FORMULATION OF GLAZES USING SELECTED AVAILABLE NATURAL MATERIALS FROM MUKONO AND JINJA DISTRICTS, UGANDA

AHAMI PHILEMON, B.A (Fine Art)

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MAY, 2024

DECLARATION

I declare that this report is my original work and has not been submitted for a degree in any other University.

Name: Ahami Philemon (M66EA/28084/2019)

Signature: ____________________

Date: _________________________

This report has been submitted for review with my approval as University supervisor.

Name: Mr. Anthony Ngondo
Department of Fine Art and Design

Signature: ____________________

Date: _________________________

DEDICATION

I dedicate this work to family and friends; Mr. and Mrs. Mpamire Justus, Michaela Tobler, Barbara Mero, Mercy Mpamire, Mpami Ezra, Marion Mpamire, Patience Mpamire who have been a great encouragement and strength throughout this study.

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ACRONYMS/ABBREVIATIONS

°C – Degree Celsius.

°F – Degree Fahrenheit.

Li_2O – Lithium Oxide.

Na_2O – Sodium Oxide.

K_2O – Potassium Oxide.

Ca_2O – Calcium Oxide.

MgO – Magnesium Oxide.

SrO – Strontium Oxide.

BaO – Barium Oxide.

ZnO – Zinc Oxide.

PbO – Lead Oxide.

Al_2O_3 - Aluminium Oxide.

SiO_2 - Silicon Oxide.

ZrO_2 - Zircon Oxide.

TiO_2 - Titanium Oxide.

Cd – Cadmium.

OPERATIONAL DEFINITION OF TERMS

Additives: A substance added to something in small quantities to improve or preserve it.

Ball mill: A drum-like, pebble-grinding mill, used for the grinding of glaze, or grog materials.

Bisque firing: The first firing is given to ceramic ware or green ware usually between 800°C-950°C.

Ball clay: A highly plastic clay, this is the basis of many pottery bodies.

Bentonite: A greatly plastic clay originating from the decay of volcanic ash. It is very fine and can be isolated widely through bodies and glazes, in which it is used to impart plasticity and the ability to retain a glaze spill in suspension.

Calcined: A method of softening some ceramic raw materials by the action of heat. For example feldspar and quartz

Cataclasites: This is a cohesive granular fault rock. They fall into the category of cataclastic rocks which are formed through faulting or fracturing in the upper crust.

DE-flocculent: To decrease or break up from a flocculent state; change into very fine particles, dissolve or maintain in a dissolved state.

Egyptian paste: Is essentially a self-glazing, low-clay modeling material. It has a high silica and high soluble alkaline flux component and an unusually low clay content.

Flux: An oxide that effects ceramic blends at lower temperatures through interacting with added oxides.

Frit: A frit is a mixture of a flux-like lead that is jointed with added materials like quartz, melted in the furnace to form an insoluble glass that is grounded to be used as a base for the creation of glazes.

Feldspar: A collection of raw materials used in amounts of up to 25 percent as flux in forms and up to 100 percent in glazes.

Glaze: A glassy substance bonded onto the body of pottery to form an impervious attractive coating.

Imperviousness: Not allowing a liquid or gas to pass through.

Kiln: A structure built to conserve heat. It is used for firing pottery or ceramic products.

Kaolin: A primary clay in its purest form. It is rich in aluminum oxide, little alkaline content and highly refractory with a melting point of over 1770^{o}C (3218°F).

Muscovite: Also known as white mica, is the lightest colored mica mineral. It is usually colorless, white, or silver, and sometimes yellow or brown.

Natural materials: A product that is made from materials and elements found in nature with little or no human involvement.

Oxidation: Firing materials or pottery in excess oxygen.

Oxide: A chemical combination of oxygen with another element. The metallic oxide and the non-metallic oxide e.g. cobalt, zinc, copper, manganese, nickel, and chromium

Quartz: A mineral rock, used as one of the sources of silica in glazes.

Tri-axial Blend: A method of blending three materials.

Vitreous: Hard, shiny, and translucent ceramics like glass, vitreous enamel, etc.

Viscosity: The stiffness of a liquid formed by the resistance amongst its particles and molecules. Viscous glazes move very little, in the firing.

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ABSTRACT

The researcher carried out a study on glaze formulation using selected natural materials collected from Mukono and Jinja districts. This was guided by geological mapping of Uganda. The topography of Uganda is made up of rolling hills, ridges, plains, and multiple drainage systems, all of which are rich in natural mineral resources. Amongst the mineral possessions are the massive sums of clay like kaolin and muscovite which was important for this study research. Although there has been development in the understanding of glaze formulation, the survey done on the three studios showed that there is a need for the researcher to conduct the study due to the imported glazes which have a direct effect on product pricing. The selected natural materials were collected and ground using the ball mill, transported to Kenyatta University ceramic studio. The chemical analysis was done using X-Ray Fluorescence to determine rock composition. The studio tests were first done at primary testing of 100% at a temperature of 1250°C and the firing temperatures were split into two categories, low temperature (1200°C) and high temperature (1250°C). Additives were part of the progressive testing using the lining blend. The tests were done on the clay test bars, the second progressive test was 85% material collected and 15% additional material, and the final progressive test was 80% material collected and 20% additional material. The research significantly added knowledge in the field of ceramics in the area of formulating glazes using locally available natural materials that are affordable for the Ugandan local ceramic market and presumably the international market. Glaze properties like viscosity, surface tension, volatilization, fusibility, and reaction with the body clay were used to determine successful glazes using a psychometric observation scale. Successful glazes were applied to creative project work.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

Ceramics stands as one of the most ancient craft art forms, with its origins dating back thousands of years. Regarded as a profound cultural artifact, it has exerted a significant influence on human civilization (Gustami, Guntur and Irfan, 2019). In the past, ceramics were commonly used as domestic appliances, building materials, food containers, home décor, body jewelry, money-saving instruments, metal-working tools, lighting equipment, and a variety of other uses (Wibisono, 2000). Ceramics comprises things like tiles, bricks, plates, glass, and toilets. Ceramics that have been shaped, are fired in high-temperature ovens known as kilns. These shaped ceramics are enclosed in decorative, water-resistant, paint-like materials known as glazes. Parmelee (2012) describes ceramic glazes as an impermeable layer or covering of a glassy substance that has been attached to a ceramic form through firing. Pottery has been around for more than three centuries. Glazed ceramics have only existed for the last hundred years, occupying a mystical place somewhere between science and sorcery. Latorre (2009) depicts a glaze as a tiny coating of glass that shelters a ceramic body. The glass can be clear, translucent, or opaque, reliant on the interface of the materials that have gone into creating that particular glass.

Ceramics are a prominent craft in many regions of Uganda, with a widespread presence and a rich tradition of innovation. Uganda has a history of pioneering advancements in clay-based products, yielding both successful and unsuccessful outcomes. Uganda's geography is made up of rolling hills, plains, ridges, and numerous drainage channels, as well as abundant natural mineral wealth. Massive amounts of clay such as muscovite and kaolin are among the mineral wealth (Katto, 2003). This enables ceramic workshops and industries to have various raw materials for ceramics production. However, there have been concerns regarding the importance of the many types of education, training, and industry-creating societies in Uganda. It is believed that educational transformation can shape and restructure traditional pottery manufacturing in schools and institutions. In Uganda, as in most African traditions, roles and practice of pottery have long been determined by the specific needs of local communities, such as the production of functional household items like cooking pots and milk jugs. The rapid shift in social status and division continues to resonate with both producers and users. Ceramics which is familiar with historical practice and social divide continue to play a smaller role in the larger community because of changes in the level of knowledge, technology, and innovations occurring in the ceramic industry. (Philip and William 2014).

Lillian (2017) concurs with Latorre’s definition of glaze, asserting that the Egyptian paste undergoes a transformative process when subjected to fire, attributed to the sodium salt content in the Egyptian clay. Tony (2021) affirms Lillian´s view and reiterates that sodium in the salt forms a vapor cloud in the kiln. That sodium, along with the silica and alumina in the clay, combines to form a glass to glaze the ware. Thomas (2020) argues that the Egyptians used local natural available materials to formulate the aqueous suspensions which was the earliest glaze made around 4000 to 3100 BC, the suspension was a mixture of quartz powder mixed with an extra flux of sodium salts or plant ash which are raw materials. The mixture was then applied to a burned clay item, where the particles bonded into a glassy layer during re-firing. Aqueous suspensions were used to create the first impermeable objects, such as glaze beads and amphoras. Stoneware glazes containing calcium oxide and wood ash were first discovered in China between 1600 and 1500 BC.

Although intense research work has gone into ceramic glazes in the last four decades and development aimed at a better knowledge and understanding of glaze materials, their properties have widened the art of glaze making and application (Ashakwu, 2015).

The pilot study, conducted in ceramic studios in the Mukono district of Uganda aimed to identify the challenges faced by practicing ceramic artists. It was revealed that none of the studios utilized local glaze formulations, which prompted further exploration in this area. The ceramic studios import glazes from Germany and Switzerland. Peter (2010) writes that the raw materials are available in Uganda but there is no evidence of their successful utilization in the production of ceramic glazes. Thomas (2020) also mentions that many of the raw materials used to formulate ceramic glazes come from locally available materials and thus are cost-efficient alternatives.

The study formulated glazes using the available local natural materials, aligning with Lillian (2017) who noted limited documentation on glaze development and technology in East Africa.

1.2 Statement of the problem

In a preliminary investigation conducted within the ceramic studios of potters located in the Mukono district, the aim was to identify the challenges faced by practicing ceramic artists in relation to glazes. The study highlighted the difficulties they experienced in obtaining glazes, as it was found that local glazes and formulations were not accessible. The studios that used glazes, imported the glazes from Germany and Switzerland which are expensive and incur a lot of taxes, (3.4). The use of locally available materials to formulate glazes can efficiently lower costs.

Although there has been development in the understanding of glaze formulation, the survey carried out among the three ceramic studios in Uganda namely; Vision for Africa pottery studio, Mukono Pottery and Potters House Workshop showed that they used imported glazes which have a direct effect on product pricing because of the duty they incurred in bringing the glazes. There was a need for research to be done in the exploration of local natural materials in the formulation of glazes that are cost-effective.

1.3 Objectives of the study

The objectives of the study were to:

i. Identify suitable available natural materials for glaze formulation in Uganda.
ii. Test fire the selected materials for glaze properties.
iii. Formulate glaze using selected additives on promising samples.
iv. Apply successful glazes on a ceramic creative project.

1.4 Research questions

i. What available natural materials can be found in Uganda?
ii. What firing tests can be done from the selected materials for glaze properties?
iii. What additives can be added to the selected promising samples?
iv. Can successful glazes formulated be applied to a ceramic creative project?

1.5 Rationale and significance of the study

The research added knowledge in the field of ceramics in terms of formulating glazes using locally available natural materials that could be affordable for the Ugandan local ceramic market and the international market.

The research study granted practicing ceramic artists in Uganda insight into locating locally available natural materials that enabled them to formulate glazes, through the following processes of natural material selection, material preparation, and glaze testing, which involve the selection of natural materials, grinding of these materials, application onto fired test samples respectively, and application on the ceramic creative project work.

The study also contributed to the formulation of new glazes generated from geological materials from Mukono and Jinja districts which availed the information to both local/ international ceramists and ceramic establishments for more research.

1.6 Scope and delimitations of the study

The study restricted itself to glaze formulation by means of locally available natural materials collected from the districts of Mukono and Jinja in Uganda because the location was easily accessible for the researcher. Samples were collected from within Jinja and Mukono, processed through crushing and grinding to powder form, fire tested by firing them in the kiln at 1250°C, analyzed through observation, re-tested using additives like kaolin and soda ash, rated using the general properties of glaze like transparent, translucent, opaque, and glossy, a ceramic creative project was developed and successful sample glazes applied.

The glaze samples were fire-tested by means of an electric kiln at 900°C low and 1250°C high temperatures on small clay test bars.

The glaze samples were mixed with different kinds of additives and fluxes that lower the firing temperature of the glazes, created a glass effect, and stabilized the glaze during firing.

CHAPTER TWO: REVIEW OF RELATED LITERATURE

2.0 Introduction

This section includes an summary of related literature that includes details on natural clays and rock materials for glaze formulation, location of study, sources of sample materials, geology of the identified sites, preparation of glazes, development of samples and sample testing, additives, variety of firing for glaze, techniques, classification of glazes, and conceptual framework. It also portrays the conceptual framework used in the study.

2.1 Natural clays and rock materials for glaze formulation.

Mamza and Jidai (2014) describes glazes as a tiny glass-like coating that is bonded to a clay surface by the heat of the kiln. The glaze is an unceasing adherent coating of glass or glass crystals on the surface of a ceramic form. Glazes are typically applied as suspensions of glaze ingredients in water, which dry on the surface of the piece as a layer. On firing, the materials respond and melt to create a thin coating of glass.

In the process of formulating and developing glazes, careful consideration should be given to the specific locations, relevance, types of natural raw materials, and their characteristics, especially in areas where clay materials are abundant. According to the research conducted by Mamza and Jidai (2014), it is essential for potters to possess in-depth knowledge of materials such as metallic oxides. This includes understanding their properties, how they interact with other elements, the ideal heat conditions for producing the best results, and the availability of compounds. Then one will be able to skillfully create glaze recipes.

Glaze rock materials are solid minerals that are granulated and mixed to create glazes. The most common materials used in glazes are feldspar, quartz/silica, limestone, kaolin, ball clay, and bentonite (Bassey 2009).

According to Hogan (1973) and Nelson (1971), in glaze formulation, three basic elements are required: silica (a glass former), a flux (which lowers the silica’s blend point), and alumina (a refractory element that adds durability and toughness to the glaze), which allows for a higher melting temperature, increased thickness, and diversification

Mamza and Jidai (2014) state that there are unlike types of glazes i.e. ash glaze, Chun, crackle, raku glazes, Temmoku, and others. Every glaze is created or prepared specifically for the products that the ceramicist will glaze. Therefore, during the formulation of glazes using naturally available materials, one has to consider that customary glazes are made up of components like silica, alumina, and flux. In this situation, the key ingredient in glazes is silica, which can be added as a natural raw material. Quartz sand or flint, for example.

2.2 Location of the study, sources of sample materials, and geology of the identified sites.

The geological resources are among the best suitable raw materials for glaze creation. Uganda's geology can be classified into seven categories based on key rock types from different eras, representing the principal hydrogeological aspects. Owor et al. (2018) mention that the geological elements comprise meta-sediments and sedimentary rocks, volcanic rocks, cataclasites, granite intrusions, metamorphic rocks, meta-igneous rocks, and sediments, as revealed in the table below;

Table 2.1: An overview of Uganda's geological formations showing seven categories showing the main elements.

Groups	Rock formation	The main sorts of rocks
Meta-sediments	Bunyoro and Kyoga series. Karagwe-Ankolean	Shales, arkoses, and quartzites Argillites and arenites with some basal meta calcareous rocks, mudstones, siltstone, tillites, sandstones, and silicified rocks
Volcanic.	Pleistocene Tertiary (& Mesozoic?) Tertiary	Volcanic rocks, carbonatite, syenite, as well as related sediments
Cataclasites	Precambrian	Cataclasites
Granites	Precambrian	Mobilized, intrusive granites Granitoid and highly granitized rock
Metamorphic	Aruan series Basement Complex Mirian Series Watian Series	Banded gneisses, undifferentiated gneisses, granulite facies, gneisses, charnockites, enderbites, and retrograded derivatives

Meta-igneous	Buganda-Toro Karasuk Series Madi Series	Phylites, schists with basal quartzites, amphibolites, acid gneisses, quartzites, marbles, and schists.
Sediments	Pleistocene	Sediments, alluvium, black soils, moraines, and Rift Valley sediments.

2.2.1 Materials for glaze formulation.

Natural local resources for glaze are obtained from treated and processed minerals. Glaze production is cost-effective as the local resources used are abundant, easily accessible, reliable, and affordable (Thomas, 2020).

Lillian's (2017) literature expounds upon the composition of the universe, elucidating that it is comprised of elements housing neutrons, protons and electrons. There are approximately 100 elements, each with a unique electronic configuration determined by its atomic number Z and the spatial distribution and energies of their electrons. This establishes the great wealth of the earth's resources and differentiates every region in the world based on the availability of natural materials within their region.
Thomas (2020), continues to say that normally, silica, alumina, and flux are the main ingredients of classic glazes. In this situation, the essential component of glazes is silica. Silica is a natural raw material that can be used. Quartz sand or flint, for example. It's also frequently advertised as a component of raw materials for other oxides.

2.3 Preparation of glazes.

Glaze materials are finely crushed in a ball mill or attrition mill and sieved through 40-80 meshes to make glazes. Glazes are often applied by spraying or dipping, and they mature at temperatures ranging from 600° to 1500°C (1110° to 2730°F) depending on their ingredients. (Mamza and Jidai 2014). Mamza continues to say that after the raw materials are picked they can be washed and dried for two days, after which, they are measured and packed into the kiln for calcination. Calcination helps to remove moisture and drive out carbon dioxide from the ore. Henrik and James (1993) continue to describe calcining as the firing of the geology at just above 600°C. This can be done in the cold regions after a first firing or in customized ovens for large productions.

Lillian (2017) argues that the commonly used glaze industrial methods include combining the ingredients, particle size reduction, dispersion in water, elimination of undesirable elements, and modest chemical additions to alter the glazing slip's physical qualities. The three first procedures are approved out together throughout wet crushing. Grinding of small quantities can be done with a hammer using eye protectors and large quantities are typically done in a jaw grinder.

Henrik and James (1993) posits that ball mills are used for well-crushing of ceramic materials. The materials have to be crushed to a sand size of approximately 2mm or less before crushing in a ball mill grinder. There are two main forms of milling: large crushers with an axle mechanism are known as ball mills, and tiny mills known as pot mills or jar mills. They go on to state that to avoid mistakes, glazes must be ordered systematically. The majority of glaze problems stem from simple factors like incorrect weighing, mistakes in locating raw ingredients, or failure to filter the glaze properly. Glaze errors are costly since they can result in the loss of a whole kiln load. It is critical to have the correct person in charge of producing glazes for this reason; cleanliness, meticulous record-keeping, and dependability are all required.

2.4 Development of samples and sample testing.

According to Henrik and James (1993), the process of formulating glazes bears resemblance to the culinary arts. They argue that differences in ingredients, firing methods, and other variables can result in a range of outcomes, much like how different chefs can create unique dishes from the same recipe. The authors emphasize the importance of conducting extensive testing of glazes, using a variety of samples to evaluate their performance under various conditions. Furthermore, they recommend thorough labelling of test samples to accurately document the complete formula and enable future reference.

Thomas (2020), says that there are several ways of sample testing when formulating glazes which include; line blending, tri-axial blending, and so many others. Therefore the research intended to use both when doing the glaze sample testing.

2.5 Additives and materials used in the formulation of glaze.

Glaze can only be made from three elements: silica, the glass former, a flux or glass, and alumina, the refractory element. It is not economically feasible to make glazes from refined and pure oxides (Mamza and Jidai 2014). In accordance with Shearer (2005), a glass former is the primary constituent of a glaze that necessitates supplementary melting from the fluxes and reinforcement from the stabilizers. In the majority of cases, silica serves as the principal glass former, while flux is an element that facilitates the melting of the glaze or assists in reducing the temperature at which the glaze will melt. A stabilizer is an essential ingredient that effectively increases the melting range of a glaze and significantly strengthens it. On the other hand, an opacifier is a key ingredient crucial for achieving opacity in glazes, especially in the production of white glaze, by effectively blocking the passage of light.

Silica, potash/soda, alumina, and calcium oxide/ magnesium oxide operate as main glass formers, modifiers, intermediate oxides, and stabilizers, respectively, in most glass and glaze batches. Feldspar is a single raw material containing three different types of oxides. Potash, Soda, and lime are the most critical ingredients in glass and ceramics. Feldspar is rarely found in its purest form. They transport contaminants like iron, calcium oxide, magnesium oxide, and clay, which, depending on the glass/glaze type, can be allowed in batches (Garkida et al, 2003).

Raw materials and additives for formulation are classified by Thomas (2020) as shown in table 2.2.

Table 2.2: Raw materials and additional oxides

To add	Raw materials	Other oxides introduced
Li_2O	Spodumene	Al_2O_3, SiO_2
Na_2O	Na-Feldspars Nepheline syenite	(K_2O), Al_2O_3, SiO_2 (K_2O), Al_2O_3, SiO_2
K_2O	K-Feldspars Nepheline syenite Muscovite mica	(Na_2O), Al_2O_3, SiO_2 (Na_2O), Al_2O_3, SiO_2 Al_2O_3, SiO_2
CaO	Wollastonite Limestone Dolomite	SiO_2 MgO
MgO	Magnesium carbonate Dolomite Talc	 CaO CaO, SiO_2
SrO	Strontium carbonate	
BaO	Barium carbonate	
ZnO	Zinc oxide	
PbO	Lead bisilicate	SiO_2
Al_2O_3	Corundum Feldspars Nepheline syenite Kaolin clay Ball clay Muscovite mica Pyrophyllite	 Na_2O, K_2O, SiO_2 Na_2O, K_2O, SiO_2 SiO_2 SiO_2 K_2O, SiO_2 SiO_2
SiO_2	Quartz sand, Flint Feldspars Nepheline syenite Wollastonite Kaolin clay Clay ball Muscovite mica Pyrophyllite Talc Zircon	 Na_2O, K_2O, SiO_2 Na_2O, K_2O, SiO_2 CaO Al_2O_3 Al_2O_3 K_2O, Al_2O_3 Al_2O_3 CaO, MgO ZrO2
ZrO2	Zircon	SiO_2
TiO2	Anatase	

Finally, modest amounts of various additions such as color pigments, crystallization agents, sticky binders, DE-flocculants, and other additives are required to change the glaze`s rheology or final qualities.

