Closure of Underground Mine of Lincang Uranium Mine

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Abstract. Linchang Uranium Mine is a small mine/mill complex and left 17 adits inclined shaft (V 1850) and 4 open raises after closure. Among them, 5 adits and the inclined shaft overflowed water, containing radioactive and non-radioactive constituents, such as, U, 226Ra, Cd, Cr6+, As, Pb, Cu, Mn, SO42- and F-.

All adits and inclined shaft released radon with concentrations of 0.126—14.9Bq/L at the exits.

The adits and inclined shaft with overflowing were flooded by combination of water-proof dam and curtain grouting, and the other adits were sealed by placing rock walls and open raises without overflowing were closed by backfilling.

All adits, inclined shaft and open raises were permanently closed down after backfilled with clay soil or mixed soil outside the water-proof dams and rock walls.

All adits, open raises and the inclined shaft do not release radon and waste water after closing down.

Introduction

Lincang uranium mine is a small mine/mill complex. It began production in 1970 and was closed in 1994. The uranium mine extracted ores of No.Ⅱ, Ⅲ, Ⅴ, Ⅵ, Ⅷ mining area containing pyrite. The mill process adopted filtration leaching of non-crashed ore by H_2SO_4 and MnO_2, and extraction of settled leachate by organic phase. The final product was $(NH_4)_4UO_2(CO_3)_3$.

The uranium mine left 1 tailings pile, 18 mining waste piles, 2 open pits, 39 surface subsidence pits, 4 patios, 17 adits and 1 inclined shaft. The remediation began in 2001 and completed in the end of 2007.

The adits and inclined shaft released radon and water containing radioactive and non-radioactive constituents, resulting in adverse environmental impact. Therefore, it is important to close the all the adits and shaft so as to stop to release radon and water from the adits and shaft.

Study Area

In this region, annual average temperature is 16.8 °C~17.7 °C; average precipitation and evaporation is 1163.9 mm and 1580.9 mm, respectively.

The orebody is hosted by the lower formation containing coal of Neogene sediments of intermont nonmarine Mengtuo Fault Basin NE-SW orientated as base of Lincang granite. The strata are quaternary (Q) and clasolite bed containing coal (N^2), sandstone- conglomerate bed ($N^{1-(2+3)}$) and granite clasolite bed (N^{1-1}) of Neogene sediments from upper to lower.

The hydrogeological type of the mine is medium. Conglomerate containing uranium ores is the main aquifer. There is not any complete aquitard. under and above ore bed. Groundwaters are mainly porous phreatic water and interstrated unconfined water. There is local interstrated confined water and fissure confined water. There is hydraulic relation between surface water and groundwater. Hydraulic connection also exits between different aquifer. Groundwater type is fistly $SO_4^{2-}.HCO_3^{-}$-$(K^+ + Na^+)$, $HCO_3^{-}.SO_4^{2-}$ -$(K^+ + Na^+)$, secondly, $HCO_3^{-}.SO_4^{2-}$-$(K^+ + Na^+).Ca^{2+}.Mg^{2+}$.

The uranium ores were mined by conventional open pit and underground methods by combination of adit and inclined shaft development (Fig.1).

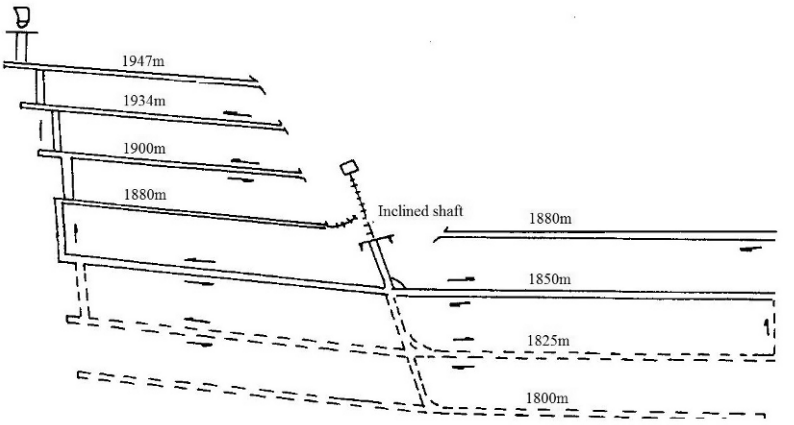

Fig.1. Development of □, □ mining area.

