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VULNERABILITY MAPPING FOR METHANE EMISSIONS AND MITIGATION STRATEGIES IN LOKOJA METROPOLIS

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ABSTRACT

Methane emissions is a potent contributor to climate change, and this is notably high in Lokoja, Nigeria, particularly in areas undergoing rapid urbanization, industrialization, and slum growth. The aim of this study is vulnerability mapping to show areas with likely sources of Methane emissions in Lokoja Metropolis. The objectives of the study include; mapping of susceptible areas and the sampling of measures to mitigate causes of global warming in the study area. The study leveraged on remote sensing data to identify the possible methane source areas and the administration of questionnaires to sample the sources and mitigation strategy of methane emission was deployed. The study generated a map highlighting potential methane emission hotspots. The findings pinpointed several areas like Felele, Sarki-noma, Adankolo, Ganaja and Kabawa, that exhibited slum-like characteristics that is contributing to methane emissions. To mitigate these emissions and foster sustainable development, the study recommended that there is the need for the Environmental sanitation agency to take proactive steps in ensuring that the environment is kept clean and free from pollution. More so, Planning Authorities should ensure that building plans are followed before, during and after construction especially laying emphasis on toilet provision to stop open defecation.

KEYWORDS: Climate Change, Methane-Emissions, Mapping, Urbanization, Remote Sensing, Sustainable Development.

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1.0 INTRODUCTION

1.1 Background of study

Global warming, a pressing concern arises from the emission of greenhouse gases such as methane, carbon dioxide, nitrous oxide, synthetic fluorinated gases, and water vapor into the atmosphere, depleting the ozone layer and absorbing excessive heat [1]. Global warming as a situation where the average global temperature is increasing, making the environment hotter [2]. The annual global temperature has increased by one degree from 1880 to 1980 and by 0.18 degrees from that time till date [3].

The escalating levels of methane, a potent greenhouse gas, in the atmosphere have become a pressing concern, with far-reaching implications for the environment, human health, and the economy. Even as Nigeria is among the world's highest source of the methane emission, this methane gas is a higher contributor to global warming than the carbon dioxide [4]. Lokoja, the capital city of Kogi State in Nigeria, is grappling with the challenges posed by methane emissions, particularly in areas experiencing rapid slum development, urbanization, industrialization, and agricultural activities [5]. These methane emission sources contribute to climate change and have detrimental impacts on local air quality, human health and the environment [6].

Mapping areas susceptible to greenhouse gas emissions is crucial for incorporating and analyzing spatial datasets, such as soil properties, digital elevation models, rainfall patterns, and vegetation types [7]. Mapping provides a visual illustration of hazard zones, facilitating communication and understanding of the threats associated with specific areas. However, concerns about data quality are vital to guarantee reliable and accurate results [8].

Inadvertently, the persistence of practices that exacerbate global warming, such as burning fossil fuels, open defecation, and inadequate waste management, poses a significant threat to environmental sustainability [9]. Despite the urgent need to reduce greenhouse gas emissions, as emphasized by the 2015 Paris Climate Agreement, some areas in Lokoja Metropolis and environs continue to exhibit these harmful practices, particularly in slum areas characterized by poor housing, inadequate sanitation, and limited access to clean water. Therefore, the aim of this study is vulnerability mapping to show areas with likely

sources of Methane emissions in Lokoja Metropolis with the objectives of mapping the susceptible areas and sampling of measures to mitigate causes of global warming in the study area. The study employed a multidisciplinary approach, combining geographic information systems (GIS), and questionnaires administering to map methane emission areas.

Recent research has demonstrated the effectiveness of utilizing geographic information systems (GIS), remote sensing, and machine learning techniques to map and analyze various natural hazards and risks. For example, in 2016, a study that aimed to identify areas prone to flash flooding, with the ultimate goal of mitigating and reducing flood risks. To achieve this, remote sensing satellite data were simulated using GIS software. The results yielded a comprehensive map that highlighted zones at risk of flooding, as well as areas deemed extremely hazardous. The study recommended that similar maps be produced to ensure the sustainability of safe settlements [10].

In another study, the significance of GIS in evaluating fire and explosion risks were explored and, modeling contaminated distributions, mathematical and physical estimations using risk modeling packages and GIS software were used. The study's findings provided valuable insights into the consequences of fire outbreaks on human populations [7].

