48.4	83	50.6	157	49.5
Child age	Less 12 months	39	25.5	38	23.2	77	24.3
	13-23 months	46	30.1	33	20.1	79	24.9
	24-59 months	68	44.4	93	56.7	161	50.8
Socioeconomic status	Low	48	31.4	132	80.5	180	56.8
	Medium	103	67.3	31	18.9	143	45.1
	High	2	1.3	1	0.6	3	0.9
Mid-Upper Arm Circumference (MUAC)	Less 11.4cm	18	11.8	6	3.7	24	7.6
	11.5-12.5cm	65	42.5	33	20.1	98	30.9
	Above 12.5cm	70	45.8	125	76.2	195	61.5
Weight for Age (WAZ) Z Scores	<-2SD	41	26.8	11	6.7	52	16.4
	2SD-2SD	110	71.9	147	89.6	257	81.1
	3SD	4	2.6	17	10.4	21	6.6
Height for Age (HAZ) Z scores	<-2SD	44	28.8	47	28.7	91	28.7
	>-2SD to 3SD	109	71.2	117	71.3	226	71.3
Weight for Height (WHZ) Z scores	<-2SD	34	22.2	9	5.5	43	13.6
	>-2SD to 3SD	119	77.8	155	94.5	274	86.4
Diarrhea 6months	Yes	100	65.4	98	59.8	198	62.5
	No	53	34.6	66	40.2	119	37.5
Access to sanitation facilities	Yes	115	75.2	123	75.0	238	75.1
	No	38	24.8	41	25.0	79	24.9
Hand washing Facilities	Yes	39	25.5	26	15.9	65	20.5
	No	114	74.5	138	84.1	252	79.5
child excreta facilities	Yes	97	63.4	66	40.2	163	51.4
	No	56	36.6	98	59.8	154	48.6

Table 2: Household socio-demographics and sanitation status

Variables	Categories	Awach Sub-county		Owoo Sub-county		Gulu District	
		Freq. (n=153)	Percent (%)	Freq (n=164)	Percent (%)	Freq (n=317)	Percent (%)
Annual cleansing	Improved	45	29.4	56	34.1	101	31.9
	Unimproved	108	70.6	108	65.9	216	68.1
Type of child excreta facilities	Open defecation	56	36.6	73	44.5	129	40.7
	Potty/Diaper	15	9.8	5	3.0	20	6.3
	Latrine-No slab	50	32.7	52	31.7	102	32.2
	Latrine-Slab	32	20.9	34	20.7	66	20.8
Soiled diaper disposal	Emptied and washed	83	54.2	87	53.0	170	53.6
	Buried	8	5.2	2	1.2	10	3.2
	Put in Latrine	55	35.9	59	36.0	114	36.0
	Wrapped and dumped	7	4.6	16	9.8	23	7.3
Hygiene education	Yes	104	68.0	114	69.5	218	68.8
	No	49	32.0	50	30.5	99	31.2
Potty training	Yes	66	43.1	61	37.2	127	40.1
	No	87	56.9	103	62.8	190	59.9
Guidelines on diaper	Yes	63	41.2	75	45.7	138	43.5
	No	90	58.8	89	54.3	179	56.5

Factor Analysis and Structural Equation Models

Three methods (EFA, CFA, and SEM) helped the study explore the links between health systems, sanitation, and child health. Researchers used the maximum likelihood method with

Varimax rotation and a factor loading of at least 0.30 to conduct EFA, detailed in Table 3. The results showed that over 70% of commonalities exceeded 0.500, showing good explanatory power for the items analysed. The key issues were public hygiene awareness, rules for children's waste, and emergency sanitation. Factor 1 explained 19.19% of the variance, Factor 2 contributed 12.49%, and Factor 3 accounted for 4.95%, with a total count of 36.63%. Bartlett's Test of Sphericity showed a significant correlation (χ^2 (317) = 525, $p < .001$), and the Kaiser-Meyer-Olkin (KMO) measure was 0.700, confirming an adequate sample size for the EFA.

Confirmatory Factor Analysis (CFA) in Figure 1 confirmed the EFA results, focusing on model fit and factor loadings. With an RMSEA of 0.0439 (CI: 0.0119, 0.0696), the CFA showed an excellent model fit. The Tucker-Lewis Index (TLI) was 0.943, and the Comparative Fit Index (CFI) was 0.965. The chi-squared statistic (χ^2) was 35.4 on 22 degrees of freedom, with a p-value of 0.035, showing that the model significantly outperforms the independence model. Maintenance infrastructure showed a strong loading of 0.60, with a significant covariance with sanitation promotion education (coefficient: 0.39).

Structural Equation Model (SEM) in Figure 2 showed a good fit to the data ($\chi^2(24) = 55.0$, $p < .001$; RMSEA = 0.064; CI: [0.042, 0.086]; SRMR = 0.094; CFI = 0.963; TLI = 0.945). The structural model showed a significant positive effect of policy guidelines on education ($\beta = 0.192$, $p = 0.019$), suggesting that policy guidelines influence education-related outcomes, such as knowledge of the proper disposal of children's excreta. However, policy guidelines had no significant effect on emergency plans ($\beta = -0.016$, $p = 0.791$).

Education influenced emergency plans ($\beta = 0.184$, $p = 0.051$), underscoring its significant impact on improving outcomes in community sanitation emergency plans.

The SEM gave insights into the relationships among policy guidelines, education, and emergency plans for child excreta disposal and sanitation, showing that effective policies can enhance education and improve emergency preparedness, improving child health outcomes.

