

# Grey Incidence analyze of Environment Monitoring Data and Research on the Disease Prevention Measures of Longmen Grottoes

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**Abstract.** Longmen Grottoes was afflicted with many diseases for a long period such as weathering, seepage water and organism growth. Those adverse factors were threatening to preserve cultural relic. Longmen Grottoes conservation and restoration project being put into effect by UNESCO in 2002. The Longmen Grottoes area environmental monitoring system was built in order to comprehensively master the distribution law of environmental factors over the Longmen Grottoes. The monitoring items contains temperature, humidity, wind direction, wind speed, precipitation, light intensity, water content in soil, the rock surface temperature and so on. At the same time, monitoring three experiment caves, monitoring the inside temperature, humidity, seepage water and the wall face temperature etc. So as to analyze the relationship between cave environment and regional environment. We statistical and arrange the data using Excel software, Kgraph software and DPS software. Through the grey incidence analyze, the incidence matrix and the correlation degree of the environmental factors was obtained[1]. The main environment factors for the formation of the disease had been researched. Based on the existing environmental monitor data, the relevance of seepage water and fracture displacement with other environmental factors had been studied, and the relational order was obtained. Corresponding preventive measures were put forward by the formation mechanism analyze of the disease.

## 1. Introduction

There are many monitored data in Longmen Grottoes, so we must analyze it with system approach. We must consider Longmen Grottoes as a system with hierarchical structure. Combinational analyze on the essential factors of the system with integrate concept. Because the fuzzy boundary, links of each factor and the interior structure, the system itself is a grey problem<sup>[2]</sup>.

### 1.1 Concept of grey incidence analyze

The grey system analyze is an important method in system research. Its raised by professor Deng JuLong in 1980s, and the grey incidence analyze is an important part of the grey system. Grey correlation analyze is the quantitative comparison or description of the relationship between the systems or the factors in the system. Relative changes over time in the process of development, the analyze of time series curve geometric shape, use them to change the size, direction and speed of proximity and size to measure the correlation between them.



### 1.2 Basic characteristics of grey incidence analyze

The analyze of grey relational degree is essentially the analyze and comparison of geometric shapes of geometric curves, The gray correlation analyze is essentially the analyze of the geometric shape of the geometric curve, the closer the geometry, the closer the development, the greater the correlation; On the contrary, the grey relational degree is smaller<sup>[3]</sup>. Grey correlation analyze has the following characteristics:

Total: (1) in any system, contains a variety of factors, the role of these factors on the system the main behavior which is the main, which is secondary; What are the development, what are the limits, and so on, these are the important content of the ash correlation analyze.

(2) the asymmetry: in the objective world, there exists a complex relationship between factors, in the same system, a correlation to b, is not equal to b on a correlation.

(3) Non uniqueness: correlation degree is related to the following factors: ①different mother sequences, correlation degree is different; ②the subsequence, correlation degree is different; ③ the original data processing method is different, and the related degree is different; ④data sequence length is different, correlation degree is different; ⑤distinguish coefficient, correlation degree is different. Therefore, the correlation is not unique.

(4) orderliness: the main research object of grey relational analyze is the system state variable of discrete form, namely time series. Unlike the relevant analyze, the data in this discrete function can't be exchanged in two or two, and it can't be reversed in any way, or it changes the nature of the original sequence.

(5) dynamic: the gray correlation of the elements varies by the length of the sequence, which means that in the course of the development of the system, the correlation between the various factors is constantly changing, and this is the dynamic<sup>[4][5]</sup>.

## 2. Methodology

DPS is an acronym for Data Processing System. It was developed by professor Tang QiYi of zhejiang university. The system adopts the multistage drop-down menu, the user use the entire screen is like a piece of work platform, adjust and operate freely, so vividly described it as the DPS data processing platform, hereinafter referred to as the DPS platform. DPS statistical software is the present domestic only a fully functional software experimental design and statistical analyze, it will be numerical, statistical analyze, model simulation and tabulation of draw line, etc.

