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Analysis and identification of glass products based on logistic regression

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Abstract: *Firstly, the correlation between categorical variables was studied, the relationship between non-parametric samples was established, the occurrence frequency of surface weathering and ornamentations, types and colors was counted, and the chi-square test model was established. Finally, the independence test was conducted. This time, for the analysis of the difference of multiple groups of data, the normal distribution test can be conducted on the chemical composition content proportion data, and the mean value fluctuation model can be established. Finally, through the significance test, it can be concluded that there is no obvious correlation between surface weathering and ornamentation, but ornamentation B is easier to be weathered than A and C. There is 99% certainty that "surface weathering is related to type", and high potassium is not easy to weathering, lead barium is easy to weathering; There was no significant correlation between surface weathering and color, but there were some differences between weathered and unweathered color species.*

Keywords: *Glass; Surface weathering; Cardinality test model; Chemical composition content*

1. Introduction

1.1 Problem Background

The Silk Road was a channel for cultural exchange between China and the West in ancient times, of which glass was a valuable physical evidence of early trade exchanges[1]. Early glass was often made into bead-shaped ornaments in the West Asian and Egyptian regions into our country, and our ancient glass absorbed its technology and made locally, so the appearance of glass products with foreign, but the chemical composition is not the same[2-3].

The main raw material of glass is quartz sand, whose main chemical composition is silicon dioxide (SiO2). Due to the high melting point of pure quartz sand, in order to reduce the melting temperature, fluxes need to be added during refining. The fluxes commonly used in ancient times were grass ash, natural alkali, saltpeter and lead ore, and limestone was added as a stabilizer, which was converted to calcium oxide (CaO) after calcination. Adding different fluxes, its main chemical composition is also different. For example, lead-barium glass adds lead ore as a flux in the firing process, and its content of lead oxide (PbO) and barium oxide (BaO) is higher, which is usually considered to be our own invented glass species, and the glass of Chu culture is mainly lead-barium glass[4]. Potassium glass is made from substances with high potassium content, such as grass wood ash, as a flux for firing, and is mainly popular in Lingnan, China, as well as in Southeast Asia and India and other regions.

Ancient glass is highly susceptible to weathering by the burial environment. During the weathering process, internal elements are exchanged with environmental elements in large quantities, resulting in changes in its composition ratio, thus affecting the correct judgment of its category. For example, the artifact1 are marked with no weathering on the surface, and the color and ornamentation of the artifacts can be clearly seen on the surface, but a lighter weathering locally cannot be excluded; the artifact2 are marked with weathering on the surface, and a large grayish-yellow area on the surface is the weathering layer, which is an obvious weathering area, and the purple part is the general weathering surface. In some of the weathered artifacts, the surface also has unweathered areas[5].

It is known that the main components of high potassium glass and lead and barium glass are in the proportion of 85%~105%. In the attachment, Form 1 is the classified information of cultural relics, Form

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2 is the corresponding proportion data of the main components of the two types of glass products, and Form 3 is the statistical table of cultural relics of unknown categories.

Based on the above background and attached information, we need to build a model to solve the following problems: According to the data in Table 1, analyze the relationship between surface weathering of glass products and glass type, decoration and color. According to different types, the statistical rule of weathering chemical composition content was analyzed, and the content of chemical composition before weathering was speculated at different weathering points.

2. Problem Analysis and Model Construction

2.1 Analysis of Question

First of all, it is required to make correlation analysis between type, decoration and color of glass artifacts and surface weathering respectively, decoration (A, B, C), type (high potassium, lead barium), color (light green, green, dark green, blue green, dark blue, light blue, purple, black), and weathered surface (weathered, unweathered) are categorical variables, and the problem of correlation analysis for categorical variables is actually to establish non-parametric sample-to-sample relationships, counting the occurrence of each parameter and establishing a chi-square test model [1].

Secondly, it is required to analyze the presence or absence of chemical components and the statistical law of the content of chemical components, and to classify the data by type and surface weathering through Excel, and to count the data on the content of chemical components of different categories and surface weathering, and to transform the problem into an analytical problem of the variability of multiple groups of data. It is possible to do the normal distribution test on the chemical composition content proportion data, establish the mean fluctuation model, and use the mean fluctuation value as the prediction of the chemical composition content before weathering.

2.2 Model establishment and solution

2.2.1 Establish the chi-square test model

(1) Put forward the hypothesis:

H0: Assuming no relationship between ornamentation and weathering surface.

(2) Calculate the chi-square value

Table 1, Table 2 and Table 3 of occurrence frequency of multiple categories of two variables are listed.