Table 3: Exploratory Factor Loading on Health System Response

Item Code	Item Description	Factor loading	Uniqueness	KMO MSA	Eigen value
PE80	Are health providers knowledgeable	0.787	0.369	0.737	1.9088
PE78	Do health providers consistently educate caregivers on excreta disposal	0.698	0.465	0.751	0.8529
PE83	Are child excreta disposal integrated into health promotion programs	0.594	0.632	0.737	0.2331
PE82	Health workers provide information on the benefits of safe disposal practices	-0.543	0.703	0.581	0.0773
IM77	Community with functional sanitation facilities experienced improved child health outcomes	-0.365	0.833	0.588	0.0257
PG85	There are policies and guidelines on child excreta and diaper disposal	0.77	0.398	0.75	-0.0529
PG86	Community laws and regulations prohibit the disposal of crude soiled diapers	0.66	0.545	0.72	-0.1317
PG88	Do they monitor and evaluate children's excreta and diaper disposal	0.37	0.859	0.802	-0.2103
SE74	Health facilities with sanitation emergency plans experience reduced child mortality	0.49	0.745	0.5	-0.2556
SE75	Communities with emergency preparedness plans have better child health outcomes	0.46	0.788	0.594	-0.5334

The 'maximum likelihood' extraction method used with a 'varimax' rotation. The KMO measure of sampling adequacy was 0.700. PE= Sanitation promotion and education, IM= Infrastructure maintenance, PG= Policy guidelines, SE=Sanitation emergency plans

Confirmatory Factor Analysis Path Diagram

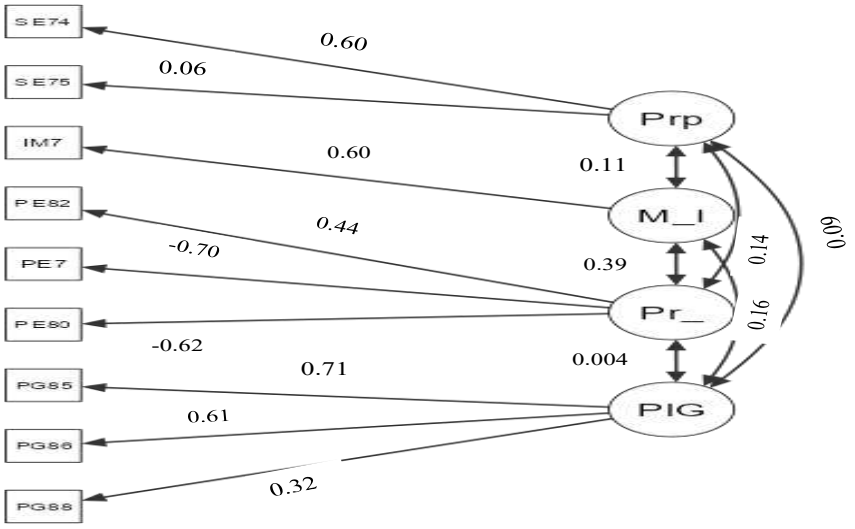


Figure 1 Confirmatory Factor Analysis

Source: primary data analysis using Jamovi software

Key: PrP = Emergency plan, M_I = Infrastructure upkeep, Pr_ = Awareness campaigns, PIG = Policy guidelines

Structural Equation Model Path Diagram

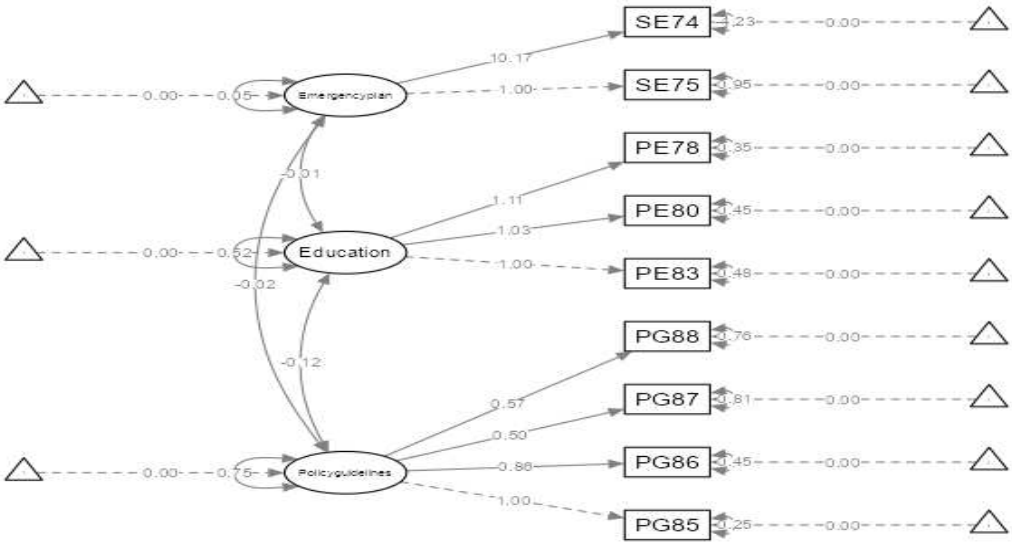


Figure 2: Structural Equation Model of the health system response

Source: Primary data analysis using Jamovi software

Key: SE= Sanitation emergency plans, PE= Promotion education, PG= Policy and guidelines

281 Three factors found in SEM: the emergency plan, education, and policy guidelines.

282 **Logistical Regression Statistics**

283 Relationship between Health System Response and Child Health Outcomes

284 Table 4: Health system response to childhood diarrhoea disease

Variables	Response	Outcome		Bivariate analysis	Multivariate analysis
		Yes	No	COR (95%CI)	AOR (95%CI)
Health Facility Preparedness Plan available	Disagree	19(73%)	7(27%)	1	1
	Neutral	2(29%)	5(71%)	0.61(0.248, 1.498)	0.77(0.280, 2.106)
	Agree	177(62%)	107(38%)	4.14(0.788, 21.69)	6.46(1.039, 40.14) **
Community response plan	Disagree	3(60%)	2(40%)	1	1
	Neutral	8(73%)	3(27%)	1.10(0.180, 6.644)	
	Agree	187(62%)	114(38%)	0.62(0.160, 2.366)	
Health Workers' Knowledge about Excreta Disposal	Highly knowledgeable	82 (56%)	64(44%)	1**	1**
	Moderately knowledgeable	78(72%)	31(28%)	1.36(0.674, 2.267)	1.41(0.720, 2.753)
	Not knowledgeable	38 (61%)	24(39%)	0.63(0.326, 1.216)	0.70(0.341, 1.429)
Give Information on Safe Disposal Practices	Disagree	38(63%)	22(37%)	1	1
	Neutral	14(88%)	2(13%)	0.89(0.496, 1.597)	0.85(0.416, 1.744)
	Agree	146(61%)	95(39%)	0.22(0.049, 0.988) **	0.17(0.034, 0.823) **
Consistency of Education by Health Workers	Yes Always	59 (61%)	38(39%)	1	1
	Sometimes	66(59%)	45(41%)	0.88(0.454, 1.691)	0.82(0.279, 2.395)
	Rarely	39(78%)	11(22%)	0.93(0.489, 1.759)	0.83(0.317, 2.171)
	Never	34(58%)	25(42%)	0.38(0.165, 0.893) **	0.29(0.091, 0.947) **
Sanitation Policies/guidelines	Disagree	72(61%)	46(39%)	1	1
	Neutral	38(63%)	22(37%)	1.10(0.665, 1.828)	0.63(0.321, 1.247)
	Agree	88(63%)	51(37%)	1.00(0.533, 1.872)	0.91(0.425, 1.969)
Community Laws Against Improper Disposal	Disagree	60(50%)	59(50%)	1**	1**
	Neutral	30(73%)	11(27%)	2.17(1.324, 3.549) **	2.32(1.239, 4.350) **
	Agree	108(69%)	49(31%)	0.81(0.375, 1.744)	0.98(0.394, 2.435)
Monitoring and Evaluation of Excreta Disposal	Disagree	61(57%)	46(43%)	1	1**
	Neutral	12(52%)	11(48%)	1.52(0.932, 2.479)	1.74(1.017, 2.964) **
	Agree	125(67%)	62(33%)	1.85(0.772, 4.424)	2.57(0.974, 6.802) **

