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Age Determination of Pookerdvall pottery samples based on Thermo-luminescence behavior and their glow curves.

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ABSTRACT

The constituent material in the pottery contains crystalline grains that can absorb emitted energies from radioactive material. Age of the pottery can be determined by measuring stored energies in the pottery and annual dose. Thermo-luminescence is the common method for pottery dating. There are several procedures for measuring total energy in the pottery (Paleodose) by this method. By thermo-luminescence dating in the age determination laboratory of Research Centre for Conservation of Cultural Relics of Tehran Province (the only age determination laboratory in Iran), additive dose always has been used for Paleodose. The major aim in this research was using regeneration method for measuring Paleodose which has much more precision than other methods and needs smaller amounts of samples. For this purpose and age determination, five samples of potteries were chosen from ancient Pookerdvall (Gorgan, Iran) site.

Keywords: Age determination, thermo-luminescence, Pookerdvall, addition method, regeneration method.

INTRODUCTION

Thermo-luminescence of ancient pottery firstly was detected in the Bern and California universities. During 1960s thermo-luminescence was developed for archaeological dating at Oxford by Aitkin and his research team [1]. In this research five pottery sample were chosen from Pookerdvall ancient site for age determination by thermo-luminescence. Pookerdvall ancient site is a hill that located about 1 kilometer of Ouzineh village in Gorgan-Gonbadkavous (Iran) in North corner of main road and at west of Pookerdvall river in the southeast of Caspian Sea.

All experiments have done in age determination laboratory of Research Centre for Conservation of Cultural Relics of Cultural Heritage and Handy Crafts and Tourism Organization of Tehran Province.

MATERIALS AND METHODS

Instruments

1. Thermo-luminescence instrument: ELESC T/L OVEN CONTROL UNIT 7188.
2. Alpha Counter: ELESC LOW LEVEL ALPHA COUNTER 728.
3. Flame Photometer 410- Sherwood.
4. Dosimeter TLD-400**.**

Sample preparation

Sample preparation begins, after a 2-mm layer from each surface has been removed by sawing a diamond- impregnated wheel. By washing the products of this operation in acetone, a suspension of fine-grains is obtained, an ultrasonic bath being used to disperse coagulation. Making use of the fact that settling time is determined by diameter, grains in the size range of 1 to 8 μm are separated; these sizes correspond to settling times of 20 min and 2 min, respectively, for a 60-mm column. The separated grains are then resuspended in acetone and allowed to deposit on aluminum discs in a thin layer of a few microns thickness [1-2]. Figure 1 show 5 pottery specimens from which the samples were prepared for age determination.

Figure 1. 5 pottery specimens which were studied in this investigation,

a)15041, b) 15153, c) FV, d) DVa, e) GX

RESULTS AND DISCUSSION

Annual dose-rate measurements

The measurement of radioactivity and its evaluation in terms of the annual dose which has been received by sample has the same importance as measurement of thermo-luminescence.

For the majority of samples, approximately the entire annual dose was provided in roughly parts, by potassium, thorium, and uranium. The remainder, a few percent, comes from rubidium and cosmic rays. The radioactivity of potassium is due to its isotope potassium-40 [1-3].

For measuring the concentration of thorium and uranium, Alfa counter was used and for measuring of potassium-40, measuring by flame photometer was applied. For measuring the radioactivity of in burial soil around the pottery samples, two dosimeters were used and for measuring environmental dose two packages (A and B) of 5 CaF_2 crystallines were used. Glow curves of natural thermo-luminescence of these samples are shown in figures 2. Based on experimental data the average dose rate was obtained 1.155 mGy/ year.

