DOI: 10.19601/j.cnki.issn1943 -9903.2024.04.006

Optimization of Open-cast Mining Procedure Based on RSR Method

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Abstract To explore the optimal evaluation mechanism of open-cast mining procedure, this paper takes the actual operation status of Huolinhe No. 1 Open-cast Mine as the research basis, and makes a deep analysis of the four representative mining procedures proposed by this mine. A detailed and comprehensive evaluation system is constructed using rank-sum ratio (RSR) method. The system covers 17 key indicators and aims to evaluate the advantages and disadvantages of each scheme in an all-round and multi-angle manner. Through the calculation and analysis by RSR method, the comprehensive evaluation of the four types of mining procedure schemes is carried out, and finally the secondary river improvement project is determined as the optimal mining implementation scheme, and the joint mining scheme of the south and north areas is the alternative strategy. The research results of this paper are objective, clear and definite, can not only reveal the effectiveness and feasibility of RSR method in solving the problem of open-cast mining procedure optimization, but also provide a strong technical support and decision-making basis for the future production development of Huolinhe No. 1 Open-cast Mine. Thus, this study is expected to further promote the scientific and refined process of mining operations.

Key words Mining procedure, Evaluation mechanism, Rank-sum ratio (RSR) method, Comprehensive evaluation, Optimization

1 Introduction

Open-cast mining procedure is a core link to ensure the smooth implementation of mining engineering, safety production, environmental protection, rational utilization of resources and maximization of economic benefits. Proper mining procedures ensure the orderly and efficient mining of ore resources. Through scientific and rational division and promotion of each mining step, mineral resources can be recovered to the maximum extent and waste of resources can be reduced. In addition, the correct mining procedure is helpful to ensure the safe production of the mine. For example, the risk of safety accidents such as landslides and collapses can be reduced by setting reasonable bench height, stabilizing the slope, and strictly controlling the scale and frequency of collapse. Open-cast mining involves a series of processes such as drilling, blasting, shoveling, transportation, *etc*. Excellent mining procedures enable these processes to be closely linked[1] to avoid interruption or waiting, thereby improving the overall production efficiency. Standardized mining procedures consider the issues of geological environment protection and surface restoration, control environmental pollution in the mining process, implement reclamation and greening after mining, and realize land reuse, which meets the requirements of green mining and sustainable development[2]. The selection of open-cast mining procedure directly affects the mining cost and economic benefit. Through proper planning and management, the stripping ratio can be minimized[3], the mining cost can be controlled[4], and the mineral value can be maximized[5].

Based on the RSR method, taking Huolinhe No. 1 Open-cast Mine as the research basis, we carried out a deep and comprehensive analysis of the mining procedures of two open-cast mines in the north and south of Huolin River. Through exploration and demonstration, we intend to reveal and determine the most scientific and reasonable mining procedure with the best economic benefits, so as to promote the overall operational efficiency and sustainable development capacity of Huolinhe Open-cast Mine to a new height.

2 Rank-sum ratio (RSR) method

Rank-sum ratio (RSR) method is a statistical analysis technique originated in China. It was innovatively put forward by Professor Tian Fengdiao, an outstanding academic expert in China, in 1988. Its unique feature is that it combines the advantages of traditional parametric statistics and modern non-parametric statistics[6]. RSR method has attracted much attention because of its wide application range and high flexibility, especially for the comprehensive evaluation and analysis of all kinds of data.

2.1 Analysis principle The core principle of RSR method is to sort the sample data according to the size of the observation value. In a matrix framework, a dimensionless statistical indicator, RSR, is obtained by rank transformation technology. Based on this core basis, we used the deep concept and precise method of parameter statistical analysis to explore the distribution characteristics of RSR. Furthermore, with the aid of RSR value, we can directly sort or classify the advantages and disadvantages of the evaluation objects, so as to achieve a comprehensive and detailed evaluation of the eval-

Received: February 3, 2024 Accepted: April 10, 2024
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uation objects. In short, the larger the calculated RSR value, the better the performance of the corresponding evaluation object.