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Key: COR= crude odds ratio, AOR= adjusted odds ratio, 95%CI=95% confidence interval, **p-value less than 0.05, outcomes =Yes and No.

The findings from Table 4 significantly illuminate the intricate relationship between health systems' sanitation responses and childhood diarrhoea outcomes, providing a nuanced understanding of these associations through crude odds ratios (COR) and adjusted odds ratios (AOR) calculated from the relative risk of exposure to a response strategy, and the outcome known as successful disease control. For policymakers and health experts, these results are significant as they show that healthy system actions result in improved child health.

Health facility preparedness plans are crucial actions that significantly enhance health outcomes. The study found that over 60% of health facilities with sanitation emergency plans saw lower child death rates during emergencies. However, the study reported an AOR of 6.46 (95% CI: 1.039-40.14), implying that the preparedness plans are more risk factors if not implemented. CI suggests that the observed effect is both real and significant. So, following these plans improves health and lowers the danger of children getting diarrhoea.

A survey showed that 62% of participants had improved child health in areas with sanitation emergency plans. The study's initial odds ratio of 0.62 (95% CI: 0.160, 2.366) suggests a protective effect. However, this association between having a response plan and better child health outcomes was in-significant. This means that while a plan contributes to better outcomes, other factors are also at play. This approach helps us see how effective health facility preparedness is in preventing illness.

The study showed that health workers with a moderate understanding were 41% prone to incorrect child excreta disposal than higher knowledgeable ones. However, the 95% CI (0.720, 2.753) includes one, showing a non-significant result. Workers categorized as "not knowledgeable" had an AOR of 0.70 (95% CI: 0.341, 1.429). They were 0.70 times less to provide proper disposal of child

excreta. However, the 95% CI (0.341, 1.429) includes one, showing a non-significant result. This suggests that a lack of knowledge increases diarrhea cases by 30%, but researchers did not find this statistically significant.

Providing information on safe disposal practices was associated with a reduction in diarrhea. The research showed that a majority (61%) discussed the advantages of safe disposal. The adjusted odds ratio (AOR) of 0.17 (95% CI: 0.034, 0.823) shows a significant association ($p < 0.05$), suggesting that providing such information is associated with a reduced likelihood of the outcome, implying a protective effect. The relative risk implication is that information on safe disposal practices reduces the risk of diarrhoea by 83%.

Health workers' continuous educational efforts are important. 58% of those who never had consistent education had an AOR of 0.29 (95% CI: 0.091, 0.947), which is significant ($p < 0.05$). This study found that not having health education increases the chance of diarrhea by 71%, highlighting how important it is to have reliable health information.

The study found that 63% of respondents agreed that sanitation policies and guidelines exist for the disposal of child excreta and diapers. The adjusted odds ratio (AOR) of 0.91 (95% CI: 0.425, 1.969) shows a protective effect, suggesting that implementing policies is associated with a 9% reduction in the risk of diarrhea.

The finding revealed that 67% participant agreed that health workers monitor and evaluate child excreta and diaper disposal in rural community with (AOR = 2.57; 95% CI: 0.974, 6.802; $p \sim 0.05$), suggesting that monitoring and evaluation of excreta disposal practices were associated with a borderline significant diarrhoea risk factor suggesting a potential risk among those without monitoring framework.

According to these findings, managing childhood diarrhea requires health systems to train staff, involve communities, and create policies. The focus is on specialized health actions to help at-risk communities. In summary, the results provide important clues about how health system issues affect children's health, with diarrhea, and offer practical advice for building health strategies to improve children's health.

Association of District Health Systems' Sanitation Response and Childhood Malnutrition

The results in Table 5 reveal the complex connection between health system actions and childhood malnutrition. To get a complete understanding of the associations, the analysis looks at both CORs and AORs.

The health workers' knowledge of excreta disposal is a key variable in this examination. Individuals classified as "highly knowledgeable" serve as the reference group, with an adjusted odds ratio (AOR) of one. In contrast, those deemed "moderately knowledgeable" have a 72% association with a 4.96-fold likelihood of malnutrition (AOR = 4.96; 95% CI: 1.574, 15.56; $p < 0.05$). This unexpected finding suggests that moderate knowledge is associated with a risk of malnutrition, warranting further investigation into the underlying factors. Meanwhile, individuals categorized as "not knowledgeable" show a low protective effect, correlating with incidences of malnutrition (AOR = 1.08; 95% CI: 0.371, 3.169), representing an 8% increase, although this association is not statistically significant.

The analysis reveals that a significant majority, 61%, agreed that health workers communicate the benefits of safe disposal practices. However, the relationship between perceptions of safe disposal and malnutrition is complex. Specifically, while perceiving safe disposal as important was associated with non-significantly higher odds of malnutrition (AOR = 3.58; 95% CI: 0.780, 16.43), neutral

attitudes showed a low, non-significant association (AOR = 1.59; 95% CI: 0.727, 3.470). These findings suggest intricate connections between knowledge, attitudes, and the risk of malnutrition.

Health workers' consistent education is a crucial factor in protecting against malnutrition and diarrhea. Respondents who reported receiving consistent education served as the reference group (AOR = 1). Those receiving education sometimes (59%) had an AOR of 0.28 (95% CI: 0.087, 0.926), while those receiving education rarely had an AOR of 0.22 (95% CI: 0.074, 0.637). Both findings were significant ($p < 0.05$). With odds ratios less than 1.0, the results show that education reduces the risk of malnutrition in children. Conversely, a lack of consistent education increases the risk of adverse childhood nutrition outcomes.

