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Understanding Clay Contamination as a Basic Step to Successful Ceramics Practice

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Abstract

Clay as a product of igneous rock has over the centuries been the major material in ceramics production. Whether it is collected from its place of formation or its secondary location is not without other materials that have come in contact with. These materials otherwise referred to as contaminants can mar or enhance the performance of clay. The aim of this paper is to highlight the effects of clay contaminants in ceramic practice. The objectives will be, to look at the formation and types of clay, the contaminants and their functions in ceramics production, the natural and artificial contaminants and modifiers in clay body formulation. The truth is that over the years, potters have not really considered clay contaminants as basic ingredients for successful ceramic practice. Data collect from primary and secondary sources will help in the proper understanding of clay contamination and its role in successful ceramics practice.

Keywords: *Contaminants, Modifiers, Body, mar, Artificial*

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Background to the Study

Ceramics has remained one of the essential synthetic activities that man has developed. As the science and art of baked clay, its products come as a result of applying sufficiently, high temperature using a special oven, the kiln, to change the physical and chemical properties of the original clay into a rocklike structure, dense and durable. Ceramics is a profession practiced, whether in traditional or modern techniques in every tradition due to its important functions in the society. In spite of the emergence of highly decorated plastic and enamel wares in modern time, ceramic wares are still preferred after gold and silver. In the building industry, ceramic wares make up eighty per cent of the materials for the skeleton, shell and internal organs due to its strength, fire and weather resistance, smoothness, coolness, beauty and durability. It stands true that clay is the only medium for ceramic production while other materials are to modify and decorate it, but the wares would not have been possible with kaolin alone as pure, uncontaminated and non-plastic clay. Therefore, while looking at the pure clay from the parent rock it is advisable to consider those things that make the clay impure, contaminated or polluted, without which ceramic practice would not have been successful. It is worthy of note that though the contaminants are not part of the materials that form the clay, they are part of the clay at the point of quarrying and thus are represented in the clay formula with the letter "x" after alumina, silica and water which combine in their respective ratios to form the pure clay, kaolin.

Aim and Objectives

The aim of this paper is to understand clay contamination as the basic step to successful ceramic practice. It is to bring to the fore, the value, importance or usefulness of clay contaminants, impurities, or pollutants in pottery. The objectives are to assess the functions of contaminants in pottery, to identify and extract some harmful contaminants from the clay, to explore the possibility of working with the contaminants, to explore the possibility of working without the contaminants and to improve the workability of clay by artificially introducing contaminants as modifiers in clay body formulation.

Literature Review

Theoretical Framework

This paper adopts the modern creativity theory propounded by Kanematsu, H and Barry, D. M. (2016), which accentuates creativity as the ability to improve on established ideas. It also stresses on the need to integrate new or borrowed ideas into previously organized system or situations, and further places emphasis on the need for existing ideas to be fused in different forms to meet contemporary trends. This theory allows a creative person to redesign by building on existing structure in order to arrive at a new and more useful result. Ocvirk at el, (1975), in line with this theory opined that "the artist is successful only when he creates a work or form in which each of the parts, the visual elements is vital, not only by itself, but in the general functioning of the whole or united entity". This means that every part aids in the purposes of expression and solving other human problems. This theory informs the writer to revisit clay and its contaminants and to find out their effects on ceramic practice. This follows the fact that each of the contaminants does not function on its own, but brought together with others in clay body formulation to modify the clay as a united entity or whole in the production of new, shock resistant, hard, durable, vitreous, functional and beautiful pottery wares.

The Material, Clay

According to Ruscoe (1975), "clay is a material difficult to define accurately as it occurs in various parts of the earth's crust". Ozkan (2017), in his contribution said that clays are very important as they occur in almost everywhere though with variations in compositions or properties due to varied locations, weather conditions, soil compositions, presence of fauna and other soil minerals that come in contact with them either at the parent site or during transportation to a secondary site. Clays are oxides of aluminum, silicon, hydrogen, oxygen and other elements in oxidized states in varying amounts and usually represented as "x" in the molecular formula for clay. Clay is generally regarded as decomposed rock or sediments of rocks from the igneous origin. It is the break-up of granite and gneiss by air and water together with changing temperature, chemical and biological decays over centuries that leave residual deposits of clay.