Thomas (2020), continues to say that it is not only an issue of getting the right final oxide composition when it comes to making a glaze. The raw materials used to create the correct glaze oxide arrangement must be selected based on their melting or dissolving characteristics throughout the firing process. To achieve defect-free glazing, melting should not begin before the fume produced by the maturation of both the glaze and the substrate has dissipated.

2.6 Variety of firing for glaze and techniques.

Understanding the temperature ranges for firing ceramic glazes is crucial for successful pottery making. Firing at the correct temperature ensures that the glazes mature properly, while avoiding excessively high temperatures prevents the glaze from melting and running off the pottery surface. A potter's success hinges upon a comprehensive grasp of the temperature ranges at which their glazes mature. According to Burleson (2001), it is recommended to conduct a test firing on a small batch of clays to clays to ascertain properties such as opacity, fluidity, and surface texture.

Lillian (2017) highlights the importance of conducting glaze tests on smaller pieces to thoroughly assess the potential of individual materials. Additionally, these tests help to understand the behavior of additives during the formulation process. Lillian continues to say that test firing showcases the melting point of a material. The results give glaze or glaze effects that require adjustments by adding additives. A low temperature range of 1050^{o}C to 1200^{o}C can be used in testing to categorize low and high-temperature recipes.

According to Williams (2006), understanding how different oxides affect glaze firing and which materials contain these oxides is crucial for developing, controlling, and ensuring the safety and quality of glazes during testing. He asserts that the primary reason for mastering the chemistry of glazes and oxides, as discussed here, is to save time, money, effort, and frustration.

Researcher Thomas (2020), says that reactions in raw glazes start with a warming temperature of 100- 200°C to drive off mechanically bound water, chemically bound water in the glaze is removed at about 600°C and carbonate decay at about 800°C and the process is termed as sintering of the glaze. Thomas claims to say once-firing is done when firing big, complex-shaped pieces like sanitary ware. The huge pieces are usually not completely covered in glaze because they can maintain themselves without alteration throughout the raw glaze firing. The primary reason for one firing is the monetary benefit of lower energy prices.

The study placed significant emphasis on the thickness of the glaze slurry and the precise measurement of ingredients. Accurate measurement is particularly crucial when incorporating ingredients into raw materials. Additionally, clear labeling of containers is essential to prevent any confusion. Burleson (2001) suggests letting the glaze rest overnight after mixing it. This is because some ceramic materials expand as they absorb water, causing the glaze to thicken during this time. Adjusting the glaze to the proper thickness for application can only be done after it has rested. The immediate application of glazes after mixing can result in expansion on the clay surface, leading to flaking or defeats. This may compromise the accuracy of the test results and should be taken into consideration.

2.7 Classification of glazes.

The classification of glaze is difficult since it is difficult to determine technically rigorous and operational organization standards. Each standard delineates a particular form of organization, the value of which is contingent upon the requirements of the interested party. Certain elements of their behavior in the manufacturing procedure (e.g. fusibility or refractoriness) or arrangement (e.g. the occurrence of a particular element or organized classification rendering to composition) might be chosen (Casasola et al., 2012). They continue to say that likely ceramic glaze classes include;

According to the fusibility: although this is an extensively used standard, it is inadequate for establishing a difficult glaze categorization since the only information is included in the melting temperature. Glazes with widely disparate appearances and possessions would be confidential in the same collection based on this criterion.

Based on the presence of a significant component. This categorization is limited to a single glazing component and, while useful in certain circumstances, is insufficient in others because it does not provide any additional information.

Table 2.3: Glaze classification according to different criteria.

Criterion	Classification
Fusibility	Fusible. Hard or less fusible.
Presence of a significant component.	Lead-containing. Non- lead-containing.
Further approach and firing process.	Single-firing covering Single-firing pavement Double conventional-firing covering. Double fast-firing covering.
Production approach	Bases. Airbrushing (pulverized). Pips. Serigraphy.
Impact on the final product.	Shining. Matte. Semi-matte. Satin Transparent. Opaque Colored.

<table>
<tr><th colspan="2">Criterion.</th><th>Classification.</th></tr>
<tr><td rowspan="2">Raw glazes.</td><td>Contains Lead.</td><td>-Using alumina.
- No alumina.</td></tr>
<tr><td>Non-lead-containing (with alumina)</td><td>-using alkaline earth.
-using alkaline and alkaline earth.
-uses alkaline, alkaline-earth, and ZnO
Uses boron.
Salt glazes</td></tr>
<tr><td rowspan="2">Fritted glazes</td><td>Contains Lead</td><td>Uses alumina
No alumina and boron.</td></tr>
<tr><td>Non-lead-containing</td><td>No boron.
Uses high BaO content.</td></tr>
</table>

A single glaze can be categorized as belonging to multiple categories at a similar time. This type of organization, which is commonly used, can be confused because two glazes of the same type can be extremely unlike in composition and possessions despite being categorized in the same group (Parmelee 2012).

According to Thomas (2020), for a long period, lead Oxide was a highly significant oxide in glaze processes. Lead Oxide is a network transformer and a useful flux up to around 1150°C. Lead-based glazes are distinguished by their low surface tension, thin thickness, wide burning range, and large catalog of refraction. However, due to the toxicity of lead, its use is now strictly regulated.

2.8 Conceptual framework

The selected available natural materials were used in the formulation of glazes. The following chart indicates the relationship among variables.

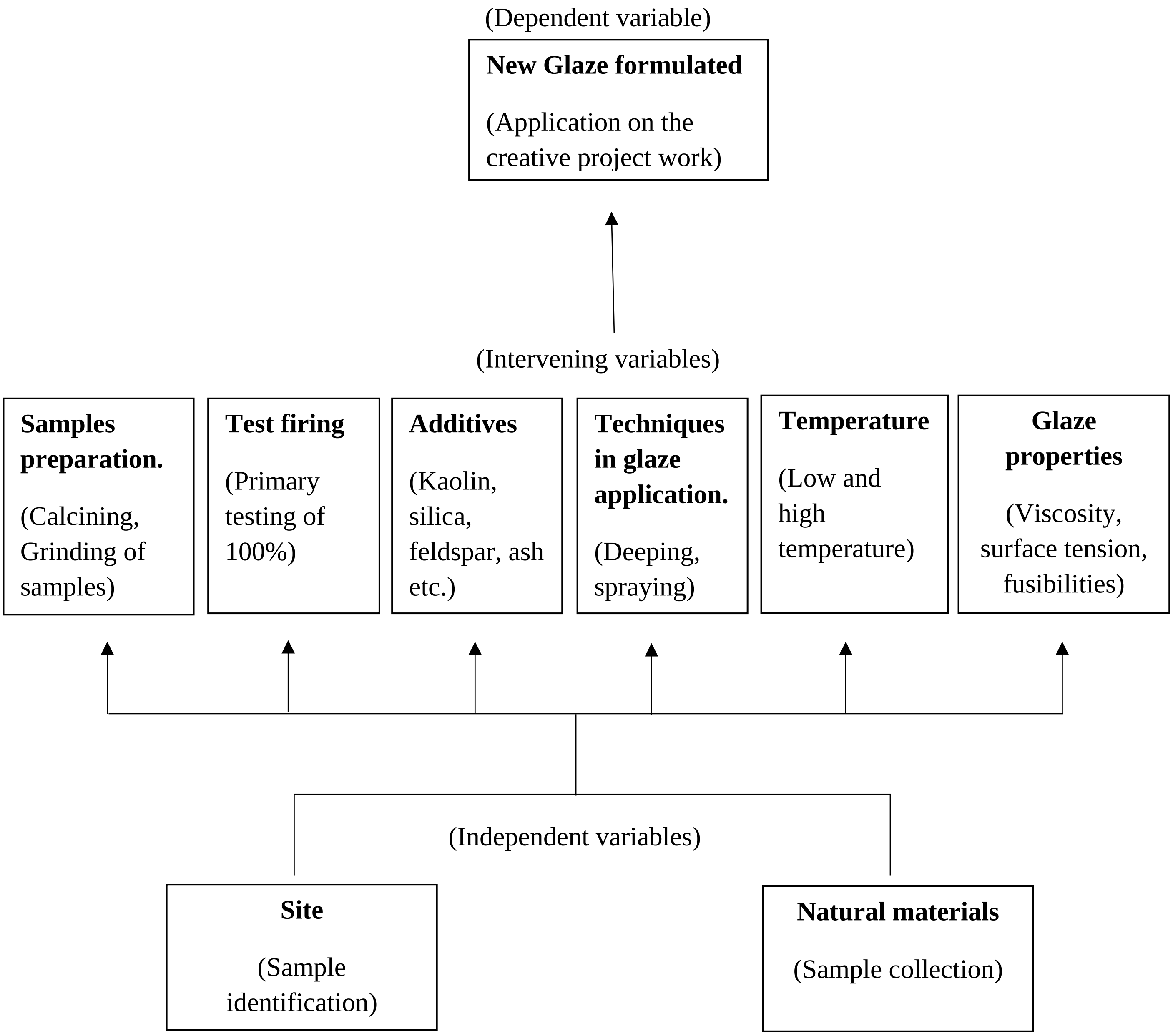


Figure 2.1: Conceptual Framework

The conceptual framework shows that while natural material was the independent variable, glaze formulation was the dependent variable. Underlying variables in glaze formulation included granulation (grinding of stones, ash washing), additives (kaolin, feldspar, silica, and other fluxes), temperature (high fire and low fire), techniques of glazing (Deeping or using brushes), tools, and equipment, and type of clay. Therefore, an adjustment in additives and recipes among other underlying variables provokes a change in glaze formulation. Glaze properties like fusibilities, viscosity, and surface tension are among the intervening variables. The location (Mukono and Jinja) were picked because it was easily accessible for the researcher and it was not costly to pick the geology to formulate glazes. However, there are numerous, unlike ways to categorize glazes, the easiest way to understand them is by firing temperature. As listed below, the useful range of temperatures for glaze melting is 900°-1300°C;

- Earthenware has a low-temperature range of 900°-1100°C.
- Stoneware has a high temperature of 1100°-1300°C.

However, most difficulties with glazes originate from simple things, like improper weighing, errors in classifying natural resources, or a glaze that hasn’t been sieved appropriately. In addition, one glaze mistake is expensive, as it can lead to the loss of a whole kiln load. For this cause, it is significant to have the correct person in charge of creating glazes- cleanliness, uniformity, meticulous record-keeping, and dependability are vital.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This chapter delineates the research design, presents the study area and size, the pilot study, sampling techniques, reliability, and dependability, data collection tools and techniques, primary information, secondary, facts investigation tools, and project application.

3.1 Research design

The study employed a quasi-experimental research design with the aim of establishing a cause-and-effect relationship between an independent and dependent variable (Mugenda, 2003). The researcher utilized the Solomon four-group design, a type of experimental research design falling under controlled group design. This approach serves the threefold purpose of evaluating the treatment's outcome, appraising the pre-test results, and examining the interaction between pre-test and treatment conditions within the study.

3.2 Study area.

The study was conducted in the districts of Jinja and Mukono in Uganda which serve as areas with the dominantly Meta sedimentary rocks. Naturally available materials which were picked from Uganda in the areas of Mukono and Jinja district (as indicated in the geological map in Appendix A) were carried to the ceramic studio located in Kenyatta University at the Department of Fine Art and Design. Several experiments and test samples were done in the ceramic studio.

3.3 Sampling techniques.

In research, sampling allows for greater overall accuracy and more time to obtain more comprehensive results (Saunders et al., 2007). The study collected a total number of 18 samples from Jinja and Mukono districts. Mukono district local Government (2021) says that there are three divisions in Mukono district namely; Katosi, Kasawo, and Nakifuma. Jinja is comprised of three divisions, Walukuba-Masese, Mpumudde-Kimaka, and Jinja Central. A selection of two or more samples per area were picked from the six divisions. The samples were coded according to the areas in which the local material was picked, and the geographical map as in Appendix B,

Table 3.1: A Table showing a list of study areas and the number of samples

JINJA			MUKONO		
No.	**Area**	**No. of samples**	**No.**	**Area**	**No. of samples**
1.	Jinja central	4	1.	Kasawo	3
2.	Mpumudde-Kimaka	3	2.	Katosi	2
3.	Walukuba-Masese	4	3.	Nakifuma	2
Total		11	**Total**		7
The total number of samples from Jinja and Mukono districts is 18					

3.4 Pilot study.

In a pilot study conducted in ceramic studios in September 2021, it was observed that ceramic producers in Mukono do not incorporate locally sourced glazes in their practice.

Vision for Africa Pottery in Mukono which is the main and one of the largest pottery ceramic studios, imports their glazes from Switzerland and Germany as reported in the questionnaire for the survey research work done. Mukono pottery primarily deals in aesthetic pieces and beadwork, mainly sold in the local market. The company imports glazes from Germany and occasionally from Vision for Africa Pottery. “The Potters House Workshop in Kalagi, located in Mukono, Uganda, specializes in creating aesthetic pieces and beads for both local and international markets. They also offer pottery lessons, source their glazes from outside Uganda, and primarily focus on other decoration technique.”

The pilot study aimed to assess the availability of local glazes and their utilization on ceramic products in the studios. Three out of the seven studios in Mukono town were found to not use local glazes due to lack of access to the necessary materials. There was a need for formulation of local glazes because according to the pilot study the three studios used glazes imported from Germany and Switzerland. These are expensive to acquire and some of the respondents say that some of the glazes do not fit the body of clay.

Table 3.2: Data collected on the use of glazes in production from three Ceramic studios in Mukono, Uganda.

No	Studio Names	Glazes used currently (Foreign Glazes)	Local glazes/ Formulations	Accessibility of local glazes	Products
1	Vision for Africa	Germany Switzerland	None	None	Crockery Beads Aesthetic pieces Table ware.
2	Mukono Pottery	Unrevealed sources, but used foreign glazes	None	None	Aesthetic pieces Beads Decorative pieces
3	Potters House Workshop	Germany	None	None	Aesthetic pieces Beads

3.5 Validity and reliability.

This study weighed the material ratios during the formulation of the recipe to ensure validity and reliability. However, during formulation, the rock material was never below 85% of the glaze recipe and the additives did not exceed 15% of the glaze recipe.

The testing involved maintaining consistent temperatures across all samples and using a uniform clay body for both high and low-temperature test pieces to ensure the reliability of the glaze recipes.

To ensure the utmost reliability of the study’s findings, we utilized a clay body sourced from Vision for Africa Ceramic Studio in Mukono to rigorously test the compatibility of the glaze findings with their clay bodies.

3.6 Data collection techniques.

The following data collection technologies and methodologies were employed in the study:

3.6.1 Collecting data on suitable available natural materials for glaze formulation.

To obtain data on available natural materials in the selection of the geological location in Uganda, photographs and maps were utilized to document the raw material`s location and physical qualities. A map for the geological location guide in Appendix A and Appendix B was employed to make a full assessment of the data.

3.6.2 Collecting data on test fire samples and selected additives on prospective samples.

(a) Experimentation.

An experimental data collection method was applied during the experimentation of glaze tests using available natural materials. After the calcination of stones, the natural materials were taken to the ball mill for crushing. The grinded samples were test-fired in the kiln without additives on clay test bars.

The second firing was experimented with 10% additives in the beginning and the test tiles were fired. Techniques in glaze application and temperature (low and high) used during the firing were part of the experimentation. Experiments continued until there were desired properties of glazes evidenced like fusibilities, viscosity, surface tension, volatilization, and reaction with the body as shown in Appendix C, and Table 4.4.

(b) Observation.

During the testing process, observation tables were utilized to systematically and directly observe the appearance of natural materials. This method aligns with Lillian's (2017) approach to observation. He argues that systematic direct observation of behavior, particularly visual, is the most preferable approach for measurement in many cases. The researcher identified the behavior of interest and formulated a systemic procedure to recognize, categorize, and record the behavior in its natural setting, employing observation following the initial test fire. The test bars were observed and different fluxes and additives were added to the glaze and fired; observations were made again to define the behavior changes in the glaze. Observation tables or structured identification tables for observing the appearance of geological materials throughout testing were also used and the test results were then recorded using a camera as shown in Appendix C, and Tables 4.2

3.6.3 Data collection on applying successful glazes to a creative project.

The researcher applied the successful glazes on the final creative project and observation tables were used in recording the outcomes of the successful glazes during the fire testing before application on the final pieces. Tables 4.4 provide a summary of each glaze's findings and the selected glaze samples for application in color.

3.7 Data analysis.

The study carried out the analysis as follows:

3.7.1 Analysis of identifying suitable available natural materials for glaze formulation.

The natural materials were surveyed and collected from the locations of Jinja and Mukono in Uganda and were transported to Kenyatta University, Kenya, Department of Fine Art, Ceramic Section studio where they were processed for the glaze formulation. This was analyzed using qualitative and quantitative chemical analysis.

3.7.2 Analysis of test-fire of the selected materials for glaze properties.

The identified natural materials were granulated to powder form and were test-fired at low and high temperatures. It included:

a) Categorization

The researcher first categorized the samples according to Regions as listed in the map in Appendix A, and B. The samples were further split into two major categories, low firing, and high firing, with temperatures of 1150^{o}C for low-temperature firing and 1250^{o}C for high-temperature firing tests respectively. 1150^{o}C, equivalent to Cone 05, is widely used by most glaze manufacturers as a low-temperature option. Meanwhile, 1200^{o}C is considered a mid-temperature glaze, which is widely accepted by ceramic artists for production. Further progressive testing was done by dividing it into three categories as listed below:

Category 1: A primary testing of 100% material mined from the ground.

Category 2: A progressive testing 1 of 10 % additives and 90% material excavated from the ground.

Category 3: A progressive testing 2 of 15 % additives and 85% material excavated from the ground.

The researcher continued recording observational data yielded after every fire test made as provided in Appendix C, and Table 4.4 which included the incorporation of intervening variables.

3.7.3 Data analysis on formulating glaze using selected additives on prospective samples and application of successful glazes on a creative project.

The researcher used additives like feldspar, silica, kaolin, soda ash, granulated glass, and wood ash to improve the performance of the glazes, and lowering down the fire temperatures of the glaze. The additives and sample tests were tested using a line test blend. The additives were analyzed by drawing tables as shown in Appendix F. The prospective glazes were applied to the project work. The observations were used to evaluate the appearance of the fired test results and the samples were rated based on their compatibility with the clay body and aesthetic appearance. This was done using a psychometric observation scale as outlined by Mugenda (2008), on a Likert scale of 1-5. The rating key is as follows: 1. Excellent (E), 2. Very Good (VG), 3. Good (G), 4. Average (A), and 5. Poor (P). This information is presented in Table 4.3.

Successful samples were applied to the creative project work as shown in objective four in data presentation and analysis.

3.8 Ethical consideration.

Permission was requested to access some of the data collection. A letter written to the postgraduate school Kenyatta University and the Ministry of Energy and Minerals in Uganda permitted the researcher to carry out the mining of the geology.

CHAPTER FOUR: PRESENTATION AND ANALYSIS OF DATA

4.0 Introduction

In this chapter focuses on statistics from the data presented and analyzed using graphs and pie charts. The data was presented and analyzed objective-wise.

4.1 Data presentation and analysis for objective one.

The researcher collected sample materials from Jinja and Mukono districts respectively in Uganda. Samples were collected in consideration of the geographical location, availability of the rock sample, accessibility of the rock sample, and chances of the rocks melting. 18 rock samples were identified and picked from Jinja and Mukono districts for glaze formulation as shown in Appendix A. 11 rock samples were collected from Jinja district and 7 rock samples were collected from the Mukono district as shown in the pie-chart below:

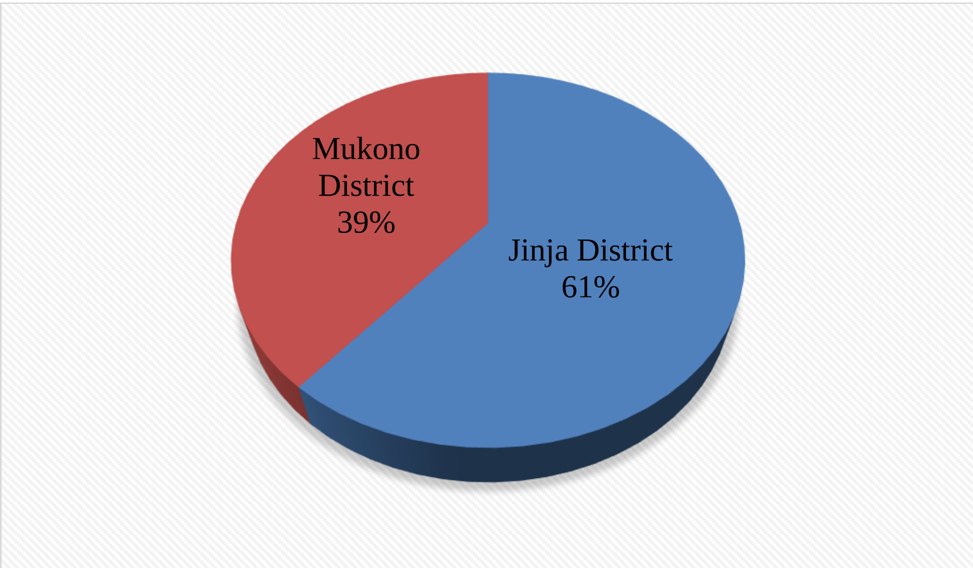


Figure 4.1: Rock samples from Mukono and Jinja Districts are represented in percentages.