RSR evaluation method is highly praised for its unique advantages, its calculation process is concise and intuitive, and its dependence on data is relatively loose, which significantly enhances the universality and application potential of the method in different industries and fields. In actual calculation, RSR cleverly gets rid of the absolute dependence on the original value and focuses on the relative ranking relationship of the data, which effectively weakens the distortion effect caused by outliers, especially for those problems caused by the zero indicator value. The dimensionless nature of the RSR value itself endows the method with excellent comprehensive analysis performance, enabling it to replace some specific comprehensive indicators, thus achieving a more accurate and comprehensive evaluation system. This method not only absorbs the essence of the rigor of parametric statistics, but also integrates the flexibility of non-parametric statistics, and constructs an inclusive statistical framework. Particularly, it is worth mentioning that the RSR evaluation method, with its unique compatibility, can seamlessly link up many other mathematical statistical methods, realize flexible and diverse docking, transplantation and integration, greatly broaden the possibility boundary of statistical analysis, and provide a powerful and efficient tool for complex evaluation problems.

2.2 Analysis steps RSR method generally includes data sorting, calculation of rank sum, calculation of rank sum ratio, judgment of statistical significance and other processes, and may need appropriate correction processing to make more accurate statistical inference and decision analysis. With the deepening of theoretical research and practical verification, RSR method has become a practical and effective comprehensive analysis and evaluation tool in the field of statistics.

2.2.1 Rank compilation. There are m evaluation objects and n indicators, and the j^{th} indicator value of the i^{th} evaluation object is b_{ij} to form an evaluation matrix $B=(b_{ij})\ m\times n$, and then the rank of each indicator corresponding to each evaluation object in the matrix is compiled. Among them, the benefit-type indicator ranks from small to large, the cost-type indicator ranks from large to small, then use the same indicator data to compile the mean rank. The corresponding rank matrix is denoted by $R=(R_{ij})_{m\times n}$. The benefit-type indicator refers to the indicator that the higher the value, the better from the perspective of professional knowledge; the cost-type indicator refers to the indicator that the lower the value, the better.

2.2.2 Calculation of the RSR. We calculated the RSR of the i^{th} evaluation object, denoted as RSR_i. When the weight of each evaluation indicator is different, the weighted rank sum ratio $wRSR$ of the i^{th} evaluation object is calculated as shown in formula (2) and recorded as $wRSRi$.

$$RSR_i=\sum_{j=1}^{m}\frac{R_{ij}}{nm} \quad (1)$$

$$wRSR_i=\frac{1}{n}\sum_{j=1}^{m}w_jR_{ij} \quad (2)$$

2.2.3 Calculation of Probit. We prepared the RSR (or WRSR) frequency distribution table, listed the frequency f_i of each group, and calculated the cumulative frequency $\sum f_i$ of each group. Then, we determined the rank range R and mean rank $\overline{R}$ of RSR (or WRSR) of each group. Next, we calculated the downward cumulative frequency $p=\overline{R}/m$, and converted the percentage P into the P_{robit}, which is the standard normal deviation u corresponding to the percentage P plus 5.

$$P_{robit}=u(p_i)+5 \quad (3)$$

where u is the standard normal dispersion function.

2.2.4 Calculation of linear regression equation. Taking P_{robit} corresponding to the cumulative frequency as the independent variable, and RSR (weighted RSR) estimated value δ_{RSRi} (δ_{WRSRi}) calculated by the regression analysis of the ith evaluation object as the dependent variable, we calculated the linear regression equation, namely, $\delta_{\text{RSRi}}=a+bP_{\text{robitak}}$ or $\delta_{\text{WRSRi}}=c+dP_{\text{robit}}$, where, a, b, c, and d are corresponding coefficients.

3 Evaluation of optimal mining procedure for Huolinhe No.1 Open-cast Mine

3.1 Project background Due to the special mining location of Huolinhe No. 1 Open-cast Mine, there are two important factors influencing the mining scope and production continuity in the mining boundary. The first is the regulation of the Heremute River in the mining boundary, which passes through the mining site from west to east. The second is the "Jinjie Trench Ancient Great Wall Site" in the mining boundary. Considering the production capacity of the south and north open-cast coal mines in Huolin River, the current situation of mining and waste disposal, the layout of semi-continuous system, the construction of intelligent mine, and the pressing coal of the waste dump along the Heremute River and Jinjie Trench, it is necessary to study and optimize the mining procedure of the Huolinhe No. 1 Open-cast Mine, so as to ensure that the open-cast mine can develop production smoothly and orderly in future.

