SPATIAL AND TEMPORAL ANALYSIS OF THE INFLUENCE OF GROUNDWATER ON LEAKAGE OF URBAN UNDERGROUND ENGINEERING

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ABSTRACT:

Based on GIS, spatio-temporal analysis in quantitative research, has formed a set of analysis methods and the technical process, in view of the leakage defects mechanism research, first analyzes the regional hydrogeological conditions and uplift area distribution and the change of time and space, and then analyzes the groundwater distribution and vertical time-space distribution of underground projects, groundwater is analyzed again and the spatial and temporal distribution and leakage of underground engineering diseases, Finally, the influence degree and correlation between groundwater and underground engineering diseases in this area are obtained.

1. PREFACE

With the construction and development of various cities in China, the utilization of underground space resources and safe operation and maintenance have become research hotspots. Underground space has the characteristics of limited resources and complex development conditions. Once the development is irreversible, the connectivity of the underground space is not strong and the system is poor; the space ownership of the underground space is not clear; multiple management and unmanned management; the safety of the underground space Insufficient operation and maintenance (Hehua Zhu et al., 2019).and other problems; in order to ensure the normal performance of underground functions, it is necessary to supervise the underground space and analyze regional data through advanced information technology to provide data support for subsequent scientific operation and maintenance.

Urban rail transit is the main form of urban underground. In recent years, various leakage problems and even safety accidents have occurred. For example, in 2008, the subway collapsed due to water seepage, which led to a sudden water seepage danger on the rail transit line under construction. Part of the tunnel collapsed, followed by a chain reaction of the danger. A nearby section of flood control wall about 30m long was affected by ground subsidence.

Groundwater is the main factor for the formation of seepage diseases in underground projects. Among the above-mentioned incidents, the accidents that occurred during the construction or operation of subway projects are basically related to groundwater. The main reason for the analysis is that most of the subway projects are built in developed cities such as rivers and coastal areas, and such developed cities have an important engineering feature that is rich in groundwater burial, intense activities, and existing design theories and scientific research capabilities corresponding to subway projects. , construction level, anti-seepage level and attention degree more or less there are certain defects in the qualitative cognition of groundwater's impact on engineering, lack of quantitative analysis research,The research on groundwater based on GIS at home and abroad has been

relatively mature (Cheng Qian et al,2016),and the impact of groundwater on subway engineering and prevention measures have also been carried out in China(Ran Wei et al,2016). Analysis.

Aiming at the impact of groundwater on leakage diseases of urban underground engineering, this paper uses GIS technology to carry out quantitative research on spatio-temporal analysis, and forms a set of analysis ideas and technical processes, which is of great significance for the study of leakage disease mechanisms, evaluation and early warning, and formulation of governance measur

Figure 1. Case of underground engineering leakage.

2. ANALYSIS OF THE INFLUENCE OF GROUNDWATER ON UNDERGROUND ENGINEERING STRUCTURES

If the underground construction quality is good, then there will be no groundwater leakage event, but in reality, Daxing civil engineering is difficult to ensure the quality of the project, so it is of great significance to study the relationship between groundwater and leakage, and during the construction period of underground engineering, the impact of groundwater is short-term, while the impact of groundwater during the operation period is permanent. The service life of the subway main structure engineering design is 100 years, so it is very meaningful to study the impact of groundwater during the operation period. For most subway stations built in rock and soil bodies, due to the long-term erosion of groundwater and pressure infiltration, water leakage is likely to occur once the waterproofing measures fail. The existence of leaking water will not only endanger the operation and equipment safety of the subway, shorten the service life of the concrete structure, but also endanger people's health due to the mold caused by the moisture of the leaking water. Therefore, in a sense, the phenomenon of water leakage has become the main problem affecting the normal operation of subway stations.

2.1 Characteristics of Underground Engineering

The basic characteristics of underground engineering design and construction are "complex geological environment and lack of basic information", which adds "complex surrounding environment" to urban underground engineering, and its construction has great uncertainty and high risk.

1. Poor geological conditions: At present, most of the urban subway projects in my country are buried within 20m, and there is stagnant water or diving in the upper layer within this depth range.

2. The surrounding environment is complex: Due to various reasons, the construction of subway projects lags behind urban construction, especially urban subway projects are often built in areas with a high concentration of buildings, passing under urban roads and near various pipelines. Its engineering construction often causes stratum deformation and surface subsidence. The damage caused by these deformations and settlements to adjacent existing buildings (structures) and facilities cannot be ignored.