The whole monitoring area of longmen grottoes as an overall research object, including atmospheric environment monitoring, air pollution monitoring. The water springs, the vertical drilling and the horizontal drilling and the detection of the caves, the interaction of each other, and the interaction of each other, it's an intricate gray system, based on the editorial status of the DPS platform, which is based on the western mountain data, which is the base data of the light intensity, the moisture content of the soil, the surface temperature of the rock, the amount of moisture in the surface of the rock, and the amount of moisture in the ten sets of the time sequence and the sorting of the data blocks as the table 1, calculating the correlation matrix and sorting the factors.

Table 1 Data editing definition table of correlation analyze of environmental monitoring data  
 (non-parent sequence data correlation analyze)

Light intensit y	Soil moisture content	Surface temperatur e of rock	rainfall	temperat ure	humidity	Spring temperatur e	Spring humidity	qianxi temple temple temperature	qianxi temple humidit y
0.91	0.032	19.6	0.018	17.04	61.30	23.20	64.69	15.9	65.3
1.05	0.072	25.1	0.054	21.78	63.87	23.88	65.67	19.9	71.1

0.89	0.093	26.9	0.190	25.66	63.25	23.94	65.38	23.4	71.4
1.03	0.188	29.1	0.327	25.89	85.45	23.94	81.05	23.9	94.5
0.96	-0.168	26.6	0.323	24.07	90.59	23.95	84.32	23.4	93.1
0.91	-0.211	24.8	0.248	21.28	88.25	23.95	29.61	20.8	90.8
0.74	-0.163	18.7	0.209	15.08	71.94	23.56	91.99	15.5	76.3
0.58	0.035	11.4	0.035	8.03	74.64	23.34	75.21	10	68.1
0.48	0.041	7.3	0.014	3.83	60.63	23.03	65.65	5.9	51.9
0.49	0.026	5.6	0.001	1.91	51.77	22.73	60.94	4.2	45
0.65	0.027	12	0.026	8.17	44.07	22.96	52.02	8.9	42.8
0.80	0.033	15.6	0.009	11.18	45.51	23.30	57.64	11.4	45.7
0.93	0.015	22.51	0.011	18.25	52.06	23.51	56.33	17.86	51.54
1.21	0.050	25.85	0.097	21.84	54.26	23.88	58.35	21.19	54.59
0.93	0.029	29.07	0.099	25.47	60.34	23.94	63.45	24.38	61.82
1.00	0.103	31.48	0.161	27.26	73.20	23.94	81.05	25.25	83.5
0.95	0.132	28.23	0.161	24.37	81.14	24.19	81.11	23.56	88.62
0.82	0.109	25.74	0.183	21.20	76.76	136.49	75.38	21.48	75.15
0.76	0.079	19.24	0.011	15.22	66.86	23.61	68.11	16.5	62.38
0.61	0.057	13.69	0.035	9.83	61.38	23.39	65.63	11.69	54.26
0.49	0.066	5.87	0.032	2.68	75.02	23.31	78.24	5.09	62.91
0.43	0.059	3.73	0	0.47	59.19	23.14	69.07	2.34	52.41
0.69	0.055	4.44	0.008	1.31	63.88	23.15	71.56	5.49	49.64
0.80	0.043	13.59	0.005	9.63	47.85	23.38	56.18	9.98	46.47

In the analyze process, the data is averaged, the resolution coefficient is 0.1, and the parameter is 0, and the absolute difference matrix is not output. The results are sorted as follows:

The result of the mean transformation is omitted, and the correlation order of all factors and other factors (the value in parentheses is the correlation coefficient).

The maximum difference of light intensity  $\Delta_{\max}=7.44623$ , related to other factors: qianxi temple humidity (0.7970) > rock surface temperature (0.7793) > humidity (0.7727) > qianxi temple temperature (0.7686) > spring humidity (0.7679) > spring temperature (0.7365) > temperature (0.7236) > rainfall (0.5156) > soil moisture content (0.4893).

The maximum difference of soil moisture content  $\Delta_{\max}=8.94663$ , related to other factors: spring humidity (0.5445) > humidity (0.5322) > qianxi temple humidity (0.5238) > spring temperature (0.5222) > light intensity (0.5209) > rock surface temperature (0.4797) > qianxi temple (0.4751) > temperature (0.4647) > rainfall (0.4236).

