ASSESSING THE QUALITY AND THE RESERVES OF HOT MINERAL WATER SOURCE IN MY LAM, TUYEN QUANG AS A BASIS FOR REASONABLE EXPLOITATION

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Abstract: *Hot Mineral Water in My Lam, Tuyen Quang is precious and is valuable in nursing and healing. Water resources are being exploited in borehole LK13 with capacity of more than 400m3/ per day. This capacity would not satisfy the demand for nursing and medical treatment in the next few years. In order to increase the capacity of mineral water exploitation, we have conducted research and evaluation of safe exploitation reserves in three boreholes within mines. Research results are the basis for the sustainable exploitation of mineral water source with a capacity reached 2.272 m^3/per day in the long run (27 years). After 27 years, drawdown calculated in the exploited holes will reach the allowed limit and water quality is stable.*

Key Words: *Hot thermal mineral water/ groundwater/Mylam Tuyen Quang/Vietnam*

Problem raised:

Hot mineral water source in My Lam, Tuyen Quang is very precious which has been exploited in borehole LK13 for many years. However, if exploitation reserves are increased to expand the services, reserves in borehole LK13 will not meet. In order to have a complete basis for evaluating, increasing exploitation capacity of mineral reserves in the mine, it is necessary to study the motives to find out the reserve and quality of mineral water for expansion of exploitation based on sustainability and protection of water resources. The purpose of the research is to study quality, reserves of mineral water in order to exploit mineral water suitably. Research content is pumping test to calculate the exploitable reserves and sampling mineral water during the pumping test to evaluate water quality over time of exploitation.

1. Geographic location

My Lam mineral water mine, Tuyen Quang located 10km southwest of Tuyen Quang City. Mine has an area of about 5.5 km^2 (Figure 1).

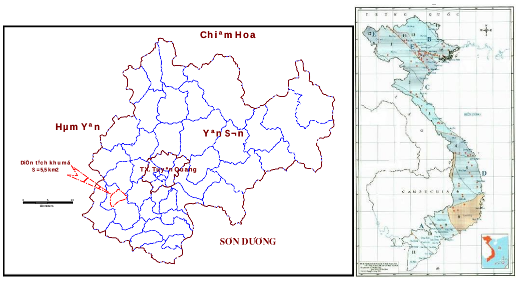

Figure 1. Location Map of My Lam Mineral Water Mine

2. Research Method

- *Pumping test one times.*

We have conducted pumping test with one times in 3 boreholes. Location map of boreholes and hydrogeological boreholes shown in Figure 2.

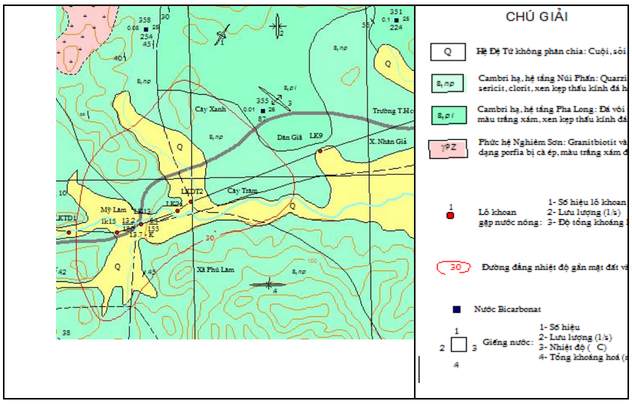

Figure 2. Location map of mineral water boreholes pumping test

In the process of pumping test, we have measured flow, temperature, drawdown in boreholes. Measurement results shown in Table 1.

Table 1. The parameters measured when pumping test in boreholes

Name of boreholes	Flow Q (l/s)	Flow rate (l/sm)	Temperature (^oC)
LK2	4,7	0,76	51
DT3	10,2	2,20	51
LK13	11,4	6,99	69

- *Pumping test exploitation:* Carrying out pumping test in all 3 wells at the same time to evaluate the maximum effect between wells, calculate the hydrogeological parameters. Sampling water for quality analysis. Total number of samples obtained 65 samples, shown in Table 2.

Table 2. Number of samples obtained and analyzed

Total sample: 17	Microbiological sample: 12	Pollution samples: 12
Samples to analyse heavy metals: 12	Monitoring samples: 12	

3. Evaluate mineral water quality

- Results analysed in the research process

Number of samples

Results analysed of 65 water samples showed that My Lam mineral water is used for treatment. Ion content has physiological effects included Axit Metasilicsic (H_2SiO_3), Sunfuahydro(H_2S), Flo. Content of the chemical composition is shown in the formula of Kurlov:

$$M_{0,19}\frac{HCO^3_{85}Cl_{14}}{Na_{95}}pH_8,T_{63^0}$$

Name of the bicarbonate - sodium, this is kind of soda popular in the market. The results of analysis of chemical composition and quantity of water are shown in Table 3.