Machine learning and remote sensing techniques, utilizing Sentinel-1 synthetic aperture radar (SAR) imageries and machine-learning algorithms has been used to develop a flood susceptibility indicator. It was concluded that machine learning has the potential to enhance monitoring and conservation efforts in the face of global warming and climate change [8]. Demarcating flood hazard zones using GIS and remote sensing techniques has emphasized the importance of flood hazard mapping in mitigating loss of life and facilitating disaster management [11].

Mitigating global warming necessitates a reduction in the emission of heat-absorbing gases, commonly referred to as greenhouse gases, into the atmosphere [12]. These gases primarily originate from power plants, vehicle exhausts, burning vegetation, and agricultural activities. It was observed by [12] that, preserving forests, soils, and oceans is crucial in absorbing and storing greenhouse gases, making them essential components of global warming solutions. This can be achieved by implementing sustainable land

practices, restoring natural habitats, and reducing deforestation. The European Union's (EU) policies have demonstrated significant reductions in emissions. For instance, the EU's 2022 policies resulted in a 31% decrease in emissions compared to 1990 levels. Currently, the EU accounts for 6% of global greenhouse gas emissions, emphasizing the importance of international cooperation in mitigating climate change [12].

It was outlined by [12] that out of the several strategies for mitigating global warming, increasing the use of renewable energy sources, such as solar energy, instead of relying on generator fuels is most recommendable. Conserving water by reducing waste is also essential, as it helps mitigate emissions. Additionally, preserving forests is crucial, as they absorb and store carbon, provide habitats, clean water and air, prevent flooding, and soil erosion. Furthermore, [12] emphasized the importance of food choices in mitigating greenhouse gas emissions. Eating less meat and more plant-based foods can significantly reduce emissions. Reducing food waste and discouraging leftovers is also crucial, as uneaten food emits methane when decomposed.

The [6] highlighted the impact of land-use alterations, such as deforestation and agriculture, on climate change. These alterations affect the quantity of CO2 absorbed by the environment. It was also suggested by [6] that mitigating global warming can be achieved by reducing agricultural emissions through reducing food waste and promoting plant-based diets.

3.0 Study Area

The study areas selected for mapping were carefully chosen based on their characteristics, which align with the definition of a slum. These areas include Andakolo, parts of Ganaja village, Kabawa, old market, cantonment, karaworo, kwatan-kwoto, parts of Felele, and opposite Army barrack, all located within Lokoja metropolis. Lokoja, situated in the Lokoja Government Area of Kogi State, lies within the geographical coordinates of 6°43'00" E to 6°51'30" E longitude and 7°45'00" to 7°53'30" N latitude as shown in figure 1. According to [14], the estimated population of Lokoja in 2006 was 195,261 people. The inhabitants of Lokoja are primarily from ethnic groups such as the Nupes, Ebira, Bassa-nges, Bassa-kwomus, and Oworo, with some migrants from other groups like the Hausa, Igalas, Ibo, Kakandas, Kupas, and Okuns. The main occupations of the residents include crop farming, animal husbandry, fishing, and

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petty trading. Lokoja is drained by major rivers like the River Niger and Osara River, with smaller rivers drying up during the dry season. The elevation of most areas around Lokoja ranges from 45-205m, with steep-sided and rough hills, and the highest mountain, Mount Patti, reaching 1500m above mean sea level [15].

Geologically, Lokoja lies within the basement complex, comprising mainly gneisis, schists, and granite. The terrain is connected with granite and limestone complexes. Climatically, Lokoja falls within the Savanna zone, characterized by low humidity, high temperatures, and a sunshiny sky for most of the year. The climate is tropical, classified under Koppen's Aw classification, with two distinct seasons: rainy and dry seasons. The temperature in Lokoja is consistently high, with monthly maxima and minima of approximately 35°C and 21°C, respectively [14].