3.2 Study on mining scheme After fully considering the production capacity of Huolinhe South and North Open-cast Coal Mines, the actual situation of the current mining and dumping site, the layout design of the semi-continuous system[7], the promotion of the construction project of the smart mine[8], and the impact of the Remute River, Jinjiehao and Yanbang dump on the coal resources and many other factors, through in-depth research and analysis, four feasible mining schemes were finally determined.

Scheme I: independent mining scheme for the south and north areas. Taking the location of river regulation as the boundary, the maximum mining scope and mining scheme of the south and north areas formed by its separation are determined. On the basis of the mining status at the end of 2022, the north area would be pushed southward to the end of the river regulation position. In order to avoid the secondary stripping volume caused by the internal drainage of the pressed slope, and at the same time, the west slope working line of the south area will be extended to prepare for the continuation of the closed pit production capacity of the north area, the west slope and the north slope will be pushed forward in the early stage of the south area (Fig. 1).

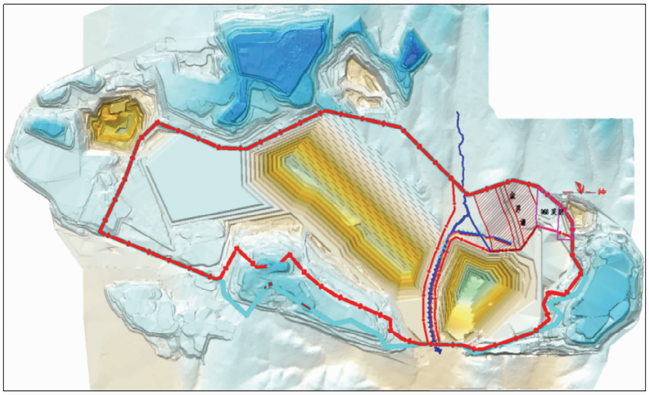

Fig. 1 Spatial layout of mining scheme I

Scheme II: The south and north areas are connected by the mining scheme. The maximum mining scope and mining scheme of the south and north areas formed by the separation are determined by taking the location of river regulation as the boundary. On the basis of the mining status quo at the end of 2022, the north area would be pushed southward to the end of the river regulation position, and the south area would continue to advance northwestward and then turned to the northeast (Fig. 2).

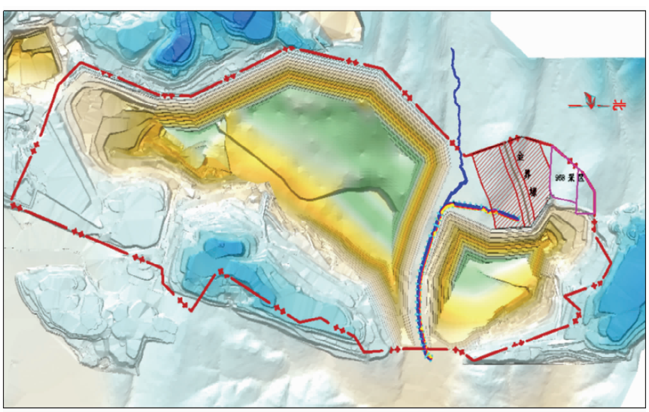

Fig. 2 Spatial layout of mining scheme II

Scheme III: Coordinated mining scheme in the south and north areas. According to the analysis of the long-term spatial layout of mining and drainage in the south and north open-cast coal mines, in the waste dump of the north open-cast mine, the permanent river-changing position of the Heremute River is formed, and the materials lacking in the final river-changing position are transported from the north side of the south area, to coordinate mining of each mining area[9] (Fig. 3).

Scheme IV: mining scheme of secondary river diversion. The location of the river channel continues to be adjusted to the south, and the river is changed for the second time near the boundary between the south and north open-cast coal mines. With the advance of the working slope to the south, the steps of the inner dump will follow, and a permanent river change location is formed in a certain production period (Fig. 4).