Kenny (1998) contends that clay is formed by the decomposition of feldspathic rock through mechanical, chemical and biological weathering processes that had taken many centuries leaving deposits of primary or residual clay and secondary or transported clay. The nature or behavior of this naturally occurring material, is clearly stated by Gilbert (1998), Surrendranathan (2015), and Konard (1996), who agreed that clay when dry, is hard or powdery and non-plastic; mixed with water, it becomes plastic and moldable; baked, it becomes rock-like and permanent. This means that it becomes moldable and cohesive which makes it easy to model, pinch, roll or shape between the hands. Once a clay form has been built and permitted to dry, it retains its given shape but remains very fragile. No matter how beautiful the form is, it remains, green ware and cannot be useful as a utilitarian piece except permanency is ensured through heat treatment in a special oven, kiln. Firing in the kiln takes the form through temperatures ranging between 700 to 1300 degrees centigrade (^{0}C) or higher. Firing burns off the organic materials, impurities, pollutants or contaminants and changes the chemical composition of the clay from alpha to beta particles, a chemical process known as "quartz invasion" where clay is calcined and can never again be slaked or made plastic.

According to Chapman (1992), "clay is a wonderful, pliable mixture of earth and water that must be studied and understood very well before use". This is because clay as collected from the depot contains so many other materials in addition to the basic materials that form it. It thus calls for proper investigation before any clay body as desired by the potter is formulated for any specific production. According to Chavarria (1999), "some clays can be used in their natural states with the addition of just water while other clays must be combined with additional materials". In the developed countries, commercially prepared clays are widely available in a variety of mixtures based on plasticity, porosity, shrinkage, colors, texture, strength and verification rage. A ceramist must certainly find a clay body suitable for his desired work. This is different from the early potters and those from the developing countries who still struggle to understand and prepare their own clay bodies for their works. Potters from these countries are faced daily with different clays from different depots with different compositions and behaviors based on plasticity, shrinkage, porosity, strength, color and maturing temperatures. As stated earlier, when clay is formed, some settle around the parent rock or its area of formation, while some are transported to a secondary site. The farther away

the particles of clay are carried, the finer and plastic the deposit. The pure forms of clay such as Kaolin, which is white, buff white or creamy in color, have an alumina- silica ratio of 1 is to 2 and are theoretically pure. China clay or Kaolin has a chemical formula of $AI_2O_32SiO_22H_2OX$. According to Ruscoe (1975), all natural clays contain some impurities or contaminants. Udoh (2005), said that "the lava flow collects rough, smooth, carbonaceous or organic and non-carbonaceous or inorganic matters, enriching itself and finds a bed; settles and remains till found as primary or residual clay." He said that another clay is that which is moved or transported from its beds of formation to another by wind, water or land slide and it is called 'secondary clay'. It is good to note that secondary clay can be non-plastic, primary clay, plastic due to the many media the clays must have rolled over. It is the media that would give the contributory factors for the clays being plastic or non-plastic with different colors.