3. The buried depth of the structure and the mutual influence with the adjacent structures: Urban subway projects have the characteristics of buried depth, mostly between 3m and 20m. The urban underground pipe network facilities, commercial streets, parking lots and other structures are row upon row, affecting and restricting each other. , which brings many special problems in design and construction technology to the construction of the project(Qilin Hu et al,2009).

2.2 The main Construction Methods of Subway Engineering

The construction of the subway is a long-term process. It is constructed in stages according to the city's economic situation and transportation capacity. With the development of science and technology, there are different construction methods in different times. At present, there are three major construction methods in the world: open-cut method (including cover-cut method and other variations), new Austrian method (NATM) and shield method, as well as various auxiliary construction methods.

At present, in the construction of subways in my country, the shield method and the shallow buried method are mainly used to build subway tunnels. Shallow burial and underground excavation method was founded by Chinese engineers on the basis of the new Austrian method and combined with China's national conditions. Improvement of stratum, grouting reinforcement and other supporting technologies to complete the design and construction of the tunnel.

2.3 Main Groundwater Problems during Subway Operation

The main impact of groundwater on subway tunnels includes three aspects: first, the weakening effect of groundwater on the structure and surrounding rock; second, groundwater as a load increases the stability of the envelope structure; third, the impact of groundwater on construction operations, drying and stability The construction environment with low water pressure can ensure the safety of construction personnel, so it is quite necessary to control the flow and pressure of groundwater during the construction of subway tunnels. In addition, the influencing factors of the operating environment, the specific environment of soil and groundwater for the shield tunnel, groundwater level changes, longitudinal uneven settlement, fire and other uncertain factors will directly or indirectly affect the durability of the tunnel structure.

3. GIS-BASED SPATIOTEMPORAL ANALYSIS METHOD

A GIS-based quantitative study on the spatiotemporal analysis of the impact of groundwater on the leakage of urban underground engineering has formed a set of analysis ideas and technical processes, as shown in Figure 2.
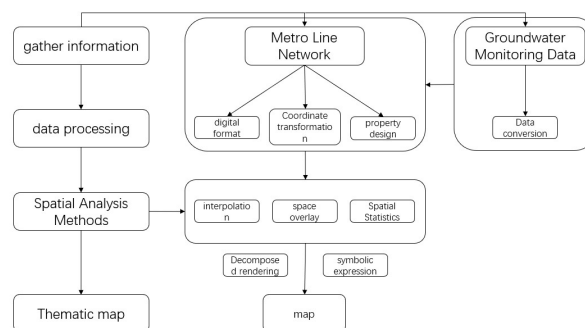

Figure 2. Technical flow chart.

3.1 Data Collection and Preprocessing

Collect groundwater monitoring data in the study area in recent years, related data on the structural basement elevation of each subway station interval, and data related to the water leakage point and drainage volume of the subway interval station, and unify the standards such as ID and field to facilitate attribute connection, and the multi-source data elevation information is divided into buried depth.

Convert level water level information. After the attributes are connected, the line network data is first refined by spatial analysis method, and its laws and trends can be better presented after decomposed rendering and symbolic expression.

Hydrological depth distribution of underground water in Metro from March to may 2022
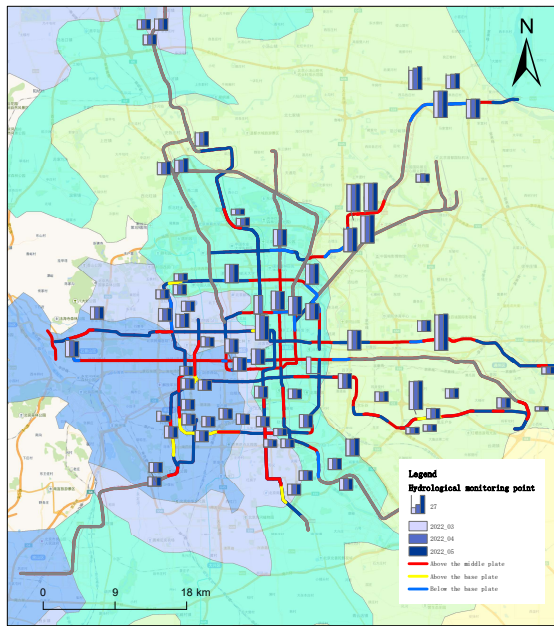

Figure 3. Distribution map of monitoring points

Groundwater leakage is a complex and comprehensive problem. The system platform realizes the retrieval, attribute query and display, and positioning of groundwater data. The system platform realizes dual-screen comparison, provides historical data comparison and analysis functions, and realizes automatic identification of groundwater changes through data analysis. Trends, and give statistical charts to display the analysis results.