The samples collected from Jinja and Mukono Districts were collected from three divisions respectively. Jinja District with three divisions; Walukuba-Masese division with 4 samples, Mpumudde-Kimaka with 3 samples, and Jinja Central with 4 samples, as shown in the pie chart below:

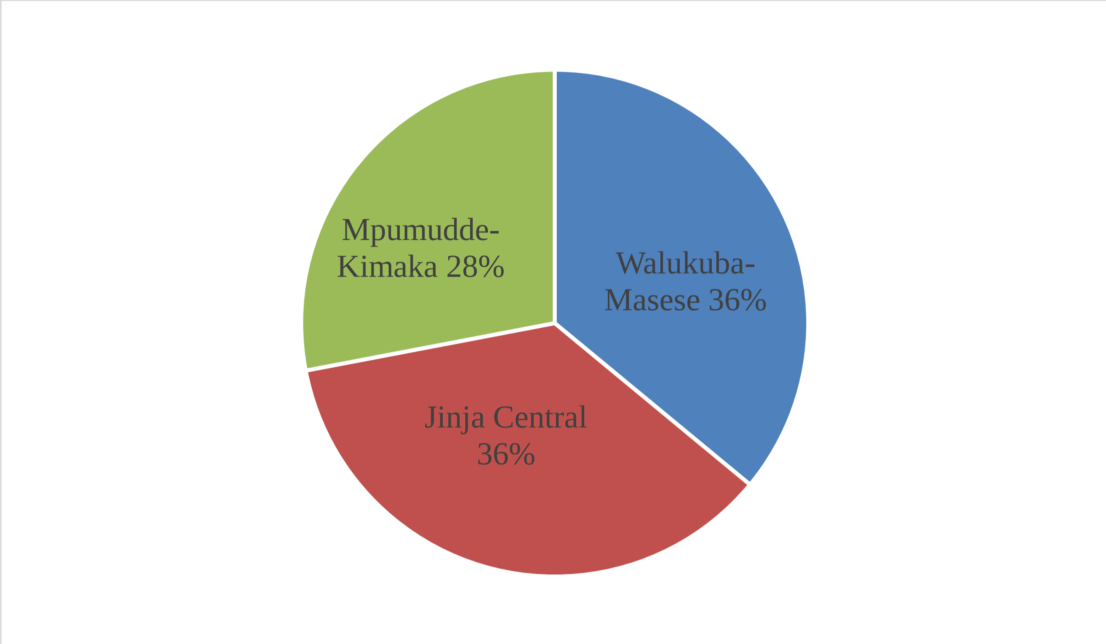


Figure 4.2: Percentage of rock samples collected in the three divisions of Jinja District.

Mukono District with three divisions; Katosi division with 2 samples at 29%, Kasawo division with 3 samples at 42%, and Nakifuma with 2 samples at 29%. As shown in the pie chart below:

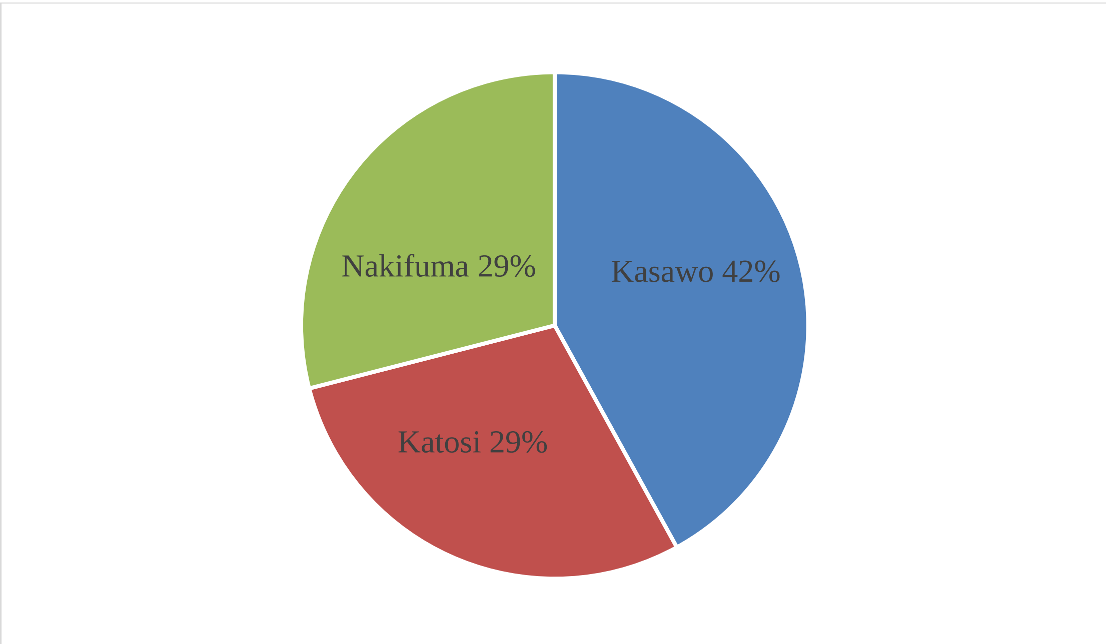


Figure 4.3: Percentage of rock samples collected in the three divisions of Mukono District.

4.2 Data presentation and analysis for objective two

The second objective was to test fire the selected materials for glaze properties after the rock samples were collected and taken to UIRI for the crushing and grinding processes to acquire the desired microstructure for test firing. The raw materials need to be crushed or disintegrated, followed by dry and wet grinding to achieve various degrees of fineness. As with some raw materials, dry preparation includes drying, crushing, grinding, and air separation. The wet preparation method is only utilized for high-quality specimens. The grinding process was done in different stages. The terms used in this context differ in their application and scope rather than their principles. Generally, "crushing" refers to reducing large lumps to a size convenient for further reduction, while "grinding" is a more general term, but in some cases, it refers to producing a fine powder. The mechanical reduction processes for crushing and grinding are as follows:

1) **The crunch of compression**. The material was crushed using jaw crushers or rotating drums called ball mills, which compel the material through a confined space.

The samples were crushed first in the jaw crusher to a reasonable size and grinded following some factors as shown below;

a) The hardness and toughness of the rocks.
b) Size of lumps to be fed in.
c) The moisture content of the material
d) The desired size of the product
e) Quantity of product required
f) Possible impurities and whether they should be rejected or crushed.

2) **Porcelain pot mill**. This is 6 to 12 inches (15-30 cm) in diameter and length which are rotated in motor or belt-driven frames. The porcelain pot mill was used in the secondary grinding for rapid very fine ground products of small quantities. This is represented in Appendix E

The crushed and ground samples were packed and transported to Nairobi in the Kenyatta University ceramic studio for fire testing and experimentation. The chemical analysis was done using the National Phytotherapeutics Research Centre laboratory to analyze the elements composed by the samples. The X-ray fluorescence (XRF) and

X-ray diffraction (XRD) analysis for some samples were analyzed using an X-ray fluorescence spectrometer and the results are shown in the table and the figure below.

Table 4.1: The laboratory tests: Atomic absorption spectrometer using X-ray fluorescence.

REF.	Si	Al	Ca	Mn	Zn	Cu	Ti	Cr	Fe	Pb	Cd
JC 3	1.74	1.486	NIL	5.9	8.637	8.046	4.512	5.415	6.405	ND	ND
MK 1	1.74	1.486	3.692	5.9	8.637	8.046	4.512	5.415	6.405	ND	ND
MK 2	1.74	1.486	3.692	NIL	8.637	8.046	4.512	5.415	6.405	ND	ND
WM1	1.74	1.486	3.692	5.9	8.637	8.046	4.512	5.415	6.405	ND	ND
MK 3	1.74	1.486	3.692	5.9	8.637	8.046	4.512	5.415	6.405	ND	ND
KAT1	1.74	1.486	3.692	5.9	8.637	8.046	4.512	NIL	6.405	ND	ND
KAS2	1.74	1.486	3.692	5.9	8.637	8.046	4.512	NIL	6.405	ND	ND
KAS1	1.74	1.486	3.692	5.9	NIL	8.046	4.512	5.415	6.405	ND	ND
KAT2	1.74	1.486	3.692	5.9	8.637	8.046	4.512	5.415	6.405	ND	ND

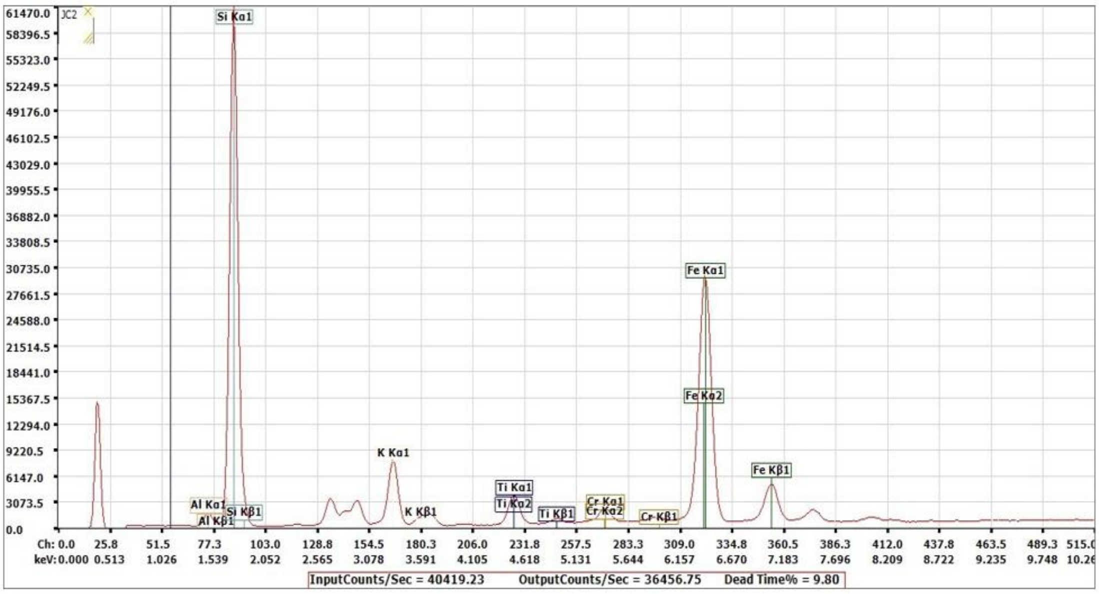


Figure 4.4: An X-ray fluorescence graphic analysis of the elements

The chemical analysis was conducted to determine the element composition of the samples. It helped in guiding the researcher during the addition of additives by understanding what additive to add in a recipe during glaze formulation. Silica had the highest percentage number of all the samples, which made the glazes to be high fire temperature glazes.

Another major reason was to find out if lead and cadmium were among the element compositions in the samples which were not part of the element composition. This made all the samples safe to be used on function pieces.

The analysis was followed by the primary test firing of a 100% ground rock sample at a high temperature of 1250^{o}C. The processed samples were brought to the studio for testing and selection. The fire testing was done in two categories namely; high temperature and low temperature. The testing started with a primary test firing of 100% rock powder of all the 18 selected sample materials. The rock samples that melted at a high temperature of 1250^{o}C after the first primary testing were selected for the low-temperature firing of 1150^{o}C as shown in the table provided below.

Table 4.2: Results of low (1150°C) and high-temperature firing (1250°C) of selected rock samples

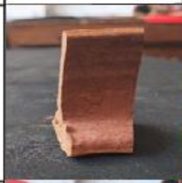
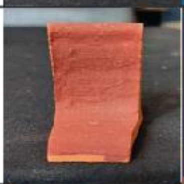
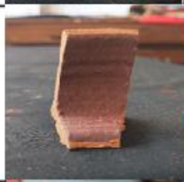
Code	Site	Low temp of 1150C	high temp of 1250C	Result Summary
JC 1	Jinja Central			The sample glaze was fused with the clay test bar in both. The glaze did not mature at the required temperature.
JC 2	Jinja Central			The glaze did not melt in both high and low- firing. The sample showed similar characteristics to the test bar in sample JC 1 above
JC 3	Jinja Central			The glaze melted on the clay test bar with bubbled cracks on top in the high firing but did not melt at low fire temperature.
JC 4	Jinja Central			The glaze fused with the clay test bar at low firing and peeled off the test bar at high firing. The glaze did not mature in both high and low firings.
MK 1	Mpumudde-Kimaka			The glaze matured at high temp of 1250C. The color of the glaze after firing was dark brown shiny and glossy. The glaze did not melt at low fire temperatures.
MK 2	Mpumudde-Kimaka			The glaze gaze a glossy/shiny appearance with coffee brown colors at high firing. The glaze did not at low firing but fused on the bar
WM 1	Walukuba Masese			The glaze exhibited glassy/ shiny effects in a dark brown color at high firing. The glaze did not melt at low firing but fused on the test bar.
WM 2	Walukuba Masese			The sample did not mature after firing. The glaze fused with the clay tile but did not melt at high and low temperatures.
WM 3	Walukuba Masese			The sample had the potential to melt when fired at high temp with a grey color. additives can be used to lower the maturity temp of the glaze.

Table 4.2: Results of low (1150°C) and high-temperature firing (1250°C) of selected rock samples

Code	Site	Low temp of 1150C	high temp of 1250C	Result Summary
MK 3	Mpumudde-Kimaka			A smooth, glossy which shows the maturity of gloss firing and glaze melting is exhibited in the sample. The glaze did not melt at low temperatures.
WM 4	Walukuba Masese			The glaze was fused with the clay test tile but it did not evidence of the melting behaviors of the glaze when fired at high and low temp.
KAS 1	Kasawo			The sample melted at high temp with a small bubble, pin-like appearance. The sample also exhibited crawling behaviors. The glaze did not melt at low.
KAS 2	Kasawo			The sample melted with small spotty effects pin-like on top of the glazed body in high firing and fused with the glaze and did not melt at low firing.
KAS 3	Kasawo			The glaze did not melt at both high and low temperatures, but the glaze was fused on the clay test bar. Although the color was white opaque.
KAT 1	Katosi			The matt-like smooth surface body appearance with coffee brown colors at high firing. The glaze did not at low firing but fused on the bar
KAT 2	Katosi			The glaze exhibited glassy/ shiny effects in a dark brown color at high firing. The glaze did not melt at low firing but fused on the test bar.
NAK 1	Nakifuma			The sample did not mature after firing. The glaze fused with the clay tile but did not melt at high and low temperatures.
NAK 2	Nakifuma			The sample had the potential to melt when fired at high temp with a white color. Additives can be used to lower the maturity temp of the glaze.

The melted glazes that were fired at high temperatures were fired again to lower the temperature melting point from 1250°C to 1200°C as shown in the Appendix

The melting properties of selected glaze tests were determined by observing the fired test result. The samples were rated based on the melting flow of the glaze on the test clay bar and aesthetic appearance. This was done using a psychometric observation scale as generated by Mugenda (2008), with a Likert scale of 1-5 as indicated below: Rating key: - 1. Excellent, 2. Very good, 3. Good, 4. Average, and 5. Poor

Table 4.3: Interpretation of the fired glaze ratings when observed (Lillian 2017).

Low temperature	High temperature	Rate
Showcases melting behavior when low-fired	Fuses well with the clay and melts uniformly	1. Excellent
Fusibility with the clay body	Melts with minor defects	2. Very Good
Bright colored tone on low temperature	Bright colored tone on high temperature/ crack effect	3. Good
Shows signs of rejecting the clay body	Fuses on the clay and does not melt	4. Average
Peels off the clay surface and does not mature	Peels off the clay body and does not mature	5. Poor

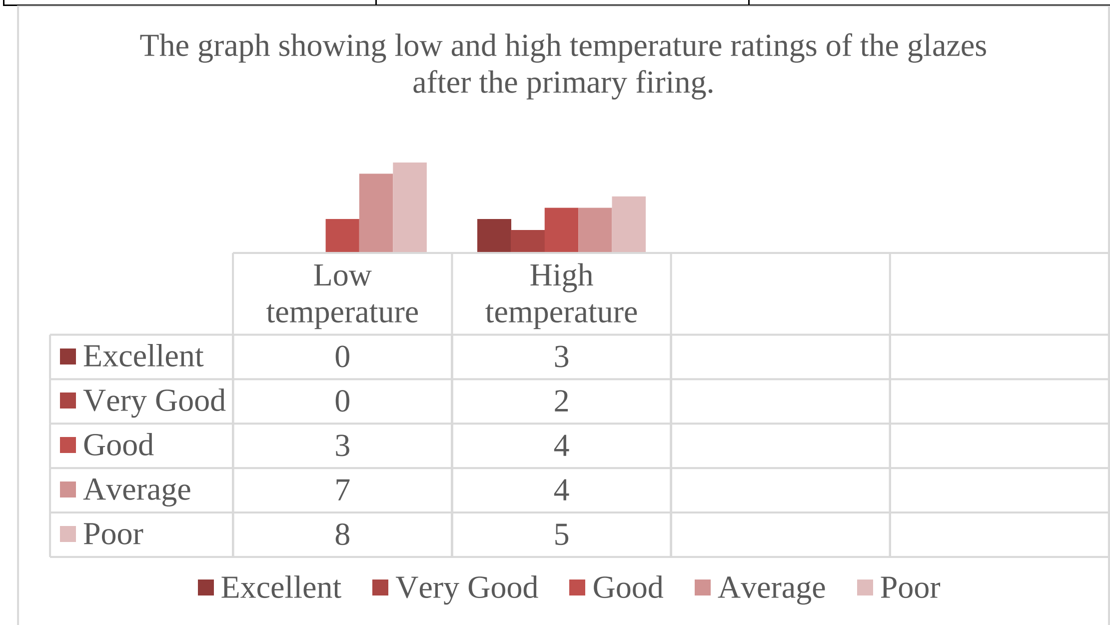


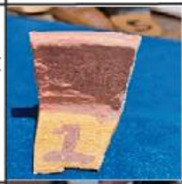
Figure 4.5: The graph showing low and high-temperature ratings of the glazes after the primary firing.

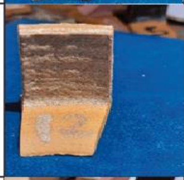
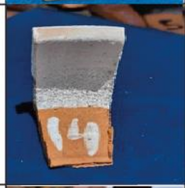
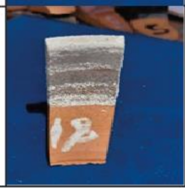
The analysis indicates that most of the samples did not do well during the low firing temperature, most of the glazes did not melt but some fused with the clay body without peeling off although most of the samples rated as average and poor. During the high-temperature firing, most of the glazes performed well and had the potential to improve when additives were added. 3 glazes melted excellently compared to none in the low temperature, 2 were in the very good category and 4 performed good. The glazes melted and fused well with the clay although a few glazes peeled off the clay test bar. In observation, the glazes melted well and the fusibility was better than the low-temperature glaze firing which shows that the glazes are high-fire glazes.

4.3 Data presentation and analysis for objective three.

Objective three entailed formulating glazes using selected additives on promising samples and out of 18 rock samples, 9 samples were promising in the high fire temperature because they had all the qualities and properties of the glaze and using the Likert scale to select the promising glazes as shown in the table below. Additives were also added to the other samples that did not melt in the first firing to bring down the melting temperature of the elements that composed the rock samples as shown in the tables below.

Table 4.4: The table below shows the identification and selection of successful glazes both for low-firing of 1150°C and high-firing of 1250°C.

No	Code	Site	Observation	Image(1150C)	Rate	Observation	Image(1250C)	Rate
1	JC 1	Jinja Central	Did not melt at low temp.		4	Did not melt at high temp		4
2	JC 2	Jinja Central	Did not melt		4	Did not melt		4
3	JC 3	Jinja Central	Did not melt low temp		4	Melted with defects		3
4	JC 4	Jinja Central	Did not melt		4	Peeled off the clay test bar		5
5	MK 1	Mpumu dde-Kim aka	Bright color but did not melt.		4	Melted with a coffee brown color		1
6	MK 2	Mpumud de-Kima ka	Did not melt		4	Melted at high temperatures		1
7	WM 1	Walukuba Masese	Did not melt		4	Melted with dark brown color		1
8	WM 2	Walukuba Masese	Did not melt		4	Did not melt		3
9	WM 3	Walukuba Masese	Did not melt		3	looks under fire		3
10	MK 3	Mpumud de-Kima ka	Did not melt		4	melted at high temperature		1

NO	Code	Site	observation	Image (1150°C)	Rate	observation	Image (1250°C)	Rate
11	WM 4	Walukuba Masese	Did not melt at low temp.		4	Did not melt at high temp.		3
12	KAS 1	Kasawo	Did not melt		3	Melted with out defect		2
13	KAS 2	Kasawo	Looks under fired		3	Melted with pins		2
14	KAS 3	Kasawo	Did not melt		5	Did not melt		5
15	KAT 1	Katosi	Bright color bu did not melt		4	Melted with a coffee brown color		2
16	KAT 2	Katosi	Did not melt		4	Melted at high temperatures		1
17	NAK 1	Nakifuma	Did not melt		5	Did not melt		5
18	NAK 2	Nakifuma	Did not melt		5	Did not melt		5

The glazes that were rated excellent, very good, and good in the high-temperature glaze fire according to the rating were selected for the addition of additives as shown in the table below;

Table 4.5: The table showing the successful glazes after the first firing which was fired at 1250°C

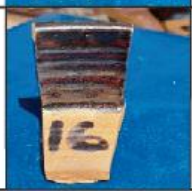
NO	CODE	SITE	IMAGE	OBSERVATION
1	JC 3	Jinja Central		Melted with defects
2	MK 1	Mpumudde-Kimaka		Melted with a coffee brown color
3	MK 2	Mpumudde-Kimaka		Melted at high temperature
4	WM 1	Walukuba Masese		Melted with dark brown color
5	MK 3	Mpumudde-Kimaka		Melted at high temperature
6	KAS 1	Kasawo		Melted with defects
7	KAS 2	Kasawo		Melted with small pins
8	KAT 1	Katosi		Melted with small pins
9	KAT 2	Katosi		Melted well at high temperatures

Table 4.6: Lowering the fire temperature from 1250°C to 1200°C by adding addition of various substances

Test number	Composition	Appearance	Appearance	Composition	Observation
JC 3	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	The glaze ran off the test bar.
MK 1	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	A good high temp glossy glaze that can be used on ceramic items
MK 2	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	A great matt finish that can work on aesthetic pieces.
WM 1	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	A great matt finish that can work on aesthetic pieces.
MK 3	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	A great matt finish that can work on aesthetic pieces.
KAT 1	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	The glaze melted with pins
KAS 2	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	Looks over fired, melted with pins
KAS 1	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	The glaze ran off the test bar.
KAT 2	Sample: 90% Soda Ash: 10%			Sample: 90% Feldspar: 10%	A great matt finish that can work on aesthetic pieces.