When examining sanitation policies for disposing of children's waste and diapers, individuals who disagreed that such policies existed were used as the reference group (AOR = 1). People who were neutral about the policies had a risk of malnutrition, with an AOR of 3.26 (95% CI: 1.579-6.748), suggesting a strong association between these policies and malnutrition risk. Meanwhile, those who agreed with the sanitation policies had a risk of malnutrition (AOR = 1.29), but this was not statistically significant.

The impact of community regulations on waste disposal was significantly associated with malnutrition risk. Compared to those disagreeing with regulations, individuals with a neutral stance had a risk (AOR = 3.16; 95% CI: 1.801, 5.545), while those agreeing had a non-significant 53% increased risk (AOR = 1.53; 95% CI: 0.736, 3.165). This suggests regulations offer protection when enforced.

The reference group for evaluating waste disposal was respondents who disagreed (AOR = 1). Those with a neutral stance had an AOR of 1.93 (95% CI: 1.120, 3.313), $p < 0.05$, showing a significantly strong association between monitoring and malnutrition risk. Odds above 1.0 showed

an increased likelihood of malnutrition risk. Individuals who agreed to monitoring exhibited a non-significant 20% surge in the association with the outcome (AOR = 1.20; 95% CI: 0.439, 3.293), implying that monitoring alone may not strongly sway the outcome without other influencing factors.

The challenges of integrating excreta disposal into health promotion elicited noteworthy findings. Respondents facing challenges made up the reference group (AOR = 1), whereas those not encountering such challenges had an AOR of 0.31 (95% CI: 0.142, 0.669), showing a significant protective effect ($p < 0.05$). Respondents expressing uncertainty about challenges had an AOR of 0.69 (95% CI: 0.371, 1.294), showing a protective effect, but the association was not statistically significant.

Table 5: Relationship between health system response and childhood malnutrition

Variables	Response	Outcomes		Bivariate analysis	Multivariate analysis
		Yes	**No**	**COR (95%CI)**	**AOR (95%CI)**
Knowledge of Health Workers about Excreta Disposal	Highly knowledgeable	82 (56%)	64(44%)	1**	1**
	Moderately knowledgeable	78(72%)	31(28%)	1.68(0.884, 3.194)	4.96(1.574, 15.56) **
	Not knowledgeable	38 (61%)	24(39%)	0.39(0.203, 0.737) **	1.08(0.371, 3.169)
Give Information on Safe Disposal Practices	Disagree	38(63%)	22(37%)	1	1
	Neutral	14(88%)	2(13%)	1.27(0.706, 2.295)	1.59(0.727, 3.470)
	Agree	146(61%)	95(39%)	2.97(0.825, 10.70)	3.58(0.780, 16.43)
Consistency of Education by Health Workers	Yes Always	59 (61%)	38(39%)	1**	1**
	Sometimes	66(59%)	45(41%)	0.41(0.202, 0.835) **	0.28(0.087, 0.926) **
	Rarely	39(78%)	11(22%)	0.43(0.215, 0.865) **	0.22(0.074, 0.637) **
	Never	34(58%)	25(42%)	0.88(0.374, 2.053)	0.40(0.118, 1.350)
Sanitation Policies/guidelines	Disagree	72(61%)	46(39%)	1**	1**
	Neutral	38(63%)	22(37%)	4.00(2.30, 6.949) **	3.26(1.579, 6.748) **
	Agree	88(63%)	51(37%)	1.50(0.816, 2.773)	1.29(0.598, 2.787)
Community Laws Against Improper Disposal	Disagree	60(50%)	59(50%)	1**	1**
	Neutral	30(73%)	11(27%)	3.13(1.845, 5.296) **	3.16(1.801, 5.545) **
	Agree	108(69%)	49(31%)	1.36(0.678, 2.724)	1.53(0.736, 3.165)
Monitoring and Evaluation of Excreta Disposal	Disagree	61(57%)	46(43%)	1**	1**
	Neutral	12(52%)	11(48%)	1.87(1.129, 3.098) **	1.93(1.120, 3.313) **
	Agree	125(67%)	62(33%)	1.82(0.717, 4.641)	1.20(0.439, 3.293)
Challenges integrating excreta disposal in health promotion	Yes	39(64%)	22(36%)	1**	1**
	No	41(38%)	66(62%)	0.22(0.118, 0.417) **	0.31(0.142, 0.669) **
	ot sure	42(28%)	107(72%)	0.67(0.372, 1.072) **	0.69(0.371, 1.294)

Key: COR = Crude Odds Ratio, AOR = Adjusted Odds Ratio, 95%CI = 95% confidence interval, *** $P < 0.05$

Qualitative Thematic Analysis Findings

Table 6's analysis revealed key themes connecting household sanitation and child health. These themes include:

Consistent education: Health education promotes sanitation practices and protects child health outcomes. Outreach programs and community discussions are effective ways for health workers to deliver this education. A key informant participant highlighted the significance of health sensitisation, noting, "We always conduct sensitisation sessions" (KI participant, personal communication, 2024). One participant highlighted the significance of community talks, noting, "We hold outreach and dialogue events." These findings align with the quantitative outcomes, as the odds were significantly less than 1.0 for sometimes and rarely.

Diarrhoea and malnutrition are ongoing serious health concerns for children in the community. Issues with medical supplies, such as shortages and delays, hinder healthcare delivery, consistent with Terfa et al.'s (2021) findings. In a focus group discussion, a participant noted: "*Medications often take a lot of time to reach us and are in short supply*" (FGD Sanitation Committee, personal communication, 2024).

To boost sanitation and child health; community engagement and mobilisation are essential. Health education and home visits encourage proper sanitation practices, aligning with Rogers's (2003) diffusion of innovation model. A key participant mentioned, "We organise mobilisation with Village Health Teams" (personal communication, 2024).

Operational Challenges: Accessibility and transportation issues impede healthcare delivery. Drug availability delays make healthcare and treatment difficult, according to a 2023 WHO report. A key participant highlighted the transport problem, saying, "Transport. One attendee pointed out prolonged waits for pharmaceuticals, saying, "It takes extensive time for medical supplies to reach here."

Health system: The health system must have policies and political backing to boost sanitation and children's health. Healthcare providers play an important role in advancing sanitation and child health. Health workers' use of policy guidelines educates the community and reinforces political commitment. One key informant says, "We instruct them on using diapers and preventing pollution."

