Instrumental Neutron Activation Analysis (INAA) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for the Analysis of Bones of Prehistoric Animals and Humans

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Bones of prehistoric animals and humans have always been a precious source of archeological information and can be frequently abundant in archeological sites. Much of interest is in their elemental composition because it can open the way for better understanding of the prehistoric environment, including climate, and also the biochemistry of the species of that time. Due to long-term contact of skeletons with soils, up to several millions of years, to decipher the true elemental composition, it is important to understand the processes of migration and accumulation of these elements from soil, as well as, possible, radiation effects e.g. spontaneous and neutron induced uranium fission these specimens could have experienced.

Instrumental Neutron Activation analysis (INAA) in which samples are irradiated by the thermal neutrons (KE<0.025 eV) followed by detection of the induced gamma activities of the radionuclides, has been a golden standard in analysis of elemental composition of various artefacts. Although being a multi-elemental technique capable of analysing the samples regardless of their chemical composition, a very high cost and low sensitivity for some elements e.g. Li, Be, B, F, S, Fe, Cu, Nb, Pb, and others, has been the main limitations. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) has been recently developed by the various vendors of the scientific equipment to become a relatively low cost product that offers table-top instruments, in some cases, equipped with several mass filters and collision/ reaction cells for manipulation of molecular beams pushing the sensitivity down to *ppb* -level for many elements. In case of bone samples, the acid digestion for under an hour is required to bring the samples into the liquid phase prior to the ICP-MS analysis which itself takes <10 min.

In this work we have applied both INAA and ICP-MS methods and analysed the elemental composition (64 elements) of bones of dinosaurs, South mammoths, prehistoric bear and archanthropus as well as the samples of surrounding soils; everything collected in different parts of Uzbekistan [1-3]. A reasonable agreement between the two methods has been observed, with expected better precision of ICP-MS for some trace elements, and INAA [4] as being more suitable for bulk analysis of e.g. Na, Ca and P. The correlation of the bone/soil elemental ratio with the age of the sample (accumulation coefficients or mobility) of several elements have been studied. The most accumulated elements are U, Cr, Zn, Sr, and lanthanides which can be due to either a long period of time the samples spent in the soil or attributed to some anomalous phenomena in the past. Cr, Co, and Ba are least mobile elements. A high concentration of uranium we detected in the bones of dinosaurs (122 mg/kg), South mammoth (220 mg/kg), prehistoric bear (24 mg/kg) and archanthropus (1.5 mg/kg) compared to surrounding soils (3.7-7.8 mg/kg) and standard bones (<0.01 mg/kg) is a bit of a puzzle. The uranium fission elements (La, Ce Nd, Sm, Eu, Tb, Yb, Lu, As, Br and Mo) have been also detected in these bones.

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