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Recent Trends in Scientific Research of Archaeological Pottery in Bangladesh

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Abstract: Pottery uniquely represents the traditions and emotions of the communities that produce and use it. This power to reflect social activities has elevated the value of pottery. Despite being the most commonly recovered cultural material from any archaeological site in Bangladesh, the research on pottery remains inadequate. There have been various ethnological, typological investigations in terms of form, colour, texture, decoration, etc. On the other hand, there is a scarcity of scientific studies focused on the ancient pottery of Bangladesh. Only a handful of petrological and mineralogical research studies have been conducted thus far, offering limited insight and attention to the raw materials, manufacturing techniques, pyro technology, slipping techniques, surface coating, provenance study and other aspects of pottery. This article gives a summary of the pottery research carried out recently in Bangladesh using scientific approaches, emphasizing the information gathered on pottery's raw materials, organic or inorganic inclusions, pyro technique, provenance and additional relevant issues.

Keywords: Scientific, Technology, Bangladesh, Pottery, Petrology, Mineralogy.

Introduction

Archaeology explores numerous dimensions of ancient human existence, including the dynamics of social organization, interactions with and utilization of the environment, dietary practices and system of communication, technological advancements and broader patterns of cultural and societal development. It is mostly based on artifacts from ancient societies that have been discovered and conserved, which are linked to behavioral and transformational processes. Past societies relied on the resources available in their surroundings to survive. Clay was among the materials utilized in the pottery-making processes of these ancient civilizations. Not only the fired clay is a relatively durable substance and resistant to most of the post-depositional deterioration processes (water, organic decomposition and erosion) but it is also an abundant resource for the researcher inherent in archaeology. Pottery, a physical representation of human culture, serves as a crucial tool for archaeologists studying the past due to its widespread production, unbreakable nature and universal discovery (Skibo et al., 1989). Because it endures for a long time and allows for multiple interpretations, it serves as a valuable tool in history.

The early people recognized and exploited the sticky sediments to be shaped and used for a variety of reasons. The transformation of clays into more durable objects by the use of fire must have occurred countless times in the past before humans began regulating and exploiting such objects on purpose (Sinopoli, 1991**)**. But it is impossible to identify the exact beginning of utilization of the clay resources. The oldest clay artifacts from Africa are just tens of thousands of years old, despite the fact that the earliest stone tools date back over a million years. It seems that the use of clay to make pottery was independently developed in a wide range of locations throughout human history rather than emerging in a single era or place (Rice, 1987).

Pottery has been manufactured, designed and utilized by multiple cultures from ancient period (Usman et al., 2005; Skibo et al., 1989). For prehistoric people, pottery was vital for food storage, cooking and creative expression (Townsend, 1985). The abundance of pottery artifacts in the archaeological record has enriched our knowledge of the past, not only because of their creation but also because of how they represent the evolving culture. The continual evolution of vessel form, production and design throughout time provides a unique perspective on the behavioral variables that influence product variance (Rutkoski, 2019). Generally, the study of pottery followed two distinct trends; the first was predominately cultural-historical and sought to establish chronological sequences and the spatial-temporal framework of pottery distribution (typological study). The second study focused on the technological characteristics of pottery, employing multiple types of raw material analysis (such as geochemical and mineralogical analysis) to determine the location of production, the systems of exchange or trade and pottery-forming techniques. Since the 1960s, archaeometry research, particularly concerning archaeological pottery, has advanced greatly (Shepard, 1964; Tite, 1961).

Research Background

Recent archaeological research has emphasized the use of material science and quantitative methods to comprehend artefact alteration (Clarke, 1973; Smith et al., 2012). Regarding pottery, there have been research focusing on technological innovation and migration, compositional analysis, performance characteristics and chemical analyses, all of which aim to improve our understanding of past human behaviour (Hoard et al., 1995; Tite, 1999).

The major objective of scientific research into archaeological pottery is to examine the full life cycle of surviving pottery, beginning with its manufacturing and continuing through its distribution, usage and eventual disposal (Tite, 1999). The analysis of raw materials and techniques utilized in the acquisition and processing of clay, the making of the pot and its surface finish, ornamentation and burning are required to reconstruct the manufacturing technology of archaeological pottery. This information can be deduced from the observed pottery's macrostructure, microstructure and chemical and mineral/phase compositions. The reconstruction of distribution (i.e., provenance studies) entails determining, based on X-ray Diffraction or thin-section petrography or chemical composition, whether pottery was made locally or imported and, if imported, identifying the manufacturing center and/or raw material source (Hunt, 2017).