3.2 Groundwater Spatial Interpolation Method

Inverse distance weighted interpolation (Inverse Distance Weighted, IDW) is based on the principle of similarity. Samples that are closest to the predicted point have more influence than sample values that are slightly further away from the predicted point.

There is a localized effect that decreases with distance. The general formula of the inverse distance weighting method is as follows:

$$\hat{Z}(S_0) = \sum_{i=1}^{N} \lambda_i Z(S_i) \tag{1}$$

Among them, $\hat{Z}(S_0)$ is the prediction value at S_0; N is the number of samples around the prediction point to be used in the prediction calculation process; λ_i is the weight of each sample point used in the prediction calculation process. It decreases as the distance between the sample point and the predicted point increases; $Z(S_i)$ is the value of the sample point obtained at S_i. The formula for determining the weight is:

$$\lambda_i = d_{i0}^{-p} / \sum_{i=1}^{N} d_{i0}^{-p}$$
$$\sum_{i=0}^{N} \lambda_i \tag{2}$$

Among them, P is the index value; d_{i0} is the distance between the predicted point S_0 and each known sample point s_i. The weight of the sample points in the calculation of the predicted point value is affected by the parameter p; that is to say, as the distance between the sampling point and the predicted value increases, the weight of the standard sample point on the

predicted point is exponential. Reduce(Wanzhen Wang et al,2018).

3.3 Correlation Analysis

In this study, the autocorrelation function of hydrogeological parameters is used to analyze their spatial distribution characteristics, that is, to analyze the spatial correlation of hydrogeological parameters. According to the principle of geostatistics, in the study area, the regional variables are sampled along a certain direction, and the number of sampling points is set to be n, and the distance between the sampling points is equal, both are Δx. The positions of the sampling points are represented by x1 , x2 , ..., xN respectively, and the measured values of the parameters of the corresponding points are represented by y(x1), y(x2), ..., y(xN). If one step is taken as the spacing, i.e. h=Δx, then y(x1), y(x2), ..., y(xN-1) and y(x2), y(x3), ..., y(xN) two groups of data series with n-1 one-to-one correspondence. The correlation analysis of these two sets of parameter values is carried out, and the obtained correlation coefficient is called the autocorrelation coefficient of the interval h=Δx. If the interval is two steps, that is, h=2Δx, two sets of data series with a total of n-2 pairs one-to-one can be formed, from which the autocorrelation coefficient of h=2Δx can be obtained, and the rest can be deduced by analogy. If the interval is taken as h, the expression of its autocorrelation coefficient r(h) is

$$r(h) = \frac{cov[y(x),y(x+h)]}{\sqrt{D[Y(x)]D[y(x+h)]}} \tag{3}$$

In the formula, D[y(x)] and D[y(x+h)] are the variances of random variables y(x) and y(x+h) respectively, and cov[y(x), y(x+h)] is the covariance of these two random variables. Obviously, the value of the autocorrelation coefficient r(h) is related to the size of the interval h, so it is called the autocorrelation function in some literatures. In general, when h*0, r(h)=1. The larger h is, the smaller r(h) is. When r(h)=0, there is no correlation, and the parameter values are independent of each other. Therefore, if there is a certain a value, when h≤a, r(h)>0, then a is called the correlation distance or correlation scale(Jianqing Guo et al,2002).

4. ANALYSIS OF RESULTS

In this paper, through the analysis of the influence mechanism of groundwater on the underground engineering structure, a GIS-based analysis idea and 60% are established. Including analysis of regional hydrogeological conditions, analysis of uplift area distribution and temporal changes, analysis of groundwater distribution and vertical temporal and spatial distribution of underground engineering, analysis of temporal and spatial distribution and characteristics of leakage diseases of groundwater and underground engineering, and then obtained the impact of groundwater and underground engineering diseases in the region extent and relevance.