The maximum difference of rock surface temperature  $\Delta_{\max}=7.64180$ , related to other factors: qianxi temple temperature (0.9495) > temperature (0.8835) > light intensity (0.7835) > qianxi temple humidity (0.7615) > humidity (0.7267) > spring humidity (0.6790) > spring temperature (0.6469) > rainfall (0.6072) > soil moisture (0.4494).

The maximum difference of rainfall  $\Delta_{\max}=8.94663$ , related to other factors: temperature (0.6680) > qianxi temple temperature (0.6423) > rock surface temperature (0.6385) > qianxi temple humidity (0.5750) > light intensity (0.5575) > humidity (0.5537) > spring humidity (0.5411) > spring temperature (0.5369) > soil moisture content (0.4236).

The maximum difference of temperature  $\Delta_{\max}=7.72064$ , related to other factors: qianxi temple temperature (0.8819) > rock surface temperature (0.8845) > light intensity (0.7301) > qianxi temple humidity (0.7109) > humidity (0.6775) > rainfall (0.6411) > spring humidity (0.6292) > spring temperature (0.6014) > soil moisture content (0.4355).

The maximum difference of humidity  $\Delta_{\max}=7.65398$ , related to other factors: qianxi temple (0.9059) > spring moisture humidity (0.9010) > spring temperature (0.7856) > light intensity (0.7772) > rock surface temperature (0.7269) > qianxi temple temperature (0.7221) > temperature (0.6758) > rainfall (0.5176) > soil moisture content (0.5055).

The maximum difference of spring temperature  $\Delta_{\max}=7.15586$ , related to other factors: humidity (0.7761) > spring (0.7739) > qianxi temple humidity (0.7720) > light intensity (0.7298) > rock surface temperature (0.6336) > qianxi temple temperature (0.6266) > temperature (0.5851) > rainfall (0.4867) > soil moisture content (0.4842).

The maximum difference of spring moisture humidity  $\Delta_{\max}=6.74675$ , related to other factors: humidity (0.8908) > qianxi temple humidity (0.8269) > spring temperature (0.7653) > light intensity (0.7518) > rock surface temperature (0.6543) > qianxi temple temperature (0.6419) > temperature (0.6004) > soil moisture content (0.4975) > rainfall (0.4765).

The maximum difference of qianxi temple temperature  $\Delta_{\max}=7.66417$ , related to other factors: rock surface temperature (0.9496) > temperature (0.8912) > illumination intensity (0.7733) > qianxi temple humidity (0.7606) > humidity (0.7223) > spring humidity (0.6683) > spring temperature (0.6407) > rainfall (0.6113) > soil moisture content (0.4448).

The maximum difference of qianxi temple humidity  $\Delta_{\max}=7.70524$ , related to other factors: humidity (0.9065) > spring humidity (0.8435) > light intensity (0.8021) > spring temperature (0.7822) > rock surface temperature (0.7628) > qianxi temple temperature (0.7614) > temperature (0.7105) > rainfall (0.5409) > soil moisture content (0.4978). The correlation matrix is as follows (Table 2):

Table 2 Correlation matrix of environmental factors

Incidence matrix	light intensity	soil moisture content	rock surface temperature	rainfall	temperature	humidity	spring temperature	spring humidity	qianxi temple temperature	qianxi temple humidity
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light intensity	1.00	0.49	0.78	0.52	0.72	0.77	0.74	0.77	0.77	0.80
soil moisture content	0.52	1.00	0.48	0.42	0.46	0.53	0.52	0.54	0.48	0.52
rock surface temperature	0.78	0.45	1.00	0.61	0.88	0.73	0.65	0.68	0.95	0.76
rainfall	0.56	0.42	0.64	1.00	0.67	0.55	0.54	0.54	0.64	0.58
temperature	0.73	0.44	0.88	0.64	1.00	0.68	0.60	0.63	0.89	0.71
humidity	0.78	0.51	0.73	0.52	0.68	1.00	0.79	0.90	0.72	0.91
spring temperature	0.73	0.48	0.63	0.49	0.59	0.78	1.00	0.77	0.63	0.77
spring humidity	0.75	0.50	0.65	0.48	0.60	0.89	0.77	1.00	0.64	0.83
qianxi temple temperature	0.77	0.44	0.95	0.61	0.89	0.72	0.64	0.67	1.00	0.76
qianxi temple humidity	0.80	0.50	0.76	0.54	0.71	0.91	0.78	0.84	0.76	1.00