Table 4.7: Lowering the fire temperature for the glazes that melted at high temperatures from 1250°C to 1200°C by adding additives.

Test number	Composition	Appearance	Appearance	Composition	Observation
JC 3	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	Can be used on aesthetic pieces, however it has a defect.
MK1	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	Glossy glaze that can be used on both functional and aesthetic piece
MK 2	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	A great matt finish that can work on aesthetic pieces
WM 1	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	A great matt finish that can work on aesthetic pieces
MK 3	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	A great matt finish that can work on aesthetic pieces
KAT 1	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	The glaze melted with pins and crawling.
KAS 2	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	The glaze melted with pins and crawling.
KAS 1	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	A great matt finish that can work on aesthetic pieces
KAT 2	Sample: 90% wood ash: 10%			sample: 90% Granulated glass: 10%	A great matt finish that can work on aesthetic pieces

Table 4.8: Lowering the fire temperature for the glazes that melted at high temperatures from 1250°C to 1200°C by adding additives.

Test number	Composition	Appearance	Appearance	Composition	Observation
JC 3	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	Can be used on aesthetic pieces, however it has a defect.
MK1	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	Glossy glaze that can be used on both functional and aesthetic piece
MK 2	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	A great matt finish that can work on aesthetic pieces
WM 1	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	A great matt finish that can work on aesthetic pieces
MK 3	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	A great matt finish that can work on aesthetic pieces
KAT 1	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	The glaze melted with pins and crawling.
KAS 2	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	The glaze melted with pins and crawling.
KAS 1	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	A great matt finish that can work on aesthetic pieces
KAT 2	Sample: 85% Kaolin: 10% Soda ash: 5%			sample: 85% feldspar: 10% Soda Ash: 5%	A great matt finish that can work on aesthetic pieces

Table 4.9: Lowering the fire temperature for the glazes that melted at high temperatures from 1250°C to 1200°C by adding additives.

Test number	Composition	Appearance	Appearance	Composition	Observation
JC 3	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	Can be used on aesthetic pieces, however it has a defect.
MK1	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	Glossy glaze that can be used on both functional and aesthetic piece
MK 2	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	A great matt finish that can work on aesthetic pieces
WM 1	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	A great matt finish that can work on aesthetic pieces
MK 3	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	A great matt finish that can work on aesthetic pieces
KAT 1	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	The glaze melted with pins and crawling.
KAS 2	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	The glaze melted with pins and crawling.
KAS 1	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	A great matt finish that can work on aesthetic pieces
KAT 2	Sample: 85% Kaolin: 10% Granulated glass: 5%			sample: 85% feldspar: 10% Granulated glass: 5%	A great matt finish that can work on aesthetic pieces

4.3.1 Data collection of formulations from progressive glaze on selected geological samples

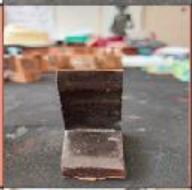
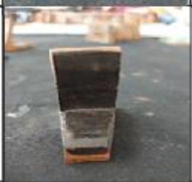
i) **JC 3: Jinja Central.**

Table 4.10: **Formulation of JC 3: Compositions, appearance, and observation fired at 1200°C.**

Test Code	Composition	Appearance	Observation
JC 3 3C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze run off the test bar when soda ash was added into the composition
JC 3 3D Temp 1200C	Sample: 90% Feldspar: 10%		Looks under fired
JC 3 3E Temp 1200C	Sample: 90% Wood Ash: 10%		Looks under fired
JC 3 3F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze melted with pins and can be used on decorative pieces
JC 3 3I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		Looks under fired
JC 3 3J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
JC 3 3K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		Looks under fired
JC 3 3L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		The glaze melted with pins and can be used on decorative pieces

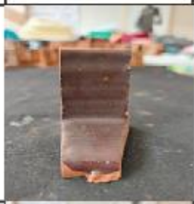
ii) MK 1: Mpumudde Kimaka

Table 4.11: Formulation of MK 1: Compositions, appearance, and observation fired at 1200^{o}C

Test Code	Composition	Appearance	Observation
MK 1 5C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
MK 1 5D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 1 5E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
MK 1 5F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
MK 1 5I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 1 5J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
MK 1 5K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 1 5L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces

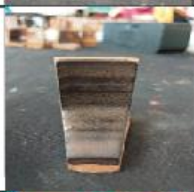
iii) WM 1: Walukuba Masese

Table 4.12: Formulation of WM1: Compositions, appearance, and observation fired at 1200°C

Test Code	Composition	Appearance	Observation
WM 1 7C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
WM 1 7D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
WM 1 7E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
WM 1 7F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
WM 1 7I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
WM 1 7J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
WM 1 7K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
WM 1 7L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces

iv) KAT 2: Katosi.

Table 4.13: Formulation of WM1: Compositions, appearance, and observation fired at 1200°C

Test Code	Composition	Appearance	Observation
KAT 2 16C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
KAT 2 16D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
KAT 2 16E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
KAT 2 16F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
KAT 2 16I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
KAT 2 16J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
KAT 2 16K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
KAT 2 16L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces

v) MK: Mpumudde Kimaka

Table 4.14: Formulation of WM1: Compositions, appearance, and observation fired at $1200^{o}C$

Test Code	Composition	Appearance	Observation
MK 2 6C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
MK 2 6D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 2 6E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
MK 2 6F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
MK 2 6I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 2 6J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
MK 2 6K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 2 6L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces

vi) MK 3: Mpumudde Kimaka

Table 4.15: Formulation of WM1: Compositions, appearance, and observation fired at 1200°C

Test Code	Composition	Appearance	Observation
MK 3 10C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
MK 3 10D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 3 10E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
MK 3 10F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
MK 3 10I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 3 10J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
MK 3 10K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
MK 3 10L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces

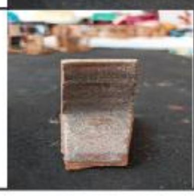
vii) KAS 2: Kasawo.

Table 4.16: Formulation of WM1: Compositions, appearance, and observation fired at 1200°C

Test Code	Composition	Appearance	Observation
KAS 2 13C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
KAS 2 13D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glaze that can be used on both functional and aesthetic pieces
KAS 2 13E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
KAS 2 13F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
KAS 2 13I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glaze that can be used on both functional and aesthetic pieces
KAS 2 13J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
KAS 2 13K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		Crawling glaze that can be used on ceramic pieces
KAS 2 13L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		Crawling glaze that can be used on ceramic pieces

viii) **KAS 1: Kasawo.**

Table 4.17: Formulation of WM1: Compositions, appearance, and observation fired at 1200^oC

Test Code	Composition	Appearance	Observation
KAS 1 15C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
KAS 1 15D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glaze that can be used on both functional and aesthetic pieces
KAS 1 15E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
KAS 1 15F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
KAS 1 15I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glaze that can be used on both functional and aesthetic pieces
KAS 1 15J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A great matt finish that can work on aesthetic pieces.
KAS 1 15K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		A great matt finish that can work on aesthetic pieces.
KAS 1 15L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		A great matt finish that can work on aesthetic pieces.

ix) KAT 1: Katosi.

Table 4.18: Formulation of WM1: Compositions, appearance, and observation fired at $1200^{o}C$

Test Code	Composition	Appearance	Observation
KAT 1 12C Temp 1200C	Sample: 90% Soda Ash: 10%		The glaze can be used on aesthetic pieces.
KAT 1 12D Temp 1200C	Sample: 90% Feldspar: 10%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
KAT 1 12E Temp 1200C	Sample: 90% Wood Ash: 10%		The glaze can be used on aesthetic pieces
KAT 1 12F Temp 1200C	Sample: 90% Granulated glass: 10%		The glaze can be used on aesthetic pieces
KAT 1 12I1 Temp 1200C	Sample: 85% Kaolin: 10% Soda Ash: 5%		A good temp glossy glaze that can be used on both functional and aesthetic pieces
KAT 1 12J Temp 1200C	Sample: 85% Feldspar: 10% Soda ash: 5%		A good high temperature for the glaze and it can be used on functional pieces
KAT 1 12K Temp 1200C	Sample: 85% Kaolin: 10% Granulated glass: 5%		Crawling glaze that can be used on ceramic pieces
KAT 1 12L Temp 1200C	Sample: 85% Feldspar: 10% Granulated glass: 5%		Crawling glaze that can be used on ceramic pieces

The chemical analysis played a big role in the selection of the additives to be added to the glazes respectively. In this case, a rock sample with lots of silica does not need you to add silica again in the composition because silica is a high-fire element, so the researcher needs to think about additives that can lower the melting point for example feldspar or table salt. The additives were added in two categories;

Category 1: A progressive testing of 10% additive and 90% rock powder was done to lower the temperature of the glaze or improve on the qualities of the melting behaviors of the glazes and which additive played its role respectively. The melting temperature of the glazes was brought down from 1250^{o}C to the mid-temperature of 1200^{o}C as shown in the Appendix C and Tables 4.6 to 4.18.

Category 2: A progressive testing of combining two additives each 15% and 85% of the stone powder. This was done on the promising selected samples for further testing and improvement on the qualities of the glazes as shown in the table above. The progressive testing helped in the finding of the successful glazes that were used in the creative project work and the highlighted glazes shown in Tables 4:11-16 above were selected to be used on the final work.

Table 4.19: Shows additives used in the glaze formulation and how they are categorized for this study.

Additives	**Category**
Silica	Glass former
Kaolin	Stabilizer
Soda Ash	Flux
Feldspar	Flux / Glass former
Granulated glass	Flux
Table salt	Flux
clay	Stabilizer
Wood ash	Flux
Iron Oxide	Colorant

The additives were mostly found locally like granulated glass, table salt, clay, and wood ash. Silica, kaolin, soda ash, feldspar, and copper oxide were sourced from the stores within the Chemistry Department of Kenyatta University.

4.4 Data presentation and analysis for objective four

Objective four which is applying successful glazes on a ceramic creative project was encompassed as follows:

a) Reference

A theme and inspiration about aquatic sea life were adopted to be used in the development of preliminary sketches, developed sketches, and final work where a series of images were collected from internet sources and the library. The images were printed out in color, cut, and glued on white paper for inspiration. The purpose of this was to make proper reference for an accurate depiction of the aquatic nature

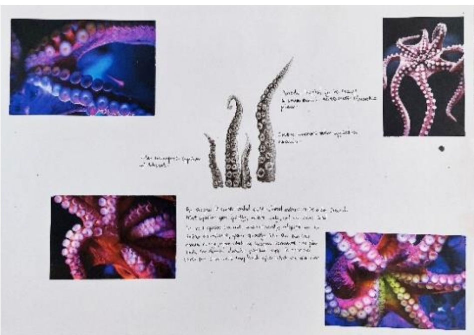
b) Preliminary sketches

The sourced images were used to formulate and gather up ideas where simple sketches were done on cartridge paper using graphite pencil and ball pen to study the shapes and texture of aquatic organisms and coral reefs.

c) Developed sketches

Advanced sketches improved the form and shape which showed more details of the aquatic nature in preparation for the final molding and construction work. A study of the octopus' tentacles in sketch development and creation of a creative project work. As shown in the sample below.

The preliminary sketch. Final sketch.



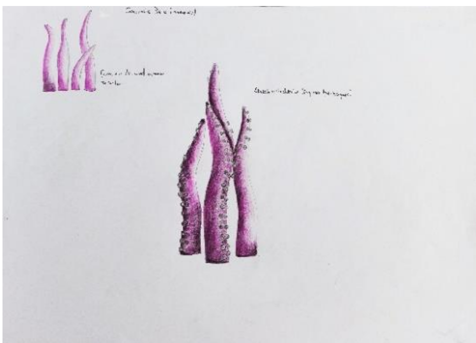


Plate 4.1: Sketches of the preliminary and final sketch.

d) Final creative project work

Construction of the forms depicting the form, texture, and shape of aquatic nature where clay was used to make the form and shapes of the artworks. Techniques like throwing, slab work, and coiling were used in the construction process. Molding of the form was first achieved and the piece was given one or two days to gain leather hard for decoration and cleaning process. The pieces were exposed to bone dry and bisque firing. The glazes were applied to the bisque-fired pieces for the second firing, as shown in the Appendix H.

CHAPTER FIVE: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter contains a summary, conclusions, and recommendations of the study.

5.1 Summary

The study used natural clays and rock materials for glaze formulation from Mukono and Jinja districts, Uganda. This was obtained by identifying suitable available natural material within Mukono and Jinja districts in Uganda where 7 samples were picked from Mukono and 11 samples from Jinja district, test firing the selected materials for glaze properties started with the primary testing of 1250^{o}C, formulated glaze using selected additives on promising samples, which involved a lot of temperature fire changes from the high temperature of 1250^{o}C and low temperature of 1150^{o}C, and finally the applied successful glazes on a ceramic creative project.

5.1.1 Discussion on identified suitable available natural material for glaze formulation in Uganda

The researcher identified suitable selected available natural materials for glaze formulation. The researcher sourced the natural materials from Jinja and Mukono districts in Uganda. 18 rock samples were collected in total from both Mukono and Jinja, 7 samples from Mukono, and 11 samples from Jinja. The samples were collected within the three subdivisions of both Mukono and Jinja, namely; Walukuba Masese, Mpumudde Kimaka, and Jinja central in Jinja district and Katosi, Nakifuma, and Kasawo in Mukono district were at least two or more samples were picked. Most rocks were Meta sedimentary, gneisses, and granulite rock types. The rocks were transported to the Uganda Industrial Research Institute for the grinding of the samples. The samples were packed and labeled to be transported to Kenyatta University ceramic studio. The chemical analysis was done first in the National Phytotherapeutics Research Centre laboratory at Kenyatta University, as shown in table 4.1.

5.1.2 Discussion on fire-tested selected materials for glaze properties.

The identified and selected materials were fire-tested first primarily, 100% of stone powder without additives. The primary testing was high-fired at temperatures of 1250^{o}C were 9 samples out of 18 samples. The samples were also tested primarily in the low fire temperature of 1150°C but all 18 samples did not melt after the low fire testing. The glaze samples proved to be high-fire temperature glazes because of the silica element which is a high-temperature firing element and had high percentages in most of the samples' composition after the chemical analysis.

The fire tests were done on the clay tests which were bisque fired at a temperature of 900°C. The sample powder was mixed with water and it was applied onto the test bar using the brush. The applications of the glaze samples were done both horizontally and vertically to see the flow of the glaze after the firing, as shown in Appendix C and tables 4.3.

5.1.3 Discussion on formulated glazes using additives promising samples.

After the primary testing, the successful or melted samples were selected for the addition of additives. The progressive testing 1 started with the addition of one additive at 10% and 90% material. The progressive testing 2 was done by the addition of two at 15% and 85% material excavated from the ground. The additives used in promising samples were; kaolin which is a stabilizer, soda ash which is a flux, feldspar which is a flux, granulated glass which is a flux, clay which is a stabilizer, and wood ash which is a flux. In this case, the stabilizer was for the stability of the glaze during the firing process. The fluxes were used to lower temperature by interacting with other oxides. The first and second progressive tests were both fired at 1200°C and most of the glaze colors were reached in brown.

5.1.4 Discussion on the application of successful glazes on ceramic creative project work.

The study sought to apply successful glazes to a ceramic creative project. The theme and inspiration were developed by form sketching and studies of aquatic sea nature. The forms and shapes of the creative project work were constructed using ceramic techniques like throwing, slab work, and coiling. The pieces were born dry and bisque-fired first and the selected glazes were applied on the bisque-fired pieces and fired at temperatures of 1200°C. Appendix H shows the final creative project work

5.2 Conclusions

This study was interested in showing the processes of glaze formulation using selected available natural materials that were used in the application of ceramic creative project work. The study set out to:

Identify suitable available natural materials for glaze formulation from Mukono and Jinja districts in Uganda. A collective total of 18 rock samples were identified.

Test firing on the 18 rock samples for glaze formulation properties and select the promising ones, 9 samples were promising after both the moderate and high-temperature firing was done.

Formulate glaze using selected additives on promising samples. Using the line blend method of addition of additives, the 9 prospective samples produced 72 tests which looked good for application and were fired at a high temperature of 1200^{o}C. The glazes gave a variety of ranges of brown color. However, a few glazes that are selected in color orange in the tables shown in chapter four were selected for application.

Application of successful glazes to a creative project was achieved by using ceramic techniques like slab work, coiling, and throwing to construct functional and decorative ceramic ware inspired by aquatic sea nature.

These steps and processes went through enabled the research to develop glazes and glaze recipes using available natural materials from the sub-divisions of Jinja and Mukono districts where at least a glaze sample that had glaze melting properties was picked for application.

5.3 Recommendations

The following are the recommendations of the study:

5.3.1 Recommendations for ceramists

This study developed glaze formulas during the formulation of glazes that can be used by ceramists in Uganda and other countries to formulate natural glazes, however, ceramists can have more freedom to explore and expand the glaze recipes using natural materials that are within their reach.

This study developed glazes that can be fired at high temperatures of 1200^{o}C. However, ceramists can do further experimentation on the lowering of the temperature of the glazes by the use of more fluxes that this study did not explore.

5.3.2 Recommendations for ceramic manufacturers

Since the study has revealed that selected natural materials can be used to formulate glazes, ceramic manufacturers can also process and package the rock materials for ceramic artists locally in Uganda so that they can be used in the large-scale production of ceramic ware.

5.4 Areas of Further Research

The following are areas of further research recommended:

This study focused on the use of selected available natural materials to formulate glaze within the districts of Mukono and Jinja in Uganda. More research can be done in other parts of the country like the western, northern, and southern parts of Uganda. This also applies to the materials within Mukono and Jinja that this research did not cover due to costs and research scope.

Most of the glazes gave varieties of brown. More research can be done to explore oxides which are colorants that could change the nature of the colors of the glazes.

Further research can be done to explore the different types of firings in different environments like wood kilns, and gas kilns because this research explored only one firing environment which was using the electric kiln.

The study used line blending during the formulation of recipes, but further research can be done on types of blends like tri-axial blends can be carried out.

Texture effect is another area that can be investigated by improving formulas and introducing other elements or glaze samples that did not melt could be explored to develop different surface texture effects.