For a 2×2 4-cell table, the chi-square value is:

$$\chi^2 = \frac{n(ad-bc)^2}{(a+b)(c+d)(a+c)(b+d)}, \quad (n = a+b+c+d) \tag{1}$$

For R×C table, the chi-square value is:

$$\chi^2 = n\left[\left(\frac{A_{11}}{n_1 p_1} + \frac{A_{12}}{n_1 p_2} + \ldots + \frac{A_{rc}}{n_r p_c}\right) - 1\right]$$

$$n_i = A_{i1} + A_{i2} + \ldots + A_{ic} \quad (i = 1,2,\ldots,r)$$

$$p_j = A_{1j} + A_{2j} + \ldots + A_{rj} \quad (j = 1,2,\ldots,c) \tag{2}$$

According to the attached form 1, the occurrence frequency of surface weathering, ornamentations, types and colors is counted. The results are shown in the following Table 1.

Table 1: Surface weathering and ornamentation

	Weathering	No weathering	Total
A	11	11	22
B	6	0	6
C	17	13	30
Total	34	24	58

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Using SPSS software, it shows that there is no significant correlation. However, according to the analysis in Table 2, B is more easily weathered than A and C.

Table 2: Surface weathering and ornamentation

	Weathering	No weathering	Total
High Potassium	6	12	18
Lead Barium	28	12	40
Total	34	24	58

According to the calculation formula of 2×2, $\chi^2 = 6.880$，, and then independence test, check the critical value table shows that $\chi^2 = 6.880 > 6.635$, that is, 99% of the certainty that "surface weathering and type of relationship".

Using SPSS software, chi-square test was carried out, and the $SIG = 0.009 < 0.05$ was obtained, which verified that the surface weathering was significantly correlated with the type.

Conclusion: High potassium is not easily weathered, and lead and barium are easily weathered.

Table 3: Surface weathering and color

	Weathering	No weathering	Total
Black	2	0	2
Blue-green	9	6	15
Green	0	1	1
Pale Blue	12	8	20
Pale Green	1	2	3
Deep Blue	0	2	2
Deep Green	4	3	7
Purple	2	2	4
Total	30	24	54

The SPSS software was used to find out, indicating no significant correlation (Table 3).

Conclusion: There are some differences between weathered and unweathered color types, black is weathered, green and dark blue are unweathered.

2.2.2 Establish the mean fluctuation model

(1) Pre-processing of data

According to the requirements of the topic, the chemical components that were not detected were assigned a value of 0. The proportion of the chemical components content was summed, and the data whose proportional sums did not lie between 85% and 105% (79.47% and 71.89% i.e. sampling points 15 and 17) were excluded.

(2) Modeling

It is assumed that the content of chemical components before weathering is recorded as Q_i, and the mean value of chemical components before statistical weathering is $\overline{X_i}$, and the fluctuation of chemical components is Δm_i, which is 10% of the mean value.

Establish the mean fluctuation model:

$$Q_i = \overline{X_i} \pm \Delta m_i,\ \left(\Delta m_i = 10\%\overline{X_i}\right) \tag{3}$$

(3) Make classified statistics on the attached data.

The statistical rule can be obtained from Table 4: after weathering, the values of sodium oxide, lead oxide, barium oxide, strontium oxide, tin oxide and sulfur dioxide are zero, the proportion of silica content increases, and the remaining proportion decreases.

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Table 4: Statistical table of chemical composition analysis of high potassium glass

	Unweathered			Weathering			Statistical rule
	Max	**min**	**Average**	**Max**	**min**	**Average**	**Percentage change**
SiO2	87.05	59.01	67.98	96.77	92.35	93.96	Significantly increased
Na2O	3.38	0	0.7	0	0	0	Reduce to zero
K2O	14.52	0	9.33	1.01	0	0.54	decreased somewhat
CaO	8.7	0	5.33	1.66	0.21	0.87	obviously decreased
MgO	1.98	0	1.08	0.64	0	0.2	obviously decreased
Al2O3	11.15	3.05	6.62	3.5	0.81	1.93	obviously decreased
Fe2O3	6.04	0	1.93	0.35	0.17	0.27	obviously decreased
CuO	5.09	0	2.45	3.24	0.55	1.56	obviously decreased
PbO	1.62	0	0.41	0	0	0	Reduce to zero
BaO	2.86	0	0.6	0	0	0	Reduce to zero
P2O5	4.5	0	1.4	0.61	0	0.28	obviously decreased
SrO	0.12	0	0.04	0	0	0	Reduce to zero
SnO2	2.36	0	0.2	0	0	0	Reduce to zero
SO2	0.47	0	0.1	0	0	0	Reduce to zero

The statistical rule can be obtained from Table 5: after weathering, the content proportions of lead oxide and phosphorus pentaoxide increased significantly, and the content proportions of calcium oxide, magnesium oxide, copper oxide, barium oxide, strontium oxide, tin oxide and sulfur dioxide also increased.

