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Original Paper

Micro-PIXE: A Powerful Technique in Measurement and Determination of Raw Materials of Glass Artifacts of Parthian period From Shaur (Susa)

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Abstract

Investigation of scientific archaeological excavation reports in Iran indicated that these excavations yielded a large number of fragments of glass objects from many archaeological sites, but a very limited number of preliminary studies on elemental analysis of a few Iranian glass objects have been published. Also, a literature survey on pre-Islamic glass objects (especially from Parthian and Sasanian epoch) indicates that there are only a few studies on a limited number of Sasanian and Parthian glasses from Iraq, too. However, a systematic analysis of the Parthian glasses artifacts from Iran is still missing and until now, no reports has been reported about the chemical composition of Parthian glasses from Iran. Therefore, for the first time, the chemical composition of Parthian glass objects from the Shaur Palace at Susa in Khuzistan Plain have been considered. Shaur Palace locates at the west of the ancient site of Susa, next to Shaur River, Khuzestan province, south-west of Iran. It has been excavated by a joint French-Iranian team since 1970 to 1976. There were recognized three Islamic, Parthian, and Achaemenid strata. In this work, 21 glass objects date back the Parthian period were analyzed by Micro- PIXE technique in order to measure the constituent elements and to investigate the types of glass and raw materials used in the manufacturing recipe. The micro-PIXE measurement was performed with scanning proton microprobe system manufactured by Oxford Instruments using the 3 MV Van de Graaff accelerators at the Nuclear Science & Technology Research Institute in Atomic Energy Organization of Iran. The samples were analyzed in a vacuum chamber using a beam of 2.5MeV protons focused to a diameter less than 10 μm. The beam current was in the range of 30 to 50 pA. Characteristic X-rays were detected using a Si(Li) detector with an active area of 60 mm^2 positioned at an angle of 135° relative to the incident beam direction and with an energy resolution of 150 eV for Fe-Kα. Analyzed samples were fragments of the body, rim, bottom, and handle of vessels such as bowls, bottles and beakers. They were generally green with a nacreous coating, resulted from surface corrosion due to long-term burial in the soil. Also, 90% of glass objects manufactured at Shaur Palace were manufactured on free blowing method and most of them were plain and undecorated. Elemental analysis of the glass artifacts by micro-PIXE indicated that the constituent elements of the samples are sodium, magnesium, aluminum, silicon, phosphor, sulfur, chlorine, potassium, calcium, titanium, manganese, and iron, with different concentration and weight percent percentage (wt%). Determination and measurement of each of these elements respond to questions raised about the technology, type of the glass and raw materials of manufacturing recipe. The micro-PIXE analysis showed that these samples are mainely composed of SiO_2 (63-65 wt %),

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Na_2O (13-18 wt %) and CaO (6-8 wt %). Consequently, all these samples are Silica- Soda- Lime glass type. However, the amounts of magnesium oxide (MgO) and potassium oxide (K_2O) in all analyzed samples were more than 2.5wt%, where their contents vary between 2.5 to 5wt%, and 2.5 to 4.5wt%, respectively. Therefore, it is was clear that the ashes obtained from halophytic plants are considered as supplying source for soda in these glasses, so these glasses are Plant ash Silica- Soda- Lime type. Moreover, the micro-PIXE results clearly revealed that in the manufacturing of all shaur glass objects the same sources of silica and plant ashes have been used. In addition, the strong linear correlation of minor elements in the samples indicated that colorants and decolorizing agents have not been intentionally added in the manufacturing process.

Keywords: Glass, Shaour, Parthian, Elemental Analysis, Micro-PIXE.