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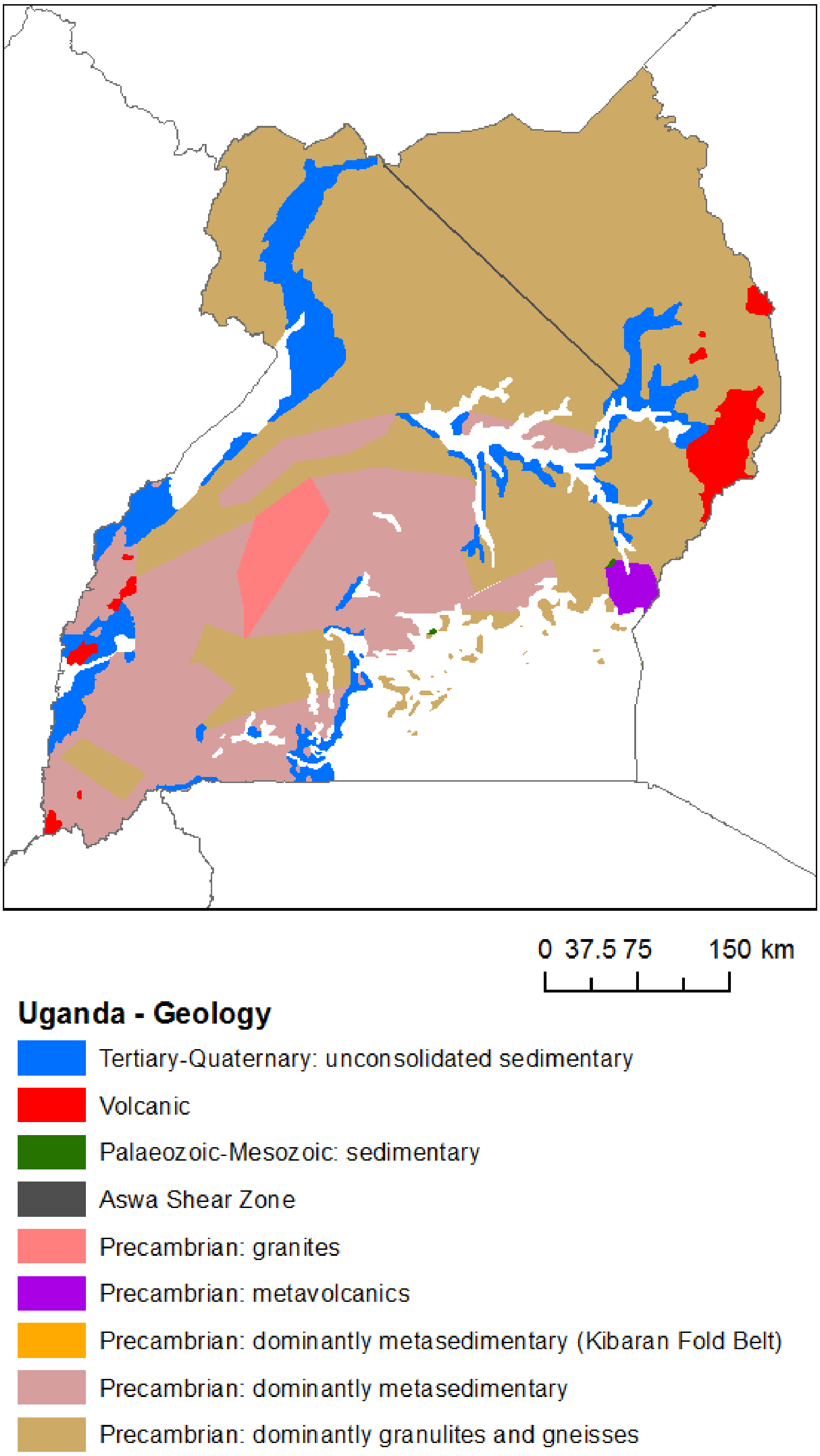
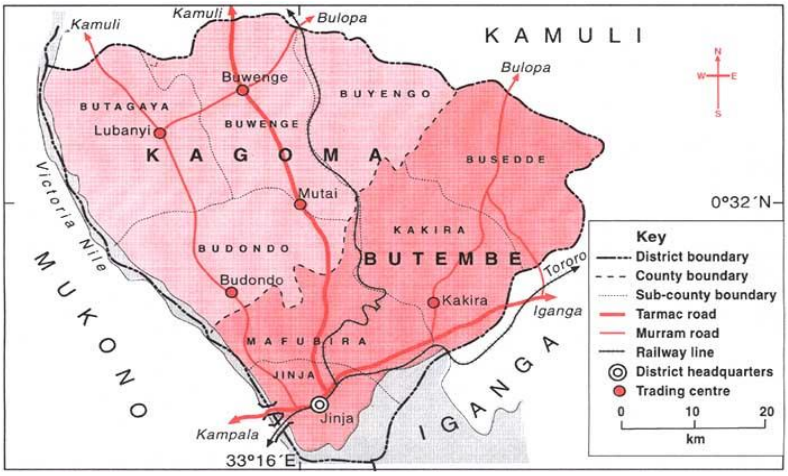
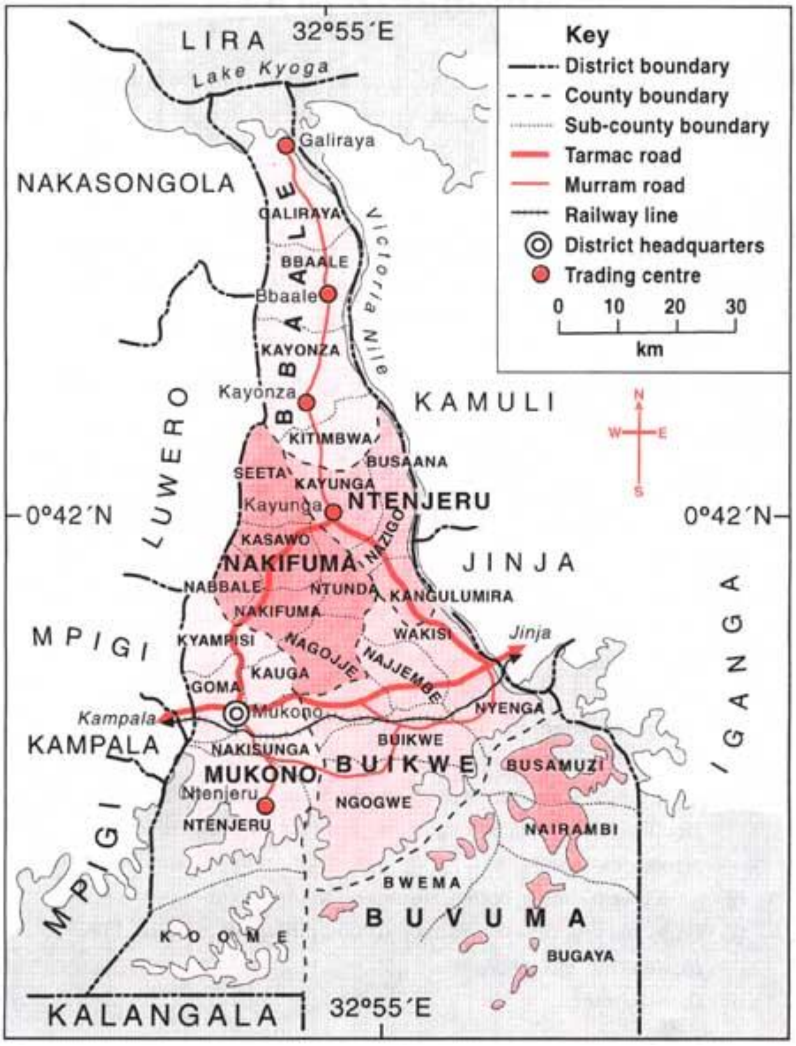
APPENDICES

Appendix A: A map showing the geology of Uganda



The detailed maps showing areas of both Mukono and Jinja district.

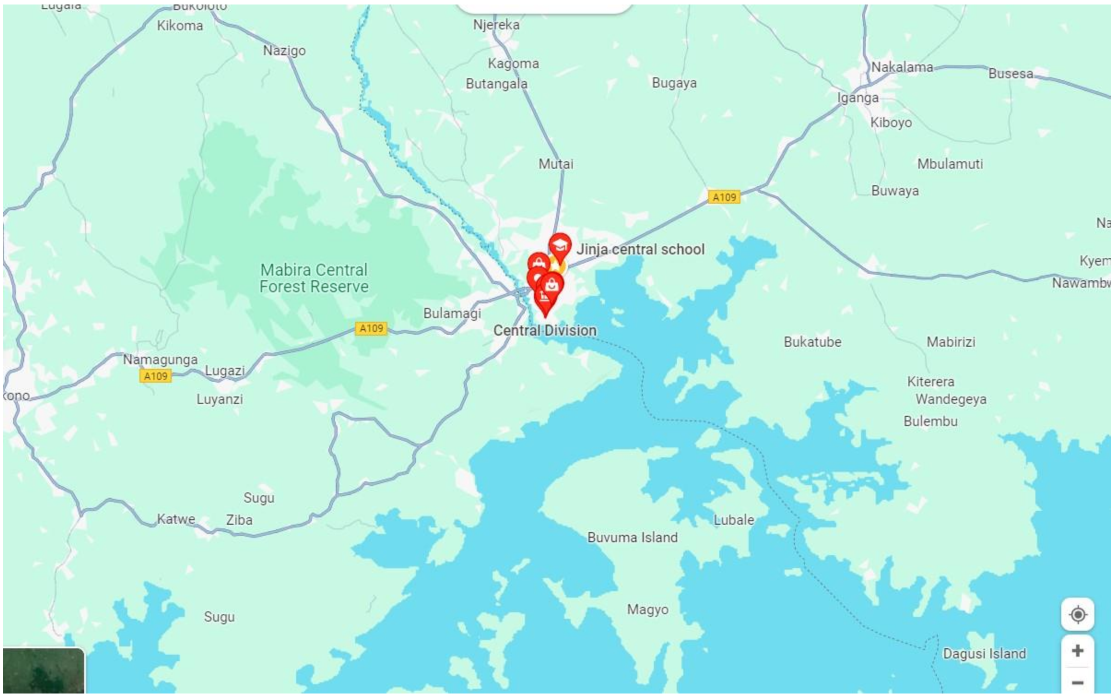




Appendix B: Data collected when identifying rock samples

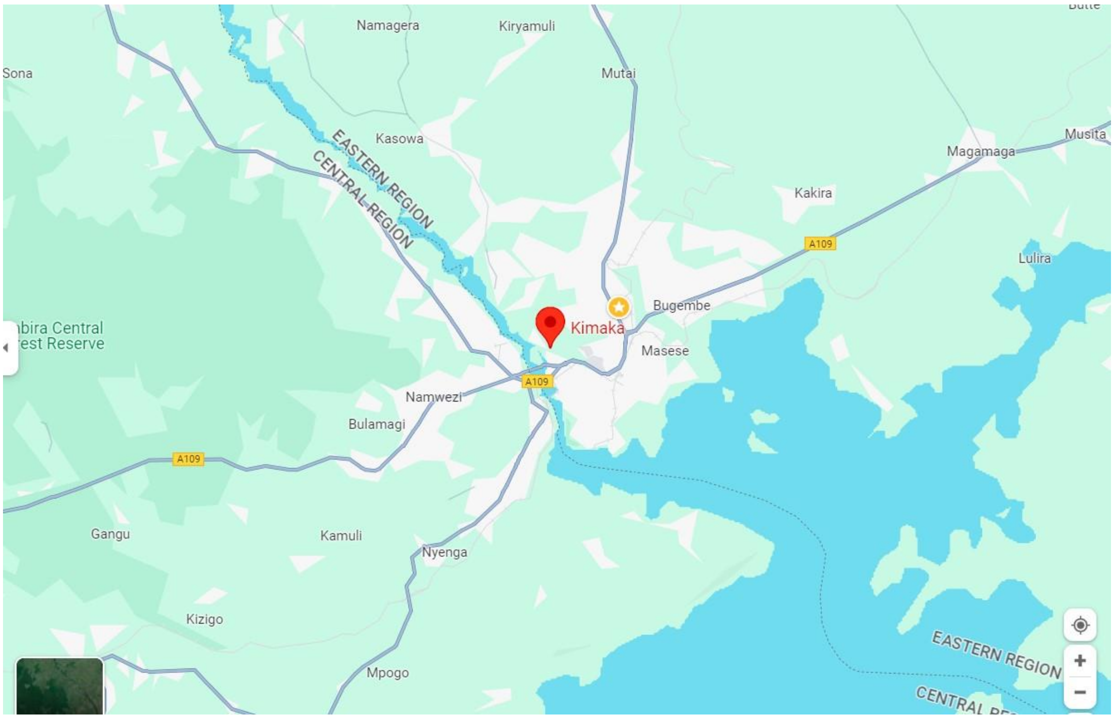
The data shown below was collected from Jinja and Mukono districts in Uganda.

i. Data obtained from Jinja district, Jinja central area.



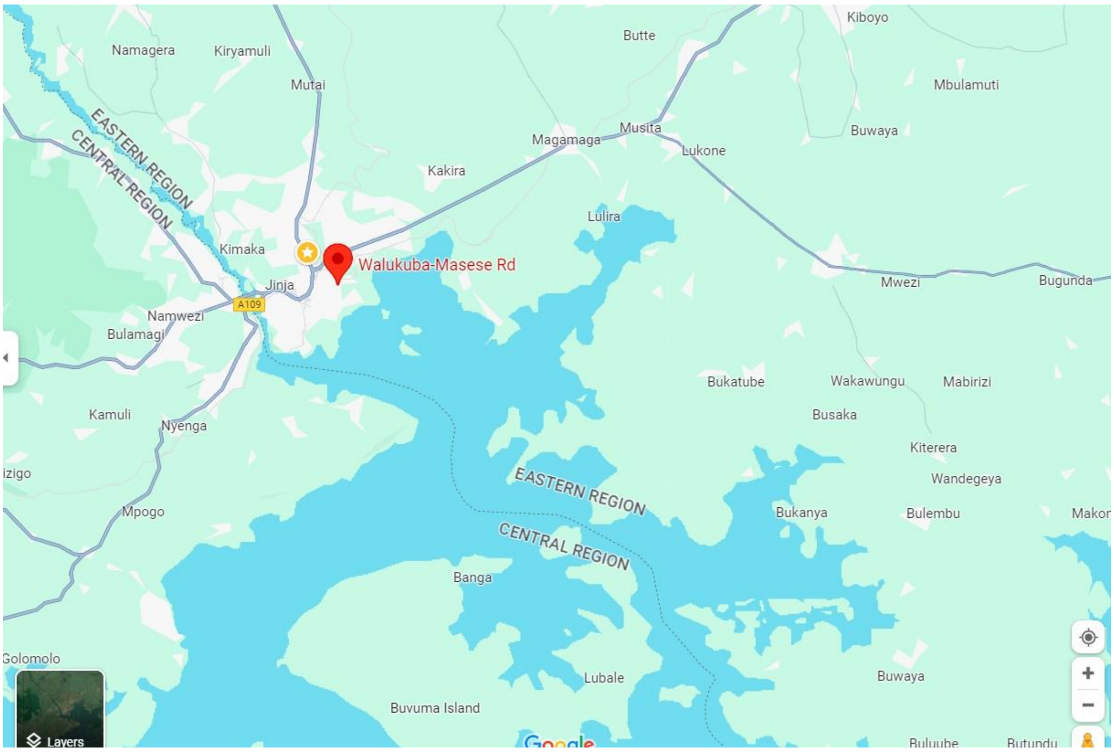
Location	Test No	Use	Color	properties	Image
Jinja central	JC 1	Construction	brown	Hard rock	
Jinja central	JC 2	Construction	brown	Hard rock	
Jinja central	JC 3	Construction	Grey	Hard rock	
Jinja central	JC 4	Construction	White	Hard rock	

ii. Data collected from the Mpumudde-Kimaka area, Jinja district.



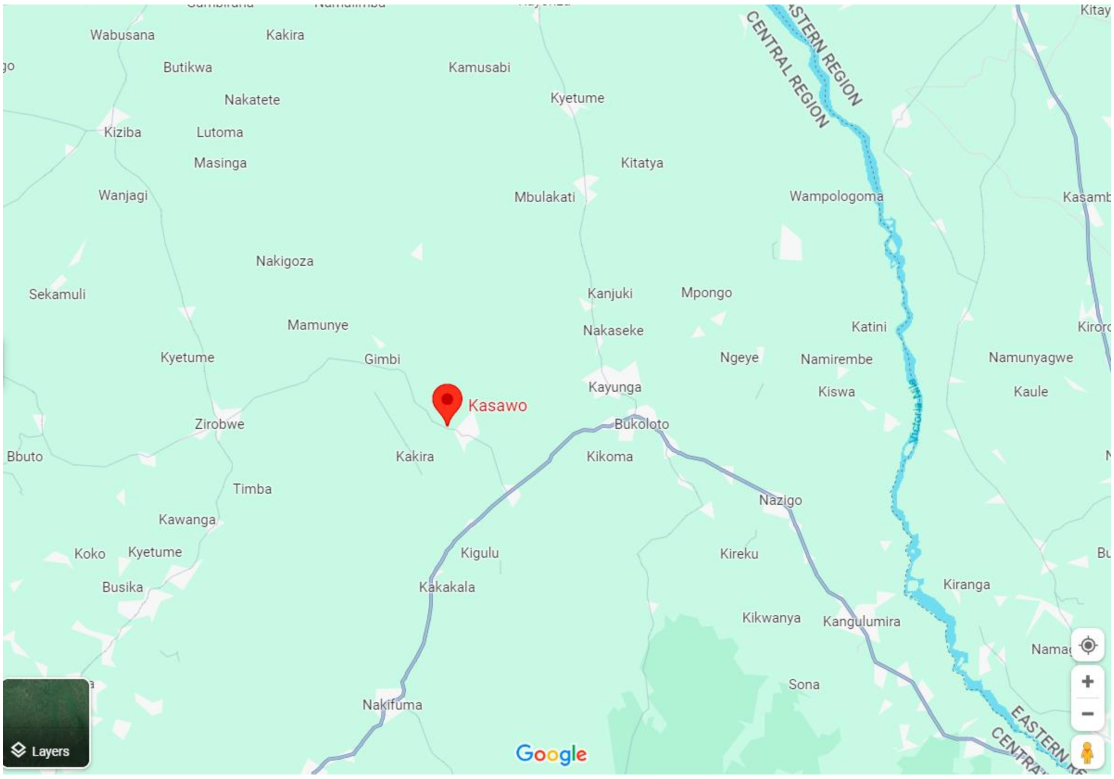
Location	Test No	Use	Color	Properties	Image
Mpumudde-Kimaka	MK1	Construction	Grey	Hard	
Mpumudde-Kimaka	MK2	Construction	Grey	Hard	
Mpumudde-Kimaka	MK3	Construction	Grey	Hard	

iii. Data obtained from the Walukuba-Masese area, Jinja district.



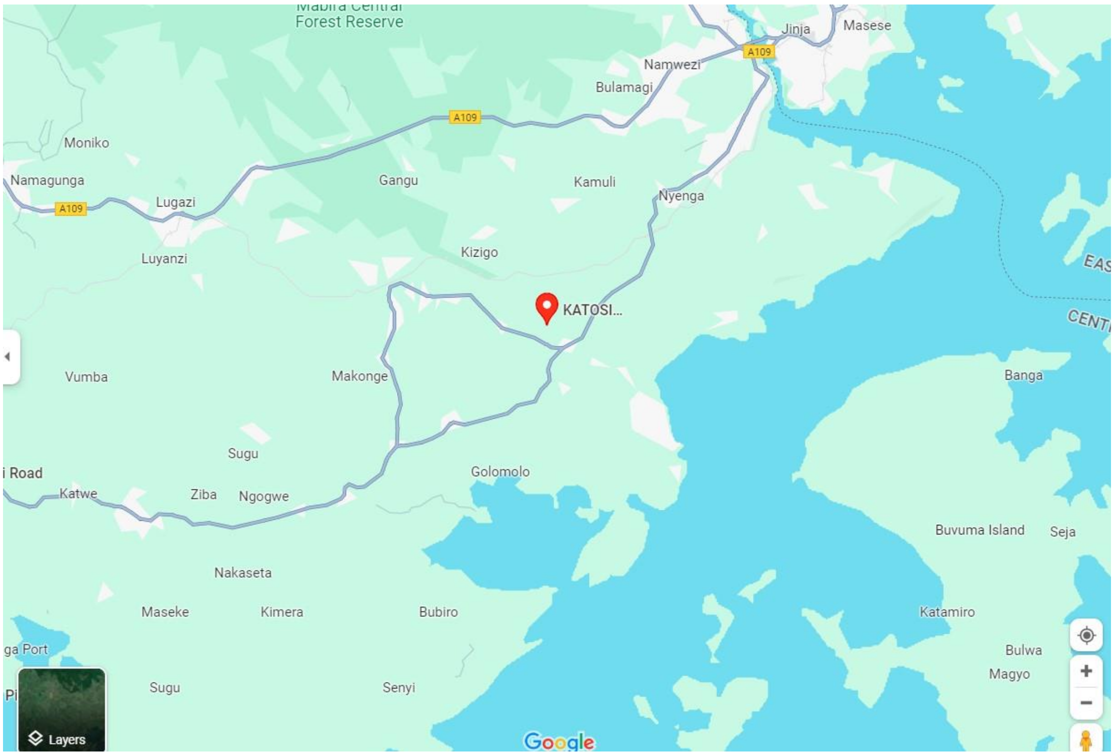
Location	Test No	Use	Color	Properties	Image
Walukuba-Masese	WM 1	Construction	Grey	Relatively hard	
Walukuba-Masese	WM 2	Construction	Red	Relatively hard	
Walukuba-Masese	WM 3	Construction	Brown	Hard	
Walukuba-Masese	WM 4	Construction	Grey-brown	Hard	

iv. Data obtained from the Kasawo area, Mukono.



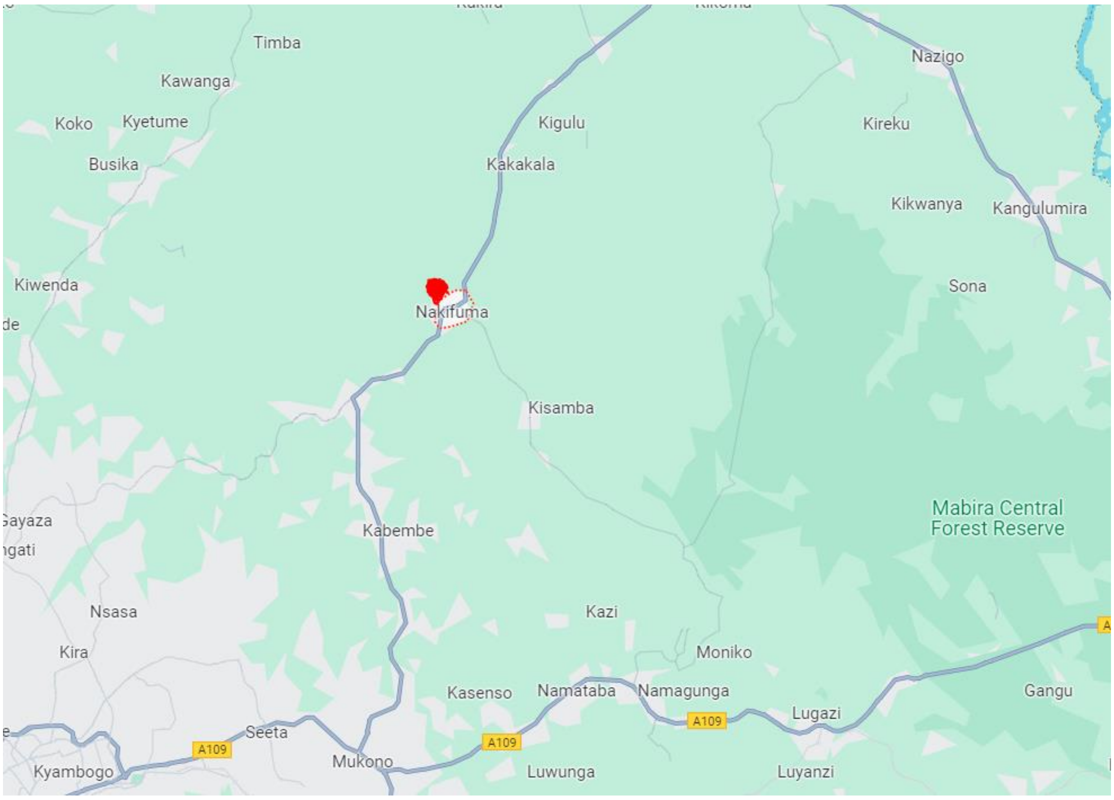
Location	Test No	Use	Color	Properties	Image
Kasawo	KAS 1	Construction	Grey	Hard	
Kasawo	KAS 2	Construction	Grey	Hard	
Kasawo	KAS 3	Construction	White	Soft	

v. Data obtained from the Katosi area, Mukono.