Challenges and barriers: economic constraints and environmental factors pose major obstacles to sanitation and child health initiatives. Issues such as water scarcity hinder sanitation efforts. During a focus group discussion, a participant underscored the impact of economic constraints, expressing, *"Poverty. No money"* (FGD participant, personal communication, 2024). Another participant highlighted environmental challenges, noting, *"In the dry season ... the water demand becomes high"* (KI participant, personal communication, 2024).

Table 6: Thematic analysis of various health system responses to child health outcomes

Themes	Descriptions	Codes	Sub-themes	note and Quotes
Consistency education	Health education influences community practices and promotes sanitation and child health.	Health education, community knowledge, and sanitation practices	Role of Health Workers: Effectiveness of Educational Methods	Health workers are vital in giving health education and promoting sanitation practices. Quote "*We always do sensitisation" (KI participant)* Effective educational methods include outreach and community dialogue, which are essential for promoting sanitation practices. Quote: *"We do mobilisation for outreach and dialogues" (KI participant)*
Difficulties in Child Health	In the community, child health challenges like diarrhoea and	Challenges in child health, including	Medical Supply Issues	Medical supply issues, such as stockouts and delays, hinder healthcare delivery. Quote: *"Drugs take a long*

Themes	Descriptions	Codes	Sub-themes	note and Quotes
	malnutrition are public health concerns.	diarrhoea and malnutrition.	Nutrition and Malnutrition	*time to come and are in short supply"* (FGD Sanitation Committee). Nutrition and malnutrition are critical concerns; education is needed to combat malnutrition. Quote *"Training needed on nutrition"* (FGD Sanitation Committee)
Engagement in the community	Promoting sanitation practices and child health relies on community engagement and mobilisation.	Community engagement Mobilisation Sanitation practices	Health Education and Home Visits Limited Support and Incentives	Health education and home visits are effective strategies for promoting sanitation practices. Quote: "*We do mobilisation with the help of VHTs"* (KI participant) Limited resources and incentives for community health workers hinder their motivation and effectiveness. Quote *"Airtime given after three months*" (KI participant)
Operational Challenges	Operational challenges, such as accessibility and transportation issues, hinder healthcare delivery.	Operational challenges, accessibility, and transportation	Accessibility and Transportation Delays in Drug Availability	Accessibility and transportation issues hinder healthcare delivery in remote areas. Quote "*Transport*" (KI participant) Delays in drug availability hinder healthcare delivery and treatment. Quote: *"The drugs take a long time to come" (KI participant)*
Health System Response	The health system response, including policy and political commitment, is critical for promoting sanitation and child health.	Health system response, policy, and political commitment	Health Care Provider Involvement Policy and Political Commitment	Healthcare providers play a vital role in promoting sanitation and child health. Quote: "*We advise them how to use diapers ... and make it not pollute the environment*" (KI participant) Policy and political commitment are essential for promoting sanitation and child health. Quote: "N*o sufficient political commitment to improve child sanitation in the area. "* (KI participant)
Challenges and Barriers	Challenges and barriers, such as economic	Challenges, barriers, economic	Economic Constraints	Economic constraints hinder access to sanitation products and healthcare.

Themes	Descriptions	Codes	Sub-themes	note and Quotes
	constraints and environmental factors, hinder sanitation and child health efforts.	constraints, and environmental factors Environmental Factors	Environmental factors	Quote: *"Poverty. No money*" (KI participant) Environmental factors, such as water scarcity, hinder sanitation efforts. Quote: "*In the dry season ... the demand for water becomes high*" (KI participant)

DISCUSSION

The Exploratory Factor Analysis (EFA) results underscored the emergence of three distinct factors: sanitation promotion and education; policy and guidelines; and emergency preparedness. This tripartite structure was corroborated by Confirmatory Factor Analysis (CFA), a robust statistical method that supports the posited diffusion-of-innovation model. The CFA findings showed a commendable model fit, explained the interrelationships among these factors, suggested that the constructs are defined, and gave a substantive basis for understanding the dynamics of the studied context. The Structural Equation Model (SEM) results were significant and illuminated the intricate relationships between district health system responses to sanitation initiatives and effects on child health outcomes, specifically diarrhoea and malnutrition.

The EFA, CFA, and SEM findings underscore the importance of reassessing the connections among policy guidelines, educational frameworks, and emergency response strategies to address sanitation challenges and their impact on child health outcomes. This study provides valuable insights for policymakers, healthcare professionals, and caregivers. Policymakers will prioritise comprehensive sanitation policies, while healthcare providers must enhance educational and emergency preparedness programs. Caregivers use these results to promote safe sanitation practices in their communities. Future research must examine the influence of district health system responses

to sanitation on child health outcomes across diverse settings, employing methods such as EFA, CFA, and SEM to further confirm these findings.

Triangulation of findings

The triangulation of findings from Structural Equation Modelling (SEM) with regression outcomes shows that community education is a robust protective factor against both diarrhoea and malnutrition in the regression model, a pattern supported by the SEM. The preparedness plans identified in the regression model are associated with reduced diarrhoea and malnutrition, as evidenced by the SEM. Policy guidelines, as an intervention, are associated with reduced risks of diarrhoea and malnutrition, underscoring their critical importance in addressing these public health challenges.

Socioeconomic Status and Diarrhoea

The results show that 56.8% of households have low socioeconomic status, with high levels (80.5%) in the rural area of Owoo sub-county, compared with only 31.4% in the urban area of Awach sub-county. This aligns with Smith et al. (2014), whose perspective, show that low socioeconomic status is associated with poor health outcomes. The high prevalence of diarrhoea (62.7% of households) is consistent with findings that lower income levels result in limited access to health resources, a situation worsened by inadequate sanitation facilities. Alarmingly, 24.9% of households lacked access to sanitation, underscoring a critical area requiring urgent attention.

This connects to Rogers' (2003) work on how new practices spread, showing why better sanitation and hygiene are difficult to implement in these areas. The low handwashing facility rate of 20.5% shows slow adoption of health innovations. This slow progress stems from limited awareness, inadequate resources, or cultural acceptance issues. Promoting hygiene innovations is complicated

by the common practice of families sharing latrines. Half (48.6%) of households lack facilities for child excreta disposal, and the high rate of open defecation (40.7%) not only raises public health concerns but also underscores the need for targeted educational campaigns tailored to the specific sociocultural contexts of these communities.