Table 1. Overflowing water chemistry, mg/L (except flow m^3/d, ^{226}Ra Bq/l, and pH)[a]

Location	flow	U	^{226}Ra	Cd	Cr^{+6}	As	Pb	Mn	SO_4^{-2}	F-	pH
II 1925	15.1	31.8	0.782	1.00	5.700	8.478	3.125	2.67	2455	2.90	2.47
V 1850	105	0.39	6.16	0.015	1.667	0.095	0.277	2.76	1381	2.02	4.95
III 1925	52.0	0.01	1.40	0.001	0.733	0.015	0.025	1.11	104	0.57	6.10
III 1942	9.68	0.005	0.035	0.016	0.333	0.094	0.025	0.42	20.2	0.24	5.95
limit		0.05		0.005	0.05	0.05	0.05	0.1	250	1.0	6.5-8.5

[a] U and ^{226}Ra: annual mean; non-radioactive constituents: single monitoring in dry season.

Table 2. ^{222}Rn concentrations of air at the exits of the adits and inclined shaft (Bq/L)

location	□1972	□1950	□1948	□1948	□1925	□1964	□1942	□1934	□1925
^{222}Rn	14.9	1.04	0.126	0.412	3.29	0.212	0.306	1.55	10.7
location	□1925-1	□1925-2	□1947	□1934	□1942	□1900	□1800	□1850	□1880
^{222}Rn	4.77	1.34	2.90	0.325	3.24	0.825	1.68	0.150.	—

Environmental Issues of the Adits and Inclined Shaft

Linchang mine left 17 adits and 1 inclined shaft (V 1850) after closure. Among them, 5 adits and the inclined shaft overflowed water, containing radioactive and non-radioactive constituents, such as, Cd, Cr6+, As, Pb, Cu, Mn and SO42-, exceeding relevant regulatory limits (Table 1). Additionally, the adits and the inclined shaft were releasing radon. Radon concentrations at the exits were 0.126~14.9Bq/L (Table 2).

Closure technologies of adits and inclined shaft

Flooding is the most environmentally friendly, technically safest option to limit contaminated water from the underground mine to overflow. VI 1880, V 1880, V 1990, III 1925, III 1942, II 1925 adits and inclined shaft with overflowing and potential overflowing were flooded by combination of water-proof dam and curtain grouting, and the other adits were sealed by placing rock walls and open raises without overflowing were closed by backfilling (Fig.2 ~Fig.7).

All adits, inclined shaft and open raises were permanently closed down after backfilled with clay soil and mixed soil respectively, outside the water-proof dams and rock walls. Effective radium of grout spreading is 0.4m. Grouting fluid ingredient is water: cement 1:1, accelerator of 0.5% sodium chloride and 0.05% Triethanol Amine and suspension agent of 7% kaoline and 10% PCC (a water-tight

patent material). The 0.2m gap between the two water-proof dams constructed in a flooding adit and some curtain grouting boreholes around the adits wall between the two water-proof dams are used to grout.

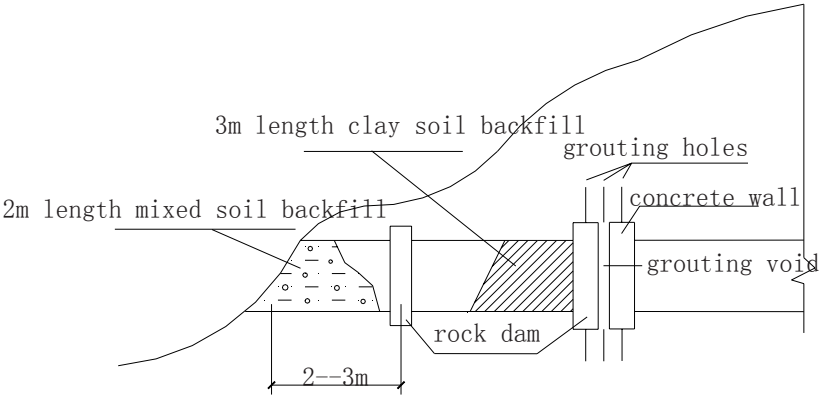

Fig.2. Cross-section of sealing adits and inclined shaft with drainage.

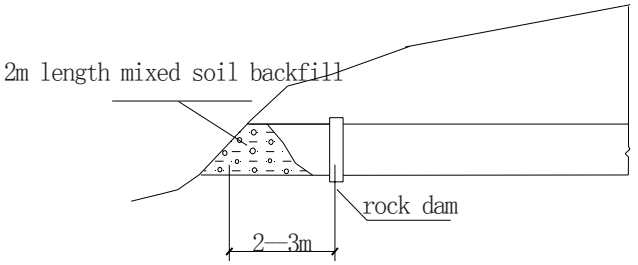

Fig.3. Sealing cross-section of adits and inclined shaft without drainage.

