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Inundation risks and habitat vulnerability in the commune of Kolleram, Zinder's Region-Niger.

ABSTRACT

Inundation are becoming more and more frequent and disastrous in Niger. This studyaims to analyzeinundationriskfactors and habitat vulnerability in the village of Kolleram, Zinder region. After a surveycarried out on the perception of the inundationphenomenon, the frequency, consequences and adaptation strategiesdevelopedwerenotedamong the populations of Kolleram. Particular attention waspaid to habitat vulnerability. A topographicsurvey and sampling of claygeomaterialsused for the construction of habitats in Kolleramwerecarriedout.Thesamplestakenwereanalyzedfrom a physicochemical and geotechnical point of view. The analysis of rainfall data and mapping wereused to explain the causes of the inundationobserved by the population of Kolleram. It emergesfromthisstudythat the recurrence of inundation in Kolleramislinked to the morphology, the presence of numerous ponds, exceptionalrains and the lack of rainwater drainage system. Indeed, the claygeomaterialsused in Kolleram are kaolin deposits. The geotechnicalparameters, the presence and proportion of the elements Fe_2O_3, C, Ti, K_2O wereassessed. And itemergesfromthisassessmentthat the claygeomaterialsused in construction in Kolleram are precarious and vulnerable. Facedwiththis, variousstrategies have been developed by the populations of Kolleram to copewithflooding and reducetheirvulnerability.

Keywords:Flood risk, Habitat vulnerability, Clay geomaterials, Kolleram, Zinder

1. Introduction

In the currentcontext of climate change and rapid population growth, inundation are among the mostfrequentnaturalphenomena on a global scale(E. Fiorillo et al, 2015 ;Mamadou and Abdou, 2016, OCHA , 2021, 2022). The damage isfrequently extensive, and the lossesassociatedwiththeseevents are estimated at severalhundred billion US dollars (Descroix et al., 2013). Like otherSahelian countries, Nigeralsoexperiencesrecurrentinundation (Mamadou et al., 2019). Thesefloodsoccuralmosteveryyear in all towns, but also in rural areas (Mamadou et al., 2019). Large-scaleinundationwithdisastrousconsequences for crops, habitats, infrastructure and humanhealthisobservedthroughout the country, withsignificantloss of life. This iswhyitisso important to analyse the phenomenon of inundation in order to understanditbetter and providedecision-makerswithdecision-makingtools for effective management of the risks and consequences of theseinundations (Eba et al.,2021 ; Brou et al., 2022 ; Babaye, et al., 2023 ;). This studyis part of that effort, looking at inundationriskfactors and the vulnerability of the habitat in the village of Kolleram in the Zinder'sregion.

2. Materials and Methods

2.1.Presentation of the study site

The rural commune of Kolleramislocated in the south-western part of the department of Mirriah, in the Zinder'sregion (Figure 1). It liesbetween latitude 13° 42‘ 53.7‘‘ N and longitude 9° 5’ 18.5‘’ E. It covers an area of 437 km² and has a Sahelianclimate. Geologically, the rural commune of Kollerambelongs to the Korama basin, an ancienttributary of the Lake Chad basin (Amadou Malam et al., 2021).

Figure 1 : Localisation of the study site

Quaternarygranitic, clayey-sandstone and sandy formations can beobserved. The population of the rural commune of Kolleramwasestimated at 16,250 villagersin 2008 (projection based on the results of the RGP/H 2001).

2.2. Surveys

The experiences and perceptions of local people regardinginundationand theirconsequencesweresurveyed. Thesesurveyswere the first phase of the study. A questionnaire and interviews wereadministered to the people of Kolleram. The survey questionnaire isindividual and wasadministered to a sample of 100 peopledrawn at randomaccording to geomorphological position. The interviews involved a number of village actors, in particular the Mayor of the commune, the Chief of the village of Kolleram and the Head of the Mirriah civil protection department.

