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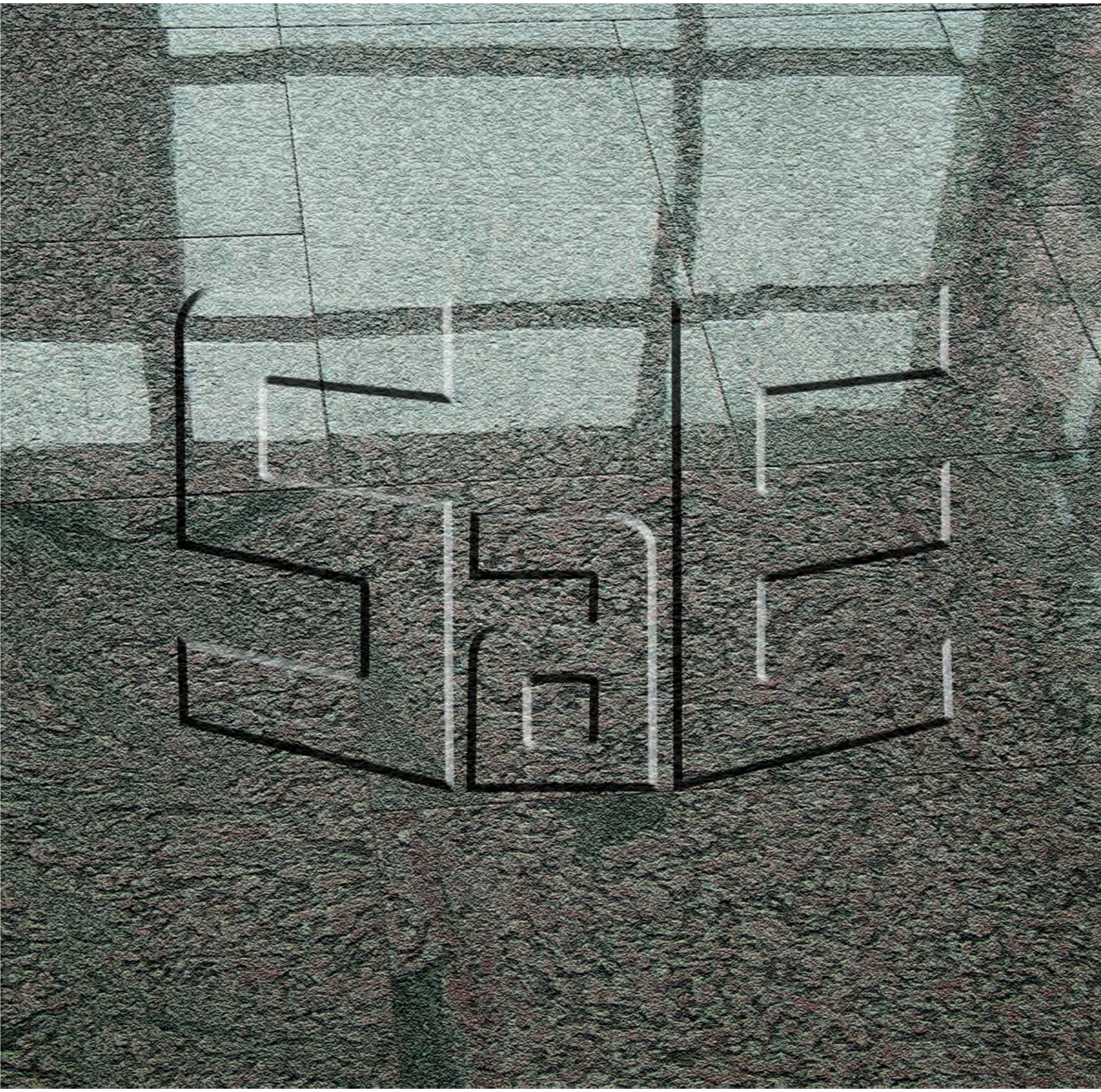

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THE MICROSTRUCTURE AND PHASE COMPOSITION OF MORTARS FROM THE 17TH CENTURY SACRED BUILDINGS

MIKROSTRUKTURA I SKŁAD FAZOWY ZAPRAW Z XVII-WIECZNYCH BUDOWLI SAKRALNYCH

Zdzisława Owsiak*, Paweł Sobczyński
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Abstract

This work aims to characterize the microstructure of mortars derived from the walls of sacred buildings from the 17th century. The tests were carried out using the X-ray diffraction method, differential thermal analysis and scanning microscopy combined with the analysis of the elemental composition in the micro area. The results of this study show that the materials bonding the elements of the wall in historic buildings are porous sand-lime mortars with an increased binder-to-aggregate ratio, also containing limestone crumbs, flints and feldspars, and fragments of bricks larger than sand particles. The binder is fully carbonated calcium hydroxide, with no pozzolanic additives. The results of the microstructure and phase composition tests of mortars used for bonding wall elements in buildings constructed at the end of the 16th and early 17th centuries can be used to select the composition of mortars used in the renovation and repair of historic buildings.

Keywords: mortar, microstructure, XRD, SEM, EDS

Streszczenie

Celem pracy jest charakterystyka mikrostruktury zapraw pobranych z muru sakralnych budowli XVII-wiecznych. Badania wykonano metodą dyfrakcji rentgenowskiej, termicznej analizy różnicowej oraz mikroskopii skaningowej połączonej z analizą składu pierwiastkowego w mikroobszarze. Wyniki przeprowadzonych badań wykazały, że zaprawy łączące elementy muru w budowlach historycznych są porowatymi zaprawami wapienno-piaskowymi, o zwiększonym stosunku spoiwa do kruszywa, zawierają także w swoim składzie okruchy skał wapiennych, krzemieni i skaleni oraz fragmenty cegieł o większych rozmiarach niż ziarna piasku. Spoiwo stanowi w pełni skarbonatyzowany wodorotlenek wapnia, niezawierający dodatków pucolanowych. Wyniki badań mikrostruktury i składu fazowego zapraw stosowanych do spajania elementów muru w budowlach wznoszonych w końcu XVI i na początku XVII wieku mogą posłużyć do doboru składu zapraw stosowanych przy renowacji i naprawach budowli historycznych.

Słowa kluczowe: zaprawa, mikrostruktura, XRD, SEM, EDS

1. INTRODUCTION

Buildings are designed and constructed to be durable and timeless. In reality, however, historic buildings undergo constant transformations in terms of significance and physical dimension [1]. Under the influence of factors from the external environment, building elements are subject to corrosion processes, and the improvement of their condition requires maintenance efforts [2]. During the conservation, repair or renovation of historic buildings, mortars

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have to be characterized in terms of their mineralogy. Mortars present in historic buildings were used to connect bricks or stones in the wall, as external and internal plasters, floor underlays or decorative mortars [3]. The most common binders in these mortars, until about two centuries ago, were clay, gypsum and lime, which were then replaced with Roman cement, and later with Portland cement, the dominant type of binder in construction today [4]. The variety of historic mortar compositions is exceptionally large and results both from the geographical location and various historical periods [5]. In Poland, the binder in mortars found in historic buildings was mainly lime, often with additions of clay or organic fibres.

One of the elements of historic buildings conservation is the replacement of mortars damaged by time, use and environmental exposure. The main concern is to identify the composition of the mortar to produce a compatible material. The necessary information on the type and content of the binder and aggregate can be obtained from microstructure tests using microscopic methods, and from the phase composition of mortars. The methods for determining the microstructure and phase composition of historic mortars are X-ray diffraction (XRD), optical microscopy, scanning electron microscopy (SEM), thermal methods and infrared spectroscopy [6, 7]. Proper sample collection and preparation is essential as in the case of historic structures or sites, minimizing destruction and damage is a priority. A combination of several methods should be used to confirm the determination and quantify the mineralogical composition.

This work aims to characterize the microstructure of mortars derived from the walls of sacred buildings from the 17th century. The tests were carried out using the X-ray diffraction method, differential thermal analysis and scanning microscopy combined with the analysis of the elemental composition in the micro area.

2. MATERIALS AND METHODS

2.1. Materials

The mortar samples were collected during conservation works on the walls of sacred buildings. The samples analysed in this study come from 17th century buildings and are the mortars connecting the elements of the wall. The buildings from which the mortars were sampled are listed in Table 1.

Table 1. Designation of samples and sampling locations

Samples	Type of building	Built in
Z1	St. Anne's Chapel in Pińczów	about 1600
Z2	Collegiate Church in Klimontów	First half of 17th c

Photographs of the 17th century historic buildings are presented in Figures 1 and 2.

Fig. 1a) St Anne's Chapel in Pinczów, 1b) sampling location

Fig. 2a) The church in Klimontów, 2b) sampling location

Figure 1a shows St Anne's Chapel in Pinczów. Designed by Santi Gucci, the chapel was built of local limestone (Pińczów limestone) in 1600 with a square body and a cupola. In the first half of the 19th century, a stone porch was added that mirrors the plan and shape of the main building. Due to its tangible and intangible meaning to the local community, the chapel has been renovated multiple times. In 2019 some remedial measures were applied, including the provision of horizontal insulation and drainage, and the repairs of the building base course. Figure 1b shows the sampling locations on the eastern wall at a height of 1.5 m above the floor.

Another building from which the test samples were derived was the Collegiate Church in Klimontów (Fig. 2a). The temple founded by Jerzy Ossoliński and constructed in the years 1643-1650 mirrored the plan of the Vatican basilica. It was designed by Wawrzyniec Senes to the rejected Vignola's design of Il Gesú church from 1568. Destroyed by the Swedes in 1656, and then by the Cossacks of Prince Rakoczy, the church was saved from destruction by Inf. Walenty Boxa Radoszewski in the years 1721-58. The temple is baroque, made of stone and plastered with hewn details. The building was built on an ellipse plan with a screen facade, flanked by two towers topped with baroque cupolas. The samples were extracted from the vault of the underground part of the northern tower, at a height of 1.5 m above foundation level (Fig. 2b).

2.2. Methods

The tests were conducted using X-ray diffraction, thermal differential analysis and scanning microscope coupled with the detector of the energy dispersion spectrometer (EDS).

X-ray diffraction analysis was carried out using an Empyrean diffractometer (PANanalitical) in Bragg-Brentano geometry, CuKα radiation with a wavelength of k = 1.79026 Å, generated at 40 keV and 20 mA, in the range from 5-75° 2Θ, at the recording rate of 0.05° 2Θ/s. The ICDD (International Center for Diffraction Data) database was used to analyse the recorded diffraction patterns.

The differential thermal analysis was performed in an SPT Q600 apparatus (TA INSTRUMENTS), 10° min, Tmax 1000°C, under nitrogen atmosphere.

Selected mortar pieces were cut into 10 mm cubes, one side of which was hardened with resin and polished. The microstructure of the samples was examined on the specimens using an FEI COMPANY QUANTA FEG 205 scanning electron microscope equipped with an energy dispersion detector (EDS) spectrometer. The SEM-EDAX test was performed under low vacuum and accelerating voltages of 20 keV, beam current of 36 mA, vacuum (column) pressure of 8.3 x 10-8 mbar, sample pressure of 4.5 x 10-6 mbar, 400 s count time on EDS and 1 μm beam size.

3. RESULTS AND DISCUSSION

The test results for the phase composition of mortars determined by the X-ray diffraction method and the image of the microstructure are shown in Figures 3 to 5, respectively.