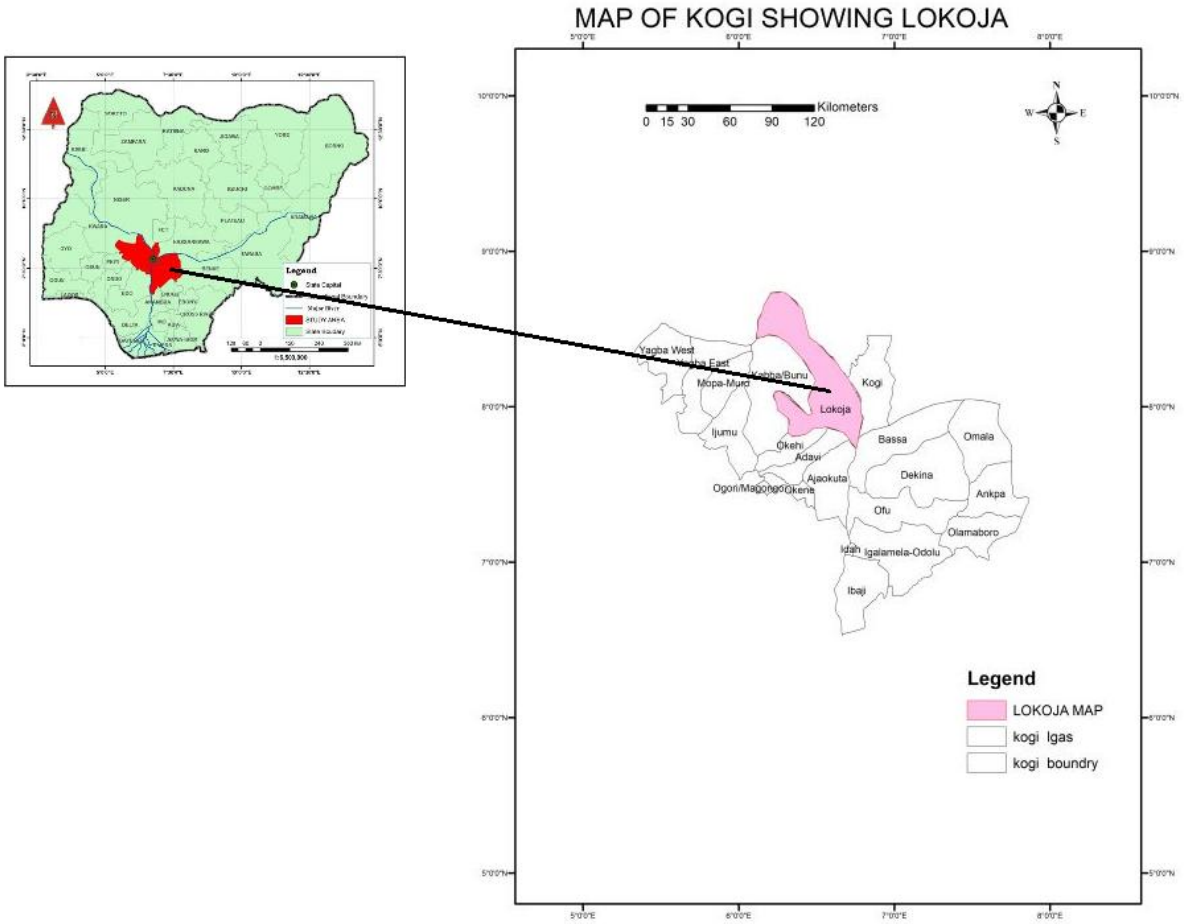

Figure 1: Map of Nigeria showing Kogi State and Lokoja.

3.2 Material and Methods

This research used remote sensing and satellite imagery of the research area to identify areas that share same physical characteristics of slum as already highlighted in section 3.0 and they are summarily; overcrowded buildings, pit latrines or open defecations, poor drainage and poor waste disposal system [16]. The instruments used for this study include; Garmin 72 handheld GPS, Mobile Topographer, Note book, Pen, Compaq 650 laptop computer. The software used are; ArcGIS 10.4, Microsoft Excel 2017. The primary data used was google earth image of Lokoja. Questionnaire was administered too to sample opinions of residents in the identified areas.

3.2.1. Data Acquisition

The research commenced with the acquisition of Google Earth imagery, specifically covering the Lokoja metropolis, which was obtained through the Google Earth Downloader tool in 2024. This initial step was crucial in providing a visual representation of the area under study.