It is a generally accepted fact that primary or residual clay is non-plastic and the secondary or transported clay is plastic. It is better therefore, to explain the above mentioned facts on plasticity to avoid confusion. If there is a great quantity of bentonite and volcanic ash or trapped organic materials during the formation, primary clay has the possibility of being plastic. On the other hand, if the secondary clay lacks the afore-mentioned materials and is being transported through the desert with very high percentage of sand, then it will remain short and non-plastic. Another fact about clay plasticity is the grain or particle size. The primary clay particle is three dimensional. This means that the particles have length, width and height and therefore, coarse, acidic, porous, refractory and non-plastic. On the other hand, the transported clay particle is two dimensional, having only length and width as a result of long term collision and grinding in the course of movement from the parent rock to its secondary site. With the fermentation and reaction of organic and inorganic contaminants, pollutants or impurities carried along in the course of movement and settlement for several years, colloidal gel is formed which surrounds each flat particle making the clay, less porous, less or non-acidic but highly plastic with high shrinkage rate and different colors. According to Rhodes (1973), "the chemical attraction between particles and carbonaceous matter present in clays also contribute to plasticity, which according to Okoli (2021), "is clay's ability at wet state to withstand pressures during manipulation or production".

Clay is a malleable, flexible or versatile material and the basic material in ceramics, whether plastic or non-plastic. It is the basic material while other materials serve as modifiers. While the plastic clay serves well in modelling, the non-plastic or fire clay due to its refractoriness is highly needed and useful for a lot of other things in ceramics including clay body formulation.

Contaminants in Clay:
Impurity can be defined as a state of being impure and contamination as a state where a pure thing is contaminated, made impure or dirty. Pollutes is defined as a state of making dirty, destroying the purity or sanctity of a thing such as water, land and air. It thus follows that materials that make pure things impure, contaminated and polluted are referred to as impurities, contaminants and pollutants respectively. If water is full of contaminants, then it cannot be good for human consumption and whenever air is polluted, it remains dangerous to health. On the other hand, if the pollutants are introduced artificially by man for the purposes

of enrichment, nourishment and pleasure then they can be tolerated as modifiers such as drinks, tea, soups, air freshener, perfumes, body sprays and manure or fertilizers.

As stated earlier, the chemical formula for pure clay is AI_2O_3 $2Si0_2$ $2H_2O$. The fact that all natural clays contain impurities therefore determines the inclusion of the letter, "X" in the formula as follows: $Al_2O_32SiO_22H_2OX$. See figure 1 below. The letter, "X" therefore signifies the presence of other elements in clay apart from the Alumina, Silica, Hydrogen and Oxygen (Chemical water) that combine in their different proportions to form pure clay. It is not to say that contaminants are all useless in ceramics practice but because they are not part of the basic materials that combine to form clay. Some of these contaminants in excess, will negatively affect the performance of clay and the entire production. These essential contaminants are therefore referred to as modifiers because they form the ingredients necessary to modify or improve the quality and performance of the clay. Contaminants therefore, either improve or mar the quality or performance of clay which will determine the success or failure of the practice.

Natural and Artificial Contaminants

As stated earlier, contaminants can occur naturally in clay and can be introduced artificially as additives and modifiers by the ceramist. The natural contaminants are those present in the clay at the point of quarrying while the artificial ones are those modifiers the potter deems necessary to introduce as additives into the clay during body formulation to arrive at the desired body for production.

Organic and Inorganic Contaminants

Contaminants can be organic (carbonaceous) or inorganic (non-carbonaceous) in nature. The organic or carbonaceous contaminants are those modifiers that consist of carbon or its compounds of which when fired, burn to release carbon dioxide. They are contaminants from living organisms such as animals, plants, insects, bacteria, etcetera, which ferment to produce the colloidal gel that promotes plasticity in clay as it settles and ages for centuries. On the other hand, the inorganic or non-carbonaceous contaminants are those modifiers such as iron, tin, zinc, lead, copper, manganese, magnesium etcetera that do not consist of carbon or its compounds and therefore do not burn to give up carbon dioxide.

Metallic and Non-Metallic Contaminants

The non-carbonaceous contaminants can be metals or non-metals. The metallic ones include iron, tin, lead, copper, zinc, silver, gold, etcetera, while the non-metals include sodium, manganese, magnesium, calcium, potassium, phosphorus, borax, cobalt, sulfur, and etcetera. These metals and non-metals and their oxides in their right proportions are very useful as modifiers, as fluxing agents, refractory agents and colorants in clay bodies, engobe, glaze and body stains. It is the presence of these contaminants in clay that gives clay its numerous colours which range from buff white, brown, green to black.