The results of the phase composition tests conducted using thermal differential analysis and X-ray diffractometry indicate a 52% volume content of hardened, carbonated lime binder, a 30% volume content of quartz sand with a varying particle size up to 0.5 mm, and particles of organodetritic limestone up to 3 mm making up the remainder in the mortar from the

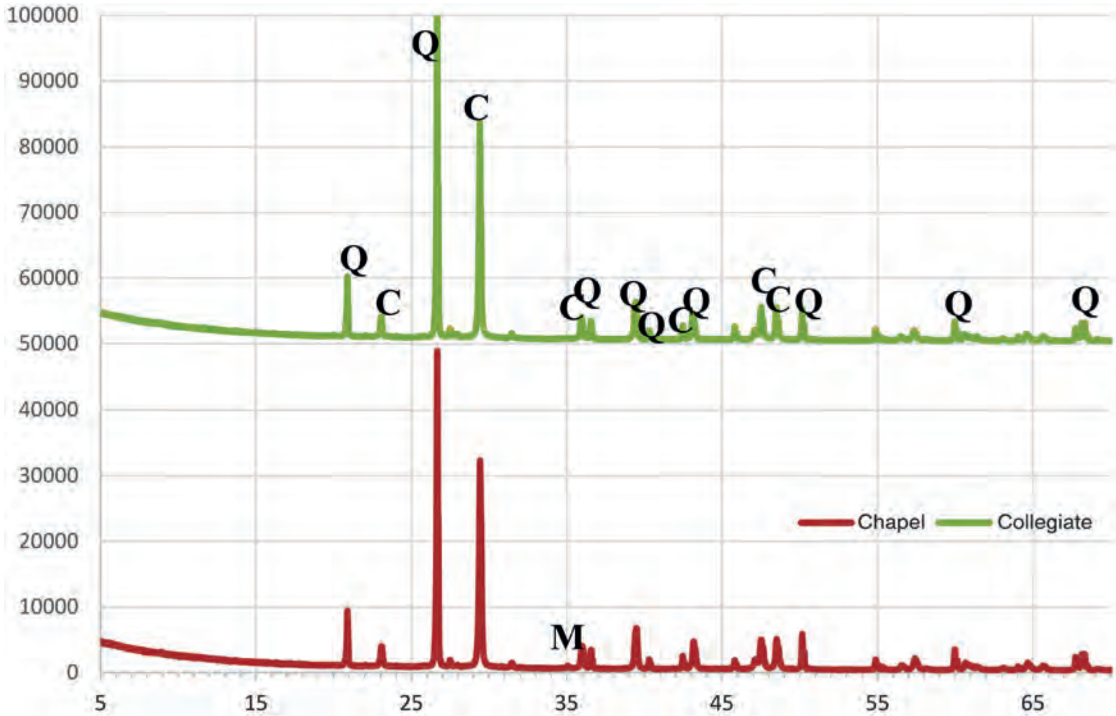

Fig. 3. X-ray photos of the mortar from St. Anne's Chapel in Pińczów and mortars from the Collegiate Church in Klimontów. Denotation: Q – quartz, C – calcite, M – feldspar

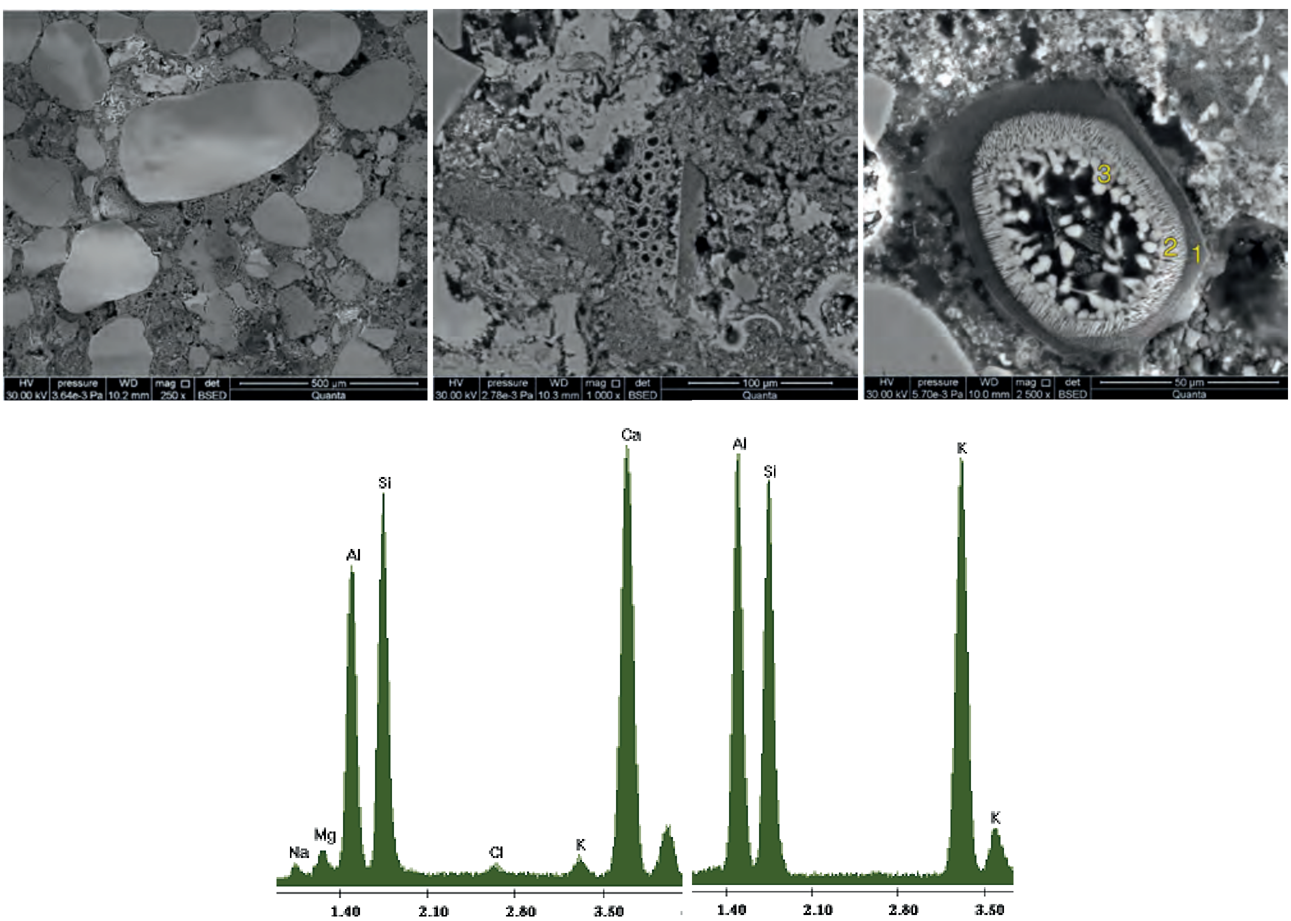

Fig. 4. Microstructure of the mortar extracted from St. Anne's Chapel in Pińczów

wall of St. Anne's Chapel. The lime binder in the mortar from the collegiate wall in Klimontów makes up about 40% by volume and is composed of microcrystalline calcite. The aggregate is mainly quartz sand (58% by volume). Other types of aggregates such as flint grains, feldspars and fine-grained sandstone with quartz-iron binder constitute about 2% by volume.

The microstructure image of the mortar derived from the wall of St. Anne's Chapel in Pińczów is shown in Figure 4. Quartz sand is the main constituent of the aggregate in the mortar. The grains are of various sizes up to 0.5 mm. Limestone crumbs from the Pińczów rock make up the remainder. The binder is now fully carbonated lime with some clay as confirmed by the presence of potassium and calcium aluminosilicates.

Analysis of the microstructure of mortar samples from St. Anne's Chapel in Pińczów shows that it is a porous sand-lime mortar. The volume ratio of the binder to the aggregate is close to 1. The quartz particle size ranges from 0.05 to about 0.5 mm, with the predominant size in the range 0.1 to 0.5 mm. Limestone shards from Pińczów stone are the second significant constituent represented by organodetritic varieties and single bioclasts. The sizes of the largest grains of organodetritic limestones are up to 3 mm. Coated micrite limestone grains are usually less common. There are also flint grains and feldspar chunks. The binder is a hardened, carbonated lime paste, composed of microcrystalline calcite with a crystal size of about 1 µm. Figure 5 shows the microstructure image of the mortar derived from the Collegiate Church in Klimontów.

In this mortar, sand particles do not exceed 0.5 mm, while the binder is fully carbonated calcium hydroxide, with a compact, microcrystalline structure. The mortar contains many voids and pores. In some of the pores, fungal hyphae are observed.

The tests of mortar samples from the Collegiate Church in Klimontów also show that it is a porous sand-lime mortar with a 2:3 binder to aggregate ratio. The aggregate consists of well-coated monocrystalline quartz particles ranging in size from 0.05 to about 0.6 mm with a predominance of 0.1 to 0.5 mm grains. The aggregate composition is complemented by limestone crumbs and brick fragments as well as less numerous flint grains, sandstone and feldspar crumbs. The crumbs of microsparite and micrite limestone crumbs, larger than the sand particles, are rounded to a varying extent and reach 5 mm. The aggregate grains

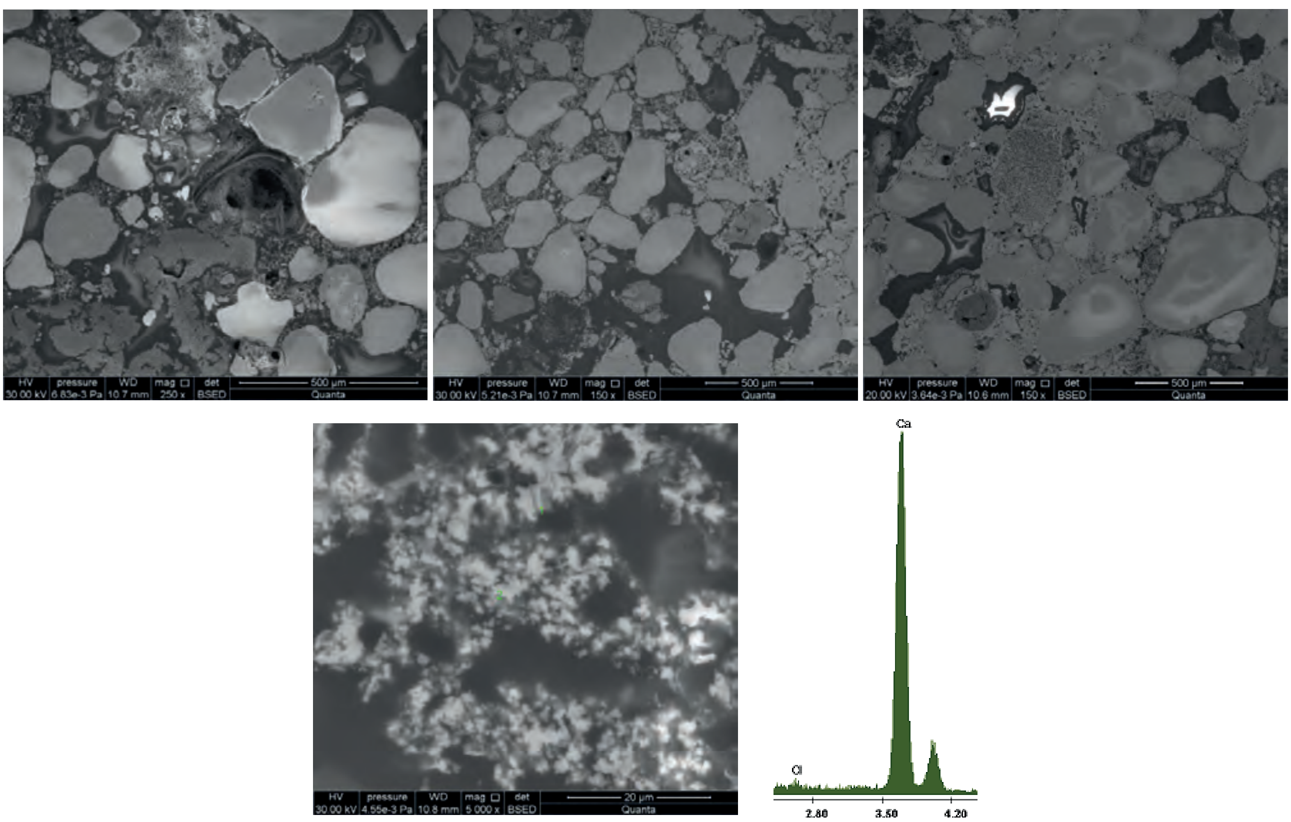

Fig. 5. Microstructure of the mortar extracted from the Collegiate Church in Klimontów

are bonded with a hardened limestone paste composed of microcrystalline calcite with crystals of a few micrometres in size.