4.1 Regional Groundwater occurrence Conditions

The study area is mainly connected by alluvial-proluvial fans of different sizes formed by the action of multiple rivers. Sand, gravel, and sand are the main water-bearing media in this area, which can be roughly divided into four parts from the piedmont to the plain. The zones are respectively the piedmont slope accumulation-proluvial gravel zone, the piedmont alluvial-proluvial fan top zone, the alluvial-proluvial fan groundwater overflow zone and the alluvial-proluvial plain area. The
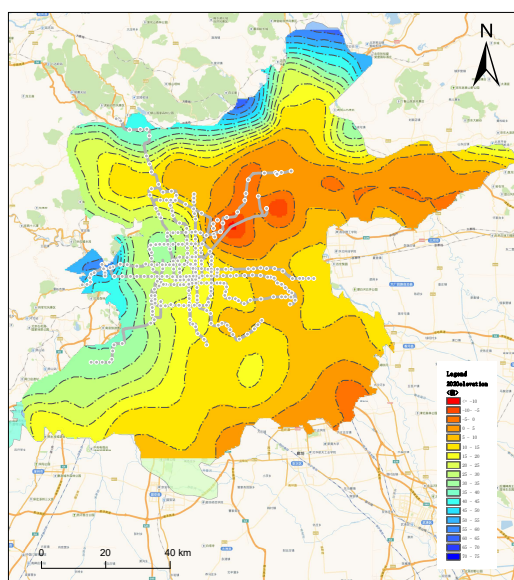
following are the permeability and water-richness of each type. The Quaternary loose sediment deposition rules of the rivers are roughly the same, that is, from the top to the lower part of the alluvial-proluvial fan and the alluvial-proluvial plain area, the aquifer particles change from coarse to fine, and the aquifer structure gradually transitions from a single layer to a multi-layer(Licai Liu et al,2012).

4.2 Analysis of Groundwater level Changes over the years

1. Distribution of groundwater level over the years

Before 1990, there was no systematic monitoring of land subsidence in the study area, and the subsidence data were mainly from leveling measurements. At present, the land subsidence monitoring network in the study area mainly includes: 7 land subsidence monitoring stations, 114 GPS monitoring points, more than 300 ground subsidence level monitoring points, more than 600 groundwater dynamic monitoring wells and 7 InSAR angle reflectors(Liya Wang et al,2014).

The overall terrain of the study area presents a distribution characteristic of high in the northwest and low in the southeast, and the depth of the groundwater level gradually becomes shallower from the northwest to the southeast. The runoff direction of groundwater is from northwest to southeast. Since 2018, the groundwater in the plain area of the study area has been affected by factors such as ecological water replenishment projects and atmospheric precipitation, and has shown an overall upward trend.

2. Distribution of groundwater uplift over the years

The two most important factors affecting groundwater uplift in the study area are ecological water injection andatmospheric precipitation. Comparative analysis of the groundwater level contour at the end of 2018 before large-scale ecological water replenishment, March 2020, March 2021, and 2022 The range of groundwater level rise in March 2009 is shown. The results show that the groundwater level uplift range in the study area in 2020 is $4583 km^2$, and the groundwater level uplift range in 2021 is $4946 km^2$, and the overall trend is rising year by year from northwest to southeast.

2020 Groundwater Contour Map

2021 Groundwater Contour Map
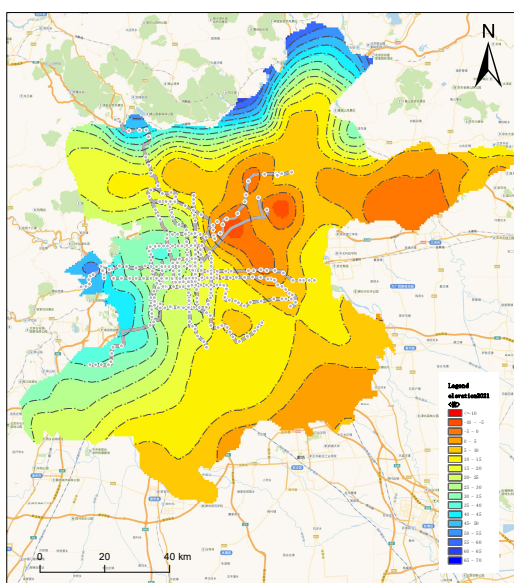
Figure 4. Contour map of groundwater level over the years.