Scientific Study of Pottery in Bangladesh

The origin of Bangladeshi pottery as an artistic material date back to the Mohenjo-Daro and Harappa civilizations. Pottery first appeared in Bengal, most likely around 1500 BCE. Fine clay is a distinguishing geological feature of an alluvial area like Bengal. This natural resource was utilized by the ancient people of the region to create several potteries. Bangladesh's archaeological sites Mahasthangarh, Govinda Bhita, Bhasu Vihara, Wari-Bateshwar, Raja Harish Chandrer Bari, Mainamati and Paharpur have yielded a variety of potsherds and pottery (Rahman, 2007).

Throughout ancient times, pots have been produced across Bangladesh. Archaeological excavations in Bangladesh have uncovered Early Historic diagnostic pottery, such as Northern Black Polished Ware (NBPW) and Rouletted Ware, establishing connections with distant regions. Bowls, bankers and goblets are the most common types of NBPW pottery discovered at Mahasthangarh and Wari-Bateshwar (Haque, 2007; Rahman, 2007).

Black-and-Red Ware (BRW), NBPW, Rouletted Ware, Black-slipped Ware (BSW) and Knobbed Ware, etc. potteries found in Bangladesh. The potteries from the Chalcolithic and early historic sites have diagnostic characteristics, but the potteries from the early medieval, medieval and late medieval periods do not have any, as metal and other utensils overtook the traditional potteries used as appliances and for everyday religious and domestic purposes (Rahman, 2007). But there has been a lack of scientifically studies devoted to the ancient ceramics of Bangladesh. There are a few research that stand out as among the most notable:

Sharmin and Okada (2012) write an article on *'Surface Coating Technique of Northern Black Polished Ware by the Microscopic Analysis'* (which is published in *Ancient Asia)*. In this study, the authors use scientific methods such as thin section analysis and scanning electron microscopy (SEM) to investigate the composition of the surface coating of NBPW potsherds discovered from the excavation of Wari-Bateshwar and Mahasthangarh (Sharmin & Okada, 2012).

Krishnan and Zulkernine (2012) publish an article on 'On the Typology and Petrography of Wari-Bateshwar Ceramics' in the journal of *Man and Environment*. In this article, they classified Wari-Bateshwar ceramics by studying selected shreds using thin section petrography method (Zulkernine & Krishnan, 2012).

Sharmin, Honda & Okada (2012) publish an article in the *Journal of Asiatic Society of Bangladesh*, which was entitled as 'The Black Surface Coating of Ancient Pottery Excavated from Wari-Bateshwar and Mahasthangarh, Bangladesh'. Here in this article, the authors have tried to identify and explain the composition of surface coating of the NBPW potsherds excavated from Wari-Bateshwar and Mahasthangarh applying different scientific methods including Thin Section and SEM analysis like the previous one (Sharmin, Honda & Okada, 2012).

Akter (2019) conduct a research on the provenance of pottery found from Wari-Bateshwar for the very first time as part of her Ph.D. dissertation. In her research, she use the X-ray Diffraction Method to determine the origin of NBPW, BSW and Red slipped ware's raw materials and estimate their burning temperatures (Akter, 2019). On the basis of her PhD, she publish a research paper titled 'X-ray Diffraction Analysis for Identifying Mineral Composition and Source of Clay in Wari-Bateshwar Pottery: A Preliminary Study' in the journal of *Pratnatattva* in 2020.

Using the X-ray diffraction method, Rafa (2020) studied ceramics from the Nateshwar site, Vikrampur region, in the thesis as a part of her master's degree. In this research, she examined closely the pyro-technology used to burn these ceramics, as well as the nature of the raw materials used in these potteries (Rafa, 2020).