4. SUMMARY

The results of this study show that the materials bonding the elements of the wall in historic buildings are porous sand-lime mortars with an increased binder-to-aggregate ratio, also containing limestone crumbs, flints and feldspars, and fragments of bricks larger than sand particles. The binder is fully carbonated calcium hydroxide, with no pozzolanic additives. The results of the microstructure and phase composition tests of mortars used for bonding wall elements in buildings constructed at the end of the 16th and early 17th centuries can be used to select the composition of mortars used in the renovation and repair of historic buildings. As a supplement to the microstructure test results, tests of mortar porosity and their physical properties will be performed.

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MODERN METHODS OF THERMAL COMFORT MEASUREMENTS

NOWOCZESNE METODY BADAŃ KOMFORTU CIEPLNEGO

Luiza Dębska*[1], Justyna Krakowiak[2], Andrej Kapjor[3]
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Abstract
The issue of thermal comfort and its subjective feelings inside a building is becoming more and more important in the modern world. It is caused by the desire to create optimal conditions in places where people stay. The article presents two methods, indirect and direct, which are typically used in the research projects. These methods enable to assess the thermal sensations of people and compare the feelings of the respondents with the value of PMV (the value of human thermal sensations) calculated using the formula from the ISO 7730 standard and the questionnaire surveys.

Keywords: thermal comfort, measurement methods, PMV

Streszczenie
Zagadnienie komfortu cieplnego oraz jego subiektywnych odczuć wewnątrz budynku staje się coraz ważniejsze we współczesnym świecie. Spowodowane jest to chęcią stworzenia optymalnych warunków w miejscach przebywania ludzi. W artykule przedstawiono dwie metody, pośrednią oraz bezpośrednią, które powszechnie stosuje się w badaniach. Metody te umożliwiają ocenę wrażeń cieplnych ludzi i porównanie odczuć osób ankietowanych z wartością PMV (wartością wrażeń cieplnych człowieka) obliczoną za pomocą wzoru z normy ISO 7730 z danymi z kwestionariuszy.

Słowa kluczowe: komfort cieplny, metody pomiaru, PMV

1. INTRODUCTION

Nowadays, man spends most of his life and time in closed rooms. That is why it is so important to create such a microclimate that every person in a given room feels thermal comfort. The definition of thermal comfort is, above all, the pursuit of the best possible conditions to meet the constantly growing needs and thermal requirements of humans. Thermal comfort or its lack (discomfort) is responsible for well-being or bad mood, for increasing or decreasing concentration or work efficiency – these factors contribute to the use of appropriate heating and air conditioning devices at the stage of design works or in the modernization of existing buildings with the use of appropriate building materials. In research on the comfort of heat, parameters such as air temperature, air flow velocity, light intensity, humidity in the room, carbon dioxide (CO_2), temperature a black ball, resistance of heat flow through conduction via clothing (in 'clo') – what the subjects are wearing at the moment [1-3]. This is not the first time that research on thermal comfort has been conducted in educational buildings (including Kielce University of Technology). In 2019, 16 people took part in such a study. For 75% of respondents, the temperature in the room corresponded, for 18.75% the temperature was still acceptable, and for 6.25% of the respondents the temperature was definitely unacceptable. It was also concluded from the questionnaires that 13 people would not want to change the temperature, 2 people would like the temperature to be higher, and 1 person

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would prefer it to be cooler. The value of PMV calculated by means of the questionnaires was 0.13, and PMV calculated with a special calculator based on the PN EN ISO 7730 [4] standard, the value was -0.08. Both of these scores ranged from -0.5 to +0.5. Based on the research, it was found that the respondents felt thermal comfort [5]. In 2020, a total of 98 people, from three classrooms, aged 19-23 participated in the study. The research concluded that the PMV calculated on the basis of the questionnaires, and the PMV calculated from the formula, differ from each other, which confirmed the importance of using appropriate thermal conditions [6].

2. MEASUREMENT METHODS

Comfort measurement methods can be divided into direct and indirect. For the direct method questionnaires are used to determine the thermal sensations of people in a given room/building. Often three questions about thermal sensations are asked: is the temperature comfortable or unpleasant during the period; whether it was too hot or cold, and whether the test person would like it to be warmer, unchanged or cooler. Moreover, two questions regarding the air humidity in the room are provided: whether it was too humid, moderately or to dry and whether the respondent would like to change the air to be more humid, drier or whether to leave it unchanged. Other questions might deal with lighting of the room and others regarding for example physical activity of people who fill those questionnaires in (whether the examined person performer intense or moderate physical exertion, walked or was in a state of rest within given time before coming to the study room). A different set of questions dealt with air quality, about the person's well, clothing and etc. Based on this information the people can be assessed regarding their direct thermal responses. The indirect method uses the ISO 7730 standard. This standard provides the formula by which the PMV value is calculated. This value is responsible for the predicted average rating of the study group. To perform the necessary calculations to obtain the PMV you need to measure room temperatures, humidity, air velocity.

During the measurements the microclimate meter is located in the center of the room. It collects the data from the probes. Figure 1 presents the meter that records the parameters during an example test (probes described in the picture).

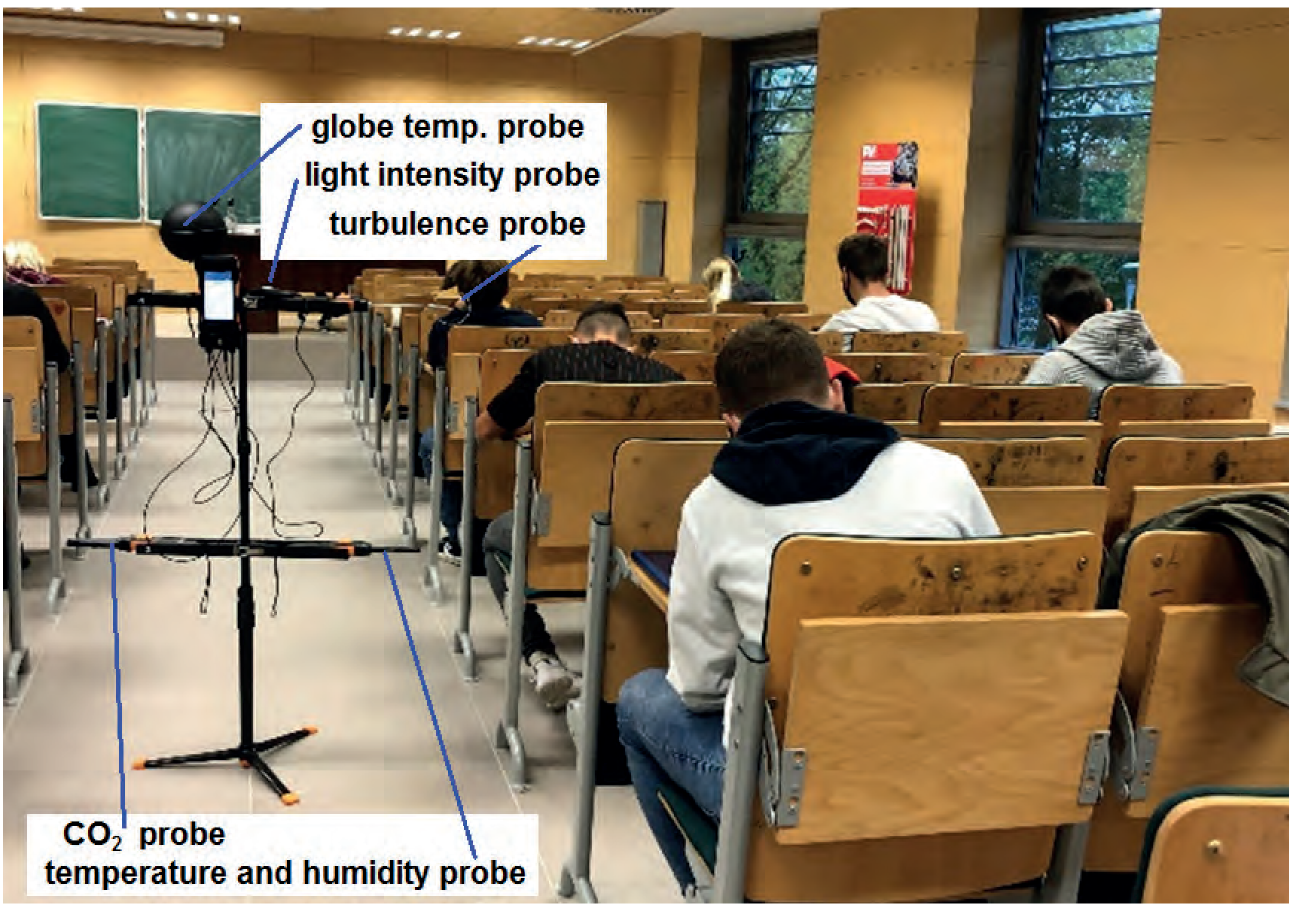

Fig. 1. The measuring station

environment

After switching on the microclimate meter all the measurements obtained had to stabilize within 15 minutes in order to show the accurate results of the parameters of the internal environment of the tested room climate. In the meantime, the surveyed persons complete the questionnaires. Figure 2 presents the view of the meter from Figure 1. Although the data are stored within the device, the current parameters (e.g. of temperature, pressure, light intensity, humidity, etc.) are visible on the screen as shown in Figure 2.

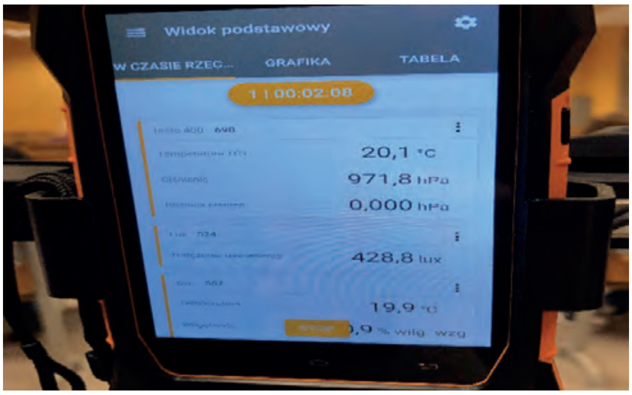

Fig. 2. The screen of the meter from Figure 1 with current data

3. TEST RESULTS OF THE QUESTIONNAIRE SURVEY IN THE SELECTED ROOM

The room selected for the test has a mechanical ventilation system with permanently programmed microclimate parameters. The touchscreen on the wall enables the programming of the air temperature and lighting level (which is usually conducted by a teacher). The values obtained by the meter during an example study of thermal comfort presented in this chapter are as follows:

- Air temperature – 29.40°C;
- Globe temperature – 28.97°C;
- Air velocity – 0.19 m/s;
- Relative humidity – 51.90%;
- Mean radiant temperature – 28.61°C.