Groundwater uplift distribution map of the whole metro network from 2018 to 2020
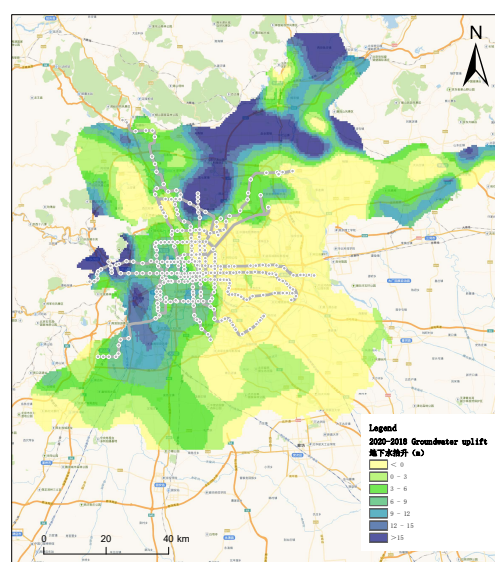
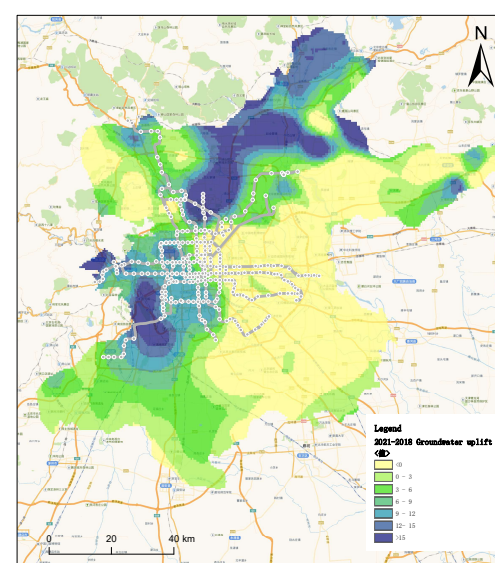Groundwater uplift distribution map of the whole metro network from 2018 to 2021

Figure 5. Range of groundwater level rise over the years.

4.3 Analysis of Groundwater Level and Vertical Temporal and Spatial Distribution of Underground Engineering

Comparing the two years of 2018 and 2020 in Figure 5, when the elevation of the subway structure base is known and unchanged, the water level has changed due to various factors such as ecological water injection, atmospheric precipitation, etc., and the vertical position of the groundwater level and the subway There has been a big change. In 2018, only a few sections in the northeast direction and the eastern direction were located below the water level, and most of the remaining lines were located on the water level line. In 2020, only some lines in the northeast and some lines in the east were located at the groundwater level. above. Among them, the groundwater level in the southwest direction has changed from bottom to high in 5 years, and the relationship between the groundwater level and the vertical position of the subway has also changed from the subway structure above the water level to below the water level.

Relationship between groundwater level and vertical position of Metro in 2021
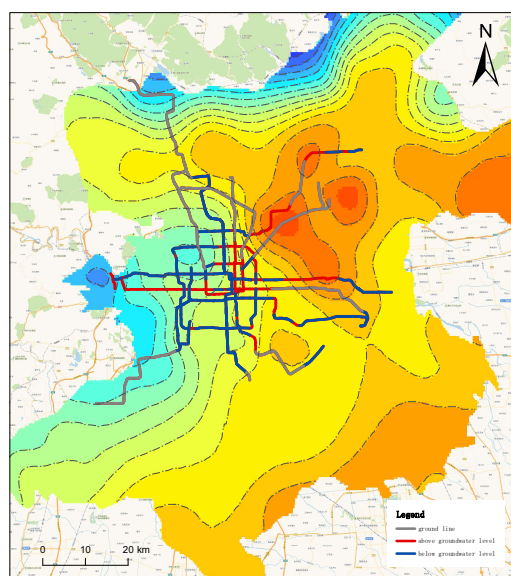
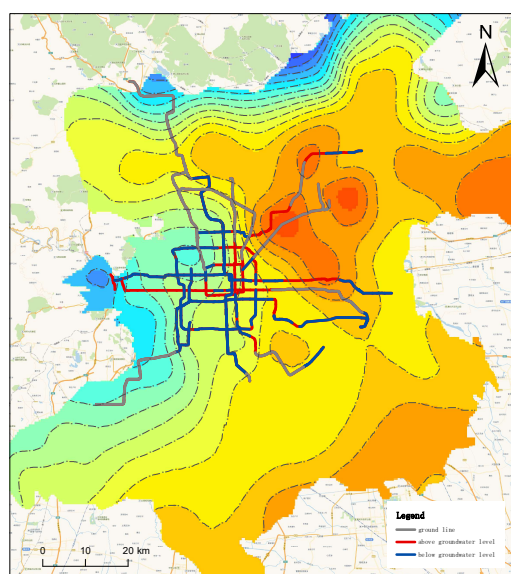Relationship between groundwater level and vertical position of Metro in 2021

Figure 6 . The relationship between the groundwater level and the vertical position of the subway.