Discussion

The application of X-ray Diffraction (XRD) in the analysis of archaeological pottery in Bangladesh has proven instrumental in identifying the mineralogical composition of ceramics. This technique aids in determining firing temperatures, raw material sources and technological processes used in pottery production, offering valuable insights into ancient cultural practices. On the other hand, microscopic analysis is a fundamental tool in the study of archaeological pottery in Bangladesh. Techniques such as petrographic microscopy provide detailed insights into the textural and compositional characteristics of pottery, enabling researchers to identify manufacturing techniques, temper materials and evidence of use. The Pyrolysis-Gas Chromatography-Mass Spectrometry (Py-GC-MS) has been employed to analyze organic residues absorbed in archaeological pottery from Bangladesh. This method allows the identification of ancient foodstuffs, oils and resins, shedding light on dietary habits, trade and the cultural significance of the pottery. And the Attenuated Total Reflectance (ATR) spectroscopy has emerged as a non-destructive analytical technique for studying archaeological pottery in Bangladesh. It enables the identification of surface coatings, pigments and organic residues, providing a deeper understanding of the materials and technologies used in pottery production. Now, we will briefly discuss the use of these scientific methods in the study of archaeological pottery in Bangladesh:

Use of X-ray Diffraction (XRD) Method

In archaeological research, X-Ray Diffraction is not a new technique. In previous times and even more so today, XRD is a popular method used for archaeological records in a wide range of research fields. X-ray diffraction identifies mineral phases, typically the inclusions and gives an estimated firing parameter. The method has proven effective for archaeologists to study a wide range of materials that necessitate a special emphasis on the structural characterization of their composition. Furthermore, XRD has been used to investigate and determine artefacts' raw materials. Because of this, archaeological studies that concentrate precisely on pottery have come to accept XRD as a basic method of research. XRD made it possible to distinguish between the wares of different workshops in the same region, each of which uses slightly different clay resources or clay mixtures (Orton & Hughes, 2013).

Two research papers have been carried out in Bangladesh using the XRD method for archaeological investigation. Both Akter's PhD dissertation and Rafa's master's thesis are examples of the XRD research projects (Akter, 2019). The two examinations were conducted associate with Md. Khairul Islam, XRD Scientist of Wazed Miah Science Research Centre, Jahangirnagar University, adhering to the sample preparation protocol established by Moore and Reynolds (1997). In these study, pottery and clay samples were ground into powder using an agate mortar and pestle to create powder samples. To prevent mineral fractionation, particles must be smaller than .062 millimetres. The sample was then swept into the cavity of a standard sample container (15 mm x 0.9 mm). After filling the container with powder, then packed the sample into the cavity using a roughened glass slide. This packing must be strong enough so that the contents do not fall out, distort, or slide, but not so rigid as to produce orientation preferences. To disrupt surface adhesion, the glass cover was carefully lifted with a little twisting motion. This was done with extreme caution, as it was the X-ray-exposed surface. The sample holder was thereafter affixed to the mounting base.

In Akter's dissertation, she examined contemporary and ancient pottery, together with soil samples from Wari-Bateshwar (Akter, 2019). For the analysis, samples were obtained from modern pottery and the clay used in pottery production at the potter's house, as well as archaeological pottery and the archaeological soil of the T2 trench. Five modern pottery samples from three potter houses in three distinct pottery villages, as well as four sediment samples (which potters employ to create pottery) from two pottery villages, were analyzed in total. In contrast, the analysis of nine archaeological potteries and five archaeological soil samples from the T2 trench excavation has been completed.

Quartz, illite, muscovite and haematite, chlorite, oligoclase, albite, kaolinite, wollastonite and diopside were the estimated mineral determined by XRD for Wari-Bateshwar shards and soil samples. In all samples, quartz, illite, muscovite and haematite were encountered as common mineralogical phases. The compositions of minerals across all samples were largely consistent, comprising quartz, illite, muscovite and hematite in varying proportions, with quartz being the predominant material in every instance. In the majority of instances, the concentration of Hematite and Muscovite was below 7%. Illite content exhibited considerable fluctuation, remaining below 15%. Similar to contemporary pottery specimens, ancient potteries lacked Wollastonite peaks. All of the ancient pottery comprises Kaolinite akin to contemporary pottery. Diopside was frequently present in ancient pottery, although contemporary pottery lacked this mineral. The metastable phase Diopside was identified as a minor ingredient in archaeological soils and pottery. In all instances, the compositions of trace mineral phases (e.g., Oligoclase, Albite, Diopside, Wollastonite, Chlorite, Kaolinite, etc.) were below 0.05%. An addition, archaeological soils contained chlorite, but archaeological potteries did not. The decomposition of chlorite was characterised by the disappearance of reflections, which occurs between 700°C and 750°C (Nodari et al. 2007). This served as a further argument in favour of archaeological pottery's utilisation of high-temperature annealing. Consequently, it was ascertained that significant amounts of resemblances were detected in the mineralogical composition of samples from all settings, including ancient pottery, contemporary pottery, trench soil and soil samples obtained from modern pottery. The X-ray diffraction study of the ancient pottery sample, modern pottery sample, trench soil and soil from modern pottery revealed commonalities in the mineralogical makeup of all samples. So, it would be plausible to assume that ancient potters utilised the locally sourced clay as their primary raw material. The determination of the firing temperature of the ceramics relied on the presence or lack of certain mineral assemblages in the soils, fired clays and pottery. The firing temperature range for potteries produced in an oxidising environment, mostly composed of quartz and including high-temperature phases like as wollastonite, was predicted to be between 1050°C and 1100°C.