14 people participated in the present study, aged from 19-26 years. They were asked to fill in the questionnaires containing a number of questions. Unfortunately, four questionnaires were rejected due to the lack of response to one questionnaire, not specifying their health condition, and practicing vigorous exercise prior to the study. It is quite important because the state of health e.g. a cold and performing intense exercise before the test, may disturb the actual perception of the prevailing conditions of the internal environment by the respondents. Consequently, the analysis included 10 correctly and fully completed questionnaire forms, which made it possible to learn about the preferences of the respondents regarding the conditions in the room under study. It needs to be mentioned that because of high temperature (the tests were carried out in the month of June) the respondents wore light summer clothes. The clothing thermal isolation (clo) for this group it was 0.62. Figure 3 shows the thermal sensations of the respondents as provided by them in the forms.

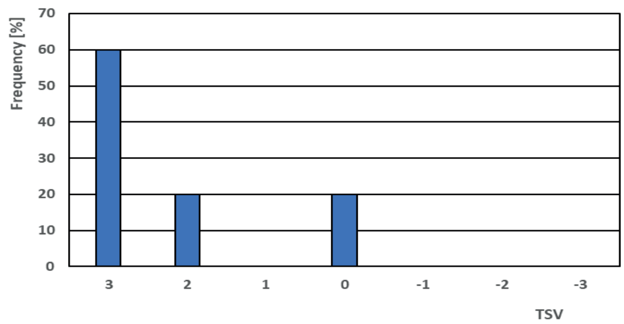

Fig. 3. Frequency of answers on thermal sensations (Thermal Sensation Vote): 3 – Too hot, 2 – Too warm, 1 – Pleasantly warm, 0 – Comfortable, -1 – Pleasantly cool, -2 – Too cool, -3 – Too cold

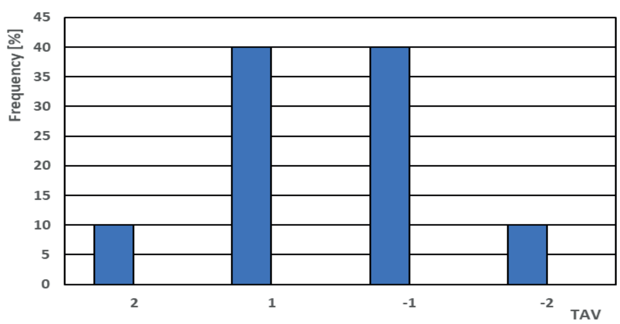

Fig. 4. Frequency of answers on temperatures felt by the respondents (Thermal Acceptability Vote): 2 – Comfortable, 1 – Acceptable, -1 – Unpleasant, -2 – Definitely unpleasant

As can be seen, for 60% of people, the room conditions are too hot, which is the result of high temperature (above the comfort level of most people). 20% of people think it is „too warm". Together, these people constitute 80% of the dissatisfied group regarding the microclimate of the considered room. Only 20% of people feel thermal comfort. Using a calculator to calculate the PMV according to the ISO 7730 standard, the PMV was calculated to be 0.96 [7]. For 6 people who answered "too hot" in questionnaires, the PMV was 2.20. There is a significant difference between the responses of the respondents and their PMVs and the PMVs calculated using the ISO 7730 standard. In Figure 4, the analysis of the respondents' opinion describing their feelings about the temperature in the room is presented.

Only 10% of people described the room temperature as comfortable, and 40% of people as still acceptable (this votes can be considered as positive responses). The temperature in the room was considered unfavorable by 40% of respondents, and absolutely unacceptable by 10% of the respondents. Such a high level of the unhappy people should be avoided (according to the standard PN EN ISO 7730). Figure 5 shows the thermal preferences of the study participants to the prevailing temperature in the considered room.

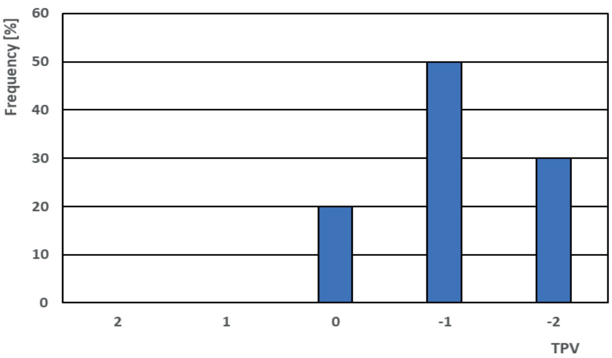

Fig. 5. Frequency of answers on thermal preferences vote: 2 – Definitely warmer, 1 – Warmer, 0 – No change, -1 – Cooler, -2 – Definitely cooler

20% of respondents would not like to change the air temperature (they seem to be satisfied with the indoor conditions in this room). Contrary to 50% of people who would like it to be cooler (this group is the largest, which is not surprising after the analysis of Figure 3). Only 30% of respondents would like it to be definitely cooler. The assessment of air humidity by the partcipants of the study has also been carried out with the application of the questionairres and is presented in Figure 6.

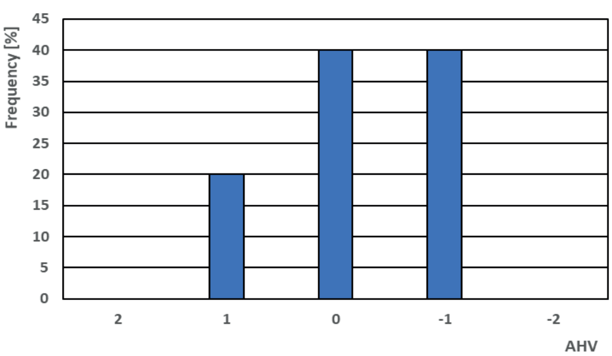

Fig. 6. Frequency of answers on assessment of air humidity vote: 2 – too humid, 1 – quite humid, 0 – pleasantly, -1 – quite dry, -2 – too dry

20% of people think that the room, in which they are located, is quite humid. 40% of respondents consider the air humidity in the room to be pleasant, which means that the conditions in the room suit these people. 40% of the group said it was quite dry in the classroom. Thus, it is difficult to make any conclusions about this parameter and its impact on thermal comfort within this group. Figure 7 shows the individual preferences of the surveyed people regarding the humidity in the room.

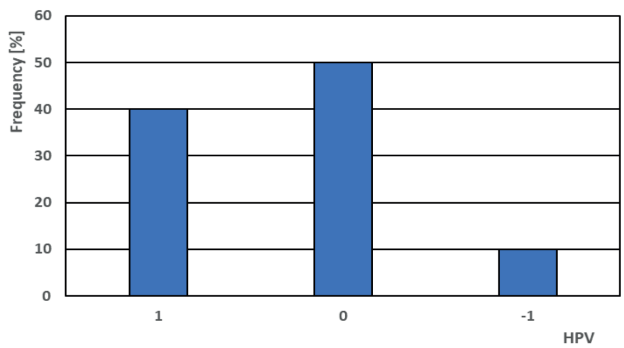

Fig. 7. Frequency of answers humidity preferences vote: 1 – more humid, 0 – no change, -1 – more dry

50% of the group would decide to change the air humidity (if they could, but the air management system does not allow such a modification of indoor air parameters). 40% express the view that it should be more humid and 10% of the respondents that it should be drier. The other half of the group would not change the humidity in the room. Maybe they could not make proper assessment of the humidity level and decided to leave it unchanged.

4. CONCLUSIONS

On the basis of the performed test of thermal comfort in the chosen room in which the air temperature was 29°C and where ten people expressed their anonymous opinions, it could be concluded that the temperature in the room did not suit the participants and that this parameter was by far the most important one in the assessment of thermal sensations. 80% of respondents considered that it was too hot or too warm there. This is the key information to conclude that the parameters set for the ventilation system's operation, without the possibility of changing these values easily, did not meet the thermal expectations of people staying in the studied room.

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ASSESSMENT OF INEQUALITY IN THE DISTRIBUTION OF WATER FACILITIES IN LAPAI, NIGERIA

OCENA NIERÓWNOMIERNOŚCI DYSTRYBUCJI URZĄDZEŃ WODNYCH W LAPAI W NIGERII

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Abstract

Rapid urban growth and expansion pose daunting challenges in urban areas of the developing world. These challenges include the provision and equitable distribution of sustainable public water supply facilities. This study therefore aimed at assessing the extent of spatial inequality in the distribution of water facilities provision among major segments in Lapai urban centre, Nigeria to aid policy formulation and framework in achieving sustainable water supply. This study utilizes the Gini coefficient composite statistical tool to examine the distribution inequality of three main sources of public water facilities in the study area, which includes; hand pump boreholes, motorised boreholes, and wells. The study area is divided into four quadrants (quadrants A, B, C, and D). It was found out that 17.31%, 21.15%, and 37.50% Gini coefficients were recorded for hand pump boreholes, motorised boreholes, and well facilities. This indicates that there is inequality in the distribution of public water supply facilities among the four quadrants in the study area. It was therefore recommended that both the public and private sectors should provide public water facilities equitably to achieve Sustainable Development Goals (SDGs).

Keywords: Distribution, inequality, Gini coefficient, Sustainable Development Goals, Urban growth, Water facilities

Streszczenie

Szybki rozwój i ekspansja miast stanowią trudne wyzwania w obszarach miejskich rozwijającego się świata. Wyzwania te obejmują zapewnienie i sprawiedliwą dystrybucję publicznych urządzeń wodociągowych. W związku z tym badania miały na celu ocenę zakresu przestrzennych nierównomierności dystrybucji wody w głównych obszarach centrum miejskiego Lapai w Nigerii w celu wsparcia formułowania polityki i ram w osiąganiu zrównoważonego zaopatrzenia w wodę. W niniejszym opracowaniu wykorzystano złożone narzędzie statystyczne ze współczynnikiem Giniego w celu zbadania nierównomierności dystrybucji trzech głównych publicznych obiektów wodociągowych na badanym obszarze, w tym: odwierty z pompą ręczną, odwierty z napędem silnikowym i studnie. Badany obszar podzielony jest na cztery ćwiartki (ćwiartki A, B, C i D). Stwierdzono, że współczynniki Giniego 17,31%, 21,15% i 37,50% odnotowano dla odwiertów z pompą ręczną, odwiertów silnikowych i obiektów studniowych. Wskazuje to na nierównomierność w rozmieszczeniu publicznych urządzeń wodociągowych w czterech ćwiartkach badanego obszaru. W związku z tym zalecono, aby sektor publiczny i prywatny zapewnił sprawiedliwe dostęp do publicznych obiektów wodociągowych tak, aby osiągnąć cel zrównoważonego rozwoju (SDG).