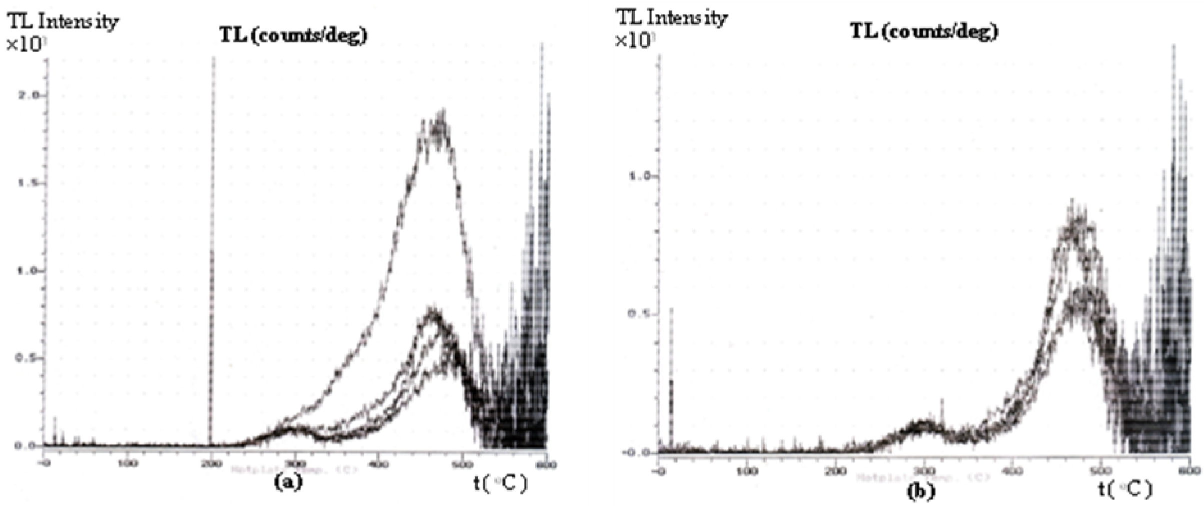

Figure 2. Glow curves of natural thermo-luminescence for (a) package A and (b) package B

Natural thermo-luminescence intensity measurement

As the samples prepared in form of pellets, natural thermo-luminescence intensity has been measured by using thermo-luminescence instrument. For example, the curves of natural thermo-luminescence intensity for MO-15041 and MO-15153 samples are shown in figure 3.

Paleodose-rate measurement

Paleodose shows the rate of accumulated radioactivity during archaeological times in the samples. The simplest approach to the evaluation of Paleodose is by the straight forward procedure of measuring the natural thermo-luminescence from a portion of quarts grains and comparing it with the artificial thermo-luminescence from the same portion of grains after exposure to a known dosage of radiation from a radioisotope source [1]. Two methods have been applied for determining the Paleodose; Additive dose and Regenerative dose method.

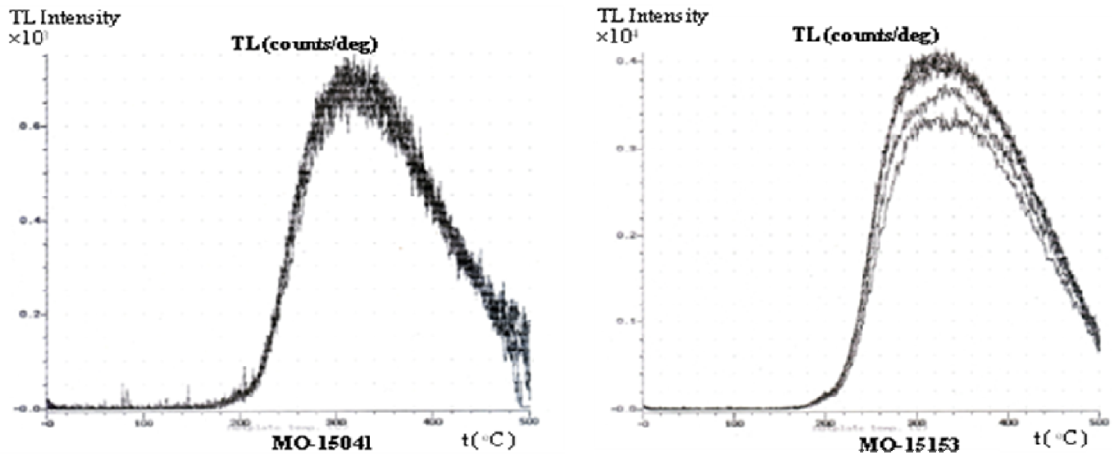

Figure 3. Natural thermo-luminescence intensity curves of MO-15041 and MO-15153

A Additive Method

The additive method was the routine method for determining the paleodose in laboratory of Research Centre for Conservation of Cultural Relics of Tehran Province. Experiences Show that additive method has more accuracy and precision than regenerative dose method.

In the additive dose method, measurements are performed on a number of weighed portions of the quartz grains, usually in the region of 5 mg of each portion. Several of these portions are used for measuring natural thermo-luminescence, others for measuring natural and natural + artificial thermo-luminescence. After normalization, according to the weight, the thermo-luminescence intensities are plotted and the equivalent dose Q is evaluated, as shown in Figure 4. Obtained Q by this method is not necessarily equal to paleodose. This is because of supralinear growth of thermo-luminescence with dose which shows the second-glow characteristic of growth obtained by measurement of the thermo-luminescence from portions which have been irradiated after drainage in the course of the first glow (Figure 5). Using the intercept I, the paleodose is taken to be $Q + I$ [1 and 4], (Table 1).