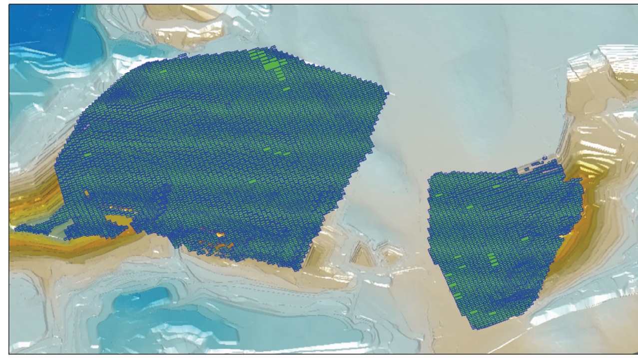

Fig. 3 Spatial layout of mining scheme III

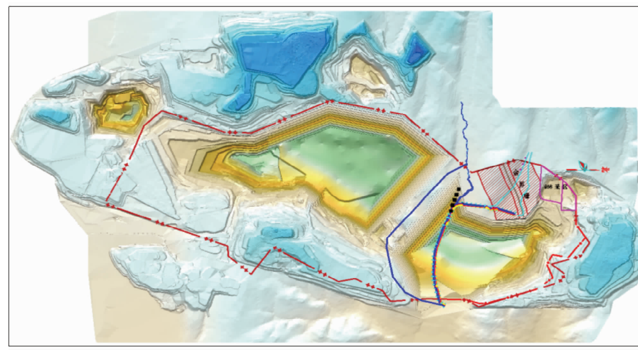

Fig. 4 Spatial layout of mining scheme IV

4 Construction of comprehensive indicator system of mining scheme

Analyzing the factors influencing the open-cast mining procedure[10], we extracted a total of 17 indicators, including minable raw coal quantity, total stripping quantity, average stripping ratio, pit closure year, remaining river-changing times, primary river-changing time, permanent river-changing time, river-changing transportation stripping quantity, river-changing backfilling coal quantity, weighted transportation distance in production period, total transportation work in production period, stripping transportation work per ton of coal, 30 million t/yr stable-production period, 20 million t/yr stable-production period, 15 million t/yr stable-production period, mining area continuity complexity and river diversion complexity[11-12], to establish a comprehensive evaluation system (Table 1).

5 Comprehensive evaluation by RSR method

According to the principle of RSR method and its analysis process, we ranked the indicators of the four schemes. Each indicator was assigned according to the same weight. After the dimensionless processing of each indicator, the rank ratio matrix was constructed, as shown in the following formula.

$$R=\begin{bmatrix} 1 & 3 & 1 & 4 & 3 & 1 & 1 & 2 & 2 & 1 & 2 & 1 & 3 & 1 & 1 & 2 & 3 \\ 1 & 3 & 1 & 3 & 3 & 1 & 1 & 2 & 2 & 2 & 4 & 2 & 1 & 1 & 2 & 2 & 3 \\ 2 & 1 & 2 & 1 & 1 & 1 & 3 & 1 & 1 & 3 & 1 & 3 & 1 & 1 & 3 & 1 & 2 \\ 3 & 2 & 3 & 2 & 2 & 2 & 2 & 2 & 2 & 4 & 3 & 4 & 2 & 2 & 1 & 2 & 1 \end{bmatrix}$$

We further calculated the corresponding RSR values and listed the results in Table 2.

Table 1 Evaluation indicators of open-cast mining procedure

Item	Unit	Scheme I	Scheme II	Scheme III	Scheme IV
Minable raw coal quantity	10^4 t	45 275	45 275	54 403	55 386
Total stripping quantity	10^4 m^3	137 232	137 232	163 328	158 903
Average stripping ratio	m^3/t	3.03	3.03	3	2.87
Pit closure year	yr	2039	2043	2051	2044
Remaining river-changing times	Number of times	0	0	1	2
Primary river-changing time	yr	–	–	–	2027
Permanent river-changing time	yr	–	–	2034	2033
River-changing transportation stripping quantity	10^4 m^3	–	0	11 834	0
River-changing backfilling coal quantity	10^4 t	–	0	983	0
Weighted transportation distance in production period	km	3.92	3.38	3.37	3.05
Total transportation work in production period	10^4 m^3 · km	538 059	478 918	550 579	484 155
Stripping transportation work per ton of coal	m^3 · km/t	11.89	10.58	10.12	8.74
30 million t/yr stable-production period	yr	13	8	8	12
20 million t/yr stable-production period	yr	–	–	–	9
15 million t/yr stable-production period	yr	–	7	11	–
Mining area continuity complexity	yr	General	General	Complex	General
River diversion complexity	yr	–	–	General	Complex