The information collectedwasthenprocessed and analysedusing SPINX and EXCEL software.

2.3. Topographicalsurvey and analysis of rainfall data

The topographicalsurveywas made using a cartographicapproach. This methodologicalapproachwasused to produce a topographical profile for the village of Kollerambased on a recent Google Earth image. This profile, takenfromwest to east over a distance of 1.33 km, made it possible to appreciate the morphology of the site'stopography and to determine the differentslopes of the site. Photo-interpretation of the same Google Earth image of the village wasused to identify areas at high risk of inundation.

Rainfall, the main source of inundation production in Kolleram, wasanalysedusingdailyrainfall data from the town of Zinder, whichisrepresentative of Kollerambecauseitisonly 11 km distant. The data wereobtainedfrom the National Meteorological Office.Intra- and inter-annualvariabilitywasanalysed and the rainfallthreshold susceptible to cause a flood eventwascalculatedusing the methodapplied by M.S. Moustapha (2016) for the town of Zinder. This is a rainfallthresholdwhoseprobability of not beingexceeded (Hazen frequency) is set at 5%.

The formula used to calculatethisthresholdis as follows:

$F(x_i) = (r-0.5)/N$

$F(x_i)$ = Frequency of non-exceedance,

n = number of rainfallevent values,

r = value of rank r

0,5 = une constante.

Afterthisstep, the probability of non-exceedancewascalculatedusing the followingformula:Prob.non dép. = 1 -F (xi).

2.3. Sampling and characterisation of claygeomaterialsamples

The vulnerability of habitats to inundation at Kolleramwasevaluatedusing the types of geomaterialsused in the construction. In order to determine the level of vulnerability of thesegeomaterials, theywereampled and characterised. Two quarriesweresampled and 10 samplesweretaken and analysedfrom a chemical and geotechnical point of view.

a. Sampling

The sampling operationconcerned the quarriesmostfrequentlyused by the villagers of Kolleram. Thus, one quarry per type of claygeomaterialwasselected and sampled, i.e. twoquarries, one withredclaygeomateriallocated on the Precambrianbasement (Zinder site) and the otherwith black claygeomaterial on the Quaternary formations (Kolleram site).

At eachquarry, five (05) points wereidentified and sampled on eitherside of the quarry, and a representativesamplefromeachlocalitywas made up in the laboratoryfrom a mixture of equal proportions of 500g of eachsampletakenfrom the quarries. The ten (10) samplestaken, respectively ZDR1, ZDR2, ZDR3, ZDR4, ZDR5 for the Zinder quarry and KOL1, KOL2, KOL3, KOL4, KOL5 from the Kolleramquarry, as well as the two (02) composite samplesrepresentative of thesetwoquarries (ZDR and KOL), were sent to the laboratory for chemicalanalysis.

b. Experimentalmethods

Afterpreliminarycrushingusing an agate mortar and pestlemeasuring 20 mm in size and 70 mm in height, the chemical compositions of the crudesamplesweredetermined by X-Ray Fluorescence spectrometry-Philips PW 2400 XRF. The mass percentages of the components (oxides) and of certain simple chemicalelements, such as carbon, making up the rawsamplesweredetermined.

c. Geotechnicalanalysis

Geotechnical tests wereinitiated in thisstudy to evaluate the vulnerability of constructions made of claymaterialsfromthesequarries. These tests werecarried out at the national public works and construction laboratory in the town of Zinder.

Sampling

Six (6) sampleswerecollected for geotechnicalanalysis at the twoquarries. Thesesamplesweretakenfromeitherside of the quarries and in sufficientquantity to allow the tests to berepeated.

d. Experimentalmethods

Two geotechnical tests werecarried out. Firstly, Atterberg limit tests werecarried out to determine and compare the plasticity of the materials and to get an idea of theirbehaviour in relation to water. Secondly, crushing tests werecarried out to assess the strength of claymaterials.