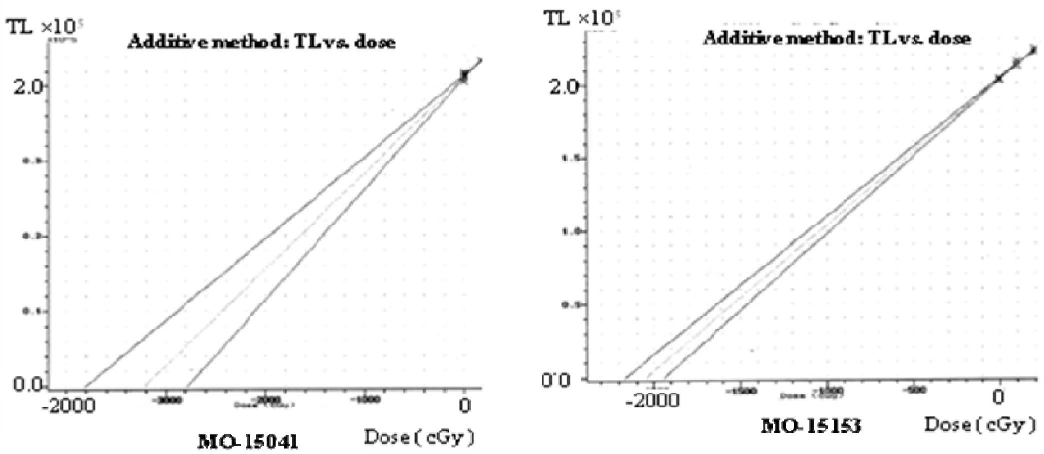

Figure 4-Evaluation of Equivalent dose *Q*, for pottery sample MO-15041 and MO-15153 by additive method

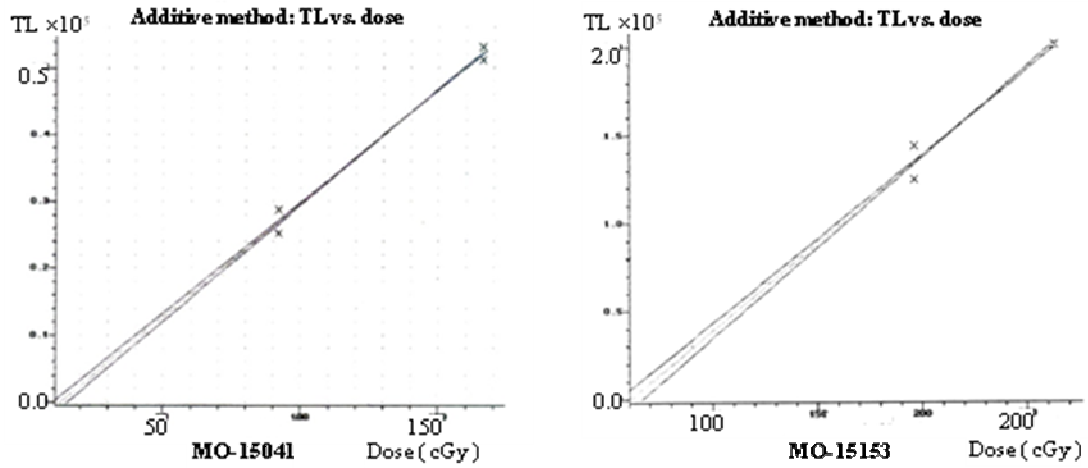

Figure 5- Second-glow characteristic for evaluation of supralinearity correction *I* for pottery sample MO-15041 and MO-15153 by additive method

Table 1. The result of paleodose calculation by additive method

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Samples	**Q (Gy)**	**I (Gy)**	**P = Q + I (Gy)**
MO – 15041	32.16	0.11	32.27
MO – 15153	20.23	0.61	20.84
MO – FV	12.95	0.62	13.57
MO – Dva	17.99	2.31	20.30
MO – GX	30.01	2.51	32.52

B Regenerative Method

In the regenerative method, except for measurement of natural thermo-luminescence, all portions are subjected to long bleaching and then artificial irradiations are administered, thereby regenerating the thermo-luminescence growth characteristic; of course a new portion must be used for each data point. The Paleodose is read off from a horizontal line as in Figure 6 drawn at the level of the natural thermo-luminescence [1]. The values of Q and P obtained by regenerative method are shown in table 2.

The results of Paleodose for both methods are presented in table 3. By attention to these results, it could be observed that the Paleodose rate is approximately close at both methods. So it is proved that the regenerative method has a good precision and accuracy.
The plateau test has been done for all the pottery samples for their thermo-luminescence glow-curves, and the stable region was recognized [1].

The sensitivity of the samples to alpha source, also, was measured [1-2].