Table 2 Calculation results of RSR

Evaluation objects	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	RSR_i
Scheme I	1	3	1	4	3	1	1	2	2	1	2	1	3	1	1	2	3	0.471
Scheme II	1	3	1	3	3	1	1	2	2	2	4	2	1	1	2	2	3	0.500
Scheme III	2	1	2	1	1	1	3	1	1	3	1	3	1	1	3	1	2	0.412
Scheme IV	3	2	3	2	2	2	2	2	2	4	3	4	2	2	1	2	1	0.574

The RSR results obtained by analysis and calculation can comprehensively evaluate the advantages of each scheme, so as to clarify the optimal position of the fourth scheme in the subsequent mining of the open-cast mine. If there is no mature condition for the secondary river diversion project under the current conditions, the decision maker of the mine can take the second scheme, namely the joint mining of the south and north areas, as an alternative scheme, which also clearly demonstrates its actual feasibility and potential advantages.

However, it is worth noting that there is a significant gap between the RSR calculation results of Scheme I and Scheme III and the optimal scheme, which means that they may not achieve the ideal state in terms of economic benefits and implementation effects. Therefore, from a scientific and rigorous point of view, we do not recommend the adoption of these two schemes as the implementation scheme for the subsequent open-cast mining.

5 Conclusions

In this paper, we innovatively constructed a comprehensive evaluation system based on RSR method for the optimal mining procedure of open-cast mine for the evaluation of the mining program of Huolinhe No. 1 Open-cast Mine. In view of the diversity and complexity of the indicators involved in the open-cast mining process, and there are significant dimensional differences among the indicators, the RSR method can effectively deal with and solve such problems. Through this comprehensive evaluation method, the optimal implementation plan in the process of open-cast mining can be accurately analyzed and scientifically evaluated, thus promoting the optimization and upgrading of open-cast mining technology and decision-making.

References

[1] CHEN G, XIN QB. Feasibility study on technical transformation of Boda Open-cast Coal Mine[D]. Fuxin: Liaoning Technical University, 2012. (in Chinese).
[2] LI MJ, ZHANG RX, ZHAO HZ, *et al.* Mining procedure optimization of lignite open pit under complicated conditions[J]. Journal of North China Institute of Science and Technology, 2015, 12(4): 31 – 35. (in Chinese).
[3] CAO B, TAO YB, BAI RC, *et al.* Block system optimization by stages for inclined seam long narrow open-cast mine[J]. Journal of Chongqing University, 2019,42(4): 101 – 110. (in Chinese).
[4] ZHANG FX, YIN YD, MENG T. Selection of mining method and procedure in Fushun East Open-cast Mine[J]. Opencast Mining Technology, 2012(S2): 7 – 8,11. (in Chinese).
[5] LIU T. Study on division and transition optimization of Huolinhe No. 1 Open-cast Min[D]. Xuzhou: China University of Mining and Technology, 2016. (in Chinese).
[6] TIAN FD. Rank-sum Ratio Method and Its Application[M]. Beijing: China Statistical Publishing House, 1993: 21 – 35. (in Chinese).
[7] WANG Q. Study on Optimization of Horizontal Mining and Internal Drainage Scheme in Zhundong Open-pit Coal Mine[D]. Fuxin: Liaoning Technical University, 2016. (in Chinese).
[8] BAI RC, LIU YX, LIU WG, *et al.* Optimization of open-pit mining process based on improved AHP comprehensive evaluation method[J]. Journal of Liaoning Technical University (Natural Science), 2018, 6(37): 463 – 468. (in Chinese).