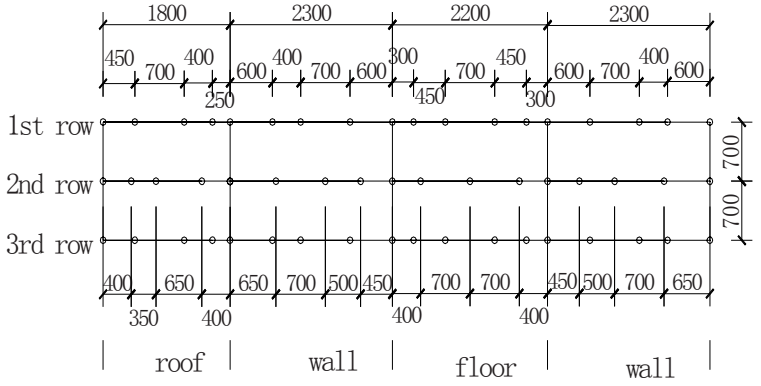

Fig.4. Diagrammatic cross-section of grouting holes for water blocking of inclined shaft.

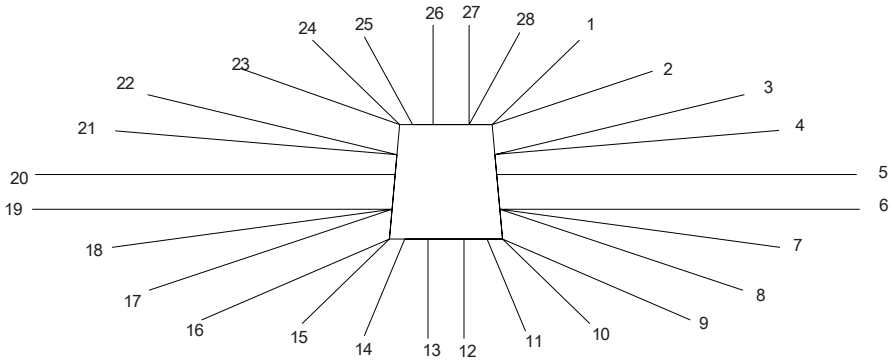

Fig.5. Grouting holes display of 1st and 3rd row for water blocking of inclined shaft.

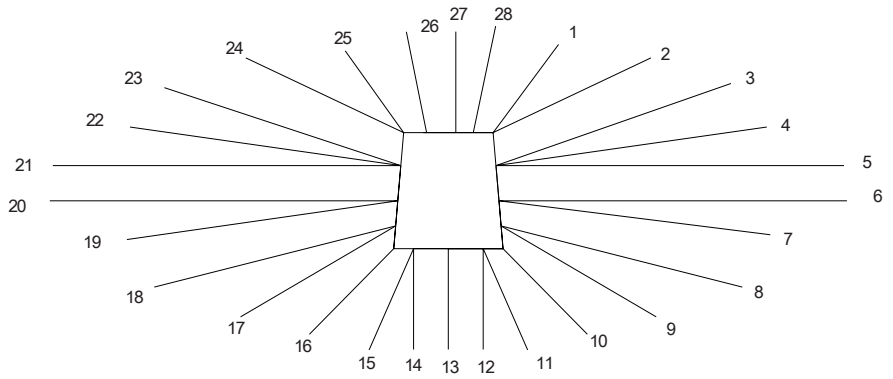

Fig.6. Grouting holes display of 2nd row for water blocking of inclined shaft.

Fig.7. The inclined shaft before and during closure

Conclusions

Linchang Uranium Mine is a small mine/mill complex and left 17 adits□1 inclined shaft (V 1850) and 4 open raises after closure. Among them, 5 adits and the inclined shaft overflowed water, containing radioactive and non-radioactive constituents, such as, U, ^{226}Ra, Cd, Cr^{6+}, As, Pb, Cu, Mn□SO_4^{2-} and F^-. All adits and inclined shaft released radon with concentrations of 0.126—14.9Bq/L at the exits.

The mine developed shallowly and has mainly porous phreatic water and interstrated unconfined water with less water yield. Therefore, it is the most effective remediation method to plug and seal the underground mine by curtain grouting and /or backfilling. All adits, open raises and the inclined shaft do not release radon and waste water after remediation.