This evidence aligns with the literature from Kar and Chambers (2019), which highlights that successful sanitation innovations must be adapted to local conditions and practices. Community participation through engagement and mobilisation is vital for promoting sanitation practices and improving child health. Effective solutions such as Sato pans, flash toilets, and VIP latrines have been shown to improve sanitation across diverse contexts. Health education and home visits encourage the adoption of these practices, aligning with Rogers's (2003) diffusion of innovation model. A key informant says, "We mobilise people with the help of Village Health Teams (VHTs)." Introducing these sanitation systems, supported by community involvement, improves hygiene and health outcomes among children. Using Diffusion of Innovation concepts in specific strategies is key to changing sanitation behaviours. The convergence of studies underscores the importance of adapting to context, while divergence highlights the complexities of behavioural change across different socioeconomic settings.

The study finding showed that 68.8% of households had access to hygiene information, suggesting hygiene education is a promising path. Despite this high level of education, only 40.1% of caregivers have participated in toilet training initiatives, and 43.5% have received guidance on best practices for diaper use and disposal. This analysis agrees with Smith et al. (2014), who highlighted that policies and better staff training are key to improving waste disposal.

The insights from this data contextualised using Rogers' Diffusion of Innovations theory. Factors such as perceived benefits and compatibility with existing behaviours influence this theory.

493 This framework enhances the development and dissemination of targeted interventions that align with
494 community norms and promote sustainable infant care practices.

495 **Association between District Health System's sanitation responses and diarrhoea**

496 This section addresses the research question: How do the district health system's sanitation
497 responses influence child health outcomes? The null hypothesis was that the district health system's
498 sanitation responses do not influence child health outcomes, such as diarrhoea and stunting. Based
499 on Table 4, the researcher rejected the null hypothesis and accepted the alternative hypothesis,
500 highlighting the critical role of health system responses in addressing childhood diarrhoea. As
501 emphasized by Shrestha et al. (2022), robust health systems provide the essential infrastructure,
502 resources, and services necessary for effective sanitation practices. The study's results suggest that
503 health facilities that agreed with a sanitation preparedness plan and reduced mortality were more
504 likelihood to achieve positive diarrhea outcomes. Health facilities that have a preparedness plan had
505 a likelihood to see lower child mortality, evidenced by a reduced risk of diarrhea. This suggests that
506 preparedness plans confer a protective effect (lower risk). This finding aligns with the Diffusion of
507 Innovations model advanced by Rogers (2003), which posits that health facilities that recognize the
508 potential benefits of innovations, such as preparedness plans, are more to adopt them. Qualitative
509 thematic analysis revealed that consistent education, community knowledge, and health worker
510 education are essential for promoting sanitation practices and child health.

511 The findings of this study further underscore the importance of community engagement and
512 sanitation policies. As Kar and Chambers (2019) emphasize, community participation is vital to the
513 success of health system interventions aimed at improving sanitation behaviors. From a quantitative
514 perspective, the study's findings show that community laws against improper disposal were
515 associated with child health outcomes (adjusted odds ratio = 2.32). If the law is not enacted, the risk

of exposure will increase, as the odds ratio exceeds 1.0. This result is consistent with Rogers's 2003 Diffusion of Innovations model, which emphasizes the importance of community engagement in policy implementation. Qualitatively, the thematic analysis revealed that community engagement and mobilization are crucial for advancing sanitation practices and child health.

The research outcomes serve to further emphasize the necessity of enhancing policy execution, oversight, and assessment. According to Santos et al. (2019), the effectiveness of health system responses is contingent upon strong governance structures and policies that ensure the persistence of sanitation enhancements. From a quantitative perspective, the study's findings show that policy implementation, monitoring, and evaluation are crucial for enhancing child health outcomes, evidenced by an AOR of 0.91 (95% CI: 0.425, 1.969). An odds ratio less than 1.0 shows a protective effect in this investigation. In line with the Diffusion of Innovations model, this finding highlights the critical role of monitoring and evaluation in generating the feedback essential for improving health practices (Rogers, 2003). The thematic analysis, from a qualitative standpoint, demonstrated that operational impediments, including monitoring and evaluation, compromise the delivery of healthcare services.

The literature by Islam et al. (2020) highlights the importance of addressing socioeconomic determinants of access to sanitation services and the diverse effects of health system responses on vulnerable populations, including children under five. The study's findings show economic constraints impede access to sanitation products and healthcare services. This result is consistent with the Diffusion of Innovations model, which underscores the significance of addressing economic constraints to ease the adoption of health innovations (Rogers, 2003). Qualitatively, the thematic analysis revealed that challenges and barriers, including financial constraints and environmental factors, impede sanitation and child health efforts.

This study's outcomes reinforce the importance of health worker education and training. Jain et al. (2020) emphasize the necessity of incorporating child-specific sanitation requirements into public health policies. The quantitative data from the investigation shows a non-significant relationship between health professionals' awareness of excreta disposal practices and child health indicators, with an adjusted odds ratio of 1.41 (95% CI: 0.720, 2.753). A 41% greater chance of diarrhea exists when few skilled health professionals oversee excreta disposal, elevating the risk. The observed result corresponds to the Diffusion of Innovations framework, underscoring the critical role of knowledge sharing in promoting the uptake of health innovations (Rogers, 2003). In qualitative terms, the thematic analysis emphasizes the critical importance of health worker education and training for advancing sanitation practices and enhancing child health outcomes.

The study's findings further underscore the significance of community engagement and participation in sanitation interventions. Kar and Chambers (2019) highlighted that community-led total sanitation (CLTS) approaches promoted sanitation behaviors and improved health outcomes. The study's results suggest that community engagement and participation are crucial for sustaining sanitation behaviors. The AOR of 2.57 shows a high risk of the outcome if implementation is not correct. This finding aligns with the Diffusion of Innovations model, which emphasizes the importance of community involvement in easing the adoption of health innovations (Rogers, 2003). Qualitatively, thematic analysis shows that community engagement and participation are essential to promoting sanitation practices and child health.

The existing literature highlights the importance of addressing environmental factors that affect access to safe disposal practices, the varied health system responses to these challenges, and their consequences for vulnerable populations, particularly children under five (Islam et al., 2020). The findings of this study show that disseminating information on safe disposal practices significantly

reduces the risk of disease development, as evidenced by an adjusted odds ratio (AOR) of 0.17 (95% CI: 0.034-0.823). This outcome is consistent with the Diffusion of Innovations model, which underscores the importance of mitigating environmental constraints to facilitate the adoption of health innovations (Rogers, 2003). Qualitative thematic analysis revealed that information provided by health workers lowers sanitation-related burdens. These findings reinforce the necessity of targeted communication efforts to enhance sanitation practices and improve public health outcomes.