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DNA analysis of lactic acid bacteria from yak milk from Tibet area[J]. Food Science, 2014, 35(23): 215 – 220. (in Chinese).
[15] PENCE MA, MCELVANIA TE, BURNHAM CA. Diagnostic assays for identification of microorganisms and antimicrobial resistance determinants directly from positive blood culture broth[J]. Clinics in Laboratory Medicine, 2013, 33(3): 651 – 684.
[16] WANG SX, DIAO J, FAN Y, *et al*. Matrix-assisted laser desorption ionization time-of-flight mass spectrometry for bacterial strain identification[J]. Journal of Agricultural Catastrophology, 2019, 9(5): 20 – 23. (in Chinese).
[17] WEI C, DAI XH, GUO LA, *et al*. Analysis of *Lactobacillus delbrueckii* isolated from natural yak yogurt by matrix-assisted laser desorption/ionization time of flight mass spectrometry[J]. Journal of Food Safety and Quality, 2019, 10(14): 4522 – 4528. (in Chinese).
[18] ZHAO YJ, NIU CH, ZHANG X, *et al*. Sequence analysis of 16S rRNA and its application in classification and identification of lactic acid bacteria[J]. Food Science, 2009, 30(7): 299 – 303. (in Chinese).
[19] BOSTAN K, UNVER AA, YALÇIN S, *et al*. Identification and characterization of lactic acid bacteria isolated from traditional cone yoghurt [J]. Food Science and Biotechnology, 2017(26): 1625 – 1632.
[20] XIA XJ, CHEN ZL, CHEN ZD, *et al*. Rapid identification of lactic acid bacteria from traditional dairy products in Tibet area by 16S rDNA sequence analysis[J]. Food Science, 2013, 34(14): 245 – 249. (in Chinese).
[21] ZHAO CP, JIANG LL, ZHANG JL, *et al*. Application of MLST in identification and diversity analysis of lactic acid bacteria[J]. Food Research and Development, 2021, 42(10): 218 – 224. (in Chinese).
[22] IBARZ PA, MAIDEN MC. Multilocus sequence typing[J]. Methods in Molecular Biology, 2009(551): 129 – 140.
[23] LIU W, SU X, DUO N, *et al*. A survey of the relationship between functional genes and acetaldehyde production characteristics in *Streptococcus thermophilus* by multilocus sequence typing[J]. Journal of Dairy Science, 2019, 102(11): 9651 – 9662.
[24] ZHAO WJ, LI Y, GAO PF, *et al*. Application of real-time fluorescent quantitative PCR in quantitative detection of lactic acid bacteria[J]. Journal of Food Science and Biotechnology, 2009, 28(4): 433 – 437. (in Chinese).
[25] SHEHATA HR, RAGUPATHY S, ALLEN S, *et al*. Real-time PCR assays for the specific identification of probiotic strains *Lactobacillus gasseri* BNR17 and *Lactobacillus reuteri* LRC (NCIMB 30242)[J]. Probiotics and Antimicrobial Proteins, 2021(13): 837 – 846.
[26] GUO QY, NIU B, YANG JL. Application of next-generation sequencing technology in the study of foodborne pathogens[J]. Journal of Food Safety and Quality, 2017, 8(4): 1332 – 1338. (in Chinese).
[27] XIE H, ZHAO M, HU ZD, *et al*. Research of the methods for DNA sequencing technology and its progress[J]. Chemistry of Life, 2015, 35(6): 811 – 816. (in Chinese).
[28] FU CP. The overview of DNA sequencing technology[J]. Biology Teaching, 2017, 42(11): 3 – 5. (in Chinese).
[29] AMBARDAR S, GUPTA R, TRAKROO D, *et al*. High throughput sequencing: An overview of sequencing chemistry[J]. Indian Journal of Microbiology, 2016(56): 394 – 404.
[30] MARZORATI M, MAIGNIEN L, VERHELST A, *et al*. Barcoded pyrosequencing analysis of the microbial community in a simulator of the human gastrointestinal tract showed a colon region-specific microbiota modulation for two plant-derived polysaccharide blends[J]. Antonie van Leeuwenhoek, 2013(103): 409 – 420.