Table 3. A unique value of indicators to analyze the chemical composition of water samples

Indicators to analyse	Units	Ranges/ Average values		
		LK13	LK2	LKDT3
pH		8,07 – 8,13 8,09	7,98 – 8,13 8,06	7,47 – 7,64 7,57
Oxidation	$mg0_2/l$	1,52 – 1,71 1,63	1,25 – 1,41 1,34	1,89 – 2,13 1,99
Total hardness	$mgCaC0_3/l$	58 – 68,6 64,2	134,2 – 152,9 143,9	109,4 – 114,4 112,47
Temporary hardness	-	58 – 68,6 64,2	134,2 – 145,2 140,6	109,4 – 114,4 112,47
Permanent hardness	-	0	0 – 7,9 3,3	0
Total dissolved solids	mg/l	120,9 – 129,7 125,8	175,6 – 182,1 178,2	149,9 – 153,6 152,07
SO_4^{-2}	mg/l	10,13 – 11,27 10,58	8,24 – 9,89 9,19	6,47 – 7,83 7,33
CO_3^{-2}	mg/l	0	0	0
HCO_3^-	mg/l	132,42 – 141,07 137,6	164,4 – 176,94 172,09	146,85 – 159,73 152,63
CL^-	mg/l	9,96 – 11,06 10,6	10,36 – 11,34 10,77	9,89 – 10,34 10,13
NO_3^-	mg/l	< 0,01	< 0,01	0,02 – 0,05 0,033
NO_2	mg/l	< 0,01	< 0,01	< 0,01
PO_4^{-3}	mg/l	< 0,01	< 0,01	0,03 – 0,05 0,043
Ca^{2+}	mg/l	15,11 – 17,43 16,42	31,27 – 33,58 32,59	24,98 – 26,47 25,56
Mg^{2+}	mg/l	4,94 – 6,57 5,67	13,71 – 16,83 15,27	11,29 – 12,47 11,84
Na^+	mg/l	38,47 – 39,79 39,04	15,94 – 19,43 17,60	23,14 – 24,75 24,02
K^+	mg/l	2,,68 – 3,27 2,03	1,48 – 2,14 1,84	1,14 – 2,45 1,92
Fe^{+3}	mg/l	< 0,05	< 0,05	< 0,05
Fe^{+2}	mg/l	0,127 – 0,186 0,156	0,12 – 0,22 0,16	0,240 – 0,370 0,31

Mn^{+2}	mg/l	< 0,05	$\frac{0,016-0,028}{0,022}$	< 0,05
NH_4^+	mg/l	< 0,01	< 0,01	$\frac{0,01-0,02}{0,02}$

Table 4. The indicators to analyse mineral water standard based on QCVN 9-1/2009/BYT