Location	Test No	Use	Color	Properties	Image
Katosi	KAT1	Construction	Grey	Hard	
Katosi	KAT2	Construction	Grey	Hard	

vi. Data obtained from the Nakifuma area, Mukono district.



Location	Test No	Use	Color	Properties	Image
Nakifuma	NAK 1	construction	Red	Soft	
Nakifuma	NAK 2	Construction	White	Soft	

Appendix C: Data collection and analysis of formulations from progressive glaze tests on selected geological samples.

i. **Lowering the temperature of glazes to 1150°C that did not melt in the first firing by the addition of additives fired at 1250°C.**

Test number	Composition	Appearance	Appearance	Composition	Observation
JC 1	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	Matured on the test bar but did not melt.
JC 2	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% Wood ash:8%	fused with the test bar but did not melt.
JC 4	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	fused with the test bar but did not melt.
WM 2	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	Did not melt when fired
WM 3	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	looks under fired
WM 4	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	fused with the test bar but did not melt.
KAS 3	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	Did not melt when fired
NAK 1	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	Did not melt when fired
NAK 2	Sample: 90% Clay: 2% Kaolin: 8%			Sample: 90% Clay: 2% wood ash:8%	Did not melt when fired

ii. **Lowering the temperature of the glazes to 1150^{o}C that melted at high temperatures of 1250^{o}C by putting in additives. As shown in the table below.**

Test number	Composition	Appearance	Observation
JC 1	Sample: 90% Clay: 2% Granulated glass: 8%		Fused with the clay body but did not melt
JC 2	Sample: 90% Clay: 2% Granulated glass: 8%		Did not melt at high temperatures
JC 4	Sample: 90% Clay: 2% Granulated glass: 8%		Did not melt when fired
WM 2	Sample: 90% Clay: 2% Granulated glass: 8%		Fused with the clay body but did not melt
WM 3	Sample: 90% Clay: 2% Granulated glass: 8%		Looks under fired
WM 4	Sample: 90% Clay: 2% Granulated glass: 8%		Fused with the clay body but did not melt
KAS 3	Sample: 90% Clay: 2% Granulated glass: 8%		Did not melt when fired
NAK 1	Sample: 90% Clay: 2% Granulated glass: 8%		Did not melt when fired
NAK 2	Sample: 90% Clay: 2% Granulated glass: 8%		Did not melt when fired

Appendix D: Number of Samples

Table 1: A list of study Areas and Number of Samples.

Mukono District (A)		
No.	**Area**	**No. of Samples**
1	Katosi	2
2	Kasawo	3
3	Nakifuma	2
Total		7
Total number of samples from Mukono district = 7		
Jinja District (B)		
No.	**Area**	**No. of Samples**
1	Walukuba-Masese	4
2	Mpumudde-Kimaka	3
3	Jinja central	4
Total		11
Total number of samples from Jinja district = 11		
Total number of samples from Mukono and Jinja = 18		

Appendix E: Site images and the grinding process.

Images showing data collection within Jinja District

Images showing data collection within Mukono District

The crushed rocks using the ball mill

The porcelain grinding mill

the grinded material well packaged

Appendix F: Images of the chemical analysis and fire testing.

Putting the rock powder to the small tins for the chemical analysis.

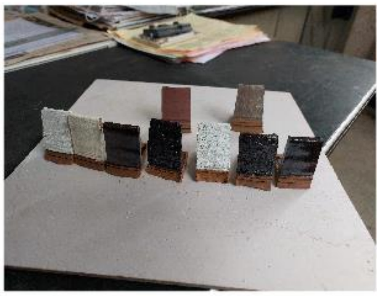
The rock powder in small tins.

Analysising the samples using the X-Ray fluorescence

The clay test bar in bisque firing.

Mixing the recipe and applying it on the test bar.

The fire testing using the test kiln.



The appearance of the glazes after the first firing.

The fired glaze test clay bars

Appendix G: Pictures of the processes showing the construction of the creative project work.

Some of the pictures showing the processes of the creative project work.

the moulded form in green ware

the finished form in green ware

the form with developing details.

the aerial view of the developing details

the green ware formm with details

the bisque fired piece.

the bisque fired piece with a row glaze

the glazed piece after the firing with a shiny effect

the form in green ware with out details

the developing form created using hand building.

the form in green ware with developing details

the form with details in green ware.

the green ware with details.

the bisque fired piece fired at 900C

the bisque fired piece with a row glaze

the glazed piece form with a star fish inspiration.

Appendix H: Final Creative Project

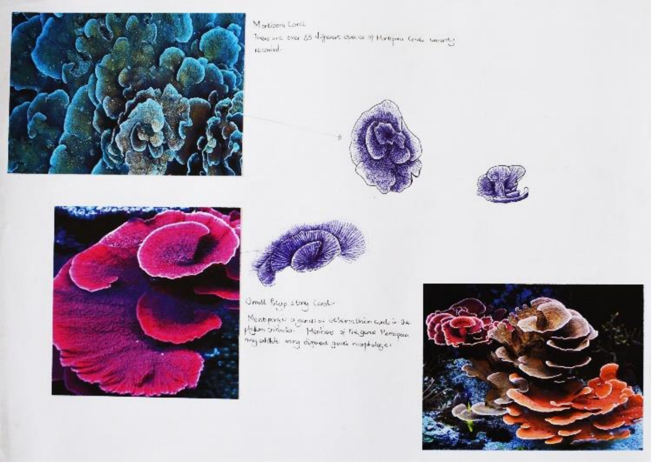
Project 1: Decorative piece. (Corals)

a) Reference

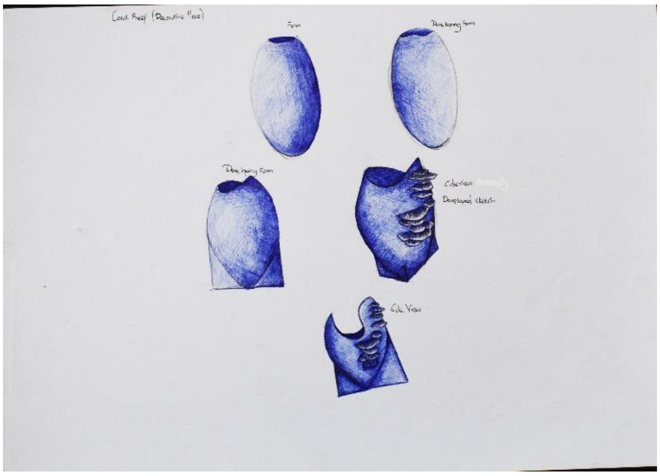
Source:
https://turtlemail.blogspot.
com/2013_07_01_archive.html
Date accessed: 15/01/2023

Source:
https://xray-mag.com/content/jewels-tanzania- -
african-safari pemba-island-diving
Date accessed: 15/01/2023

b) Preliminary sketch



c) Developed sketch



d) Final Glazed piece: Decorative Piece.

Item	Decorative piece.
Fire temperature	Glossy/ MK 1 5D, 1200^{o}C
Application technique	Brush and Dipping the pieces in the glaze
Use	Decorative piece
Size	(height, width) 55cm×40cm
Observation.	The glaze melted better with some parts showing crawling of the glaze in the upper parts where it was dipped.

Project 2: Decorative Piece (coral reef)

a) Reference

Source:

https://www.freetheocean.com/journal/images-of-sea-sponges

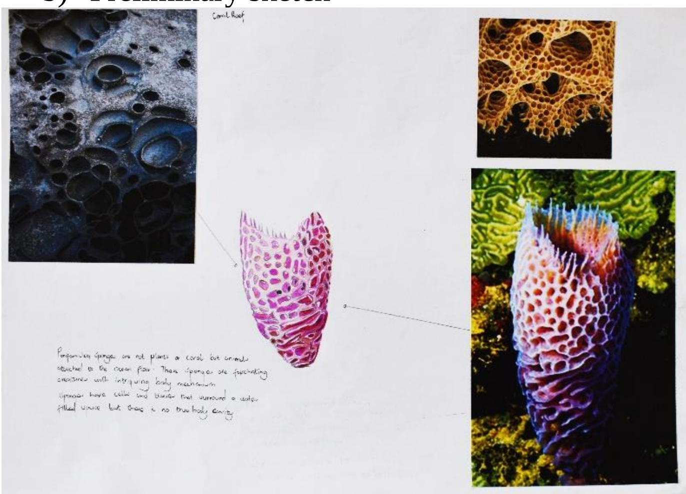
Date accessed: 15/01/2023

Source:

https://www.flickr.com/photos/19387539@N00/161916349/in/photostream

Date accessed: 15/01/2023

b) Preliminary sketch



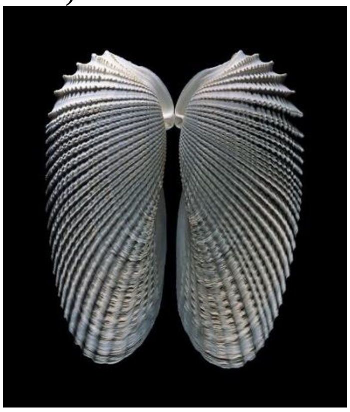
c) Developed sketch

d) Final Piece: Decorative Vase

items	Decorative piece	Items	Decorative piece
Fire temperature	KAT2 16D(1200°C)	Fire temperature	WM1 7L(1200°C)
Application technique	Dipping technique	Application technique	Brush.
Use	Decoration	Use	Decoration
Size	(height ×width) 55cm×40cm	Size	(height × width) 35cm×30cm
observation	The application was a success and the matt glaze melted evenly on the piece	observation	The glaze melted on the piece although some parts were missed because of the application technique.

Project 3. Vase (Sea Shell)

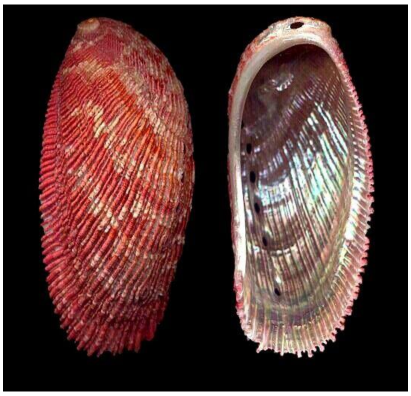
a) Reference



Source:

https://www.amnh.org/explore/news-blogs/news-posts/search-for-these-shells?

Date accessed: 15/01/2023

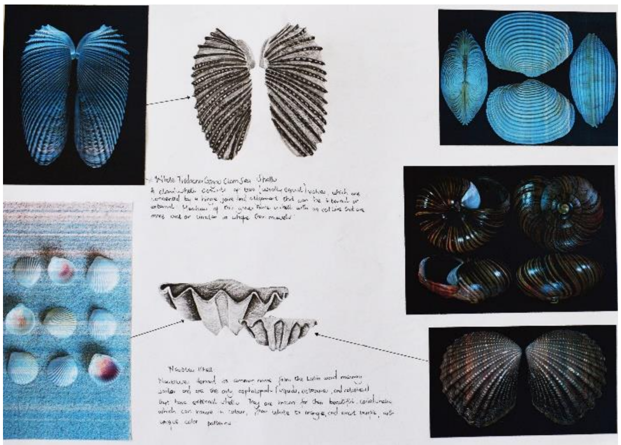


Source:

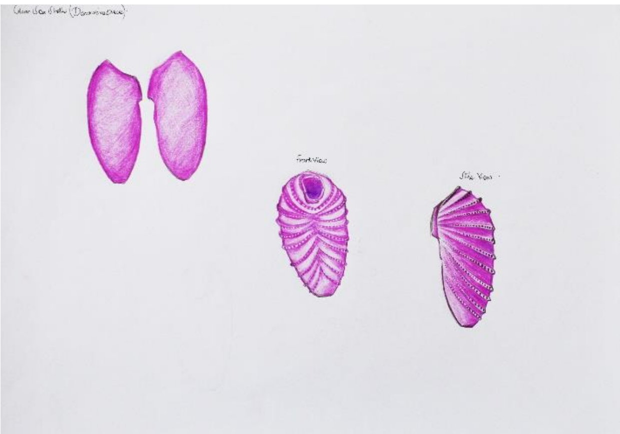
https://www.liveinternet.ru/users/3162595/post290635689/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developed sketch



d) Final Piece: Decorative piece (Shell).

Item	Decorative piece.
Fire temperature	WM 1 7L (1200°C)
Application technique.	Pouring the glaze.
Use	Decoration
Size	(Height ×width) 50cm× 30cm
Observation	The glaze melting flowed nicely on the piece and the application looks good.

Project 4: Decorative Piece (Seashell)

a) Reference

Source:

https://www.pinterest.com/pin

/687744017306/

Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin

/14073817574899765/

Date accessed: 15/01/2023

b) Preliminary sketch

c) Developed sketch

d) Final Piece: Ceramic Vase (Seashell)

Item	Vase
Fire temperature	WM1 7L (1200°C)
Application technique	Pouring
Use	Decorative piece
Size	(height × width) 45cm × 25cm
Observation	The glaze melted well on the piece and the application of the glaze on the piece.

Project 5. Seashell

a) Reference

Source:

https://www.pinterest.com/pin/

450852612711772309/

Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin/

64035625944987323/

Date accessed: 15/01/2023

b) Preliminary sketch

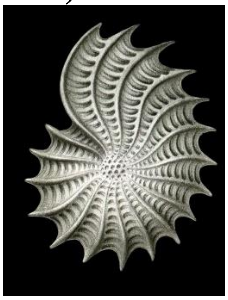
c) Developed sketch

d) Final Piece: Decorative piece

Item	Vase
Fire temperature.	MK1 5D (1200°C)
Application technique	Dipping and brushing
Use	Decoration
Size	(height × width) 45cm×25cm
Observation	The application looks good and they melted well on the piece with a shiny effect.

Project 6. Seashell

a) Reference



Source:

https://www.pinterest.com/pin/

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Date accessed: 15/01/2023

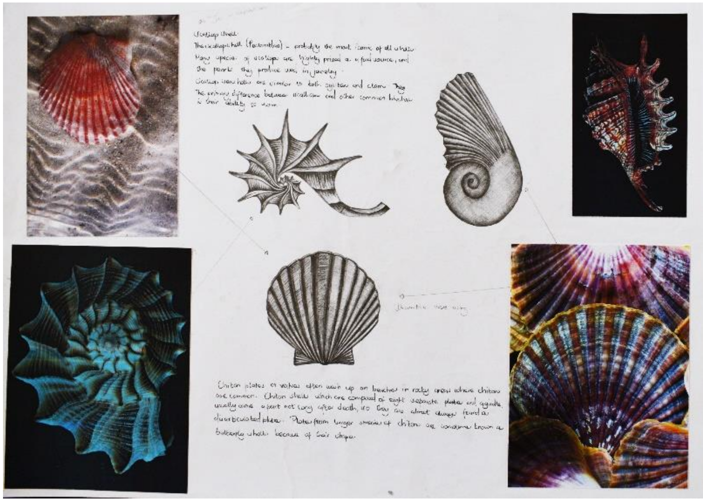
Source:

https://www.pinterest.com/pin

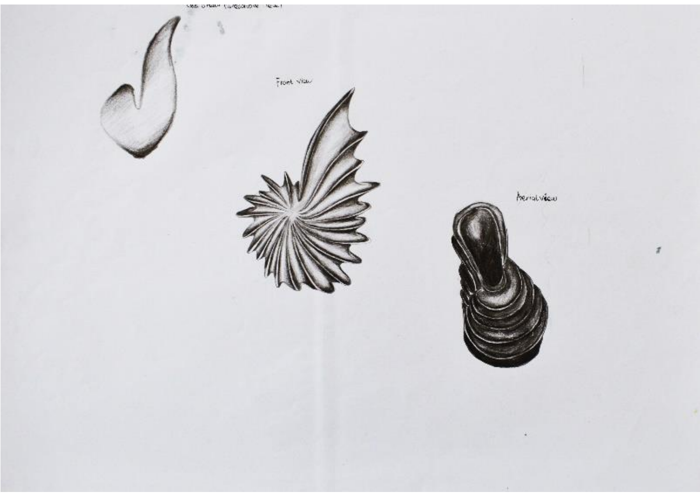
/2533343534838067/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developed sketch

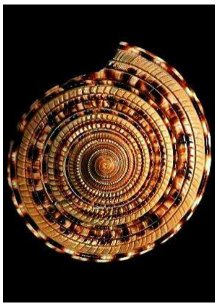


d) Final Piece: Decorative piece

Item	Vase
Fire temperature.	WM1 7L (1200°C)
Application technique	Dipping
Use	Decoration
Size	(Height × width) 30cm × 25cm
Observation	The application looks good and the melting too.

Project 7. Seashell

a) Reference



Source:

https://www.pinterest.com/pin/687744017336/

Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin/777645060685014862/

Date accessed: 15/01/2023.

b) Preliminary sketch

c) Developing sketch

d) Final Piece: Decorative Piece (seashell)

Item	Vase
Fire temperature	KAT2 16D (1200^{o}C)
Application technique	Dipping and brushing
Use	Decoration
Size	Height × width (35 cm ×35cm)
Observation	The application looks good although the melting has parts where the glaze is much more than the other.

Project 8. Sea shell.

a) Reference

Source:

https://www.pinterest.com/pin/293719206958831546/

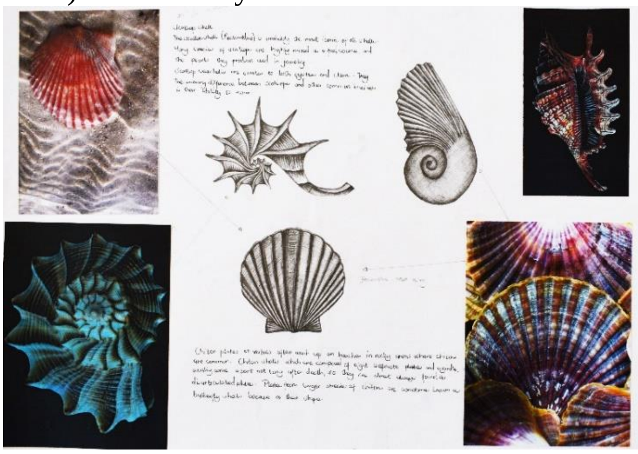
Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin/15129348742426757/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Decorative sea shell

Item	Vase
Fire temperature	WM1 7L (1200°C)
Application technique	Dipping
Use	Decoration
Size	(height ×width) 25cm ×20cm.
Observation	The glaze melted evenly which made the application a success.

Project 9: Coral Reef

a) Reference

Source:

https://www.pinterest.com/pin/733242383096602344/

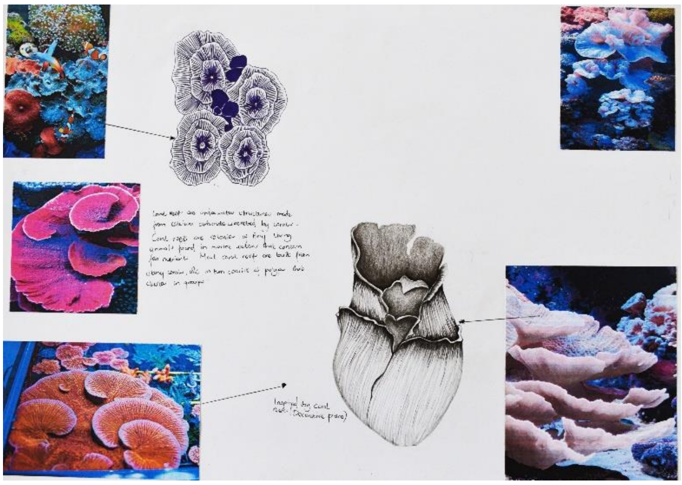
Date accessed: 15/01/2023

Source:

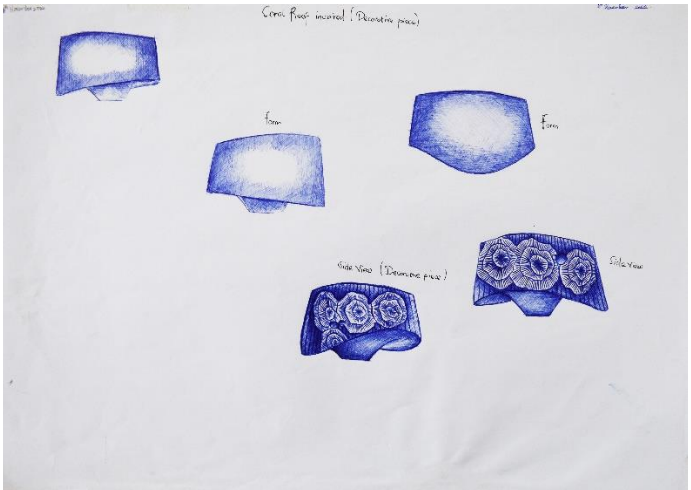
https://www.pinterest.com/pin/429812358185260540/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch



d) Final Piece: Decorative piece.