The results of grey correlation analyze of environmental monitoring data and the specific situation of Longmen grottoes area can be seen as follows:

With the highest correlation between soil moisture content is spring humidity, the second is humidity, qianxi temple humidity. In three months (6, 7, 8 months) with a high humidity, the moisture content of the soil is significantly higher, and finally the rainfall, although the relation between the rainfall and the soil moisture content is minimal, however, I think it is due to the effect of heavy rainfall, which causes the rainwater to accumulate in the soil in large quantities, and the soil moisture content increases to a certain extent before it is discharged in time. Figure 1 shows the relationship between soil moisture content and sunshine and rainfall. It is made by Japanese geologists Jin Tian Feng. It can be seen from the figure that in June and July, when the rainfall is more concentrated, soil moisture content is significantly higher than that in January and February. During a rainfall process, as the moisture content of the rainfall increases significantly, the precipitation starts to decrease gradually after the rain stops, and then starts to stabilize after a certain value, and then changes with the next rainfall process. The correlation between soil moisture content and light intensity is not obvious, but it is found that the soil moisture content of the soil is increased to a certain extent during the day, and the night is reduced, so it can be seen that the study the effect of light on the cultural relics is necessary to the protection of cultural relics<sup>[6]</sup>.

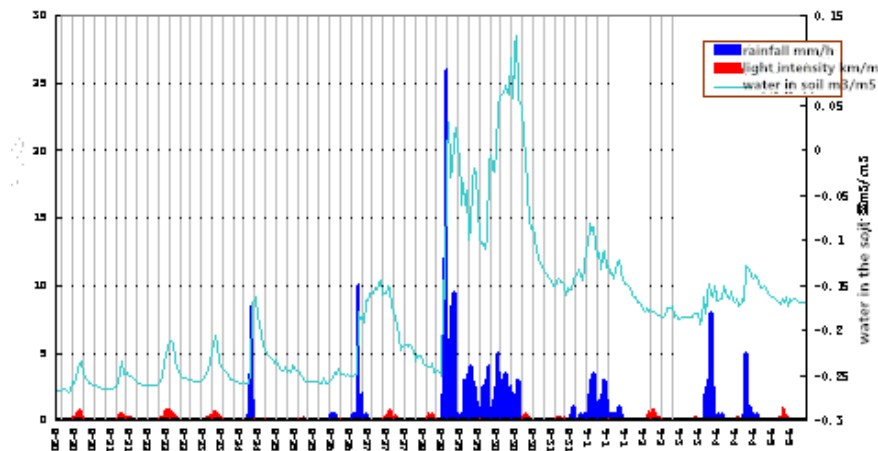


Figure. 1 relationship between soil moisture content and light and rainfall

The maximum correlation between rainfall and three temperatures (in turn, the atmospheric temperature, the temperature of the submerged stream temple and the surface temperature of the rock) is the largest, with the smallest correlation with soil moisture content. In late June and early July, luoyang began to enter the rainy season and began to appear rainfall. Air temperature gradually raised, relatively high temperature of June and July, It is the month with the heaviest rainfall.

The highest degree of correlation with the spring temperature is humidity, followed by the humidity of spring water, the humidity of the submerged stream temple, and finally the soil moisture content. The highest degree of correlation between the water and the humidity is the humidity, followed by the qianxi temple humidity, the spring temperature, and finally the rainfall. Humidity and the humidity of qianxi temple are closely related to water temperature and humidity.