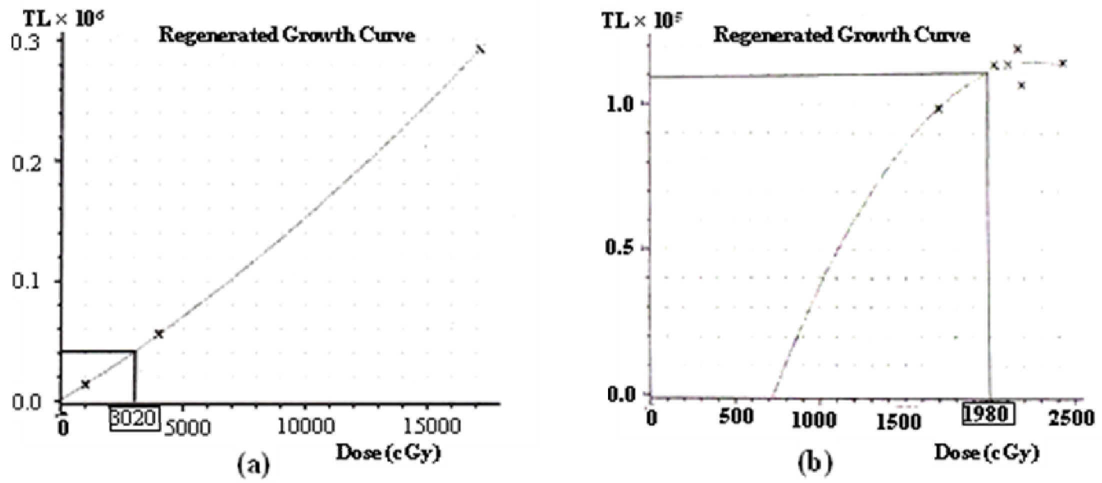

Figure 6. Evaluation of paleodose, for pottery samples (a) MO-15041 and (b) MO-15153 by regenerative method.

Table 2. The values of Q and P by regenerative method

Samples	***P = Q* (Gy)**
MO-15041	30.20
MO-15153	19.20
MO-FV	13.07
MO-DVa	21.52
MO-GX	31.67

Table 3. Paleodose rate results from both additive dose and regenerative dose methods

Samples	***P = Q + I* (Additive dose)**	***P = Q* (Regenerative dose)**
MO-15041	32.27	30.20
MO-15153	20.84	19.20
MO-FV	13.57	13.07
MO-DVa	20.30	21.52
MO-GX	32.52	31.67

Determination the value of Alfa and Beta rays effective energy and *k*

The artificial dose of alpha radiation has been done by Alpha Source ^{241}Am, 721/A,182 µm Curies, and the artificial dose of beta radiation has been administered by Beta Source ^{90} Sr, 732, 100 m Curies. The value of *k* is used for determination of paleodose rate.

The values of Q_α, Q_β and *k* are shown in table 4.

Table 4. Obtained values of Q_α, Q_β and *k*

Samples	Q_α (Gy)	$Q_{\beta(additive)}$ (Gy)	$Q_{\beta(regenerative)}$ (Gy)	$k = Q_\alpha / Q_\beta$ (additive)	$k = Q_\alpha / Q_\beta$ (regenerative)
MO-15041	240.21	32.16	30.20	0.134	0.126
MO-15153	189.70	20.23	19.20	0.107	0.101
MO-FV	263.68	12.95	13.07	0.049	0.050
MO-DVa	137.34	17.99	21.52	0.131	0.157
MO-GX	270.95	30.01	31.67	0.111	0.117

Correction of limiting factors

Correcting the results of age determination, decreasing errors, increasing accuracies and trust obtained results, the factors which affect on conserved energy as saturation phenomenon, thermal de-trapping, fading, spurious thermo-luminescence, Radon emanation, moisture and bleaching must be considered [1 and 2]. In this study the required corrections were performed.

Age determination

The age of five pottery samples of Pookerdvall site have been determined by both additive dose and regenerative dose methods [1-2]. These results are shown in Table 5.

Table 5. The Age results from both additive dose and regenerative dose methods

Samples	TL Age (Year, Additive dose)	TL Age (year, Regenerative dose)
MO-15041	7389 ± 420	7087 ± 390
MO-15153	4516 ± 360	4253 ± 325
MO-FV	3781 ± 340	3633 ± 300
MO-DVa	4074 ± 320	3974 ± 295
MO-GX	7249 ± 375	6916 ± 360

CONCLUSION

The results of paleodose for additive dose and regenerative dose methods are close and also the results of the age determination are also close (table 5). The most probable reason for paleodose obtained by regenerative dose method is that there are not mechanical and advanced instruments for thermo-luminescence studies. So in major artificial irradiation, when sample disks are placed and picked up by hand and by a tweezers on the nichrome plate of thermal system, the sample disks should be scratched. So it is observed that the paleodose results for regenerative method, mostly is less than the paleodose results for additive method.

Also, there are some problems because of changes in sensitivity. It should be mentioned that this article is the first search by using regenerative method for age determination in laboratory of Research Centre for Conservation of Cultural Relics of Cultural Heritage and Handy Crafts and Tourism Organization of Tehran Province, and it needs more surveys and also advanced instruments.

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