Item	Vase
Fire temperature	MK3 10D (1200^{o}C)
Application technique	Brushing
Use	Decoration
Size	(height × width) 30cm × 40cm
Observation	The glaze melted unevenly in some parts because of the brushing technique.

Project 10. Decorative piece(Coral Reef)

a) Reference

Source:

https://www.pinterest.com/pin/

141511613282635411/

Date accessed: 15/01/2023

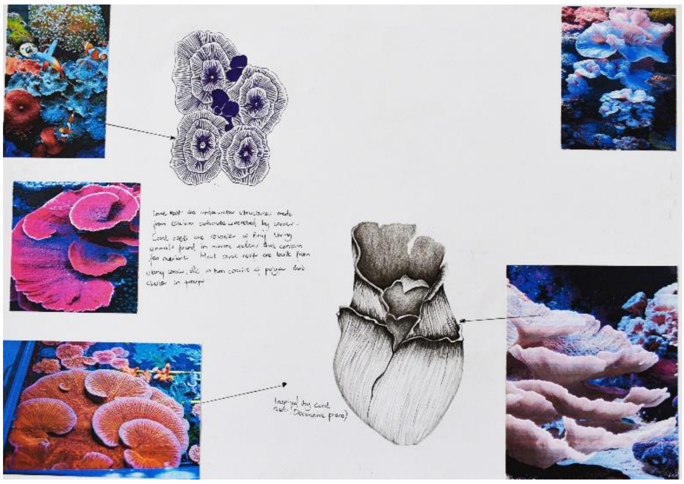
Source:

https://www.pinterest.com/pin

/174515172978865 19/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Decorative piece

Item	Vase
Fire temperature	KAT2 16D (1200^{o}C)
Application technique	Pouring
Use	Decoration
Size	(height ×width) 40cm ×30cm
Observation	The application looks good and the glaze melted well on the piece.

Project 11. Wall hanging (Coral Reef)

a) Reference

Source:

https://www.pinterest.com/pin/174515172978865 19/

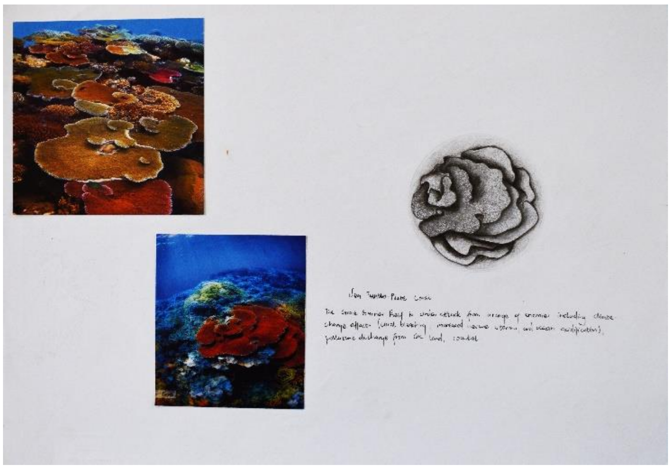
Date accessed: 15/01/2023

Source:

https://pinterest.com/pin/ 368732288257020497/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Wall hanging

Item	Wall hanging
Fire temperature	MK3 10D (1200°C)
Application technique	Dipping
Use	Decoration
Size	(height × width) 2cm ×30cm
Observation	The applied glaze looks good.

Project 12. Wall hanging.

a) Reference

Source:

https://www.pinterest.com/pin/498773727498997412/

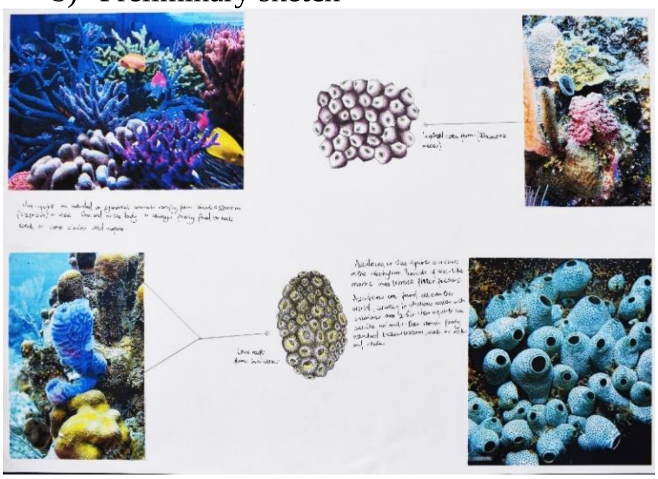
Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin/3307399717721639/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Wall hanging.

Item	Wall hanging
Fire temperature.	MK3 10D (1200^{o}C)
Application technique.	Dipping
Use	Decoration
Size	(height ×width) 2cm×30cm
Observation	The glaze application looks good and the glaze melted well onto the wall plate

Project 13. Vase (Octopus)

a) Reference

Source:

https://www.pinterest.com/pin/329185054024933040/

Date accessed: 15/01/2023

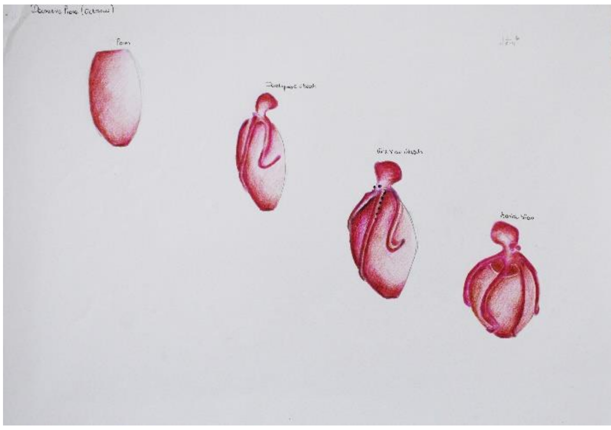
Source:

https://www.pinterest.com/pin/702843085623271369/

Date accessed: 15/01/2023

b) Preliminary sketch

c) Developing sketch



d) Final Piece: Vase

Item	Vase
Fire temperature	WM1 7L (1200^{o}C)
Application technique	Dipping
Use	Decoration
Size	(Height × width) 40cm×25cm
Observation	The glaze melted well on the piece with some small parts that missed the glaze. The application looks good

Project 14. Bowls (Octopus)

a) Reference

Source:

https://www.pinterest.com/pin/577516352241004477/

Date accessed: 15/01/2023

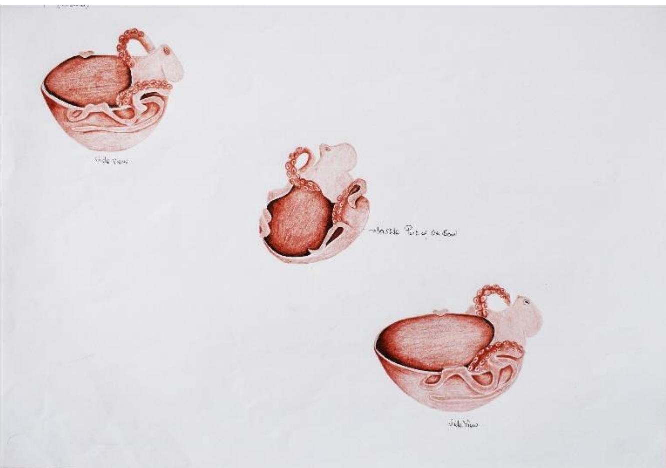
Source:

https://www.pinterest.com/pin/6403624461396865/

Date accessed: 15/01/2023

b) preliminary sketch

c) Developing sketch



d) Final Piece: Bowl

Item	Fruit bowls
Fire temperature	KAT2 16D (1200^{o}C)
Application technique	Dipping and brushing
Use	Functional
Size	(height × width) 10cm×20cm
Observation	The glaze shows some light small parts where the glaze did not stick well. But the rest of the bowls have a heavy glaze. The application of the glaze looks good.

Project 15. Side plates (tortoise)

a) Reference

Source:

https://www.pinterest.com/pin

/774124919243676/

Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin/

387239267934164252/

Date accessed: 15/01/2023

b) Preliminary sketch

c) Developing sketch

d) Final Piece: Side plates

Item	Slide plates
Fire temperature	KAT2 16D (1200°C)
Application technique	Dipping
Use	Functional
Size	(height × width) 3cm × 15cm
Observation	The matt glaze melted evenly on the plates which appears to show a good glaze application.

Project 16. Tea Pot

a) Reference

Source:

https://www.pinterest.com/pin/AaFINlu0yWsEabW6HlVQ3NMp1O1y1Qo7x3SwyHLWeS6Fby5QDTvdJ0A/

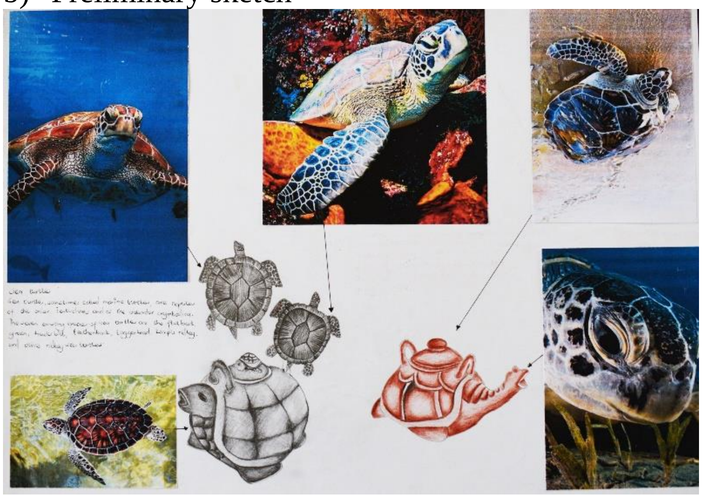
Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin/820781100856116163/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Teapot

Item	Teapot
Fire temperature	KAT2 16D (1200^{o}C)
Application technique	Dipping
Use	Functional
Size	(height × width) 10cm × 6cm
Observation	The glaze melted evenly on the clay body of the thrown teapot.

Project 17. Vase (Star Fish)

a) Reference

Source:

https://www.pinterest.com/pin/

3729612227938909/

Date accessed: 15/01/2023

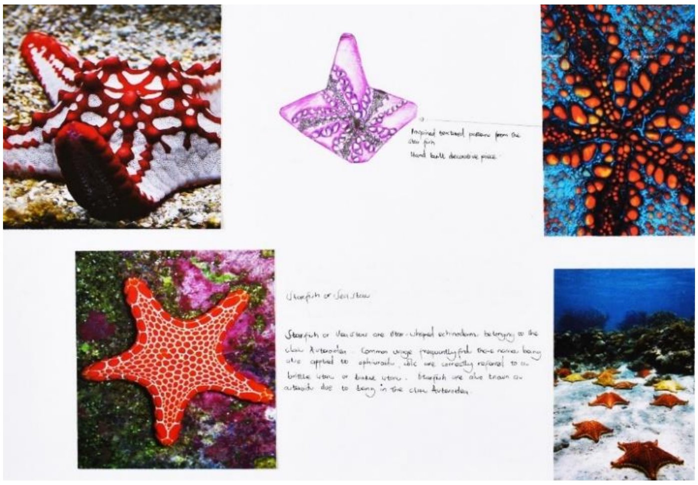
Source:

https://www.pinterest.com/pin

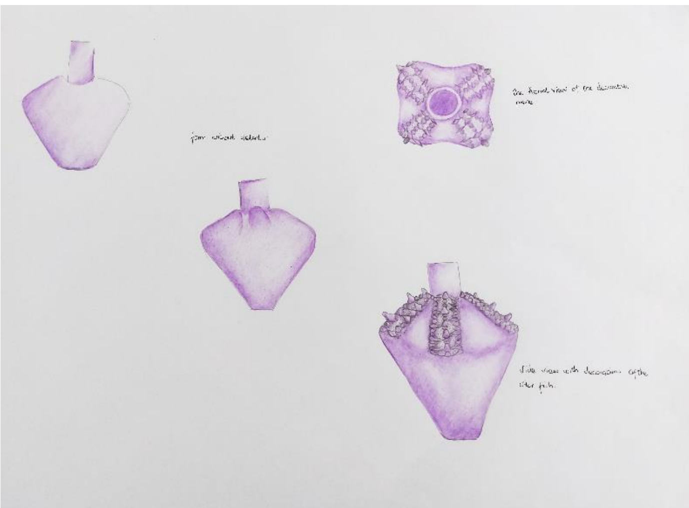
/7036943160117662/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch



d) Final Piece: Vase

Item	Vase
Fire temperature	WM1 7L (1200^{o}C)
Application technique	Pouring
Use	Decoration
Size	(height × width) 20cm × 15cm
Observation	The application looks good and the glaze melted evenly on the piece apart from the small part on the neck.

Project 18. Vase (Brain Coral Reef)

a) Reference

Source:

https://www.pinterest.com/pin/4714774601225542/

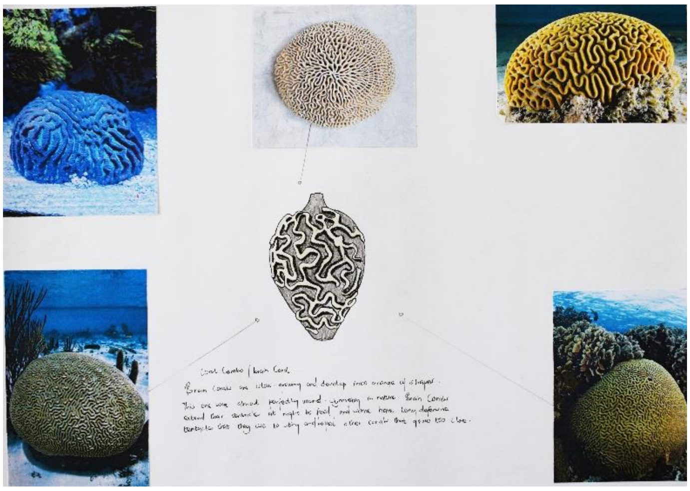
Date accessed: 15/01/2023

Source:

https://www.pinterest.com/pin/437693657555166959/

Date accessed: 15/01/2023

b) Preliminary sketch



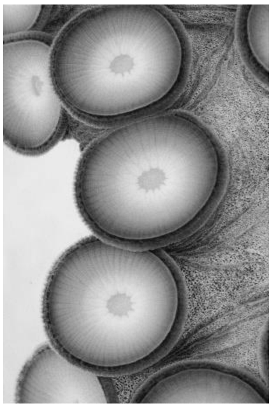
c) Developing sketch

d) Final Piece: Vase

Item	Vase
Fire temperature	MK2 6C (1200°C)
Application technique	Brushing and pouring
Use	Decoration
Size	(height × width) 45cm×20cm
Observation	The application looks good and the glaze fitted on the piece well.

Project 19: Decorative piece (Octopus)

a) Reference.



Source:

https://www.pinterest.com/pin/

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Date accessed: 15/01/2023

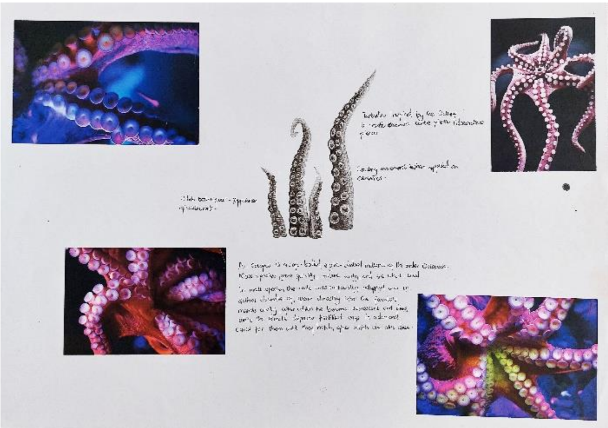
Source:

https://www.pinterest.com/pin/

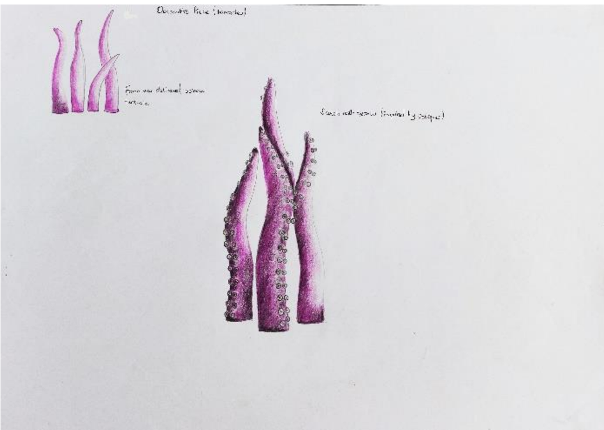
103160647687253908/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch



d) Final Piece: Decorative piece.

Item	Tentacles.
Fire temperature	WM1 7L (1200°C)
Application technique	Pouring
Use	Decoration
Size	(height) small 20 cm, medium 30 cm, and largest 50cm
Observation	The glaze melted evenly on the decorative piece and the application looks good.

Project 20: Decorative piece (Coral Reef).

a) Reference

Source:

https://www.pinterest.com/pin/

1970393579280538/

Date accessed: 15/01/2023

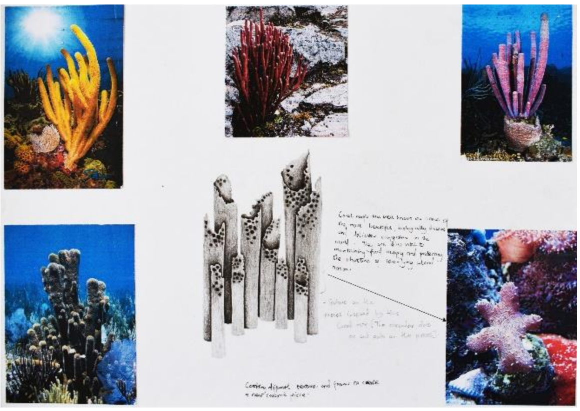
Source:

https://www.pinterest.com/pin/

631911391482954153/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Decorative piece.

Item	Coral inspired pieces
Fire temperature	WM1 7L (1200^{o}C)
Application technique	Pouring
Use	Decoration.
Size	(height) small 20cm, medium 25cm, and 50cm
Observation	The application looks good and the glaze melting looks good too.

Project 21: Decorative piece (Coral Reef).

a) Reference

Source:

https://www.pinterest.com/pin/

669911131985957778/

Date accessed: 15/01/2023

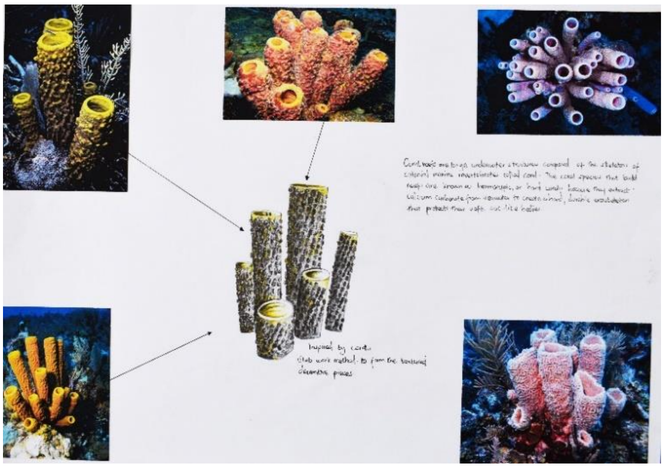
Source:

https://www.pinterest.com/pin/

299630181465343471/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Decorative piece.

Item	Candle holders
Fire temperature	KAS2 13I/ WM 3 (1200^{o}C)
Application technique	Dipping the pieces and splashing
Use	Functional
Size	(Smallest) 5cm ×5cm, (medium)20cm ×5cm (large)30cm×5cm
Observation	The glaze reacted well during the glaze firing.

Project 22: Vase (Coral Reef)

a) Reference

Source:

https://www.pinterest.com/pin/

1048283250743784623/

Date accessed: 15/01/2023

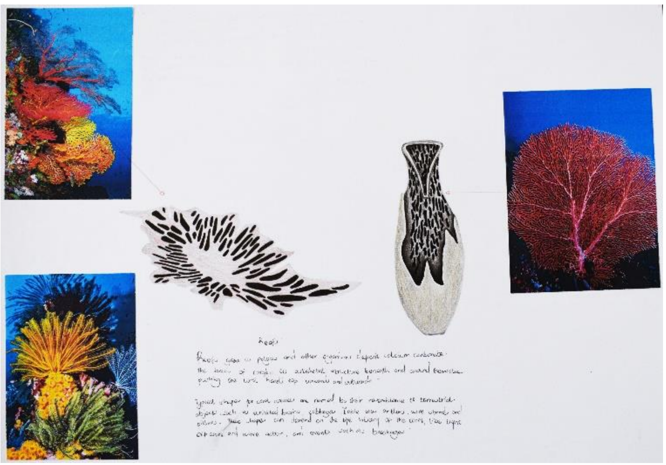
Source:

https://www.pinterest.com/pin/

519462138280789778/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Vase

Item	Vase
Fire temperature	WM1 7L (1200^{o}C)
Application technique	Pouring the glaze onto the piece.
Use	Decorative piece
Size	(Height × diameter) 40cm ×15cm
Observation	The glaze melted evenly onto the hand-built piece and the application looked good.

Project 23: Decorative piece (Coral Reef)

a) Reference.