3. Results

3.1.Thepopulation'sexperience and perception of inundation in Kolleram

3.1.1. The population's perception of inundationperiods

In the study area, inundationisessentially pluvial. Their occurrence isthereforecloselylinked to the rainfallrecordedduring the rainyseason. According to the population surveyed, itisunanimouslyagreedthatinundationonlycomesduring the rainyseason, fromjune to october. For 86% of thosesurveyed, inundationoccurs in the middle of the season, coincidingwith the months of July and August. However, 11% saidthatinundationoccurstowards the end of the season. In contrast, only 3% of respondentsthoughtthatinundationoccurred at the beginning of the season (Figure 2).

Figure 2:Population perception of inundationperiods in Kolleram

3.1.2. The population's perception of the origins of inundation in Kolleram

To explain the causes of inundation in their village, the population interviewed in Kolleram gave severalreasons, the most relevant of whichwereretained for the survey. The reasonsgivenwere, in order of response, the absence of a rainwater drainage system, heavyrainfall, topography, the poorconsistency of building materials, the growth of habitats, the degradation of plant cover, divine will and the occupation of inundation areas (Figure 3).

The surveyrevealedthatthree of the above-mentionedreasons are the main causes of flooding. The absence of a rainwater drainage system is one of the reasonscited by 63% of the population surveyed. The second main reasoncitedwas the abundance of rain (heavyrains), which 54% of the population surveyedthoughtwasresponsible for the inundation of Kolleram. The thirdreasonwas the topography of Kolleram, which 43% of the population surveyedthoughtwas the cause of flooding in their village (Figure 3).

Figure 3:Survey population's perception of the causes of inundation in Kolleram

3.2 Types of habitat at Kolleram

The extent of inundation damage can beassessedaccording to the type of habitat. In the study area, three types of habitat wereidentifiedduring the fieldvisit and according to the surveyresults:clay habitat, straw habitat and ciment habitat. According to the surveyresults, 90% of the people surveyed live in houses made of clay. According to them, most of the flood damage in Kolleramoccurred in these types of habitat. Straw habitat account for 7% of the homes of the people surveyed, and are alsoveryvulnerable to floodingbecausethey are builtfromstraw and tree brancheshabitat and infrastructure made of ciment are rare in the study area, accounting for only 2% of respondents' habitats (Figure 4).

Figure 4:Type of habitat at Kolleram

3.3.Types of claymaterialsused to buildclay habitats

With regard to construction materials, the results of the surveys show that 84% of the people surveyedwithclay habitat used black clayextractedlocallyfromquarries in the village of Kolleram. Only 3% of thosesurveyedhadtheir habitats builtwithredclaysourcedfrom the town of Zinder. However, 13% had mixed thesetwo types of material to maketheir homes more resistant to the effects of heavyrain and inundation (Figure 5).

Figure 5 : Types of claymaterialsused in clay habitat construction

3.4. Experience and description of inudation damage

With regard to the damage caused by the inundations, the people surveyedmentionedhuman, animal and material damage. Material damage wasmentioned by all the people surveyed (100% of respondents) and mainlyconcerned the destruction of habitations and school infrastructure (Figure 5). According to the inundation report drawn up by the Mirriah civil protection department, the number of habitations collapsed as a result of inundation in Kolleramwas 69 habitations and 4 secondaryschoolclassroomsin 2019, comparedwith 93 habitations in 2020 following the rainsrecorded on 06 and 07 September 2020. The number of people affectedis 626 and 527 respectively for 2019 and 2020, for a total of 69 and 67 households. The death and weakness of animals (mentioned by 48% of respondents) isalso a significant factor in the inundation damage experienced by the population. Collapsessometimesresult in loss of human life (although not veryoften) and injuries (19% of respondents). (Figure 6).