Indicators to analyse	Units	Ranges/ Average values			Standard QCVN 9-1/2009/BYT
		LK13	LK2	LKDT3	
Color	TW	$\frac{5-5,5}{5,1}$	5,5	5	≤ 15
Odor		No strange odor	No strange odor	No strange odor	No strange odor
Turbidity	NTU	$\frac{1-5}{4}$	$\frac{5-8}{6,7}$	$\frac{4-6}{5,33}$	≤ 2
Total dissolved solids	mg/l	$\frac{120,9-129,7}{125,8}$	$\frac{175,6-182,1}{178,2}$	$\frac{149,9-153,6}{152,07}$	*
F^-	-	$\frac{8,19-8,81}{8,41}$	$\frac{7,11-8,02}{7,62}$	$\frac{7,97-8,73}{8,30}$	**
Sb	μg/l	0,196	$\frac{0,174-0,243}{0,204}$	0,196	≤ 5
As	-	$\frac{0,406-0,580}{0,49}$	$\frac{0,387-0,490}{0,432}$	$\frac{0,474-0,528}{0,498}$	≤ 10
Ba	-	KPT	KPT	KPT	≤ 700
Bo	-	KPT	KPT	KPT	≤ 5000
Cd	-	$\frac{0,006-0,007}{0,006}$	0,008	0,003	≤ 3
Cr	-	$\frac{0,482-0,558}{0,524}$	$\frac{0,392-0,436}{0,414}$	$\frac{0,546-0,588}{0,569}$	≤ 50
Cu	-	$\frac{0,371-0,513}{0,435}$	$\frac{0,204-0,288}{0,245}$	$\frac{0,22-0,34}{0,27}$	≤ 1000
CN	-	KPT	KPT	KPT	≤ 70
Pb	-	$\frac{0,052-0,064}{0,057}$	$\frac{0,037-0,044}{0,041}$	$\frac{0,027-0,036}{0,031}$	≤ 10
Mn	-	< 0,05	$\frac{0,016-0,028}{0,022}$	< 0,05	≤ 0,5
Hg	-	$\frac{0,352-0,435}{0,399}$	$\frac{0,163-0,215}{0,189}$	$\frac{0,049-0,058}{0,053}$	≤ 1
Ni	-	$\frac{0,035-0,048}{0,042}$	$\frac{0,024-0,035}{0,029}$	$\frac{0,184-0,191}{0,187}$	≤ 20
NO_3^-	mg/l	<0,01	<0,01	$\frac{0,02-0,05}{0,033}$	≤ 50
NO_2^-	-	<0,01	<0,01	<0,01	≤ 0,02
Se	μg/l	$\frac{0,389-0,446}{0,423}$	$\frac{0,246-0,328}{0,295}$	$\frac{0,152-0183}{0,170}$	≤ 10
	mg/l	< 0,1	< 0,1	< 0,1	≤ 1
Surface active agents	-	< 0,05	< 0,05	< 0,05	≤ 0,1
	-	$< 10^{-4}$	$< 10^{-4}$	$< 10^{-4}$	≤ 0,7
Pesticide	-	KPT	KPT	KPT	≤ 30

residue					
Br^-	-	$\frac{0,01-0,013}{0,011}$	0,015	< 0,01	KQ§
Be	μg/l	$\frac{0,299-0,357}{0,327}$	$\frac{0,166-0,203}{0,185}$	$\frac{0,496-0,518}{0,506}$	KQ§
Zn	-	$\frac{0,112-0,201}{0,167}$	$\frac{0,076-0,04}{0,084}$	$\frac{4,215-5,065}{4,542}$	KQ§
Ti	-	$\frac{2,33-2,45}{2,39}$	$\frac{1,983-2,757}{2,395}$	$\frac{2,245-2,414}{2,332}$	KQ§

According to the results of previous analyzes (1985, 1999, 2003), the chemical composition of My Lam mineral water is bicarbonate- sodium. However, the result of current analysis (2010) shows that in borehole LK13 (often exploitation), the chemical composition is bicarbonate- sodium, calcium, and in borehole LK2 the chemical composition is bicarbonate – calcium, magnesium, sodium and in borehole LKDT3 the chemical composition is bicarbonate – calcium, sodium, magnesium (Table 5)

Table 5. Result of analyzing water chemical composition and Kurlov Formula

No	Indicators to analyse	LK3			LK2		
		mg/l	mgdl/l	% mgdl/l	mg/l	mgdl/l	% mgdl/l
	Anion						
1	HCO_3^-	137,6	2,26	80	172,10	2,82	85
2	SO_4^{-2}	10,60	0,22	8	9,20	0,19	6
3	Cl^-	10,60	0,35	12	10,80	0,31	9
	Total		2,83	100		3,32	100
	Cation						
1	Na^+	39,04	1,70	55	17,60	0,77	21
2	K^+	3,03	0,08	3	1,84	0,05	1
3	Ca^{+2}	16,42	0,82	27	32,59	1,63	44
4	Mg^{+2}	5,67	0,45	15	15,27	1,27	34
	Tæng		3,07	100		3,72	100
Kurlov Formula		$M_{0,13}\frac{HCO^3_{80}Cl_{12}}{Na_{55}Ca_{27}Mg_{15}}pH_8$			$M_{0,18}\frac{HCO^3_{85}}{Ca_{44}Mg_{34}Na_{21}}pH_8$		

From the above analysis we can draw some comments:

- The chemical composition can be changed slightly compared to the moment it has not exploited yet. In LK13 water has changed from the form of a bicarbonate-sodium into the form of bicarbonate -sodium, calcium. In

LK2 water is in the form of bicarbonate – calcium, sodium, magnesium

Cause: Preliminary assessment may be due to the infiltration of groundwater and My Lam spring water on mineral water when pressure of the mineral water zone lowers during the process of exploitation. Only Borehole LK2 and LHDT3 have changes in chemical composition of mineral because water from the upper layer is absorbed directly through the gap between the screen, casing and drill holes. But the nature of mineral water has not changed.