[31] CHEN ZY, ZHOU GH. Research progress of focal sequencing technology [J]. Progress in Modern Biomedicine, 2008, 8(8): 1573 – 1576. (in Chinese).
[32] ZHANG GL, JING RX, LIU KM, *et al*. Progress of next generation sequencing technology and its application and development trend in drug quality control[J]. Chinese Journal of Pharmaceutical Analysis, 2021, 41(1): 1 – 12. (in Chinese).
[33] LIU YH, WANG L, YU L. The principle and application of the single-molecule real-time sequencing technology [J]. Hereditas (Beijing), 2015(3): 259 – 268. (in Chinese).
[34] LAURA C, HECTOR R, CARLOS F. Nanopore sequencing and its application to the study of microbial communities[J]. Computational and Structural Biotechnology, 2021(19): 1497 – 1511.
[35] GONG YW, REN XY, HU CJ. Identification of clinical common pathogenic by pyrosequencing[J]. Chongqing Medicine, 2010, 39(22): 3009 – 3010. (in Chinese).
[36] GARCIA-GARCIA S, PEREZ-ARGUELLO A, HENARES D, *et al*. Rapid identification, capsular typing and molecular characterization of *Streptococcus pneumoniae* by using whole genome nanopore sequencing [J]. BMC Microbiology, 2020(20): 347.
[37] ASHTON PM, PETERS T, AMEH L, *et al*. Whole genome sequencing for the retrospective investigation of an outbreak of *Salmonella typhimurium* DT8[J]. PLoS Currents, 2015, 1(5): 1 – 7.
[38] UNDERWOOD AP, DALLMAN T, THOMSON NR, *et al*. Public health value of next-generation DNA sequencing of enterohemorrhagic *Escherichia coli* isolates from an outbreak[J]. Journal of Clinical Microbiology, 2013, 51(1): 232 – 237.
[39] DING RX, GENG LJ, ZHANG TH, *et al*. Dynamic analysis of changes in residual bacteria in pasteurized milk during storage based on next-generation sequencing[J]. Food Science, 2019, 40(14): 77 – 83. (in Chinese).
[40] DOYLE CJ, GLEESON D, OTOOLE PW, *et al*. High-throughput metataxonomic characterization of the raw milk microbiota identifies changes reflecting lactation stage and storage conditions[J]. International Journal of Food Microbiology, 2017(255): 1 – 6.
[41] CAI HY, LIU WJ, SHEN LL, *et al*. Analysis of the structure of lactic acid bacteria in Xinjiang fresh mare milk and koumiss using three generation sequencing technology[J]. Journal of Chinese Institute of Food Science and Technology, 2022, 22(2): 291 – 300. (in Chinese).
[42] ZHENG YQ, YU YX, ZHAO HX, *et al*. Preliminary study on bacterial diversity in low-temperature yogurt from Shanghai supermarket [J]. Food and Fermentation Industries, 2022, 48(6): 58 – 63. (in Chinese).
[43] ZHOU XG, REN LF, LU YT, *et al*. Next generation sequencing technology: Technical review and prospect[J]. Science in China Series C, 2010, 40(1): 23 – 37. (in Chinese).
[44] LIU YJ, HU HY. Third generation sequencing and its innovation in the field of biology[J]. Science and Technology & Innovation, 2021(5): 34 – 39. (in Chinese).

(From page 26)

[9] LIU C, BAI RC, LIU WG, *et al*. Optimization of mining sequence based on coordination mining technology between two adjacent open pits[J]. Journal of Chongqing University (Natural Science), 2016(4): 103 – 111. (in Chinese).
[10] XU ZY. Study on Turning Mode of Mining Area and Optimization of Development and Transportation System in Large Surface Coal Mine[D]. Xuzhou: China University of Mining and Technology, 2007. (in Chinese).
[11] YE YC. Decision to mining procedure selection[J]. West-China Exploration Engineering, 1995(2): 34 – 36. (in Chinese).
[12] MA PZ. Optimization of Mining Technology for Huolinhe No. 1 Opencast Mine Expansion Project[J]. Coal Engineering, 2006(5): 5 – 6. (in Chinese).