Soluble and Insoluble Contaminants

Contaminants can be insoluble or soluble in nature. The insoluble ones such as plants and

animal's fossils, rock and metal fragments, excess sand, etcetera, can be sorted out if they are visible before slaking the clay. If not visible, they can be sieved, drained and magnate from the clay in its slip state. During kneading and wedging, some insoluble materials that had found their ways into the prepared clay can still be removed by picking, while air pockets are expelled by cutting, slamming and the spiral kneading technique. The soluble contaminants are those materials that dissolve in water, stain the clay and cannot be separated through physical means. Two of such soluble materials that are dangerous to production are calcium carbonate and sulfur. When the studio potter slakes some clay in plenty water and allows for some days, calcium carbonate appears as a silvery film on the water surface. The water is drained, more water added and stirred and the process repeated until the silvery film appears no more. In the course of doing this, some other soluble substances such as sulfur are also reduced if not totally eliminated. The truth is that some other useful modifiers may be lost through this practice.

Acidic, Alkaline and Amphoteric Contaminants

1. It is worthy of note that some contaminants can occur as acidic, alkaline or amphoteric (neutral) mediums in clay. Interestingly, ceramic materials are classified under these threes mediums. Some of the contaminants are in very insignificant amount that cannot mar the performance of clay, while some are found in large quantities that must be brought under control, and when the need arises, some are introduced as modifiers to the clay body.
2. A good knowledge of these contaminants and their effects in clay body will position the ceramist for a successful ceramics practice. It is the presence or absence of these contaminants in clay that calls for clay body formulation and blending in ceramic practice.