Figure 6 : Type of inundation damage experienced by victims

3.5. Inundationriskfactors at Kolleram

3.5.1.Rainfallvariability in Kolleram

Figure 7 shows that the length of the rainyseasonis six (06) months. Monthlyrainfall varies from 0 mm (november, december, january, february) to 164.42 mm (august), with a monthlyaverage of 29.79 mm between 1984 and 1990 and 35.54 mm between 1990 and 2018. The largestaveragemonthlyrainfallamounts are distributedbetween the months of july, august and september in the study area. Thesethree (3) monthsaccount for most of the cumulative seasonalrainfall. They aloneaccount for 75.65% of cumulative rainfall. It isduringtheseperiodsthatinundationismainlyobserved in the village of Kolleram, with an increase in cumulative rainfall in July and August, which corresponds to the middle of the rainyseason (aviewshared by 86% of thosesurveyed).Inter-annualrainfallvariabilitywasobserved at Kolleram. Figure 8 shows thatannual cumulative rainfall varies in a sawtooth pattern from one year to the next.Analysis of data on dailyrainfallfrom the Zinder meteorological station made it possible to describe the variation in rainfall at Kolleram. Figure 8 shows the inter-annual change in cumulative rainfallfrom 1984 to 2018. Analysis of this figure shows thatannual cumulative rainfall varies in a jagged pattern from one year to the next.

The threshold for potentialinundationrainfall in the study area wasdetermined. This threshold corresponds to rainfallwith a probability of not beingexceeded (Hazen frequency) set at 5%. This refers to rainfall of at least 35mm (Figure 9). Applyingthisthreshold over the period 1984-2018 shows that a total of 82 rainfalleventswith a thresholdgreaterthan or equal to 35mm have been recorded at Kolleram. The diagram shows an increasing trend in the amount of rainfalllikely to cause inundationin Kolleram (Figure 9).

Figure 7:Variation of averagemonthlyrainfallfrom 1984 to 2018 at Kolleram

Figure 8 : Interannual variation of cumulative rainfallfrom 1984 to 2018 at Kolleram

Figure 9:Variation of the number of raineventswiththreshold>= 35 mm

3.5.2.Topography and typology of areas at risk of inundation in Kolleram

The topographicalmorphology of the village of Kolleramtakes the form of a dune system characterised by the presence of high ground and low-lying areas (Figure 9). The high groundisvisiblydominated by dunepeaks, while the low-lying areas represent the depressional zones that cross the village fromnorth to south (Figure 10). Analysis of the topographical profile, carried out fromwest to east over a distance of 1.33 km using a Google Earth image, shows that the altitude of the land varies from 445 m (low-lying areas) to 454 m (high-lying areas), a difference in height of 9 m. The average altitude is 449 m. Maximum slopesvaryfrom 4.6% to 5.4%. Averageslopes range from 2.2% to 2.5%.

Figure 10:West-East topographical profile of the village of Kolleram

Analysis of the generaltopography of Kolleram has made it possible to definethree types of area at risk of inundation in the village of Kolleram. These are

- Low-lyingareas;
- near ponds
- near large ravines.

The village of Kolleramessentially has two large low-lying areas that cross the localityfromnorth to south. It also has six (6) temporary ponds aroundwhich the population uses the materials to make bricks. In addition, gullyingisvery active from one place to another due to the fragility of the dune soilsthatdominate the area. This givesrise to large gullies/gullies in the village. Because of theirlow altitude, thesethree sites (low-lying areas, near ponds and gullies) are the main drainage and/or stagnation areas for the village'srainwater.

3.6. Characterisation of geoconstructionmaterials

3.6.1.Chemical characterisation

Tables 1 and 2present the results of the chemicalanalysis of the samplesfrom the twoquarries (Kolleram and Zinder) in terms of major constituent elements. These constituent elements have a total mass percentage of over 98% in eachsample. This shows thatthey are sufficient to characterisethesesamples.