Słowa kluczowe: dystrybucja, nierówność, współczynnik Giniego, cele zrównoważonego rozwoju, rozwój miast, obiekty wodne

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1. INTRODUCTION

Rapid urban growth and expansion pose daunting challenges for human settlements most especially in recent decades (UN-Habitat, 2015). For the first time in human history, more than half of the human population lives in urban areas. The United Nations figure shows that in 2014, 54 percent of the world's population is urban residence and it is expected to continue to grow so that by 2050, 66 percent of the world population will be urban dwellers (United Nations, 2014). In Africa, the common challenges brought by population growth are wide-spread poverty and interrelated threats to the human habitat most especially in terms of utilities and services such as domestic water and sanitation (UN-Habitat, 2014). Western Africa is the continent's fastest urbanizing sub-region after Eastern Africa. The sub-region is projected to increase its share of urban dwellers from 44.9 percent urban in 2011 to 49.9 percent by 2020, and 65.7 percent by 2050 (UN-Habitat, 2014). Nigeria being the most populous country in Africa, have serious consequences of this regional urbanization estimates. Consequently, this has pushed urban utilities and services into a pathetic situation which has caused shortages in urban water supply services that does not meet the domestic need of urban residents (UN-Habitat, 2014).

Uncontrolled urbanization increases spatial inequality (UN-Habitat, 2010). The inequality exists where some regions benefit more from facilities and services than others (Tammaru et al., 2019). From a neoclassical perspective, unless regions and their cities have identical exposure to facilities and similar comparative advantage, urbanization is likely to increase spatial inequality (Cha et al., 2017).

According to Wei (2015), spatial inequality is the unequal amounts of qualities or resources (water, vegetation, soil, mineral, and atmospheric) and services (medical and welfare) depending on the area or location. Spatial inequality is very common in developing countries (Renkow, 2006). Where there exists an imbalance in development among different spatial units in the same geographic unit, which is one of the challenges facing sustainable water supply in developing cities (Mycoo, 2018).

In Lapai town, the problems of water supply are glaring and manifest themselves in three different forms (i.e adequacy, quality, and accessibility). The inadequacy of water supply is evidenced by the number of people seen around the available streams and earth wells scouting for water whose quality is quite doubtful, thus the problems accompanying the consumption of unsafe (untreated) water such as cholera, diarrhea, and guinea worm infections cannot be ruled out. This is also coupled with the uneven distribution of public water facilities.

Although, water need is to be supplied by all the sources available in the town including pipe-borne water, boreholes, wells, streams, and rain harvesting. Niger State Water Board (NSWB) is the sole supplier of pipe-borne water in Lapai and however, at the moment it is unfortunately not supplying any amount of water required by the inhabitants. Thus, other sources remain the only sources to meet the needs to achieve sustainability and given the exponential growth in the population due to the establishment of Ibrahim Badamasi Babangida University Lapai (IBBUL).

The rapid spatial extension of the town in the last decade has not been fully supported by infrastructural developments. While the town grew spatially, expansion of water supply service did not. There has been a wide gap, particularly in the water supply service when compared with other infrastructural developments in the area. In addition to this, the available water facilities on the ground are not unequally distributed which could make it difficult to ensure sustainability as required by the SDGs specifically the SDG 6. Hence, these necessitate new research to critically look into the extent of spatial inequality of available water facilities in Lapai to aid policy formulation and framework in achieving the SDGs. This study therefore aimed at assessing the extent of spatial inequality in the distribution of water facilities provision among major segments in Lapai urban centre, Nigeria to aid policy formulation and framework in achieving sustainable water supply.

2. LITERATURE REVIEW

SDG 6 known as 'the water goal' attracted a lot of literature suggesting formulation of policies, programs, frameworks, and methods in achieving it. For example, Hall et al. (2017) present a micro-level modeling approach that can quantitatively assess the impacts associated with rural water interventions that are tailored to specific communities. It focuses on how a multiple-use water services (MUS) approach to SDG 6 could reinforce a wide range of other SDGs and targets. Mycoo (2018) using Trinidad as a case study, analyses water governance challenges in meeting SDG 6, which addresses the sustainability of water resources by generating a blend of policies, good practices, and tools to confront growing threats to water security and to attain sustainable development. Giupponi, Gain, & Farinosi (2018) examines the spatial assessment of water use efficiency (SDG 6) for regional policy support. Ortigara et al. (2018) examine issues on how those involved in education, training, and research could contribute to enabling and accelerating progress towards achieving SDG 6. These studies were limited to frameworks, policy guidelines, country reports, and good practices without considering spatial inequality in the distribution of water facilities.

Measuring spatial inequalities is one of the major requirements of the SDGs (Cole et al., 2018; Winkler & Satterthwaite, 2017). Spatial inequalities of water facilities and provisions have been assessed by several works of literature. For instance, Cole et al. (2018) examine spatial inequality in water access and water use in South Africa where it is suggested that there is a high level of inequality in the distribution of water facilities which could delay success in achieving the SDGs. Adams (2018) who examines intra-urban inequalities in water access among households in Malawi's informal settlements opined that households and neighbourhoods in predominantly poor and under-resourced urban settings suffer water accessibility compared to others. Chaudhuri & Roy (Chaudhuri & Roy, 2017) confirmed rural-urban spatial inequality in water facilities provision among the households in India.

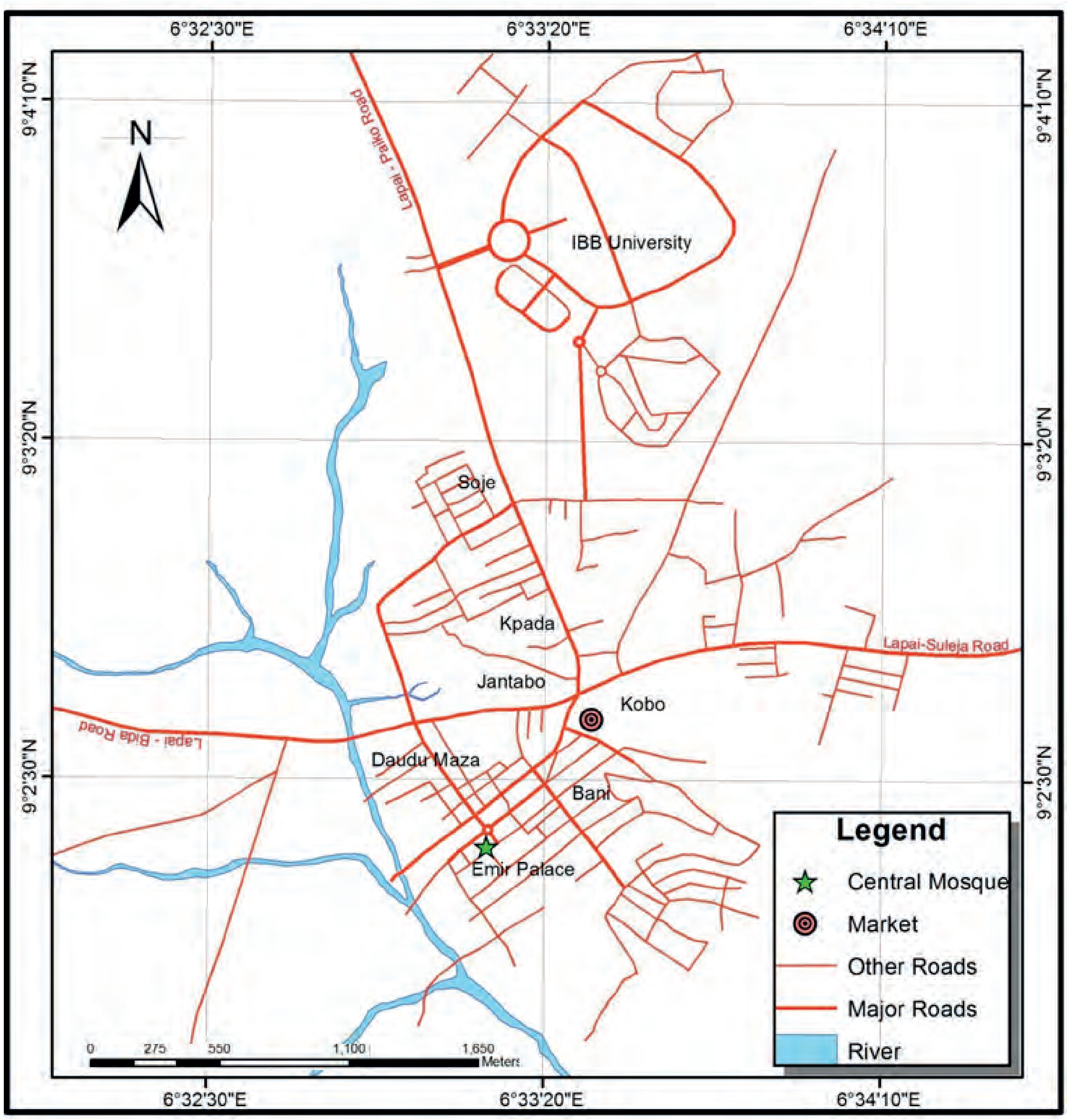

Fig. 1. Lapai Town in Niger State of Nigeria
Source: Ministry of Lands and Housing, Minna (2018).

Afifah et al. (2018) argued that there are inequalities in access to improved drinking water and sanitation by subnational region in Indonesia, where monitoring within-country inequality indicators serves to identify underserved areas, and is useful for developing approaches to improve inequalities in access that can help Indonesia make progress towards the 2030 Agenda for sustainable development. Cassivi, Waygood, & Dorea (2018) also argued that in Ethiopia there is inequality in water accessibility in terms of collection time. He et al. (2018) discovers spatial inequality of access to improved drinking water supply in Nepal where it was argued that without addressing the problem it could be very difficult to attain the SDGs. Ohwo (2019) argued that achieving the SDGs particularly the SDG 6 requires the elimination of all forms of inequalities. However, studies on inequalities in water facilities provisions are not found in the study area.

3. RESEARCH METHODOLOGY

3.1. Study Area

Lapai is located within latitude 9°03′00″N and Longitude 6°34′00″E. Lapai is a medium town and covers an area of 3,730 Km^2 with an estimated population of 12, 859, based on the census (NPC) of 2006. The town is about 56 Km East of Minna, Niger State Capital. Lapai Local Government Area of Niger State is situated in a rural setting, and the major occupation of the people is farming. Few are either employed in white-collar jobs or are involved in private businesses. The locational map of the study area is shown in Figure 1.

3.2. Data and Materials

The locational position of water facilities in terms of X and Y coordinates were taken using hand-held GPS before further analysis, to provide detailed information on the nature and condition of the existing water facilities. The total numbers of public water facilities found in the study area were 45, which include 2 public water taps, 26 motorised boreholes, 13 hand pump boreholes, and 4 wells (see Table 1 for details). Average water supply by these facilities per day is: hand pump borehole, 1,500 litres; motorised borehole, 6,000 litres; well, 500 litres. Data needed for Gini coefficient analysis on the motorised boreholes, hand pump boreholes, and wells were collected, The data on the public taps is excluded because it was not functional as at the time of the study.

Table 1. Number of Public Water Facilities by Quadrants

Public Water Facilities	Quadrant A	Quadrant B	Quadrant C	Quadrant D
Hand Pump Borehole	3	2	3	5
Motorised Borehole	5	4	6	11
Well	1	0	2	1

Source: Authors' fieldwork, 2018.