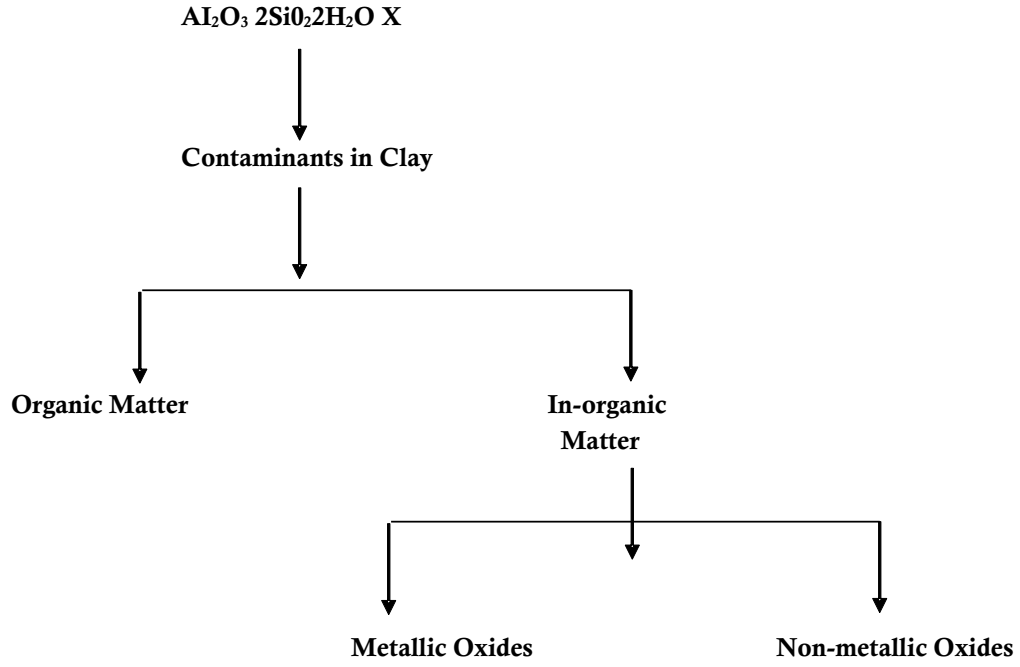

Fig 1: The components of letter "x" in the clay formula

Clay body formulation

A clay body is an acceptable and workable lump of clay. It is a formulated lump of clay ready for ceramic production. Umoh (2021), said that "clay body formulation is a mixture of clay and other essential additives or ingredients, carefully blended as modifiers to achieve a specific ceramic purpose". The act or process of extracting, adding and blending is known 'as clay body formation, composition or formulation'. It is the removal and reduction of harmful materials from the clay and the introduction of useful ingredients as modifiers. A clay body is therefore formulated to have the desired color, texture, shrinkage, verification range, porosity, plasticity and strength in clay that will ensure success.

There are three clay bodies namely, earthenware body, stoneware body and porcelain body that the ceramist must choose from depending on what he wants to produce and the temperature range of the available kiln. Other ceramic bodies the ceramist formulates include casting slip, engobe and glaze. According to Microsoft Students (2008), "to formulate a clay body is to say that not many natural occurring clays have both good working and firing properties, and almost none combines two properties with a good white colour, Among the three clay bodies, earthenware and low stoneware clays occur freely on the earth crust but the high stoneware and especially porcelain bodies must be formulated. While the low stoneware body can be developed to the high stoneware body, porcelain body does not exist at all and therefore must be formulated. A combination of various clays and other materials as additives, artificial contaminants or modifiers gives a better result with each contributing to some specific desirable qualities. This means that if one ingredient should deviate slightly from what is anticipated, the total effect on the body will be minimal.

When clay samples are brought into the studio, the ceramist first of all tries to analyze, identify, label and arrange the materials. This is followed by removal of some visible, solid and un-decayed organic and inorganic contaminants such as rock fragments, pieces of wood, bones etcetera, from the clay. Slaking the clay in plenty of water for many days will help to dissolve some soluble impurities such as alkalis and lime or calcium oxide and calcium carbonate as the clay disintegrates. Draining the water for several days will help to remove reasonable amount of some of those soluble impurities which are likely to mar the production, especially during firing. This is closely followed by sieving with a suitable mesh, to remove excess sand and other tiny but solid impurities. At this point, the ceramist who knows the type of work he wants to produce will determine the type of clay body he needs for the production which in turn determines the essential substances, additives or ingredients to be introduced as modifiers into the sieved clay while in its slip state to allow easy mixing. He may want to reduce or increase plasticity, porosity, shrinkage or maturing temperature. One thing is very certain in clay body formulation, as one introduces the essential substances as modifiers to the clay to improve a property, he must sacrifice another property. It follows that, when plasticity is reduced, porosity is increased and shrinkage is reduced, and when plasticity is increased, porosity is reduced and shrinkage is increased. Thus, when one clay property is increased, another one must reduce.

When the desired clay body has been successfully formulated, the ceramists goes ahead to knead the clay to make it homogeneous. He combines this with wedging which is done to

remove any solid matter found in the clay and most importantly, air which has been trapped in pockets during the formulation and packing processes. In the industry, the de-airing of the clay and the extraction of iron filings as contaminants are done mechanically as mentioned earlier. According to Peters (2001), "Ceramic clay bodies can be formulated using the line blending and the triaxial blending techniques". The line blend involves only two materials, a and b, while the triaxial or triangular blend involves three materials, a, b and c. Where triangular and square pyramids are used for clay body formulation, 4 and 5 materials or clays are used respectively.

Advantages of Contaminants in Clay

To formulate a suitable clay body is to say that some natural impurities such as alkalis, calcium carbonate, excess sand or mineral fragments and excess organic fragments will mar the performance of the clay and therefore must be eliminated or brought under control. It is also to say that certain ingredients need to be introduced as artificial contaminants or modifiers to arrive at a desired clay body for a successful production. It is good to note that clay at its pure state as kaolin is not plastic and therefore will be difficult to shape into forms. Fire clay which serves as main body in clay body formation is also non-plastic in nature. This makes clay contamination either naturally through its movement and fermentation or artificially introduced by the ceramist very necessary for a successful practice.