In Rafa's thesis masters dissertation, the X-ray diffraction method was employed to analyze 10 sherds from Nateshwar in order to ascertain the raw materials used in the pottery's production and to identify the mineralogical and technical characteristics along with firing parameters of the pottery during the various cultural phases (Rafa, 2020). Nateshwar comprised sixty-four units and three units—K-09, K-08 and L-08—were randomly selected for this study. Regarding this investigation, the sample selection started within layers 4, 5 and 7, which were obtained from 2017-2018 excavations. A completely random sample method was employed to choose the ceramics and ten distinct types of pottery, including tableware, cookware and utilitarian pieces were selected. This experiment incorporated the following samples: two from layer 7, four from layer 5 and four from layer 4. Based on the results of an XRD test conducted on the shards of ancient pottery, it has been determined that these fragments contain minerals such as quartz, muscovite, albite, illite, vermiculite, diopside and wollastonite. The X-ray diffraction analysis of these pottery samples demonstrated that the mineral composition of the samples from Layers 7, 5 and 4 is nearly identical. Layer 7, 5 represents the First period (770-950 AD), while Layer 4 represents the Second period (800-890 AD). As a result of the mineral compositions' similarities, it would be possible to infer that the supply basin of raw materials for pottery remained identical each phase. So, it was clear that potters had been producing pottery using the same raw materials and method for an extended period of time. The pottery from the Nateshwar site contained various minerals such as diopside and wollastonite, which are derived from calcite. It appeared that the majority of the pottery was likely produced using soil that contained calcium (calcareous) based on the XRD information. According to the findings of the XRD, the presence of a good amount of calcareous types of minerals in all of the samples suggested that the potteries were made from a calcareous source. Conversely, the presence of minerals that are stable at temperatures between 700 and 950ºC, such as albite, wollastonite and diopside, indicates that the potters fired their wares at temperatures between these parameters (Gliozzo, 2020). In general, calcareous potsherds were burned between 700-950ºC in both oxidization and reduction environment. Despite the fact that the mineral contents are nearly identical, there is a discernible distinction in the mineral composition of cookware and tableware. The mineral vermiculite was found in trace amounts only in tableware. Given the significant functional disparity between the two categories of utensils, it is logical to infer that the process of preparing raw materials for cookware and tableware was conducted in a distinct manner.

Use of Microscope

A remarkable achievement of modern scientific research is being able to use the microscope to observe substances invisible through the normal eye. Microscope permits us to look into objects beyond the capacity of the unaided sight, granting access to realms that scientists could not conceive a few centuries ago. The microscopic examination of materials, including minerals, rocks, ores, ceramics and other synthetic products, in emitted and reflected light, remains one of the classic and still essential mineralogical methods of analysis (Guide to Thin Section Microscopy, 2011). Thin sections of archaeological ceramics are typically examined under a microscope. The relationship between thin sections and microscopes is essential in ceramic studies; the absence of one would provide only a partial account of the ceramic's basic substances. Thin section gives researchers more information about ceramic technology, origin and trade and it additionally assists them to discover more about the ceramic object they are working with (Riederer, 2004).

Two thin-section investigations have been conducted in Bangladesh using microscopes. Among these, Dilruba used both optical and SEM to examine thin slices of pottery, while Zulkernine applied a polarizing microscope to examine thin sections of pottery.