Subsequently, a field reconnaissance was conducted to verify whether the identified locations within the Lokoja metropolis exhibited characteristics typical of slum areas. This exercise involved physically visiting the sites to gather firsthand information and corroborate the findings from the satellite imagery. To further enhance the accuracy of the mapping process, handheld GPS devices were employed to collect 2D coordinates of the identified locations. This ground-truthing exercise enabled the validation of the spatial characteristics of the areas under investigation and facilitated the georeferencing process, which is essential for creating accurate maps.

The mapping process itself involved several stages, with data acquisition being the first critical step. This entailed downloading the imagery of the susceptible areas, which provided valuable visual information about the terrain, infrastructure, and environmental conditions. In conjunction with the satellite imagery, structured questionnaires were administered to residents living in and around the identified areas. The questionnaire was carefully designed to elicit information about specific issues, such as open defecation, drainage mismanagement, and other environmental concerns.

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3.3 Data Processing

The questionnaire was used to validate the areas identified in the satellite and remote sensing imagery. The likert scale was used to process the respondents. It contains the assigned nos., ID, number of respondents, assigned number multiplied with the number of respondents and finally, the likert scale intervals. If the result falls within 1.00 to 2.59, then the respondents have answered in a likelihood manner and if the computation result falls within 3.40 to 5.0 then, the respondents' response fall under unlikelihood. Values that are within 2.60 to 3.39 show that the respondents are indecisive. Same goes with other responses as; Very true, somewhat true, neutral, somewhat false, and very false.

4.0 Results and discussions

4.1 The susceptible area mapping

The likert scale technique was used to process the responses of the questionnaires sent out. Some forms were filled by direct questions to residents too. A total of 234 responses were received back. Sarki-noma 30, Adankolo 41, Kabawa /old market axis – 50, Opposite Army Barrack – 46, Part of Ganaja - 34, Felele axis -33

Table 2: Response to the awareness of slums causing methane emissions.

Assigned Nos.	Id	Nos. of respondents	Assign nos x nos. of respondents	Interval
1	Strongly agree	152	152	1.00 – 1.79
2	Agree	30	60	1.80 – 2.59
3	Undecided	10	30	2.60 – 3.39
4	Disagree	16	64	3.40 – 4.19
5	Strongly Disagree	*26*	130	4.20 – 5.00
	Total	**234**	**436**	

$$= \frac{\sum \text{Assign nos} \times \text{nos. of respondents}}{\sum \text{Nos. of respondents}} = \frac{436}{234}$$

$$= \mathbf{1.86}$$

From the analysis of Table 2, the result is 1.86 which falls within the interval of 1.80 – 2.59. The ID is Agree. This result shows that a vast majority agreed that Sarki-noma, Adankolo, Kabawa-old market axis, opposite Army Barrack, Lokoja, and Part of Ganaja and Felele axis are slums and this response is aligned with the analysis of the remote sensing imagery.

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Table 3: Non-availability of toilet, poor drainage and waste disposal facilities.

Assigned Nos.	Id	Nos. of respondents	Assign nos x nos. of respondents	Interval
1	Strongly agree	97	97	1.00 – 1.79
2	Agree	70	140	1.80 – 2.59
3	Undecided	7	21	2.60 – 3.39
4	Disagree	50	200	3.40 – 4.19
5	Strongly Disagree	*10*	50	4.20 – 5.00
	Total	**234**	**508**	

The results of the survey indicate a Likert scale value of 2.17, which suggests that a significant majority of respondents affirmed that most compounds or houses in the area lack adequate toilet facilities. This finding implies that the absence of proper sanitation infrastructure is a widespread issue in the region.

Furthermore, some respondents explicitly stated that the lack of toilet facilities leads to an increase in open defecation, as individuals are often forced to respond to nature's call without access to proper amenities. This situation highlights the urgent need for improved sanitation infrastructure to prevent the proliferation of open defecation.

Notably, respondents residing in riverine areas, such as Adankolo and Ganaja, candidly admitted to practicing open defecation in the rivers. This revelation underscores the severity of the sanitation crisis in these areas and emphasizes the need for targeted interventions to address this critical issue.