Overall, all 12 samplesfrom the two sites are composedmainly of silica (SiO_2) and alumina (Al_2O_3). This meansthat all the samples are aluminosilicates and thereforeclaymaterials. However, differenceswereobserved in the silica/alumina ratios and in the presence or absence of certain elementssuch as iron oxide and carbon.

Table 1:Chemical analysis (% by mass) of rawsamplesfrom the Kolleramquarries (black clay)

Sample	SiO_2	Al_2O_3	Fe_2O_3	C	CaO	MgO	K_2O	Totals
KOL1	41,453	22,008	7,836	19,982	3,62	1,898	1,51	98,307
KOL2	41,498	22,039	7,918	19,933	3,629	1,962	1,521	

98,5

KOL 3

41,497

22,026

7,916

19,961

3,621

1,862

1,519

98,402

KOL 4

41,468

22,007

7,895

19,907

3,608

1,957

1,561

98,403

KOL 5

41,403

22,028

7,918

19,968

3,638

1,927

1,521

98,403

Standard deviation

0,0390602

0,0137949

0,0352392

0,0300283

0,0111669

0,0419011

0,0198696

KOL

41,138

22,816

7,952

19,592

3,712

1,912

1,864

98,986

Analysis of the resultspresented in tables 1 and 2 shows that the materialsfromKolleram and Zinder consistmainly of silica and alumina. The silica/alumina ratio of the Zinder quarrysamplesisrelativelyhigher (0.41) thanthat of the Kolleramquarrysamples (1.80). The presence of the elementsCaO, MgO and K2O in the Kolleramsamples and Ti in the Zinder samplesisparticularlynoteworthy. Iron oxides (Fe2O3) are more abundant in the Zinder samples (32.1%) than in the Kolleramsamples (7.95%). In contrast, the carbon content washigher in the Kolleramsamples (19.59%) than in the Zinder samples (1.12%).

Table 2:Chemical analysis (% by mass) of rawsamplesfrom the Zinder quarry (Red clay)

Sample

SiO2

Al2O3

Fe2O3

C

Ti

Totals

ZDR1

18,626

45,081

32,358

1,281

1,741

99,087

ZDR 2

18,555

45,098

32,348

1,301

1,798

99,1

ZDR 3

18,691

45,088

32,353

1,305

1,661

99,098

ZDR 4

18,696

45,071

32,354

1,155

1,824

99,1

ZDR 5

18,576

45,091

32,381

1,101

1,847

98,996

Standard deviation

0,064

0,010

0,012

0,094

0,074

ZDR

18,628

45,398

32,108

1,128

1,742

99,004

3.6.2.Geotechnicalanalysis

a. Atterberg limit test on clayeymaterials

The Atterberg limit tests werecarried out on four (4) samplesfromtwoquarries (Kolleram and Zinder), i.e. twosamples per test and per quarry. A comparative analysis of the resultspresented in tables 3 and 4 shows that the samplesfrom the Kolleram and Zinder quarriesdiffer in terms of liquiditylimits, plasticitylimits and atterbergplasticity indices. Overall, the percentages of theselimits and indices are muchhigher for the Zinder samplesthan for the Kolleramsamples. The sameapplies to the average water content, whichis 40.45% for the Zinder samples and 18.97% for the Kolleramsamples.The Zinder materials are much more plastic and therefore more clayeythan the Kollerammaterials. It isthereforeclearthattheirbehaviour in the presence of water wouldalsobedifferent, depending not only on the plasticity of the materials but also, and above all, on theirswellingpotential.

b. Strength test on claymaterials

To assess the strength of the materials and to get an idea of the loadthat the materials can support, bricks were made and thencrushed by compression using a CBR press. The results of the strength tests on materialsfrom the Kolleram and Zinder quarries are shown in tables 5 and 6below. Analysis of Table 5 shows that bricks made with black materialsfrom the Kolleramquarries are crushed at stresses rangingfrom 5.55 to 6.66 bar. The average stress calculatedis 6.16 bar (Table 5).In comparison, bricks made with black materialsfromKolleramquarries are relativelylessresistantthan bricks made withredmaterialsfrom Zinder quarries. This justifies the choice of Zinder materials for construction by somevillagers, whodescribethem as consistent materials and use them to reinforce local (black) materials (Figure 6).