An extremely potent technique for investigating the microstructure of ceramics is provided by SEM with attached analytical facilities. This technique is capable of determining the composition, identity, shape and distribution of the various crystalline and glassy phases present (Tite & Maniatis, 1975). Ms Dilruba collected a total of 30 black potsherds from Wari-Bateshwar & Mahasthangarh. Out of these, 18 were procured from Wari-Bateshwar and the remaining 12 artefacts were retrieved from the Mahasthangarh site. The focus of her research was on the scientific investigation of surface coatings to determine their origin, material properties and future conservation. She conducted this analysis using four fundamental methodologies. She employed the 'Polished thin section method' to produce a thin section of potsherds for examination in a scanning electron microscope (SEM) and an optical microscope (Nikon Digital Camera DXM 1200F, Japan). The thin section of the collected potsherds was prepared using the 'Polished Thin-Section Method' in this research. The potsherds that were to be used for thin sections were split into multiple fragments, each measuring approximately 2.5-4.0 mm. The potsherd specimens were subsequently inserted into epoxy resin. Subsequently, the embedded samples' surfaces were polished and ground level using wet-type sandpaper. The samples were affixed to the slide glass with epoxy resin (Adeka resin) and the upper surfaces were observed using a stereoscopic or metallurgical microscope. The sample's opposite side was polished and ground until it reached a thickness of approximately 20 µm. Next, the optical microscope and SEM were employed to examine the prepared slide. The Art Research Institute's laboratory at Kyoto University of Art and Design in Kyoto, Japan, was the site of all microscopic analyses. In her study, microscopic examination indicated that the surfaces of all 30 pieces of black pottery potsherds were thickly coated. A binocular microscope (Olympus SZH10) with Fibre light FL-50 was used to look at these potsherds from Wari-Bateshwar. Based on what was seen, 17 of the potsherds had a black, shiny layer on both the inside and outside [Type A]. On the other hand, one shard was not shiny and had a lot of clay piled up on both sides [Type B]. At the Mahasthangarh site, twelve pieces of black pottery were retrieved and ten of these potsherds had the same traits as Wari-Bateshwar [Types A and C]. But the last two pieces [Type D and Type E] were looked at with binoculars, they were found to be different from each other also.

All the collected potsherds were examined by optical and scanning electron microscopic and the results showed that the coatings of the potsherds of Type A and Type C were produced using the same technology and they contained a two-stage layers with two separate origins.

The original potsherds of NBPW are Type A and Type B potsherds. The black-coloured potsherds of Type B, Type D and Type E that were examined were distinct from those of Type A and Type C. A solid and dense coating was observed on the outermost layer of the potsherds of Type B, Type D and Type E during the thin section observation. This solid coating was directly affixed to the main surface of the pottery and there was no clay-made slip, as was the case with Type A and Type C. The technique of coating of the black-coloured potsherds of Type B, Type D and Type E differs from that of Type A and Type C (NBPW).

Zulkernine and Krishnan (2012) has classified the ceramics from Wari-Bateshwar based on variables including colour, surface treatment, texture, hardness, embellishments (such as paints, incised motifs and imprints) and vessel shapes. Representative samples of these ceramics underwent thin-section analysis. A polarizing microscope (Leitz Laborlux 12 Pol-D) was used to examine the sample thin-sections. The mineralogy of non-plastic inclusions above 30 µ in size was determined by their optical characteristics. Inclusions less than 30 µ were regarded as components of the matrix. The ceramic microstructure's composition led to the categorization of the thin sections into several fabric groups. 29 ceramics from Wari-Bateshwar were thin-sliced in order to determine the origin of the raw materials, the clay paste's texture and the microstructural characteristics of the various items. The thin section samples were categorized into five primary groups based on their mineralogical composition: A, B, C, D and E, with fabric group A containing a subgroup A1. Differences in texture were used to define the subgroup. The mineralogical composition suggests that clay may have been sourced from two distinct locations. This conclusion is derived from analyzing the fluctuations in the relative abundance of certain minerals. In Fabric A, the predominant mineral in Al and D is quartz. The differentiation between A and its subgroup A1 is mostly attributed to the change in texture. Fabric A, A1 and D may be classified as quartz fabric, with A and A1 being sand-tempered due to their higher proportion of extremely fine sand compared to silt. Fabric D is tempered with silt. Pottery associated with Fabric groups B, C and E may have been crafted from identical clay types. These exhibit a relatively high percentage of altered plagioclase, with quartz being the second most prevalent mineral in these fabrics. Nonetheless, a distinct disparity in their texture is evident. Fabrics B and C are sand tempered due to a greater quantity of extremely fine sand compared to silt, exhibiting a bimodal grain size distribution. Fabric E has a significant proportion of silt, with sand being the secondary component. The mineralogical resemblance among B, C and E suggests a shared geological origin of the raw material, however the textural variation implies a divergence in clay paste fabrication methods.