3.3. Gini coefficient

The Gini coefficient was used for the measurement of the inequality of water facilities distribution in Lapai. This is because Gini is considered to be one of the best measure of inequality. In this research, the Gini coefficient plots the proportion of the total facilities provided which forms the (y-axis) by the bottom x% of the water facilities. The town was divided into four quadrants where each quadrant was measured using its Gini index. Gini coefficient measures from 0% to 100%, where 0% indicates perfect equality and 100% indicates perfect inequality. This means that the higher the Gini coefficient, the higher the level of inequality. According to WHO (2003) average water demand per capita per day for drinking, cooking and personal hygiene is at least 15 litres. Water deficit is calculated by subtracting water supply from demand. Gini coefficient was also adopted in examining inequality in water deficit across the quadrants in the study area.

4. FINDINGS AND DISCUSSION

Water facilities found in each quadrant were recorded to calculate a water facilities provision Gini Coefficient. To obtain a better measure of the inequality of water facilities, all the records of each type of water facility for each quadrant were grouped before determining the water facilities' Gini Coefficient. However, the public tap facilities were not considered due to their non-functionality as discussed earlier.

From Figure 2 it is clear that spatial inequality exists among all the variables. The inequality coefficient is 17.31% for Hand Pump Borehole facilities, 21.15% for Motorised Borehole facilities, and 37.50% for Well facilities in the study area. This indicates that public well facilities are the most unequal water facilities among the quadrants in the study area.

The inequality as represented by the Gini coefficient is better appreciated with the use of a graphical device known as the Lorenz curve. Lorenz curve demonstrates graphically the magnitude of

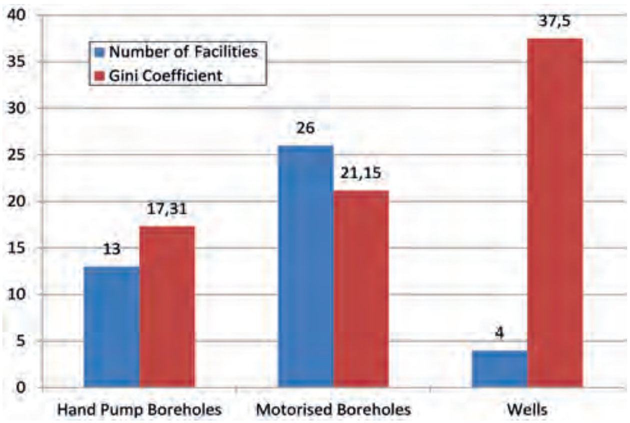

Fig. 2. Gini Coefficient for Water Facilities Distribution
Source: Authors' fieldwork, 2018.

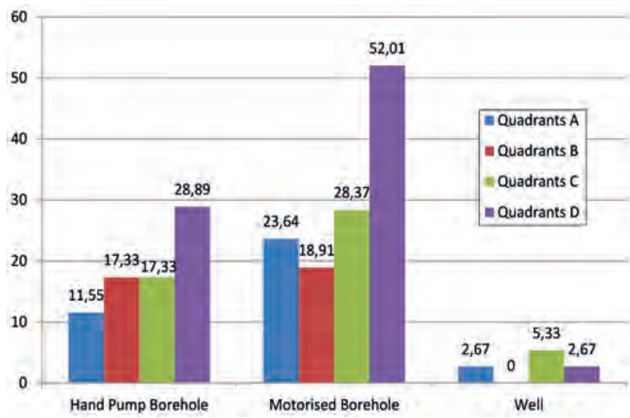

Fig. 3. Contributed Gini Coefficients for Each Quadrant by Water Facilities
Source: Authors' fieldwork, 2018.

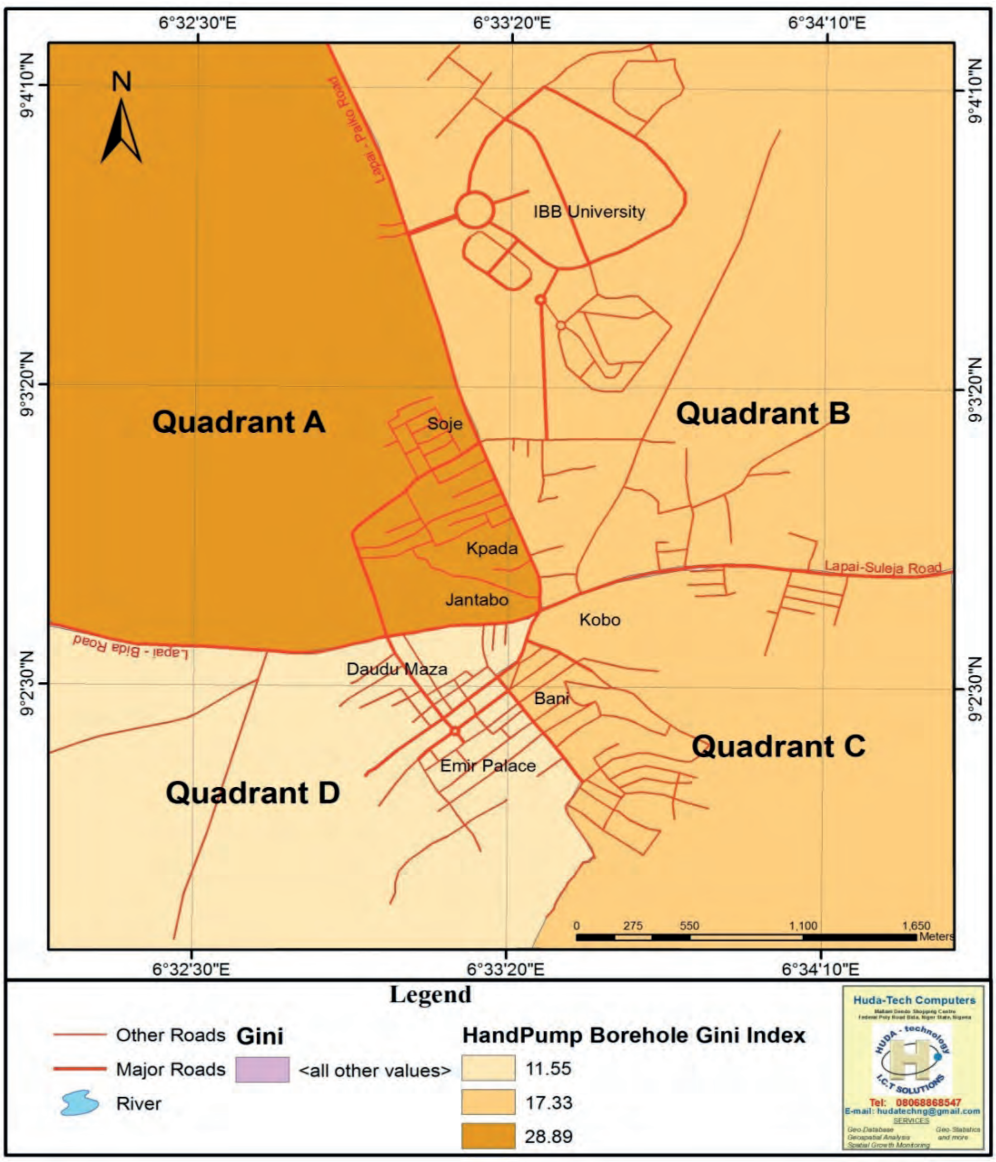

Fig. 4. The Gini Coefficient Map of Hand Pump Borehole to different Quadrants
Source: Authors' fieldwork, 2018.

environment

inequality. In the Lorenz curve, a straight line diagonal of 45° indicates perfect equality (see Appendix). This is equivalent to zero Gini coefficients. Among the variables shown, are the number of public wells representing the highest Gini coefficient followed by several motorised boreholes and the number of hand pump boreholes representing the smallest.

The Gini coefficient is more spatially presented in maps.

Results in Figure 3 are spatially represented in maps (Figures 4, 5, and 6). These results signify the densities of contributed Gini coefficients. The results of the research show the variation in the contribution of quadrants against each water facility in terms of their Gini coefficients. The hand pump borehole facilities in quadrant "D" contributed higher with 28.89% Gini coefficient, quadrant "D" also contributed higher in terms of motorised borehole facilities Gini coefficient with 52.01%, while quadrant "C" contributed higher in terms of public well facilities Gini coefficient with 5.33% respectively.

Figure 4 shows the contribution of quadrants to hand pump borehole facilities' Gini coefficient. The result revealed that quadrant "A" contributed more in terms of the Gini coefficient of hand pump borehole with a 28.89% Gini coefficient, followed by quadrant "B and C" which contributed 17.33% Gini coefficient each and quadrant "D" which contributed lower with 11.55% Gini coefficient.

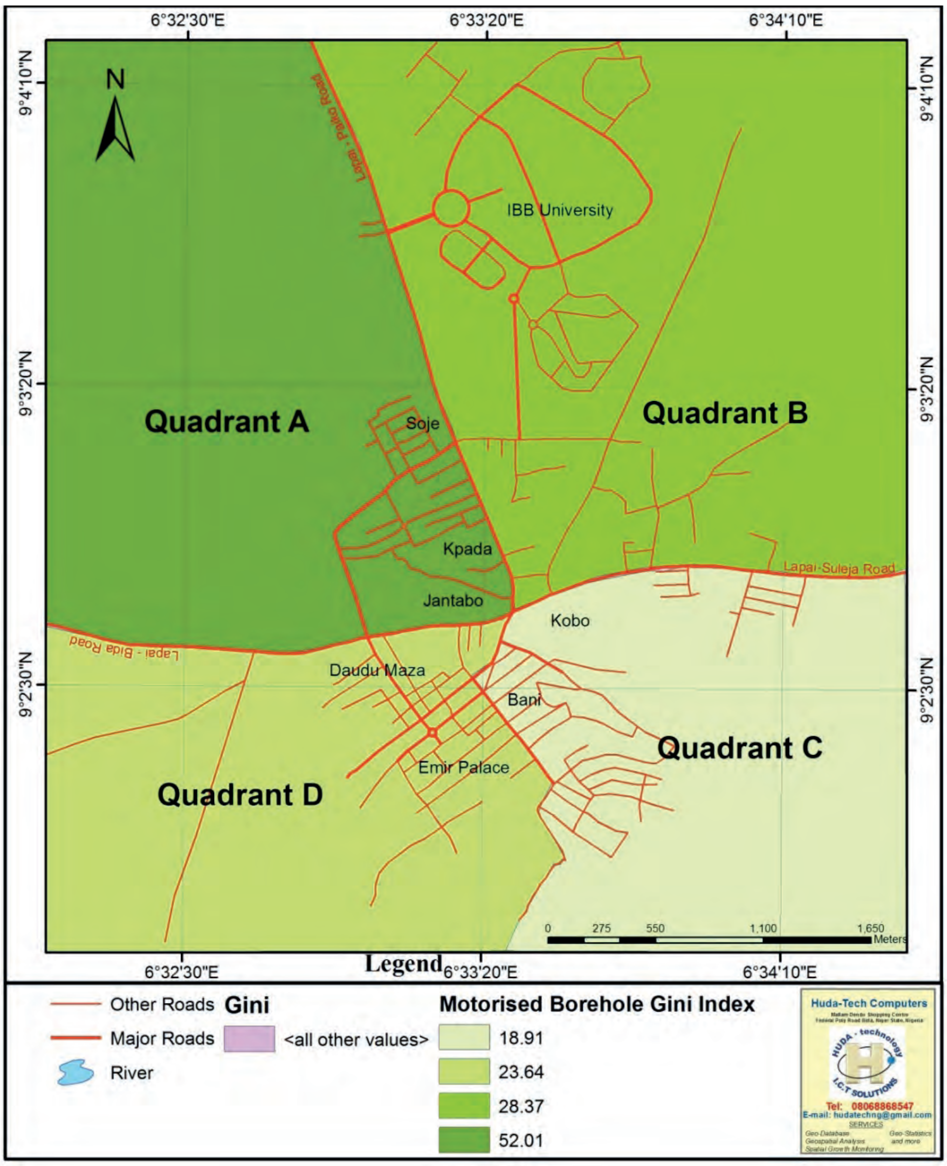

Fig. 5. The Gini Coefficient Map of Motorised Borehole to different Quadrants
Source: Authors' fieldwork, 2018.