Table 3:Atterberg limit test results for Kollerammaterials

Atterberg limit

KOL1

KOL2

KOL

WL (%)

18,5%

20,5%

19,5%

WP (%)

14,66%

14,3%

14,48%

IP (%)

3,84%

6,20%

5,02%

Table 4:Atterberg limit test results for Zinder materials

Atterberg limit

ZDR1

ZDR2

ZDR

WL (%)

39,95%

44%

41,97%

WP (%)

27,11%

26,12%

26,61%

IP (%)

12,84%

17,88%

15,36%

Table 5:Test of resistance on black claymaterials of Kolleram

N° Brick

Measuring

(mm)

Resistivityweight

(KN)

Contraint (bars)

average contraint

(bars)

KOL1

0.60

13,33

6,665

6,16

KOL2

0.55

12,22

6,11

KOL3

0.50

11,11

5,555

KOL4

0.57

12,67

6,335

Table 6:Test of resistance on redclay of Zinder

N° Brick

Measuring

(mm)

Resistivityweight

(KN)

Contraint (bars)

average contraint

(bars)

ZDR1

0.81

18

9

12,305

ZDR2

1.32

29,33

14,665

ZDR3

1.07

23,78

11,890

ZDR4

1.23

27,33

13,665

4. Discussion

4. 1. Trends in inundationfactors in Kolleram

In the village of Kolleram, floodingisessentiallyrain-fed. Their occurrence isthereforecloselylinked to the rainfallinundationrecordedduring the winterseason. To explain the causes of in this village, the people interviewedmentionedseveralreasons, the most important of whichwere the lack of a drainage system, the abundance of rainfall, the topography of the site and the lack of consistency in the building materialsused (Ibrahim Moussa et al 2020). Many of thesereasonswerealsocited by the population of Ouagadougou in Burkina Faso to explain the inundation. For example, Bani and S. Yonkeu (2016) reported in a studythat the risk of inundation in Ouagadougou islinked to the nature of the bedrock. In addition to this, generalrainfall trends in Kolleram show a return to wetperiodsfrom 1990 onwards, with an increase in average cumulative rainfall and the number of rainydays. Over the period 1990-2018, an increase in exceptionalrainfallevents and potentialinundationrainfall in Kolleram (rainfallgreaterthan or equal to 35 mm) has also been observed. This recentimprovement in rainfall has been confirmed by severalauthorsacross the Sahelianregion (A. Ali and T. label, 2009;B. Sarr ,2011;Panthou, 2014, Salissou et mamadou, 2021).In addition, the generalmorphology of the Kolleram site, whichtakes the form of a basin withvaryingdegrees of slope, ishighlyconducive to inundation. (I.Mamadou et al, (2019, Hantchi et al., 2022) foundthatthistopographicalshapeplayed a decisiverole in the floodingobserved in the town ofKantché, whichbelongs to the same large Korama catchment area. According to J. Harvatt et al (2011), the location of a town in such a morphologyimpliesseriousproblems of evacuation of rainwateroutside the urban area.Despite all thesefavourable conditions for flooding, Kolleram has a large number of dwellings in flood-prone areas, consisting of ponds and twolow-lyingareas.This situation increases the vulnerability of people and theirproperty in the event of flooding (I. Mamadou and A. Abdou, 2016).