Therefore, it can be asserted that the clay utilized for the production of the examined pottery originates from two distinct sources.

Use of Pyrolysis-Gas Chromatography-Mass Spectrometry (Pyro-GC-MS)

Pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) is an essential instrument for evaluating cultural heritage materials, especially those with sophisticated polymerised structure, regardless of their natural or synthetic source (Poulin et al., 2022). In addition, the use of Pyrolysis-Gas Chromatography/Mass Spectrometry (Py-GC/MS) is extending our ideas of ancient ceramic material — instead of static archaeological artifacts from the past, these materials can be treated as dynamic historical records, speaking in a molecular language. Such a qualitative analytical approach goes deep into ceramic internal, demonstrating stories that conventional means cannot tell. At a fundamental level, Py-GC/MS enables researchers to read the molecular (and more) memories locked away in ceramic artifacts. Pyrolysis of a ceramic sample occurs when thermal depolymerization takes place quickly enough to produce an output of by products at high enough temperatures to char — hot air pyrolysis — and disrupt molecular bonds, leading to gas-phase toxicant fragmentation in output gases, leaving behind chemical signatures that signify its past. These signatures represent so much more than just scientific data

In the laboratory of the Department of Applied Chemistry at the School of Science and Technology at Meiji University in Tokyo, Japan, Dilruba employed the Py-GC/MS method to determine the origin of the applied coating on seven potsherds that were collected for her research. Four of the seven pieces are classified as Type A, one as Type B, one as Type D and the remaining piece is classified as Type E. The Agilent 6890N/5975 GC/MS instrument (Agilent Tech. Santa Clara, CA) and a vertical micro-furnace-type pyrolyser PY-2020id (Frontier Lab, Japan) were employed to conduct the Py-GC/MS measurements. The separation was conducted using a stainless-steel capillary column (0.25 mm i.d × 30 m) that was clad with Ultra Alloy PY-1 (100% methyl silicon). Initially, a modest quantity of the sample (0.5 milligramme) was dissolved in 1 µg of tetra methyl ammonium hydroxide [TMAH]. Subsequently, the sample was subjected to reactive pyrolysis gas chromatography/mass spectrometry analysis [TMAH/Py-GC/MS] in a thermal cracking furnace. At approximately ambient temperature, a sample cup was positioned on top of the pyrolyser. The gas chromatograph oven's temperature program was initiated after the sample cup was inserted into the furnace at 500ºC. The gas chromatograph chamber was programmed to maintain a constant temperature increase of 20ºC per minute from 40 to

280ºC and then to maintain this temperature for 10 minutes. The helium gas flow rate was 1 ml/min and the injection and interface temperatures were maintained at 280ºC. The energy of ionisation in the EI-mode of mass spectrometry was 70 eV.

The Py-GC/MS data concluded that oil (fatty acid methyl ester) and thitsiol [3-(12-phenyl-dodecacyl) catechol] were detected in the surface coating of these potsherds. This study serves as a preliminary resource for examining the production process of antique black pottery from Bangladesh and South Asia. This study asserted that there were two distinct varieties of coating on NBPW, which were derived from two separate resources. Additionally, tree-based lacquer coated ceramics was employed in antique Bangladesh. Therefore, the existence of lacquer-coated pottery in the current Bangladeshi context could indicate two possibilities: Initially, the lacquer harvested tree was extant in ancient Bangladesh and the harvested lacquer was employed in the indigenous pottery as a surface coating. Secondly, lacquer was imported from outside of Bangladesh and applied to the surface of indigenous pottery as a coating material. Third, lacquer-coated pottery was imported from sources outside of Bangladesh.

Use of Attenuated Total Reflectance (ATR) Spectroscopy

In Bangladesh, just one piece of black potsherd was examined using ATR spectroscopy by Dilruba. A thermo-Nicolet iN10MX FT-IR microscope equipped with an MCT detector chilled by liquid nitrogen was used. The ATR spectra were obtained within the range of 4000-650 cm^{-1} with a spectral resolution of 4 cm^{-1} applying a slide-on ATR objective with glass. A background single-beam spectra of the pristine ATR crystal was first acquired with the slide-on ATR objective positioned but not interacting with the sample surface. A total of 32 scans were documented for the purpose of interferogram averaging. For the ATR mapping of a designated region (420×110 µm for sample Type D), a step size of 20 µm in the x-direction and 10 µm in the y-direction was selected, using an aperture of 10.25 µm. The ATR mapping of the potsherd from the Mahasthangarh site (Type D) was performed to reveal a significant concentration of a component containing a C=O bond on the surface of the examined potsherd. If organic acid permeated the pottery from the surrounding soil before burial, the C=O bond should be consistently present throughout the body clay. Nonetheless, the ATR mapping results reveal that the coating was evenly applied to the surface of the analysed earthenware (Type D). Based on this measurement result, it is possible that oil was utilised as a coating material on the surface of the analysed potsherd and that this coating does not constitute any kind of pollution.