Table 5: Statistical table for chemical composition analysis of glassy lead and barium

	Unweathered			Weathering			Statistical rule
	Max	**min**	**Average**	**Max**	**min**	**Average**	**Percentage change**
SiO2	75.51	31.94	53.44	53.33	3.72	24.91	obviously decreased
Na2O	4.66	0	0.77	2.22	0	0.22	decreased
K2O	1.41	0	0.26	1.05	0	0.13	decreased
CaO	4.49	0	1.23	6.4	0	2.7	Rise
MgO	1.67	0	0.49	2.73	0	0.65	Rise
Al2O3	5.45	1.44	3.19	13.65	0.45	2.97	decreased
Fe2O3	4.59	0	0.93	2.74	0	0.58	decreased
CuO	8.46	0	1.56	10.57	0	2.28	Rise
PbO	39.22	9.3	23.59	70.21	15.71	43.31	Significantly increased
BaO	26.23	3.42	10.5	35.45	0	11.81	Rise
P2O5	5.75	0	0.9	14.13	0	5.28	Significantly increased
SrO	0.91	0	0.3	1.12	0	0.42	Slight increase
SnO2	0.44	0	0.06	1.31	0	0.07	Slight increase
SO2	3.66	0	0.28	15.95	0	1.37	increase slightly

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The statistical regularities obtained from Table 6 are as follows: the contents of sodium oxide, magnesium oxide and alumina are significantly increased, while the contents of iron oxide, copper oxide, lead oxide and barium oxide are decreased.

Table 6: Statistical table of chemical composition analysis of glass lead and barium continued

	Unweathered			Weathering			Statistical rule
	Max	**min**	**Average**	**Max**	**min**	**Average**	**Percentage change**
SiO2	75.51	31.94	53.44	68.08	45.02	56.24	Essentially unchanged
Na2O	4.66	0	0.77	5.74	0	2.87	Significantly increased
K2O	1.41	0	0.26	0.35	0	0.17	decreased
CaO	4.49	0	1.23	3.12	0	1.44	Slight increased
MgO	1.67	0	0.49	1.49	0	0.83	Rise
Al2O3	5.45	1.44	3.19	14.34	3.53	6.1	Rise
Fe2O3	4.59	0	0.93	1.27	0	0.48	decreased
CuO	8.46	0	1.56	2.72	0.33	1.27	decreased
PbO	39.22	9.3	23.59	30.61	12.31	20.12	Range narrowing
BaO	26.23	3.42	10.5	10.88	2.03	7.06	Significantly decreased
P2O5	5.75	0	0.9	6.34	0	1.24	Rise
SrO	0.91	0	0.3	0.35	0	0.23	Slight decrease
SnO2	0.44	0	0.06	0.23	0	0.02	Slight decrease
SO2	3.66	0	0.28	0	0	0	Reduce to zero

(4) The solution results of the model are shown in Tables 7 and 8 below.

Table 7: Mean content fluctuation of high potassium glass before weathering

	$\overline{X}_i$	Δm_i	Q_i
SiO2	67.98	10.198	67.98±10.198
Na2O	0.7	0.104	0.70±0.104
K2O	9.33	1.4	9.33±1.40
CaO	5.33	0.8	5.53±0.80
MgO	1.08	0.162	1.08±0.162
Al2O3	6.62	0.993	6.62±0.993
Fe2O3	1.93	0.29	1.93±0.29
CuO	2.45	0.368	2.45±0.368
PbO	0.41	0.062	0.41±0.062
BaO	0.6	0.09	0.60±0.09
P2O5	1.4	0.21	1.40±0.21
SrO	0.04	0.006	0.04±0.006
SnO2	0.2	0.03	0.20±0.03
SO2	0.1	0.015	0.10±0.015

Table 8: Mean Content fluctuation of lead and barium glass before weathering

	$\overline{X}_i$	Δm_i	Q_i
SiO2	53.44	8.017	53.44±8.017
Na2O	0.77	0.116	0.77±0116
K2O	0.26	0.039	0.26±0039
CaO	1.23	0.185	1.23±0.185
MgO	0.49	0.074	0.49±0.074
Al2O3	3.19	0.479	3.19±0479
Fe2O3	0.93	0.14	0.93±0.140
CuO	1.56	0.234	1.56±0.234
PbO	23.59	3.539	23.59±3.539
BaO	10.5	1.575	10.50±1.575
P2O5	0.9	0.136	0.90±0.136
SrO	0.3	0.045	0.30±0.045
SnO2	0.06	0.01	0.06±0.010
SO2	0.28	0.042	0.28±0.042

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3. Conclusions

This paper mainly studies the correlation between categorical variables, establishes the relationship between non-parametric samples, counts the occurrence frequency of surface weathering and ornamentations, types and colors, establishes the chi-square test model, and finally conducts the independence test. This time, for the analysis of the difference of multiple groups of data, the normal distribution test can be conducted on the chemical composition content proportion data, and the mean value fluctuation model can be established. Finally, through the significance test, it can be concluded that there is no obvious correlation between surface weathering and ornamentation, but ornamentation B is easier to be weathered than A and C. There is 99% certainty that "surface weathering is related to type", and high potassium is not easy to weathering, lead barium is easy to weathering; There was no significant correlation between surface weathering and color, but there were some differences between weathered and unweathered color species.

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