The study shows that establishing community rules for proper waste disposal is essential for reducing diseases associated with improper waste disposal. The results show that people living in areas with these community laws are more to manage their health. Specifically, they are 2.32 times to experience outcomes. This means that creating and enforcing community regulations lead to successful improvements in disease control, such as diarrhea and malnutrition. Investing in these laws and ensuring their implementation makes a big difference. Health educators also use these rules to help explain their importance to the community.

The study highlights the importance of monitoring and evaluating excreta disposal practices. According to Thomas (2016), these processes are essential for understanding how well sanitation programs function and for identifying areas for improvement. The results show that monitoring and evaluation are crucial for maintaining safe disposal methods, as shown by an adjusted odds ratio (AOR) of 2.57, suggesting a risk among non-implementers. This finding aligns with the Diffusion of Innovations model, which emphasizes the role of monitoring and evaluation in providing feedback that enhances health practices (Rogers, 2003). The thematic analysis also showed that monitoring and evaluation play a key role in promoting improved sanitation practices and enhancing disease control for child well-being.

This study's findings, as summarized, highlight the crucial importance of health system responses for tackling childhood diarrhoea. The strong associations revealed through the odds ratios highlight the effectiveness of preparedness, knowledge dissemination, community laws, and monitoring in influencing outcomes. These statistical measures suggest that targeted public health interventions reduce the incidence of diarrhea among children. By leveraging the principles of the Diffusion of Innovations model, health systems enhance the adoption of effective practices, improving the health and well-being of vulnerable populations. The odds ratios underscore the importance of these strategies, showing that initiative-taking measures increase the likelihood of improving health outcomes.

Influence of District Health System's Sanitation Responses on Malnutrition

Children's nutritional status is concerning, with 38.5% identified as malnourished based on Mid-Upper Arm Circumference (MUAC) measurements below 12.5 cm. This includes 7.6% who are severely malnourished, defined by MUAC readings under 11.5 cm. Notably, an urban area in Awach has a high prevalence of undernourished children at 54.3%, compared with 23.8% in the Owoo sub-county. According to the World Health Organization (WHO) Z-score standards, 28.7% of children are stunted (Height-for-Age Z-score < -2 SD), 16.4% are underweight (Weight-for-Age Z-score < -2 SD), and 13.6% are wasted (Weight-for-Height Z-score < -2 SD).

These findings align with the existing literature by UBOS and ICF International (2022), which emphasizes the critical state of child nutrition, influenced by various socio-economic factors. The implications are paramount: high rates of malnutrition lead to long-term health consequences and hinder child development, which affects educational outcomes and economic productivity in the community. Addressing these challenges requires targeted interventions to improve food security and

606 health services, especially in under-resourced areas. This approach aims to enhance individual health
607 outcomes and promote societal well-being by investing in the next generation.

608 The analysis showed that health workers' knowledge and education are crucial for
609 encouraging waste disposal practices and reducing childhood malnutrition. The data revealed that
610 those considered "moderately knowledgeable" had a risk of malnutrition, with an odds ratio of 4.96,
611 meaning they were 4.96 times more to develop malnutrition compared to those with better
612 knowledge. This finding aligns with existing studies that highlight the importance of health worker
613 training in improving sanitation and child health. The Diffusion of Innovations model also suggests
614 that sharing knowledge and effective practices among health workers influences community health
615 behaviors.

616 The qualitative findings also emphasize the crucial role of continuous health education in
617 promoting proper excreta disposal practices. This is aligned with the quantitative analysis, which
618 shows that participants receiving consistent education had a reduced risk of malnutrition (AORs of
619 0.28 and 0.22 for "sometimes" and "rarely"). This finding is consistent with existing literature,
620 underscoring the necessity for ongoing training and education of health workers to ensure adequate
621 health interventions (Mohammadi et al., 2018). The theoretical underpinning of the Diffusion of
622 Innovations model supports the notion that sustained and consistent education eases the adoption of
623 health practices.

624 The thematic analysis highlighted that community engagement is crucial to improving waste
625 disposal practices and mitigating malnutrition among children. Quantitative data revealed that
626 individuals who are neutral toward community regulations on waste disposal are 3.16 times as to
627 experience malnutrition outcomes as those without such regulations. This finding aligns with prior
628 research emphasizing the need for community involvement in sanitation initiatives (Kar & Chambers,

2019). The Diffusion of Innovations model underscores the importance of community engagement in the successful implementation of health interventions.

The qualitative findings also highlighted the need to integrate sanitation practices into health promotion efforts. The quantitative analysis complements this finding, as revealed through the analysis that respondents who did not encounter difficulties in incorporating excreta disposal into health promotion initiatives were observed to be protected from malnutrition, as shown by an adjusted odds ratio (AOR) of 0.31. This finding is consistent with the literature, underscoring the need for comprehensive sanitation interventions that address the social, cultural, and economic determinants of health (Jain et al., 2020). The Diffusion of Innovations model reinforces this notion by highlighting the importance of overcoming adoption barriers to give health innovations purchase.

This study highlights the need for a comprehensive approach to combat childhood malnutrition. Health systems will focus on training health workers, providing regular health education, involving the community through laws and policies, integrating sanitation into health promotion, and regularly monitoring the progress of sanitation efforts. By drawing on the Diffusion of Innovations model, public health initiatives help spread effective practices that improve children's health. The results are important because they suggest needed changes in policies and practices to reduce childhood malnutrition. Overall, this study clarifies how health systems, cultural factors, and education interact to address childhood malnutrition, setting the stage for further research on these connections.

Future research will focus on long-term studies examining how specific interventions affect children's health. It must also investigate how social and cultural factors impact health behaviors. The results are applied across different regions and situations, leading to better future interventions. Understanding the causes of childhood malnutrition helps create effective, tailored solutions for

different communities. By addressing both the health systems and individual-level factors that contribute to malnutrition, the study improves children's health and reduce disparities in healthcare access and quality. This brings hope for a better future.