The results in Figure 5 revealed that quadrant "A" contributed more in terms of Gini coefficient of motorised borehole with 52.01% Gini coefficient, followed by quadrant "B" which contributed 28.37% Gini coefficient, quadrant "D" contributed 23.64% Gini coefficient, while quadrant "C" contributed lower with 18.91% Gini coefficient.

Figure 6 revealed that quadrant "B" contributed more in terms of the Gini coefficient of public well facilities with a 5.33% Gini coefficient, followed by quadrant "A" and "D" which contributed 2.67% Gini coefficient each and quadrant "C" contributed 0.0% Gini coefficient respectively.

In summary, the results of field analysis show the variations in the contribution of quadrants against each public water facility in terms of their Gini coefficient.

The study revealed that there is inequality in the provision of water facilities in the study area. This result is similar to that of Cole et al. (2018) who confirms spatial inequality in water access and water use in South Africa and argued that a high level of inequality in the distribution of water facilities could make SDG 6 not achievable. Also, the result is in line with He et al. (2018) who discovers spatial inequality of access to improved drinking water supply in Nepal where it was argued that without addressing the problem, attaining the SDGs particularly SDG 6 could not be realistic.

Furthermore, population of the residents, water demand, water supply and water deficit were considered to further assess the inequality in the provision of water facilities in the study area.

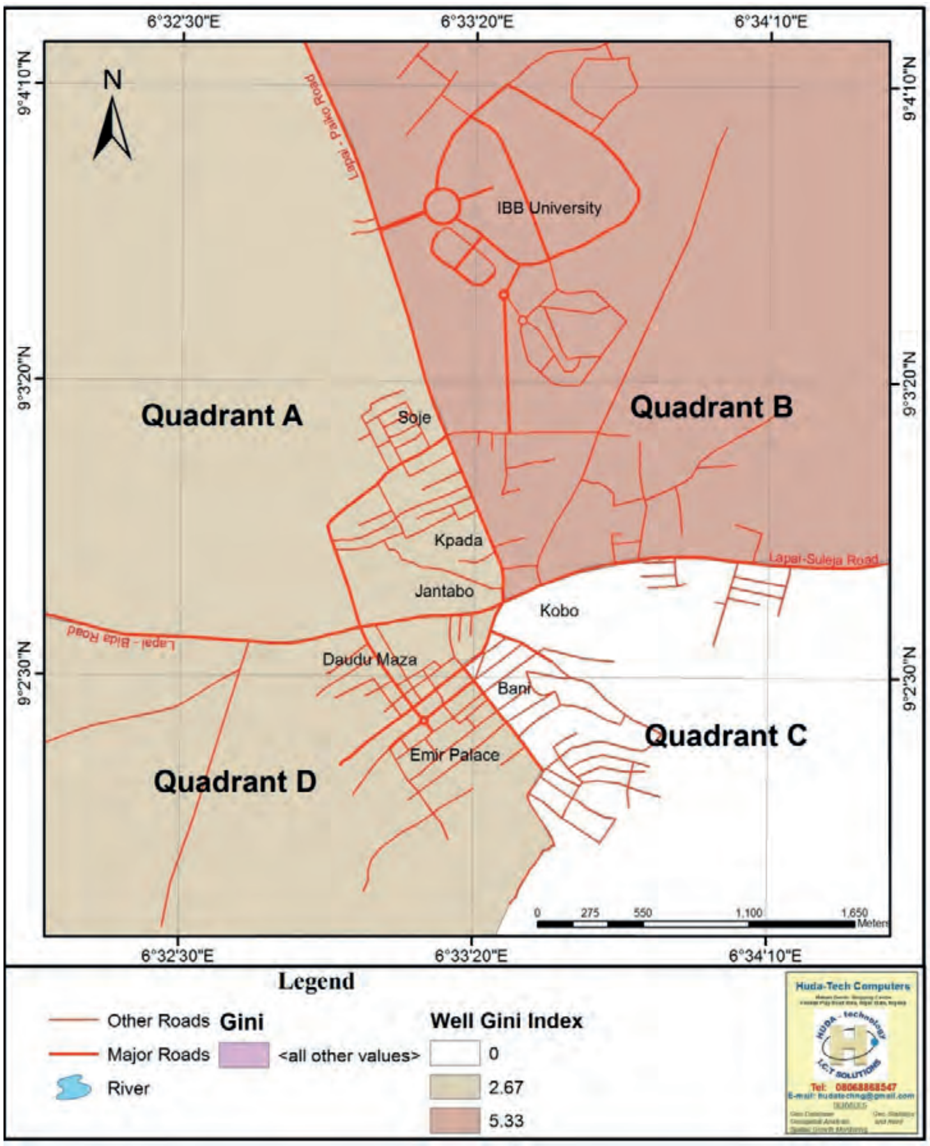

Fig. 6. The Gini Coefficient Map of Well to different Quadrants
Source: Authors' fieldwork, 2018.

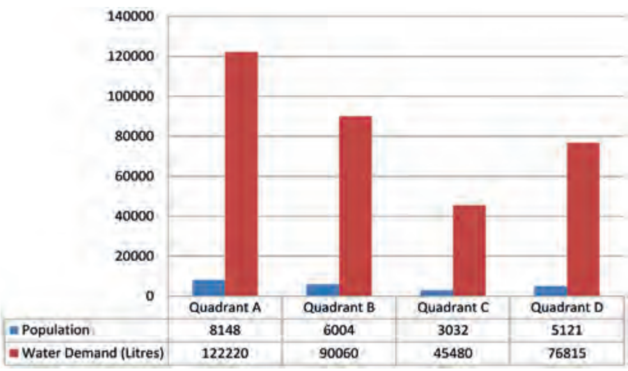

Fig. 7. Population and Water Demand
Source: Authors' fieldwork, 2018.

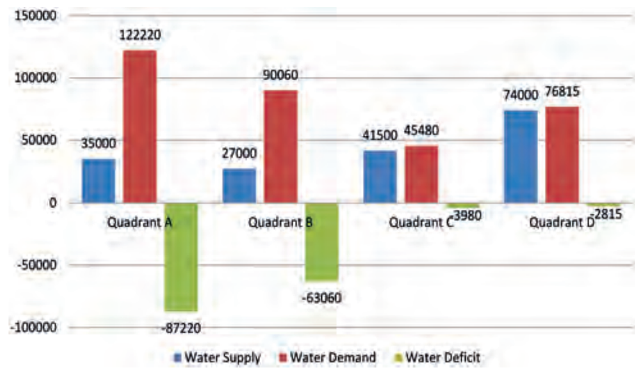

Fig. 8. Water Demand, Supply and Deficit
Source: Authors' fieldwork, 2018.

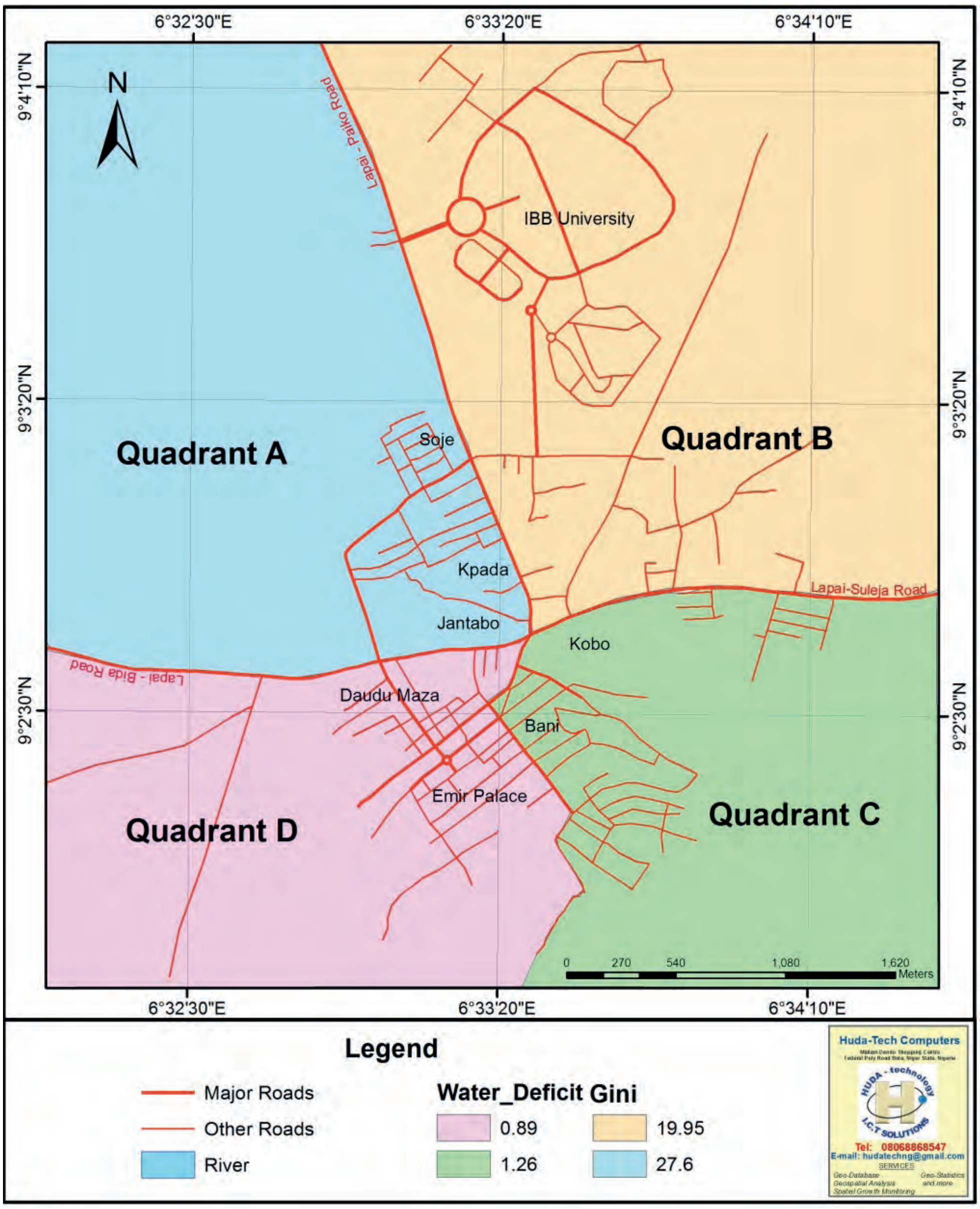

Fig. 9. The Gini Coefficient Map of Water Deficit
Source: Authors' fieldwork, 2018.

The study revealed in Figure 7 that Quadrant A has highest population of residents with 8,148 persons and about 122,220 litres of water need per day, while Quadrant C has lowest population with 3,032 persons and about 45,480 litres of water needed per day.

Findings of the study revealed in Figure 8 the water demand, supply and deficit across all the quadrants. It revealed that Quadrant A has highest water deficit with -87,220 litres per day i.e. additional 87,220 litres of water is needed per day by the quadrant to meet its need. Also, the findings revealed that Quadrant D has lowest water deficit with -2,815 litres per day, i.e. about 2,815 litres of water is needed per day by the quadrant to meet its water need.