Table 4: Presence of deplorable Housing conditions in the area

Assigned Nos.	Id	Nos. of respondents	Assign nos x nos. of respondents	Interval
1	Strongly agree	105	105	1.00 – 1.79
2	Agree	68	136	1.80 – 2.59
3	Undecided	12	36	2.60 – 3.39
4	Disagree	20	80	3.40 – 4.19
5	Strongly Disagree	*5*	25	4.20 – 5.00
	Total	**234**	**382**	

The calculated value of 1.63 falls within the range of 1.00-1.79, indicating a significant issue with proper spacing in the area. This finding suggests that the lack of adequate spacing between buildings and structures is a pervasive problem, which was also corroborated by one of the respondents. According to the respondent, access roads are often sold, and houses are constructed on them, further exacerbating the spacing issue. This situation has led to inconvenient living conditions, where residents who own vehicles are forced to park in distant locations and walk home. The absence of proper spacing and planning has resulted in a haphazard and disorganized built environment.

Moreover, the lack of adherence to planning regulations is a significant contributor to the spacing issue. Most buildings and structures are constructed without obtaining necessary approvals from planning regulatory bodies. This oversight has severe consequences, including the omission of essential amenities like toilets in some buildings. The absence of toilets in some structures is a direct result of the lack of planning and regulatory oversight, highlighting the need for stricter enforcement of building codes and regulations.

Table 5: Presence of high rate of insecurity and drug related activities.

Assigned Nos.	Id	Nos. of respondents	Assign nos x nos. of respondents	Interval
1	Strongly agree	109	109	1.00 – 1.79
2	Agree	108	216	1.80 – 2.59
3	Undecided	1	3	2.60 – 3.39
4	Disagree	14	56	3.40 – 4.19
5	Strongly Disagree	*2*	10	4.20 – 5.00
	Total	**234**	**394**	

The calculated Likert scale value of 1.68 falls within the interval of 1.00-1.79, indicating a significant affirmation of the statement. This interpretation suggests that it is indeed true that the identified areas of study are plagued by high levels of unemployment, which in turn contribute to an alarming rate of crime. The prevalence of idleness among the youth in these areas has led to a disturbing trend of drug abuse, with many young people indulging in substance abuse on a daily basis. This situation not only perpetuates a cycle of poverty and crime but also contributes to the release of methane gases into the ozone layer, exacerbating environmental degradation.

With reference to all the analysis of the respondents' information, the mapping of the susceptible areas becomes imperative. After digitizing the map of Lokoja, the metropolis was extracted. The ground truthing coordinates were imputed into the ARCGIS software and the required polygons were assigned to the various identified areas of interest. Hence, a map of the susceptible and methane vulnerability areas is plotted. The vulnerable places are coloured in light green for emphasis as shown in figure 2.

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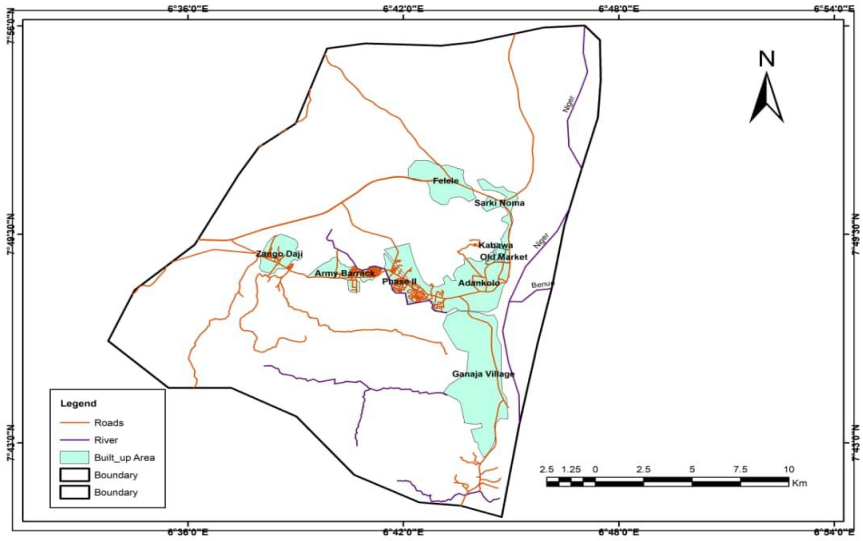

Figure 2: Map showing the vulnerable locations of Methane Emissions in Lokoja Metropolis

4.2 Mitigating the causes of global warming

In an effort to mitigate these practices and their attendant environmental consequences, respondents were asked to suggest measures to address the issues. Their responses were documented in Tables 6 and 7, providing valuable insights into potential solutions to the problems of unemployment, crime, and substance abuse in these areas.