Concluding Remarks

Pottery is one of the tangible products of human culture. Pottery has a 'reflective character' because it represents the needs, religious views and preferences of past cultures and is one of the most potent socioeconomic indicators available to us. Archaeologists heavily rely on pottery because of its mass production by various cultures, longer preservation periods and widespread use, making it an invaluable resource for learning about the past. Archaeologists want to reconstruct the manufacturing technology of ancient pottery by analyzing raw materials, sources of energy, manufacturing techniques, surface polish, decoration, burning and procedures used in clay acquisition and processing. The macrostructure, microstructure, chemical composition and mineral/phase compositions of the pottery provide this information. Consequently, we can estimate the significance of scientific research on historic pottery. However, scientific research on pottery is infrequently carried out in Bangladesh.

To date, researchers have applied four different types of scientific methods to archaeological pottery in order to identify the raw materials, pyro technology, surface coating, inclusion and provenance. The use of XRD to the pottery of Wari-Bateshwar and Nateshwar revealed the characteristics of the raw material and the combustion temperature. Researchers have established the burning temperature of the pottery from Wari-Bateshwar to be between 1050-1100ºC. Researchers have identified the mineralogical properties of the raw materials utilized in the pottery, which primarily comprise quartz. Moreover, a comparative analysis of the mineralogical composition of modern pottery and soil samples against historical samples support the local manufacture of this pottery. Conversely, pottery from Nateshwar has a firing temperature ranging from 700 to 950ºC, as revealed by its mineralogical properties. Their mineralogical composition (diopside and wollastonite are calcium-based minerals) suggests that their raw materials originate from calcareous soil. Consequently, the calcareous floodplain in the Padma basin demonstrates that these products are native to the area. The microscope has introduced an innovative dimension to pottery studies by yielding intriguing insights. Researchers used a polarizing microscope on the thin section of potsherds to determine the mineralogical composition of the Wari-Baleshwar's pottery. Pottery was divided into 5 categories based on its mineral composition. The raw materials of pottery are plagioclase-based with an abundance of quartz minerals. Additionally, some pottery uses a sand-based temper, while others use a silt-based temper, resulting in a variation in texture. By looking at the mineralogical resemblances of the pottery, their geological origin can be understood to be the same. The mineralogical similarities of the ceramics indicate a common geological origin. However, the variance in textures indicates variation in the preparation of clay paste. Researchers have examined the surface coating of Wari-Bateshwar and Mahasthangarh pottery using optical and scanning electron microscopes on thin sections of the potshards. The thin section analysis indicates a thick coating on both the black and NBPW samples. Furthermore, researchers discovered evidence indicating the application of two layers of slip on NBPW ceramics. Also, the NBPW's top coat achieved glossiness by either impregnation or the application of a non-clayey substance above the slip. To determine the top coating, NBPW and black pottery from Wari-Bateshwar and Mahasthangarh were examined using Py-GC. The presence of oil (fatty acid methyl esters) on the topmost layer of Type A and Type C (NBPW) potsherds is confirmed by the Py-GC/MS test. So, the slip was applied to achieve the black colour of the surface and the top coating was for the lustrous black surface of NBPW. However, Black Pottery (Types B, D and E) uses a different coating method. ATR mapping analysis was conducted by the researchers on a single potsherd (Type D) from the Mahasthangarh site to verify the coating application procedure. The ceramic they examined had a thick, even layer on its surface. This measurement result raises the possibility of using oil as a barrier to the surface of studied potsherd. This limited yet significant information illustrates the nature and character of the Bangladeshi antique ceramics. But we anticipate that there will be significant developments in pottery research as technology evolves in the near future. Scientific investigation of pottery from all Bangladeshi archaeological sites will reveal many of the technological and enigmatic aspects of the past.

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