Source:

https://www.pinterest.com/pin/720716746640460604/

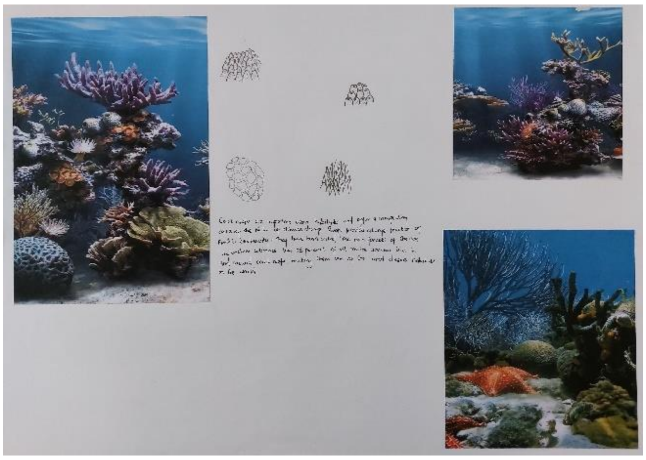
Date accessed: 15/01/2023

Source:

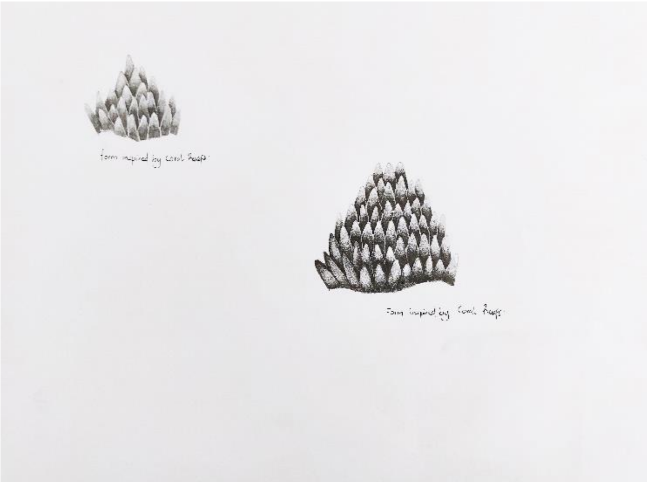
https://www.pinterest.com/pin/193303008992854176/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

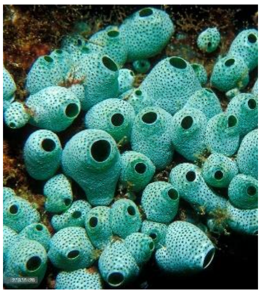


d) Final Piece: Decorative piece.

Item	Decorative piece
Fire temperature	KAT 2 16D (1200^{o}C)
Application technique	Pouring
Use	Decoration
Size	(Height ×width) 7cm ×15cm
Observation	The glaze melted well on the decorative piece and the application looks good too

Project 24: Decorative piece (Coral Reef).

a) Reference



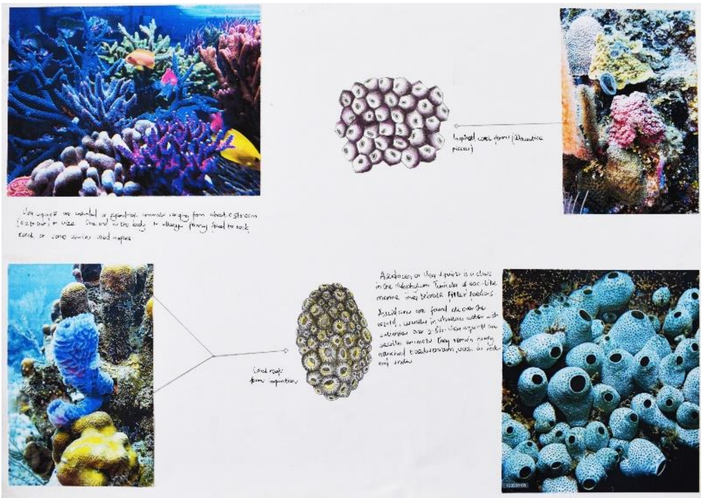
Source: https://www.pinterest.com/pin/99923685474349827/

Date accessed: 15/01/2023

Source: https://www.pinterest.com/pin/25614291622637939/

Date accessed: 15/01/2023

b) Preliminary sketch



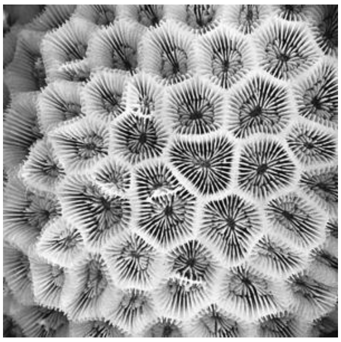
c) Developing sketch

d) Final Piece: Decorative piece.

Item	Coral inspired piece
Fire temperature	KAS2 13I 1/ WM 3 (1200^{o}C)
Application technique	Pouring and splashing with the brush
Use	Decoration
Size	(height ×width) 5cm ×15cm
Observation	The two combined applications look good and the melting of the two different glazes was good

Project 25: Decorative piece (Coral Reef).

a) Reference



Source:

https://www.pinterest.com/pin/

1618549859767314/

Date accessed: 15/01/2023

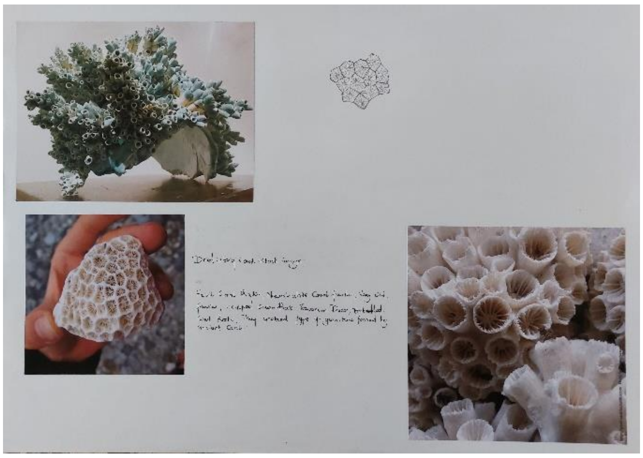
Source:

https://www.pinterest.com/pin/

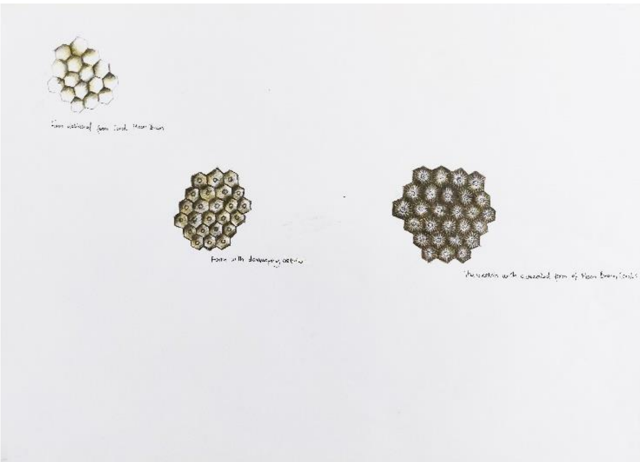
1618549859767310/

Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

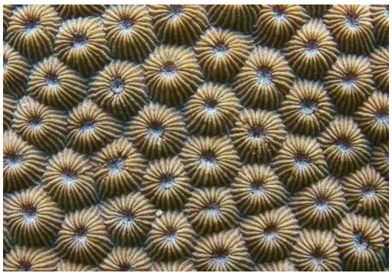


d) Final Piece: Decorative piece.

Item	Coral-inspired piece.
Fire temperature	KAT2 16D (1200°C)
Application technique	Pouring
Use	Decoration
Size	(height ×width) 5cm ×15cm
Observation	The shiny glaze application looked good.

Project 26: Decorative piece (Coral Reef)

a) Reference



Source:

https://www.pinterest.com/

pin/626281891954020417/

Date accessed: 15/01/2023

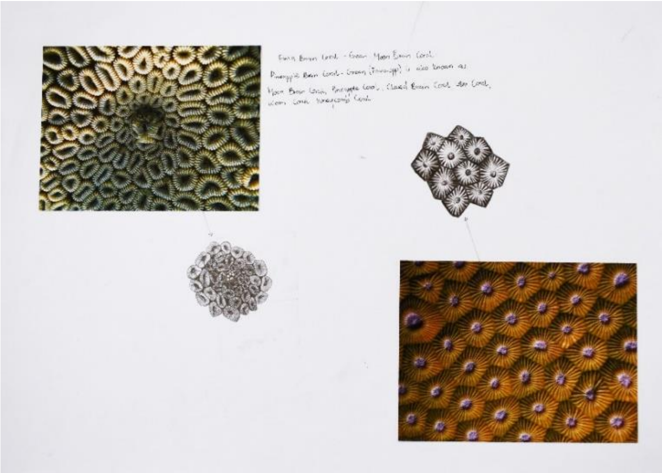
Source:

https://www.pinterest.com/pin/

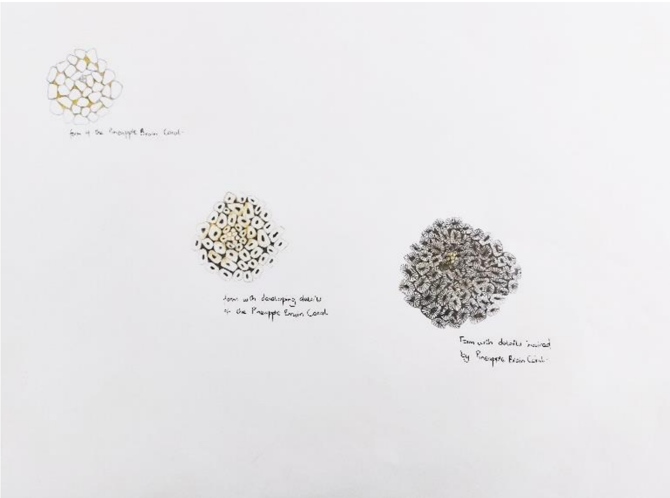
99853316715281922/

Date accessed: 15/01/2023

b) Preliminary sketch.



c) Developing sketch.



d) Final Piece: Decorative piece.

Item	Coral-inspired piece.
Fire temperature	WM1 7L (1200°C)
Application technique	Dipping
Use	Decoration
Size	(height ×width) 5cm ×15cm
Observation	The glaze application looks good and the glaze melted well and is shiny on the piece

Project 27: Decorative piece (Coral Reef).

a) Reference

Source:

https://www.pinterest.com/pin/

3518505933370267/

Date accessed: 15/01/2023

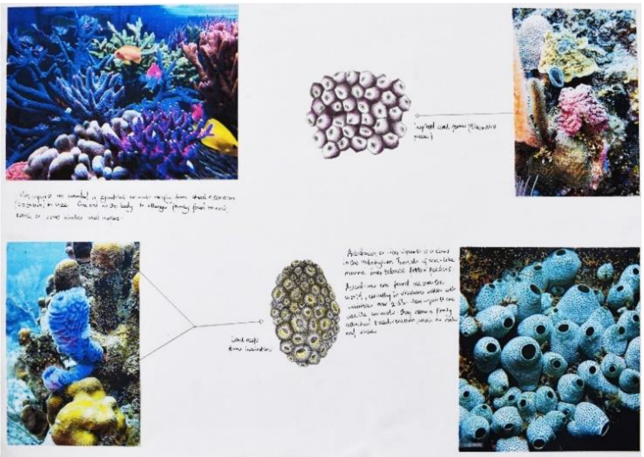
Source:

https://www.pinterest.com/pin/

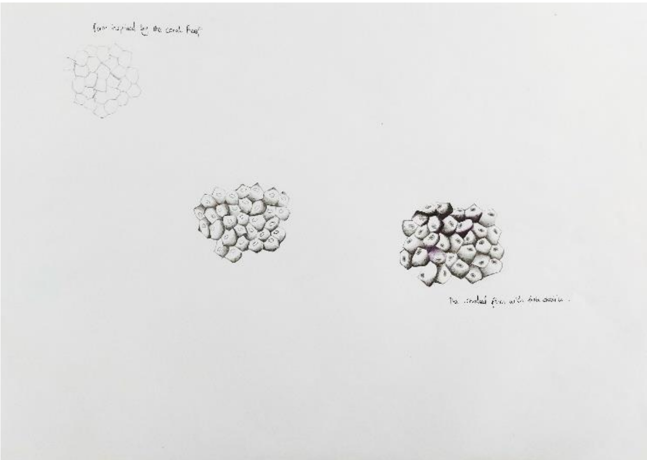
964058668662463l/

Date accessed: 15/01/2023

b) Preliminary sketch.



c) Developing sketch



d) Final Piece: Decorative piece.

Item	Coral inspired piece
Fire temperature	WM1 7L (1200^{o}C)
Application technique	Pouring
Use	Decoration
Size	(height ×width) 5cm×15cm
Observation	The glaze melted evenly on the glaze which makes the application good.

Project 28: Decorative piece (Coral Reef).

a) Reference

Source:

https://www.pinterest.com/pin/

373095150350808056/

Date accessed: 15/01/2023

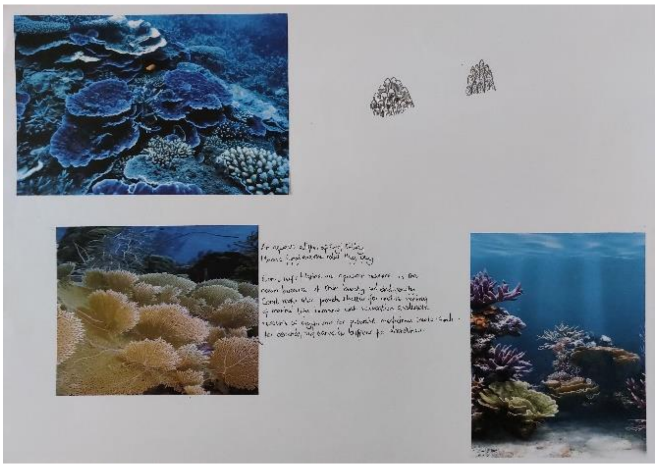
Source:

https://www.pinterest.com/pin/

281543718648698/

Date accessed: 15/01/2023

b) Preliminary sketch



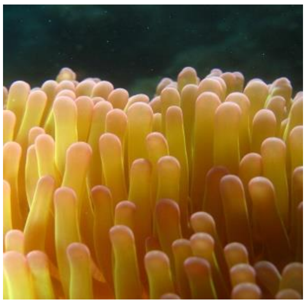
c) Developing sketch

d) Final Piece: Decorative piece.

Item	Coral inspired piece
Fire temperature.	KAS2 13I 1/ WM 3 (1200^{o}C)
Application technique	Dipping and splashing with brush
Use	Decoration
Size	(height ×width) 5cm ×15cm
Observation	The two applied glazes looked well on the piece.

Project 29. Decorative piece.

a) Reference



Source:

https://www.pinterest.com/pin/

379288218564083O7/

Date accessed: 15/01/2023

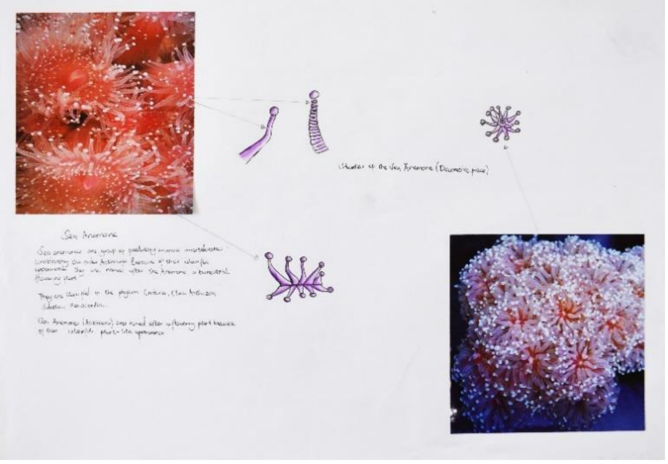
Source:

https://www.pinterest.com/pin/

112449321938760031/

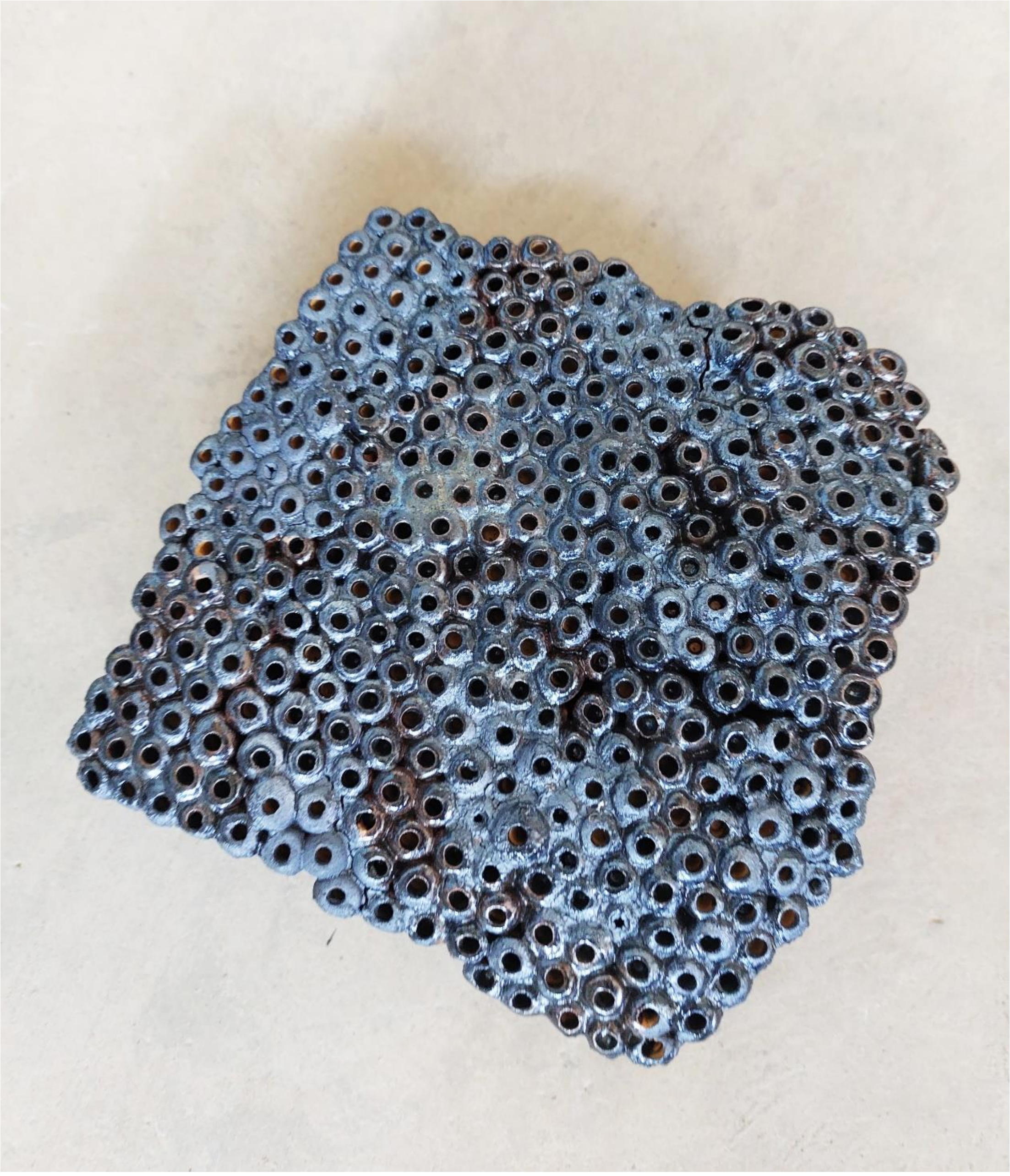
Date accessed: 15/01/2023

b) Preliminary sketch



c) Developing sketch

d) Final Piece: Decorative piece.



Item	Coral inspired piece
Fire temperature	WM1 7L/ WM 3 (1200^{o}C)
Application technique	Dipping and splashing
Use	Decoration
Size	(height ×width) 6cm×15cm
Observation	The application looks good although some parts of the glaze look matt

DIRECTORATE OF GEOLOGICAL SURVEY AND MINES
06 JUN 2022
RECEIVED BY: Susan
SECURITY REGISTRY

Ag. DGSM
Pls support the candidate in his research.
31/5.

KENYATTA UNIVERSITY

DEPARTMENT OF FINE ART AND DESIGN

E mail: ahamiphilemon14@gmail.com Tel: 256 757665407/254 110004782

P.O. BOX 43844-00100

NAIROBI, KENYA

Date: 31st May, 2022

To

The Permanent Secretary,

Ministry of Energy and Mineral Development

SUBJECT: AHAMI PHILEMON, REGISTRATION NUMBER M66EA/28084/2019

This is to confirm that the above named is a second year Postgraduate student under taking Masters in Arts (Fine Art) student at Kenyatta University's Department of Fine Art and Design, School of Creative Arts, Film and Media Studies.

He is conducting research titled. "***The formulation of glaze using selected available natural materials from Mukono and Jinja districts, Uganda***".

Any assistance accorded to him in the data collection of the geology, including the ferrying of research materials, will be highly appreciated.

Thank you.

AHAMI PHILEMON

REG. NO. M66EA/28084/2019

MINISTRY OF ENERGY AND MINERAL DEVELOPMENT
P. O. BOX 7270, KAMPALA
31 MAY 2022
RECEIVED BY:.................
SECURITY REGISTRY

OFFICE OF THE PERMANENT SECRETARY
Ministry of Energy & Mineral Development
RECEIVED