4.4 Analysis of the Spatiotemporal Distribution of Groundwater and Seepage

The relationship between groundwater level rise and subway leakage. The points with larger leakage are mainly distributed in the aquifer structure zone of a single sand and gravel layer and 2-3 layers of sand and gravel layers in the west of Beijing, from west to east by a single sand and gravel layer. From the aquifer structure to the multi-layer sand aquifer structure, the leakage of the operating subway gradually decreases. Changes in leakage in recent years The leakage of Beijing's operating subways in 2019 and 2020 was 205,200 m^3, 396,500 m^3 and 1,674,000 m^3 respectively, and the leakage increased year by year.

4.5 The Relationship between Groundwater Level Rise and Subway Leakage

A graph of monthly leakage changes from January 2019 to December 2021 was drawn, and the leakage of operating subways increased year by year over time. For intra-year variation, the leakage is relatively large from January to March and September to December, and the leakage from April to August is relatively small. The subway tunnel is located in a single sand and pebble layer aquifer, and the leakage of the tunnel increases significantly with the uplift of the subsurface, and the change process is basically the same. Establish an impact analysis idea: analyze the regional hydrogeological conditions, analyze the distribution and space-time changes of the uplift area, analyze the groundwater distribution and the vertical space-time distribution of underground engineering, analyze the space-time distribution and characteristics of leakage diseases of groundwater and underground engineering, and then obtain the groundwater and underground engineering in this area. Influence degree and relevance of engineering diseases.
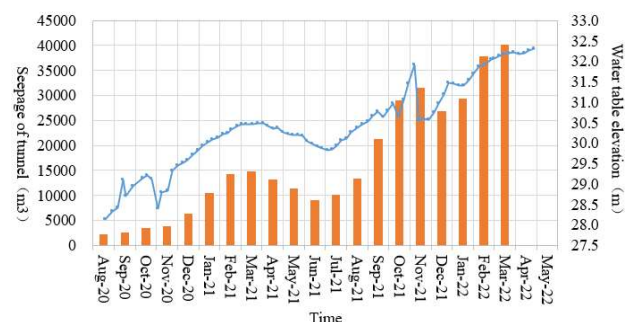

Figure 7. Variation curve of groundwater level and leakage in Liuliqiao ~ Qilizhuang.

4.6 Relationship between Construction Technology and Leakage

According to the construction technology, section tunnels are divided into open-cut method, under-cut method and shield method, among which under-cut method and shield method are the main methods of Beijing subway construction. From the statistical data of tunnel leakage in the interval, the shield tunneling method is obviously better than the undercut tunneling method. The number of leakage in the undercut tunnel accounts for about 90% of the total, including more than 85.5% of the leakage and wet places, and about 4.5% of the water jets. The statistics are shown in the table below. According to the different

locations of water seepage, it can be divided into water seepage in deformation joints, water seepage in construction joints and water seepage at common cracking positions of lining.

interval type \ leak type	Wetness, dripping, backwater	Line leakage, splash
Undercover interval	85.5%	4.5%
Shield interval	9.5%	0.5%

Table 1. Statistical table of water leakage types in the tunnel section.

The number of leaks in shield tunnels accounts for less than 10% of the total, and most of them are drips. The locations are vaults, spandrels, and annular seams. The number of leakage in undercut tunnels accounts for more than 85% of the total, so it is inferred that there is a certain correlation between the undercut construction process and leakage.

5. CONCLUSION AND DISCUSSION

In view of the impact of groundwater on leakage diseases of urban underground engineering, a set of feasible analysis ideas and technical methods are proposed. The analysis results intuitively and scientifically reflect the temporal and spatial relationship between groundwater and diseases. For the research on leakage disease mechanism, evaluation and early warning and formulation of governance Measures play an important role.

According to the obtained spatiotemporal distribution map and correlation analysis results, analyze the impact of groundwater on structural diseases. From the figure, we can see that the groundwater uplift changes in this area have obvious correlations with the spatiotemporal location, distribution density, and evolution trend of diseases. Qualitative recognition of disease impact and quantitative analysis showed that groundwater is the main and direct cause of underground engineering leakage.

On the basis of this study, combined with data fusion of surface subsidence, deformation monitoring, hydrogeology, and external engineering, further quantitatively analyze the causes and risk classification distribution of underground engineering leakage diseases.

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