Therefore, the result of research shows that :

- My Lam Mineral Water is silic, sunfuahydro, fluorine water with high temperature. Indicators of chemical composition and microbiology analysed meet the demand of Standard QCVN 9-1/2009/BYT of bottled natural mineral water. Water chemical composition has changed from the form of a bicarbonate-sodium into the form of bicarbonate-sodium, calcium.

- My Lam Mineral Water is kind of very hot water (69^oC), sterile.

4. Mineral water reserve

- *Evaluating mineral water reserves based on documents of pumping test in LK13.* LK13 was conducted pumping test with 3 times of drawdown. When pumping test, water was exploited in 2 boreholes LK2 and LKDT3. Result of pumping tests is shown in Table 6.

Table 6. Result of pumping tests in LK13

Times of drawdown	Flow Q (l/s)	Drawdown levels			Temperature T (^0C)
		LK13	LKDT3	LK2	
1	11,40	2,43	0,37	0,31	69,50
2	7,00	1,88	0,06	0,35	67,50
3	8,33	1,93	0,10	0,46	67,50

From documents of pumping tests, we have set up the relationship between Q and S, table 7.

Table 7. Documents of pumping test in Borehole LK13

Times of drawdown	Q(l/s)	S (m)	q(l/s.m)	S/Q (ms/l)	lgQ	lgS
1	11.40	2.43	4.69	0.21	1.06	0.39
2	7.00	1.88	3.72	0.27	0.85	0.27
3	8.33	1.93	4.32	0.23	0.92	0.29

From Table 7, we build graphs and establish equations to perform relationship between Q and S shown in Table 8.

Table 8. Relationship between Q, (S_{2tt}) and (S_{2db}) when pumping test in LK13

Relationship	Equation	Q_2 (l/s)	S_{2tt}(m)	S_{2db}(m)	Error balance △S (m)
Duyquy	Q=4,25S	7	1,88	1,64	0,24
Kenler	S/Q=0,356-0,015Q	7	1,88	1,76	0,12
Antopski	Q=-14.6+80lgS	7	1,88	1,86	0,02
Smoreke	lgQ=0,062+0,21lgS	7	1,88	1,31	0,57

Evaluation of reserves was based on documents of pumping test in borehole LK2. Like the borehole LK13, borehole LK13 was carried out pumping test with three times of drawdown. The result of pumping test is shown in Table 9.

Table 9: The result of pumping test in borehole LK2

Times of drawdown	Flow Q (l/s)	Drawdown levels			Temperature T (^0C)
		LK2	LK13	LKDT3	
1	4,70	6,22	0,06	0,08	49
2	2,10	2,08			49
3	1,40	1,12			49

From the above table, we have calculated the parameters to build graphs and establish equations to perform relationship between Q and S (Table 10).

Table 10. Parameters of pumping test in Borehole LK2 to perform relationship between Q and S

Times of drawdown	Q(l/s)	S (m)	q(l/s.m)	S/Q (ms/l)	lgQ	lgS
1	4,7	6,12	0,76	1,32	0,67	0,79
2	2,1	2,08	1,01	0,99	0,32	0,32
3	1,4	1,12	1,25	0,80	0,15	0,05

Drawdown in reality and in forecast based on the relationship is shown in Table 11.

Table 1. Drawdown level in reality (S_{2tt}) and in Forecast (S_{2db})

Relationship	Equation	Q_2(l/s)	S_{2tt}(m)	S_{2db}(m)	Error balance △S (m)
Duyquy	Q=0,73S	2,1	2,08	2,84	0,76
Kenler	S/Q=0,664+0,14Q	2,1	2,08	2,01	0,07

Antopski	Q=0,422+5,26lgS	2,1	2,08	2,08	0,00
Smoreke	lgQ=0,102+0,71lgS	2,1	2,08	2,04	0,04

From the Table 11, it can be seen that Q and S follow the relationship of Antopski like in Borehole LK13.

Relationship Equation Qkt= 0,422+5,26 lg 6,22.2= 6,15l/s or 531m3/per day.

Evaluation of reserves was based on documents of pumping test in borehole DT3.

The way of calculation was done like the borehole LK13, borehole LK12. The result of pumping test, calculate the relationship is shown in Table 12, 13 and 14.