Table 6: The Environmental Sanitation Penalties.

Assigned Nos.	Id	Nos. of respondents	Assign nos x nos. of respondents	Interval
1	Very true	118	118	1.00 – 1.79
2	Somewhat true	83	166	1.80 – 2.59
3	Undecided	5	15	2.60 – 3.39
4	somewhat false	6	24	3.40 – 4.19
5	very false	5	25	4.20 – 5.00
	Total	**234**	**348**	

The Likert scale result of 1.48 falls within the affirmative interval, indicating a strong consensus among respondents that the environmental sanitation agency of the state has a critical role to play in maintaining environmental decorum. This result suggests that respondents firmly believe that the agency has a statutory obligation to monitor and preserve the environment, protecting it from degradation and destruction. In essence, the respondents are emphasizing the need for the environmental sanitation agency to take proactive steps in ensuring that the environment is kept clean and free from pollution. This includes

enforcing regulations, providing adequate waste management infrastructure, and educating the public on the importance of environmental conservation.

By assigning a high level of importance to the agency's role, respondents are acknowledging that environmental protection is a shared responsibility between the government and the citizens. However, they are also emphasizing that the agency has a critical leadership role to play in coordinating and enforcing environmental protection efforts.

Table 7: Ensuring Toilet Provision in construction Projects.

Assigned Nos.	Id	Nos. of respondents	Assign nos x nos. of respondents	Interval
1	Very true	190	190	1.00 – 1.79
2	Somewhat true	8	16	1.80 – 2.59
3	Undecided	20	60	2.60 – 3.39
4	somewhat false	6	24	3.40 – 4.19
5	very false	*10*	50	4.20 – 5.00
	Total	**234**	**340**	

The calculated value of 1.45 falls within the interval of 1.00-1.79, indicating a strong consensus among respondents in support of the notion that authorities responsible for planning and building approval should exercise stringent oversight on construction projects. This oversight should encompass monitoring constructions at various stages, including before, during, and after completion. Respondents emphasized the importance of placing greater emphasis on ensuring that toilet provisions are made in these construction projects. By doing so, the scourge of open defecation can be eradicated, and the environment can be protected from the attendant health hazards and pollution. In essence, respondents are advocating for a more proactive and rigorous approach to planning and building regulation, one that prioritizes the provision of adequate sanitation facilities. By enforcing stricter standards and monitoring compliance, authorities can help prevent the proliferation of open defecation and promote a cleaner, healthier environment for all.

5.0 CONCLUSION

This study aimed to identify areas susceptible to methane emission in Lokoja metropolis, with a focus on slum areas. Following an exhaustive field exercise, several areas were identified as potential methane emission hotspots, including parts of Felele, Crusher, Sarki-Noma, opposite Army Barrack, Kabawa area,

Adankolo, and Gadumo axis. These areas were characterized by substandard housing conditions, inadequate access to basic amenities such as proper ventilation, sanitation facilities, running water, and electricity. The housing structures in these areas were poorly erected, prone to fire outbreaks, and possible collapse. Furthermore, the lack of proper drainage systems led to stagnant water, resulting in the emission of greenhouse gases and breeding of mosquitoes. The identified areas lacked access to clean water and sanitation facilities, forcing residents to rely on shared unhygienic conditions for fetching water. These areas have developed into informal settlements, with communities regulating land sales, leading to insecurity and land mismanagement. The absence of government presence and limited law enforcement has contributed to higher rates of social unrest, limited access to essential services, and increased vulnerability to environmental hazards such as flooding, landslides, and pollution.

Furthermore, authorities responsible for planning and building approval must exercise stringent oversight on construction projects. This oversight should encompass monitoring constructions at various stages, including before, during, and after completion, to ensure that toilet provisions are made and adequate sanitation facilities are provided. In addition, planning and building regulations should prioritize the provision of adequate sanitation facilities, including toilets and waste management infrastructure. This requires enforcing stricter standards and monitoring compliance to prevent the proliferation of open defecation and promote a cleaner, healthier environment.

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