According to Chapman (1992), "The clay as the ceramics main material is very elusive and subtle in nature therefore it is right to say that it is impossible for the ceramists to claim to know everything about it". Naturally, certain ceramics materials such as alumina, silica, kaolin and a lot more are highly refractory in nature, thus refusing fusion except at very high temperature. It is these contaminants that combine as fluxing agents or eutectic materials to bring down their melting or maturing temperatures. These substances of high melting points which combine to melt at lower temperature different from what they are known for are referred to as eutectic materials, the new temperature, eutectic temperature and the point at which it matures, eutectic point. It is the contaminants in clay that make clay to vitrify at $1,150^{0}$C makes clay plastic and gives various colors to clay. This makes ceramics practice very interesting, adventurous, always an experiment with new discoveries and opportunity for improvement.

It is the contaminants such as wood dust and straw artificially introduced into clay as additives that produces insulating bricks for kiln and furnace building. At the Raw Material Developing Agency in Enugu, South-Eastern Nigeria, coal is broken into tiny chips as additive in the clay body used in producing insulating bricks. The dry bricks are arranged systematically for an open firing. As the coal beneath the arranged bricks is lit, the entire bricks gradually fire themselves with the coal chips in them which finally burns out to create the desired pores with very light weight that makes good insulating bricks.

It is a known fact that there is no free occurring porcelain clay body on the earth surface thus it is formulated by adding the necessary ingredients as artificial contaminants to the clay. When fired to its verification point, it produces a white body, dense, completely vitreous and translucent at thin areas. Slip casting would not have been possible without the introduction of

additives or contaminants such as sodium silicate (water glass), sodium carbonate (soda ash) etcetera as dispersants, electrolytes, or de-flocculants to modify the clay into casting slip for industrial ceramics.

The function of glaze in ceramics which includes rendering ceramic wares smooth to touch, impervious to liquid, more hygienic, more durable, more colorful, beautiful, attractive, and washable cannot be ignored. The truth is that clay alone cannot form glaze without the necessary contaminants naturally present or artificially added. Silica is added as the glass former, alumina in clay as a binder, fluxing agents to lower the melting temperature, refractory agents to raise the melting temperature and oxides as colorants for surface character.

Beautiful surface character or color ascent is also achieved through the use of engobe on wares and clay alone cannot be used without the addition of some glaze materials as contaminants to the clay slip. These glaze materials as contaminants make engobe to fire to a more vitreous state than the body it covers without melting as glaze. Other interesting effects such as in-laid decoration, and marbling or agate effect cannot be possible without the introduction of various oxides into the clay for variety of colors.

Conclusion

Clay which is the major material in ceramics as a product of rock comes in contact with a lot of mineral substances which are referred to as impurities or contaminants. These contaminants determine the different colors of clay and its plasticity, porosity, shrinkage, strength and firing range. While these contaminants serve as modifiers in clay, the presence of some in large quantities can mar the clay and practice. It is therefore the presence or absence of these impurities that calls for clay body formulation to arrive at a workable clay body. The advantages of these contaminants in ceramic practice cannot be over emphasized as they help to modify the clay as fluxing and refractory agents, fillers, de-flocculants and colorants.

A good knowledge of clay and its contaminants will help the ceramists in achieving his desired result in ceramics practice. This is true because the ceramist or potter will know how to handle what is in excess and how to introduce what is lacking, to enhance the performance of his ceramic bodies such as clay bodies of earthenware, stoneware and porcelain, casting ship, engobe and glaze for a successful ceramic practice. From the data carefully collected from available sources and the vetting of this paper by Professor G. Udom of the Department of Geology, University of Port Harcourt, it is clear that clay is contaminated and the contamination plays a key role in the behavior of clay and in the success or failure of ceramic practice, this, the ceramist must understand.

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