Table 12. The result of pumping test in borehole LK DT3

Times of drawdown	Flow Q (l/s)	Drawdown levels			Temperature T (^{0}C)
		LK2	LK13	LKDT3	
1	11,47	4,56	0.42	0,10	51
2	4,40	3,11			48
3	2,20	1,46			48

Table 13. Parameters of pumping test in Borehole LK DT3 to perform relationship between Q and S

Times of drawdown	Q(l/s)	S (m)	q(l/s.m)	S/Q (ms/l)	lgQ	lgS
1	11,47	4,56	2,52	0,40	1,05	0,66
2	4,40	3,11	1,41	0,71	0,64	0,49
3	2,20	1,46	1,51	0,66	0,34	0,16

Table 14: Drawdown level in reality (S_{2tt}) and inForecast (S_{2db}) according to documents of pumping test in LKDT3

Relationship	Equation	Q_2(l/s)	S_{2tt}- (m)	S_{2db}(m)	Error balance △S (m)
Duyquy	Q=2,25S	4,40	3,11	1,96	1,15
Kenler	S/Q=0,77-0,03Q	4,40	3,11	2,81	0,30
Antopski	Q=-2,5+15lgS	4,40	3,11	2,88	0,23
Smoreke	lgQ=0,03+1,43lgS	4,40	3,11	2,68	0,43

The result of calculation in Borehole LK DT3 shows that the relationship between Q and S also follows the Equation of Antopski S_{kt}= $2S_{max}$= 2*4,56=9,12m we have Q_{kt}= -2,5+15lg 9,12= 11,9 m/s or 1028 m^3/per day

- Evaluate the capacity of exploitation in three boreholes analysed according to document of group pumping test.

To assess the exploited reserves when all 3 boreholes are simultaneously working, during the process of research we conducted group pumping test in three boreholes in the period of 19.5 times.

Results of group pumping test are shown in Table 15.

Table 15: Results of group pumping test in three boreholes LK13, LK2, LKDT3

No	Borehole	Water level (H_t m)	Flow Q (l/s)	Drawdown level S (m)	Flow rate q (l/s.m)	Water temperature T(^{0}C)
1	LK13	2,54	11,40	1,90	6,00	69,50
2	LKDT3	6,91	10,20	4,80	2,13	51,00
3	LK2	3,17	4,70	6,44	0,73	51,00

From the documents of pumping test, we have found out the rule of changes of Drawdown level over time in each borehole as following:

LK13: S = 1,18 + 0,18lgt

LKDT3: S = 3,44 + 0,32lgt

LK2: S = 5,05 + 0,27lgt

The result of calculation according to documents of pumping test in 3 Boreholes proves that in Borehole13 it can be exploited 11,4 l/s or 985m^3/per day, in LKDT3: 10,2 l/s or 881m^3/per day and in LK2: 4,7 l/s or 406m^3/per day. Drawdown level at the end of exploitation time was calculated for each borehole as follows.

LK13: S_{kt}= 1,9 + 1,18+0,18.lg(t_{kt}- t_{tn})

LKDT3: S_{kt}= 4,8 + 3,44+0,32.lg(t_{kt}- t_{tn})

LK2: S_{kt}= 6,44 + 5,05+0,27.lg(t_{kt}- t_{tn})

Among them:

S_{kt}: Drawdown level at the end of exploitation time

t_{kt}: Time of exploitation (alw ays about 27 years)

t_{tn}: Time to carry out pumping test

The result to forecast the drawdown level after 27 years is shown in Table 16.

Table 16. Drawdown level in boreholes after 27 years anf 50 years of exploitation

Time of exploitation (days)	LK13	LKDT3	LK2
9855	3,62	9,52	12,57
18250	3,85	9,60	12,64

The calculated result shows that after 27 years of exploitation, drawdown level in LK13, LKDT3 is lower than allowed drawdown (S_{cp}=10m). However, in LK2, S_{kt} is slightly higher than S_{cp}. This proves exploitation reserve is ensured.

5. Conclusion

5.1. The calculated result according to documents of pumping test in three boreholes proves that flow that can be exploited in LK13 is 985m^3/per day, in LKDT3 is 881 m^3/per day and in LK2 is 406m^3/per day.

With the mentioned above flow, afetr 27 years of exploitation, drawdown level in all boreholes is lower than allowed drawdown (S_{cp}=10m). This proves exploitation reserve is ensured.

5.2. In order to exploit mineral water in three boreholes: LK13, Lk2 and DT3, it is necessary to have a method to change the exploration boreholes into exploiation wells (LK2 and DT3).

5.3. Due to high Floride content, it is essential to indicate on the label of the product that mineral water contains fluoride and the product is not suitable for the children under 7.

6. Reference

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