Rock surface temperature and qianxi temple temperature changes along with the change of atmospheric temperature, two temperature and light intensity has a certain relationship, the greater the intensity, the longer the duration, the rock surface temperature and qianxi temple the higher the temperature, especially exposed carving temperature change is more apparent. At 12:00 noon and 14, the temperature at the surface of the rock is at maximum temperature. The change of long-term temperature difference is the main factor that causes the weathering on the surface of the grottoes, especially the impact of the engraving. For most cultural relics, low temperature is more conducive to preservation of cultural relics. The relationship between the two temperatures was the least with the soil moisture content<sup>[7]</sup>.

The highest degree of correlation is humidity, followed by spring humidity, light intensity, water temperature, and finally soil moisture content. The humidity of qianxi temple changes with the change of atmospheric humidity. The humidity in the atmosphere has exceeded 100% since the beginning of June, and the humidity of qianxi temple reaches its maximum in August. Humidity has a direct impact on the preservation of cultural relics<sup>[8]</sup>. The weathering phenomenon in moist places in grottoes is also more severe than that in dry places. In addition, the humid environment may provide necessary living conditions for the development of biological diseases, further damaging the integrity of the sculpture and affecting the overall aesthetics.

### 3. Results and discussion

Because of the fissure in the longmen grottoes, there is a universal existence, which seriously affects the integrity of the sculpture. Due to the interaction between fissures and corrosion, the wall stability of the shroud is also affected. The intersecting of fissures, which destroys the integrity of the rock mass, creating the seepage network, which aggravates the karst, weathering, peeling and moss growth diseases of the grottoes. So, its very important to the prevention and treatment of fissures. Structural reinforcement is applied to the existing cracks to maintain the overall stability of the superstructure. For example, during August 2006 to April 2007, the right to fengxian temple statues and cave wall cracking in binding reinforcement, the grouting of unstable rock mass and the anchor rod anchor



method of combining the reinforcement (Figure.2), the stability of vertical rock mass is enhanced and the hidden danger of grottoes is eliminated. It can also be used for grouting reinforcement in rock mass fractures. For example, in the early 1990s, a mixture of epoxy resin and cuttings was used for grouting treatment of seepage cracks in the surrounding rock of each cave, and the good results were obtained. Some caves have been basically kept intact. This grouting material is valid for about 10 years, and new materials can be selected, such as the anti-seepage slurry or Japanese anti-seepage material of the Remmers company (Figure.3).



Figure.2 repair and reinforcing site of fengxian temple



Figure.3 dedusting, decontamination and repairing of The Great Buddha of Lushan

#### 4. Conclusion

Longmen grottoes has built a first-class environmental monitoring system in China, which is in the leading position in the field of monitoring projects and monitoring methods. In this paper, the monitoring data of longmen grottoes were classified and sorted. Then, the environmental monitoring system of longmen grottoes was analyzed by means of grey correlation analyze, and the correlation degree between fissures and seepage and environmental factors was obtained. The calculation results show that<sup>[9]</sup>:

- (1) Environmental factors interact and restrict each other.
- (2) The correlation between affecting factors of water seepage sorting: rainfall > soil moisture content > atmosphere humidity > springs humidity > qianxi temple humidity > spring temperature = qianxi temple temperature > air temperature > intensity of illumination > rock surface temperature.
- (3) On the influence factor of fracture displacement correlation sort: light intensity > spring humidity > qianxi temple humidity > rainfall > atmosphere humidity > soil moisture content > atmosphere temperature > spring temperature > rock surface temperature > qianxi temple temperature.

According to the analyze results, the following works should be done to better protect longmen grottoes:

- (1) The protection of grottoes is based on the prevention of waterproofing work, and the measures of wind protection and rain protection are adopted, and pay attention to reduce the temperature difference of the engraving surface and enhance ventilation;
- (2) Take measures from the soil moisture content and springs, in order to determine relationship between soil moisture content and caves of the leakage, specific measures need to be research, such as observation soil moisture content of different depths during rainfall;
- (3) The construction time for the protection of the gantry cave is to avoid the peak of the tourist season, avoiding the rainy season and the high temperatures and the cold temperatures, and it's the most appropriate time period of the last ten to November.

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