Findings of the study revealed that Quadrant A has the highest contribution to the inequality in a water supply deficit in the study area with 27.6% Gini coefficient. This is followed by Quadrant B with 19.95% Gini coefficient and the least by Quadrant D with 0.89% Gini coefficient. The findings imply a very wide variation in the provision of public water facilities in the study area. Despite the high population in Quadrant A, it has the highest level of a water supply deficit, which indicates that population is not considered when providing these facilities.

The findings of this study have proven a high level of spatial inequality in terms of water facilities provision and water supply deficit. Studies have proven that spatial inequality in water supply facilities may hinder the achievement of the SDGs, particularly the SDG6 (Wei, 2015). The findings have also provided an aspect of the monitoring framework for the SDG6, this is another aspect that is paramount in achieving the goal (McIntyre, 2018).

5. CONCLUSION

The study shows a variation in the contribution of quadrants against each public water facility in terms of their Gini coefficient. This indicates that there is inequality in the distribution of public water supply facilities among the four quadrants in the study area. Also, the facilities provided did not commensurate with the population of the spatial segments of the town. There is a high level of water deficit across all parts of the town, where in some cases water deficit is more than the supply. The water supply deficit is also highly unequally across the spatial segments of the study area. This high level of inequality in the distribution of water facilities could make it difficult to achieve the global agenda for sustainable development in the year 2030. This study serves as an eye-opener for policymakers particularly those in charge of the SDG 6 framework. It was therefore recommended that both public and private sectors should provide public water facilities equitably to achieve SDGs (particularly, the SDG6).

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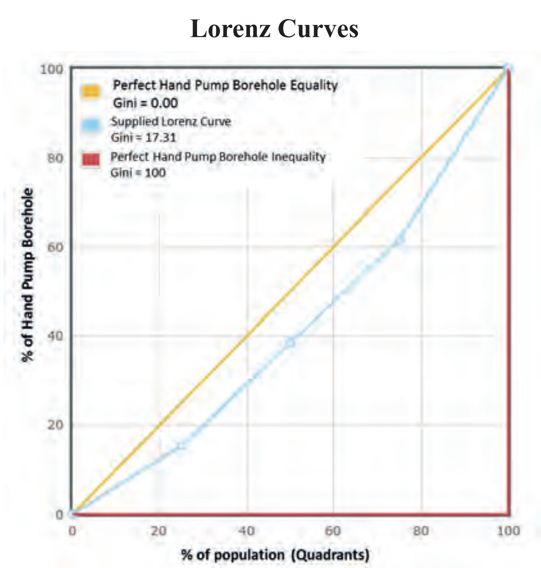
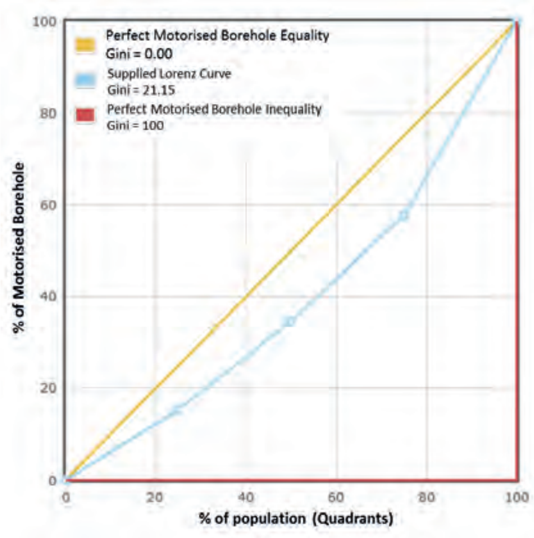
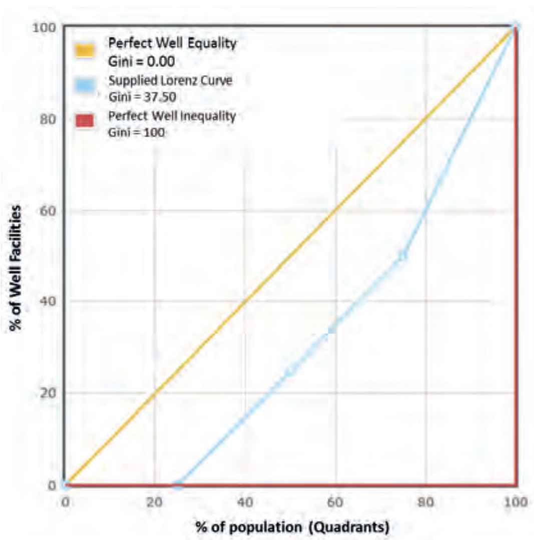
APPENDIX



Lorenz Curve of Spatial Inequality in Number of Hand Pump Borehole Facilities



Lorenz Curve of Spatial Inequality in Number of Motorised Borehole Facilities



Lorenz Curve of Spatial Inequality in Number of Well Facilities

Water Supply by Facilities

Public Water Facilities	Quadrant A		Quadrant B		Quadrant C		Quadrant D	
	No. Facilities	Water Supply (Litres)	No. Facilities	Water Supply (Litres)	No. Facilities	Water Supply (Litres)	No. Facilities	Water Supply (Litres)
Hand Pump Borehole	3	4500	2	3000	3	4500	5	7500
Motorised Borehole	5	30000	4	24000	6	36000	11	66000
Well	1	500	0	0	2	1000	1	500
Total		35000		27000		41500		74000

THE MICROSTRUCTURE AND PHASE COMPOSITION OF MORTARS FROM THE 17TH CENTURY SACRED BUILDINGS

MIKROSTRUKTURA I SKŁAD FAZOWY ZAPRAW Z XVII-WIECZNYCH BUDOWLI SAKRALNYCH

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Abstract

This work aims to characterize the microstructure of mortars derived from the walls of sacred buildings from the 17th century. The tests were carried out using the X-ray diffraction method, differential thermal analysis and scanning microscopy combined with the analysis of the elemental composition in the micro area.

The results of this study show that the materials bonding the elements of the wall in historic buildings are porous sand-lime mortars with an increased binder-to-aggregate ratio, also containing limestone crumbs, flints and feldspars, and fragments of bricks larger than sand particles. The binder is fully carbonated calcium hydroxide, with no pozzolanic additives. The results of the microstructure and phase composition tests of mortars used for bonding wall elements in buildings constructed at the end of the 16th and early 17th centuries can be used to select the composition of mortars used in the renovation and repair of historic buildings

Streszczenie

Celem pracy jest charakterystyka mikrostruktury zapraw pobranych z muru sakralnych budowli XVII-wiecznych. Badania wykonano metodą dyfrakcji rentgenowskiej, termicznej analizy różnicowej oraz mikroskopii skaningowej połączonej z analizą składu pierwiastkowego w mikroobszarze.

Wyniki przeprowadzonych badań wykazały, że zaprawy łączące elementy muru w budowlach historycznych są porowatymi zaprawami wapienno-piaskowymi, o zwiększonym stosunku spoiwa do kruszywa, zawierają także w swoim składzie okruchy skał wapiennych, krzemieni i skaleni oraz fragmenty cegieł o większych rozmiarach niż ziarna piasku. Spoiwo stanowi w pełni skarbonatyzowany wodorotlenek wapnia, niezawierający dodatków pucolanowych. Wyniki badań mikrostruktury i składu fazowego zapraw stosowanych do spajania elementów muru w budowlach wznoszonych w końcu XVI i na początku XVII wieku mogą posłużyć do doboru składu zapraw stosowanych przy renowacji i naprawach budowli historycznych.

MODERN METHODS OF THERMAL COMFORT MEASUREMENTS

NOWOCZESNE METODY BADAŃ KOMFORTU CIEPLNEGO

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Abstract

The issue of thermal comfort and its subjective feelings inside a building is becoming more and more important in the modern world. It is caused by the desire to create optimal conditions in places where people stay. The article presents two methods, indirect and direct, which are typically used in the research projects. These methods enable to assess the thermal sensations of people and compare the feelings of the respondents with the value of PMV (the value of human thermal sensations) calculated using the formula from the ISO 7730 standard and the questionnaire surveys.

Streszczenie

Zagadnienie komfortu cieplnego oraz jego subiektywnych odczuć wewnątrz budynku staje się coraz ważniejsze we współczesnym świecie. Spowodowane jest to chęcią stworzenia optymalnych warunków w miejscach przebywania ludzi. W artykule przedstawiono dwie metody, pośrednią oraz bezpośrednią, które powszechnie stosuje się w badaniach. Metody te umożliwiają ocenę wrażeń cieplnych ludzi i porównanie odczuć osób ankietowanych z wartością PMV (wartością wrażeń cieplnych człowieka) obliczoną za pomocą wzoru z normy ISO 7730 z danymi z kwestionariuszy.

ASSESSMENT OF INEQUALITY IN THE DISTRIBUTION OF WATER FACILITIES IN LAPAI, NIGERIA

OCENA NIERÓWNOMIERNOŚCI DYSTRYBUCJI URZĄDZEŃ WODNYCH W LAPAI W NIGERII

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Abstract

Rapid urban growth and expansion pose daunting challenges in urban areas of the developing world. These challenges include the provision and equitable distribution of sustainable public water supply facilities. This study therefore aimed at assessing the extent of spatial inequality in the distribution of water facilities provision among major segments in Lapai urban centre, Nigeria to aid policy formulation and framework in achieving sustainable water supply. This study utilizes the Gini coefficient composite statistical tool to examine the distribution inequality of three main sources of public water facilities in the study area, which includes; hand pump boreholes, motorised boreholes, and wells. The study area is divided into four quadrants (quadrants A, B, C, and D). It was found out that 17.31%, 21.15%, and 37.50% Gini coefficients were recorded for hand pump boreholes, motorised boreholes, and well facilities. This indicates that there is inequality in the distribution of public water supply facilities among the four quadrants in the study area. It was therefore recommended that both the public and private sectors should provide public water facilities equitably to achieve Sustainable Development Goals (SDGs).

Streszczenie

Szybki rozwój i ekspansja miast stanowią trudne wyzwania w obszarach miejskich rozwijającego się świata. Wyzwania te obejmują zapewnienie i sprawiedliwą dystrybucję publicznych urządzeń wodociągowych. W związku z tym badania miały na celu ocenę zakresu przestrzennych nierównomierności dystrybucji wody w głównych obszarach centrum miejskiego Lapai w Nigerii w celu wsparcia formułowania polityki i ram w osiąganiu zrównoważonego zaopatrzenia w wodę. W niniejszym opracowaniu wykorzystano złożone narzędzie statystyczne ze współczynnikiem Giniego w celu zbadania nierównomierności dystrybucji trzech głównych publicznych obiektów wodociągowych na badanym obszarze, w tym: odwierty z pompą ręczną, odwierty z napędem silnikowym i studnie. Badany obszar podzielony jest na cztery ćwiartki (ćwiartki A, B, C i D). Stwierdzono, że współczynniki Giniego 17,31%, 21,15% i 37,50% odnotowano dla odwiertów z pompą ręczną, odwiertów silnikowych i obiektów studniowych. Wskazuje to na nierównomierność w rozmieszczeniu publicznych urządzeń wodociągowych w czterech ćwiartkach badanego obszaru. W związku z tym zalecono, aby sektor publiczny i prywatny zapewnił sprawiedliwe dostęp do publicznych obiektów wodociągowych tak, aby osiągnąć cel zrównoważonego rozwoju (SDG).

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