4.2. Vulnerability of the habitat to inundation

Among the habitats identified in Kolleram, habitat made of clay are the most dominant (90% of respondents). Clay soils are widelyused by local populations in Africa, as is the case in Burkina Faso and Niger, where the main uses of clay are the construction of individualvillagers' habitats and pottery or ceramics in the broadsense (H. Y. Tahirou et al., 2018 ;Moussa Issaka et al., 2020,Maloukou et al., 2022 ; Hantchi et al., 2024).In Kolleram, these habitats are essentiallybuiltwith black claymaterialsextractedfrom local quarries (84% of the habitats of the respondents) and rarelywithredclaymaterialsfrom the quarries in Zinder.

Chemical analysis of samplesfromthesetwoquarries (Kolleram and Zinder) shows thatsilica (SiO_2) and alumina (Al_2O_3) make up more than 63% of all samples. The proportion of theseelements varies from one sample to another and from one site to another. The silica/alumina ratio provides information about the claymineral content of a material (JA. De Senna, 2008). This ratio wasestimated at 1.8 for the representativesamplefrom the Kolleramquarries, comparedwith 0.41 for the Zinder quarries. The ratio for the Kolleramsamplesislow, which can beexplained by the presence of a high proportion of free quartz and the lowclaymineral content of thesematerials. Thesematerials are therefore close to kaolin deposits (Ledoussalh, 1985; E. Sagbo et al., 2015 ,Thiam, 2023).Chemical analysis of the samplesfromthesetwoquarries (Kolleram and Zinder) shows thatthey all contain more than 63% silica (SiO_2) and alumina (Al_2O_3). The proportion of theseelements varies from one sample to another and from one site to another. The silica/alumina ratio provides information about the claymineral content of a material (JA. De Senna, 2008, Diene, 2024). This ratio wasestimated at 1.8 for the representativesamplefrom the Kolleramquarries, comparedwith 0.41 for the Zinder quarries. The ratio for the Kolleramsamplesislow, which can beexplained by the presence of a high proportion of free quartz and the lowclaymineral content of thesematerials. They are therefore close to pure kaolins, which have a ratio of 1.1 (OH. Yah et al., 1979; F. Guerraoui et al., 2008, TiegoumWembe, 2023). The ratio of samplesfrom Zinder is high and shows thatthesematerials are richer in clayminerals and thereforecloser to kaolin deposits (Ledoussalh, 1985; E. Sagbo et al., 2015).

Mineralogicalanalysis of representativesamplesfrom the Kolleram and Zinder quarriesrevealsthattheyconsistmainly of kaolinite, a claymineralwith quartz content. Kaolinite is a mineralthatdoes not favourshrinkage/swellingduring drying and rewetting. This wasconfirmed by landingberglimit tests, whichshowedthatbothmaterialsswellonlyslightly (Thiam et al., 2023 ; Makela et al., 2025). These tests alsorevealed the high plasticity of the Zinder materialscomparedwith the Kolleram materials, which are not very plastic and have a lowclay content. In addition, the high plasticity and liquiditylimits of the Zinder materials show thatthey can withstandinundation and humiditybetterthan the Kollerammaterials, which have low values for theselimits.

The lowclay content of Kollerammaterialsmakesthemveryunfavourable for making bricks, unlike Zinder materials, whichproducevery consistent bricks. This wasdemonstrated by materialstrength tests, whichshowedthatKollerammaterialshadverylowstrengthcomparedwith Zinder materials. The precarious nature of Kollerammaterialsmeansthat homes builtwiththem are more vulnerable to inundation or long-term contact with water.

5. Conclusion

This study has shownthatinundationis a recurrentphenomenon in Kolleram and thatit causes significant damage to the population. It alsoshowedthatinundation in Kolleramis due to severalfactors, includingrainfall, topography and the occupation of areas at risk. The nature of the geomaterialsused to build homes determines the level of damage caused by inundation. Laboratory analyses of samples of thesematerials show theirvulnerability to inundation at Kolleram.

Major stepsneed to betaken to build a more resilient population with more sustainable habitats.

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