The triangulation of findings showed convergence between qualitative and quantitative results, underscoring the impact of health system interventions on positive child health outcomes. The qualitative thematic analysis highlighted the importance of health worker knowledge and education, community engagement, and adequate sanitation policies in promoting appropriate excreta disposal practices and addressing childhood malnutrition (see Table 2). This was further complemented by the quantitative analysis, which identified a substantial positive association between health facilities with a preparedness plan and improved child health outcomes (AOR: 6.46, 95% CI: 1.039-40.14, p-value < 0.05). The odds ratio of 6.46 shows that health facilities with a preparedness plan to reduce child mortality had a 546% higher odds of a malnutrition outcome than those without such a plan.

The complementary nature of the qualitative and quantitative findings provides an understanding of the factors influencing childhood malnutrition. According to the quantitative analysis, statistical evidence shows associations between child health outcomes and health worker knowledge/education, community engagement/participation, as well as sanitation policies/laws. The qualitative analysis provides in-depth insights into the significance of these factors in promoting sanitation practices and child health. Combining these findings, this study provides a comprehensive account of the complex interplay among health system responses, sociocultural factors, and education in addressing childhood malnutrition.

Contribution to knowledge, policy, and practice

The study contributes to knowledge by improving understanding of how health systems affect childhood diarrhoea and malnutrition. It shows that health system preparedness, health worker knowledge, community participation, and monitoring practices influence child health outcomes. Policymakers will prioritise sanitation preparedness, train health workers, and engage communities. Health facilities need emergency sanitation plans. Continuous training for health workers on sanitation is crucial. Health facilities must have structured plans and engage communities. Community-driven initiatives are key to improving health outcomes. The study aligns with the Diffusion of Innovations Model, showing that preparedness plans enhance healthcare. Sociocultural factors and education also affect child health. The study used a mixed-methods approach and the diffusion of innovations model to understand health system responses.

Limitations of the Study

This study identifies notable methodological limitations that require careful consideration. Although the analysis shows strong associations between health system responses and outcomes related to childhood diarrhea and malnutrition, adjusted odds ratios (AORs) did not account for potential confounders. The evaluation of sanitation policies also reveals flaws. While policies connect with health outcomes, the lack of statistical significance in others suggests that policy existence alone is insufficient; This points to a disconnect between policy formulation and implementation, which undermines the effectiveness of interventions to improve child health. The challenges of incorporating sanitation practices into health promotion reflect systemic barriers that health systems face. These obstacles impede the adoption of health innovations and limit the overall effectiveness of efforts to reduce childhood malnutrition and diarrhea. Addressing these limitations is vital to informing future research and to developing comprehensive public health strategies that integrate educational, community, and systemic approaches to improve child health outcomes.

CONCLUSION

The sanitation response within the Gulu District health system is essential for improving child health by reducing illnesses such as diarrhoea and malnutrition. This study highlights the urgent need for effective sanitation interventions in northern Uganda, where poor sanitation contributes to high child morbidity and mortality. Key findings reveal strong associations among improved child health outcomes, health worker knowledge, community involvement, and emergency sanitation plans. To mitigate these risks, prioritising ongoing health worker training, sanitation infrastructure development, community engagement, and strict policy enforcement is crucial. Implementing these strategies reduce child illness and death in Gulu District and similar vulnerable communities. The Diffusion of Innovations Model (DIM) is a framework for understanding how communities share and adopt new health practices and innovations. The implications for policymakers and public health practitioners are paramount, emphasising key intervention areas to enhance health outcomes in vulnerable populations, with clear recommendations for handling childhood illnesses, as outlined:

RECOMMENDATIONS

1) Policymakers will secure funding and engage the community in efforts to combat childhood illnesses related to diarrhoea and malnutrition.
2) Line ministries and agencies must enhance training and preparedness for health workers to improve responses to health crises.
3) Districts will prioritise initiatives focused on sanitation, hygiene, and nutrition to reduce childhood illnesses.
4) Establish legal frameworks to prevent improper waste disposal and enhance health outcomes, including bylaws, ordinances, and relevant legislation.

5) Development partners and line ministries will undertake ongoing training for health workers, emphasising community health practices in hygiene and sanitation.
6) Families and community leaders will be encouraged to advocate for healthy nutrition and sanitation behaviours.
7) Implement community-centred policies that incorporate nutrition education, sanitation, and waste management.
8) Households will adopt effective hygiene practices, such as regular handwashing and safe waste disposal.
9) Future studies will investigate the impact of health interventions and community factors on health practices.
10) Leverage technology and data management systems to analyse community efforts in enhancing childhood health through improved waste management and sanitation.

Abbreviations

CI: Confidential Interval; EFA: Exploratory Factor Analysis; CFA: Confirmatory Factor Analysis; SEM: Structural Equation Model; KI: Key Informants; FGD: Focus Group Discussion; COR: Crude Odds Ratio; AOR: Adjusted Odds Ratio; QDA: Qualitative Data Analysis; CLTS: Community-Led Total Sanitation; ODF: Open Defecation Free.

Declarations

Ethical approval and consent from participants

The research study was conducted with the utmost consideration for ethical principles. In compliance with the Helsinki Declaration, it minimised harm and maximised the benefit to participants. Before the commencement of the study, ethical approval was obtained from the Lacor Hospital Institutional Review Board (LHIRB), with reference number (LACOR-2014-347), and Uganda National Council

for Science and Technology (UNCST), with reference number (HS4991ES). The LHIRB reviewed and approved the research protocol, ensuring ethical principles were followed throughout the study. Informed consent was obtained from participants before their involvement in the study. Participants were given a detailed information sheet outlining the study's purpose, risks, and benefits. They were also informed of their right to withdraw from the study without penalty. Written consent was obtained from participants, and their confidentiality and anonymity were ensured throughout the study. Compliance with the Helsinki Declaration throughout the study ensured that the principles outlined were upheld. Participants' autonomy and dignity were respected, and their rights and welfare were protected. The researchers were aware of their responsibilities to the participants, the institution, and the community and took steps to ensure that the study was conducted with integrity and transparency.

Consent for publication

Not applicable

Availability of data and materials

Data and materials used in this study are available from the editor upon request, ensuring transparency and facilitating further research. The corresponding author is also available to give any other information or clarification.

Competing Interests

The author declares no competing interests.

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No external funding was received during the study. The views expressed in this article are original and reflect the author's independent research and analysis.

Authors Contributions

YI, a key contributor, made input to the study's conception and design, developed the questionnaire, led the data collection and analysis, and drafted the first manuscript. NDN and AB, as co-authors, contributed their abilities by proofreading and approving the manuscript for submission, enhancing the study's credibility.

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