Comprehensive Utilization of Urmia Salt Lake Resources

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Abstract *Urmia Salt Lake is one of the largest salt lake in Middle—east district. On the basis of the composition of the lake brine and local condition of natural geography, we have studied the feasibility for the comprehensive utilization of potassium, soldium, bromine and magnesium in the lake. In this paper, we have proposed a possible scheme for the developing scale, chemical processes of separation and manufacture, environmental evalation of the processing, the choice of place for building factory and the feasibility concerning technology and economy. The study reveals that the bromine and sodium of Urmia Salt Lake are of significant utilization value.*

Keywords: Urmia salt lake, Salt lake resources, Comprehensive utilization
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1. Possibility of exploiting valuable resources from Urmia Lake

Urmia Salt Lake is the largest salt lake in Iran. The lake is located in the northwestern Iran as shown in figure 1 and contains huge salt resources.

In the summer of 1995 we investigated Urmia Salt Lake and took some samples from Urmia Lake. We analyzed the contents of the compositions of the brine and the results are listed in table1.

Table. 1 The concentration distribution of the ions of the brine in Urmia Lake

number	K^+	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	B_2O_3	Br^-	I^-
B22	0.143	8.62	4.2×10^{-2}	0.69	14.53	0.306	9.1×10^{-3}	3.5×10^{-2}	2.1×10^{-2}	1.2×10^{-5}	
B30	0.5859	0.52	1.6×10^{-2}	6.38	18.37	1.842	0.21	$<1.5\times10^{-4}$	0.42	0.30	3.5×10^{-4}
B34	1.238	2.07	$<3.2\times10^{-2}$	5.23	16.46	3.944	0.17	$<2.6\times10^{-4}$	0.32	0.20	2.5×10^{-4}
B36	0.0286	0.04	$<1.2\times10^{-2}$	8.87	24.24	1.714	0.39	$<3.6\times10^{-4}$	0.61	0.44	8.1×10^{-4}
Yws−1	0.0735	4.57	4.2×10^{-2}	0.35	7.67	0.692	7.4×10^{-3}	1.8×10^{-2}	8.7×10^{-3}	8.0×10^{-3}	1.1×10^{-5}
Yws−2	0.0710	4.36	4.7×10^{-2}	0.32	7.31	0.654	$6.8\times^{-3}$	1.8×10^{-2}	1.4×10^{-2}	$7.3\times^{-3}$	1.1×10^{-5}
Iran	0.14	8.54	0.06	0.62	14.24	1.16	0.015			0.0216	

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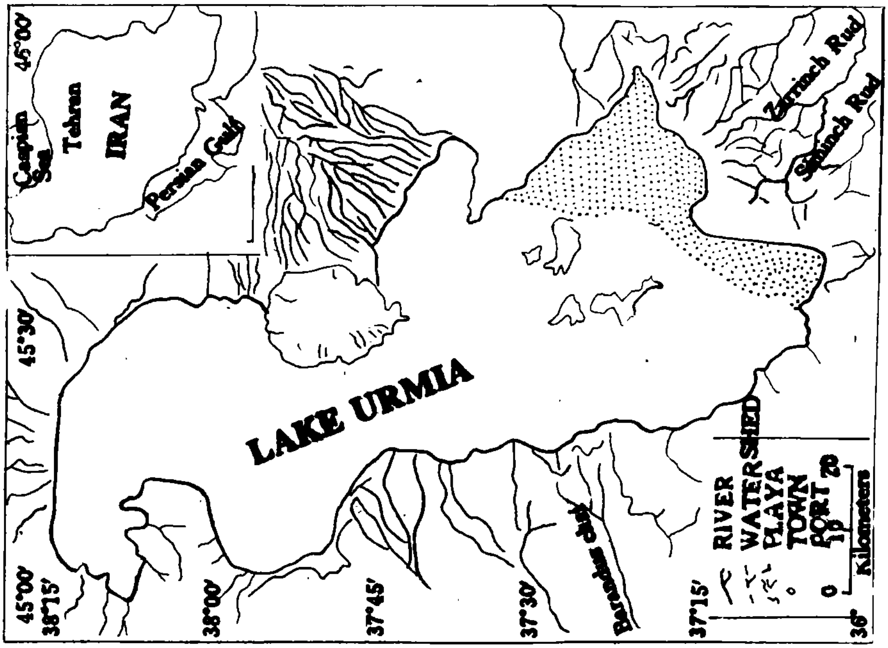
Note: The Yws — 1, 2 was taken by us on June 12, 1995. B22 — 36 are the samples supplied by Corundum Geological and Mineral Research CO. (CGMRC). B22—36 represent the sample with 22—36 Baume degrees. Iran is the sample supplied by CGmrc.



Firure 1. Urmia Salt Lake

Urmia Lake shows a smooth fluctuation in the level of lake water during the past two decades as shown in figure 2. According to the components of Urmia Lake, the brine of Urmia Lake contains sodium chloride of about 20%, sulfates of 3%, potassium chloride of 0.2% and bromine of 0.02%. These mineral resources are of great exploitable and economic value. Sodium chloride, potassium chloride, magnesium sulfate, potassium sulfate, magnesium chloride and bromine can be extracted from the brine. The concentrations of Yws — 1 and Yws — 2 samples are half high compared with the data supplied by CGMRC. The difference in the concentration can be attributed to the dilution of the samples Yws — 1 and Yws — 2 by summer rainwater.

When we investigated Urmia Salt Lake, the technicians of Research Mining Co. of Azabaijian suggested an exploiting plan for Urmia Lake. The plan suggested an annul production amount of 200,000 tons of NaCl, 50,000 tons of K_2SO_4 and proper scale of Br_2. We suppose that the suggestion was made in the light of Iranian and the relative international market for the requirement of inorganic salt products. If K_2SO_4 and Br_2 by—products are only produced from the residue mother liquor after the extraction of NaCl, the production amount of K_2SO_4 and Br_2 can only be attained to 4000 and 500 tons based on the equilibrium of components for the Uramia Lake brine and phase equilibrium for the production scale of 200,000 tons NaCl per year. So, if one tries to attain a production capability of 50,000 tonsof

K_2SO_4 only by using the potassium resources of Uramia brine, the capacityof NaCl has to be attained to 2,000,000 tons in the first stage of sloar pond evaporation. In this case, 6,000 tons of Br_2 and 60,000 tons of MgCl\—2 by—products can be produced from the residue mother liquor. A problem of market requirement for so large amount of NaCl has to be solved, although the production scale of 6,000 tons of Br_2 is probably suitable for the requirement of local market. Moreover, the big investment in building solar pond for the production of 2,000,000 tons of NaCl is also a serious problem because the production of NaCl itself will spend 70% of the total investment.

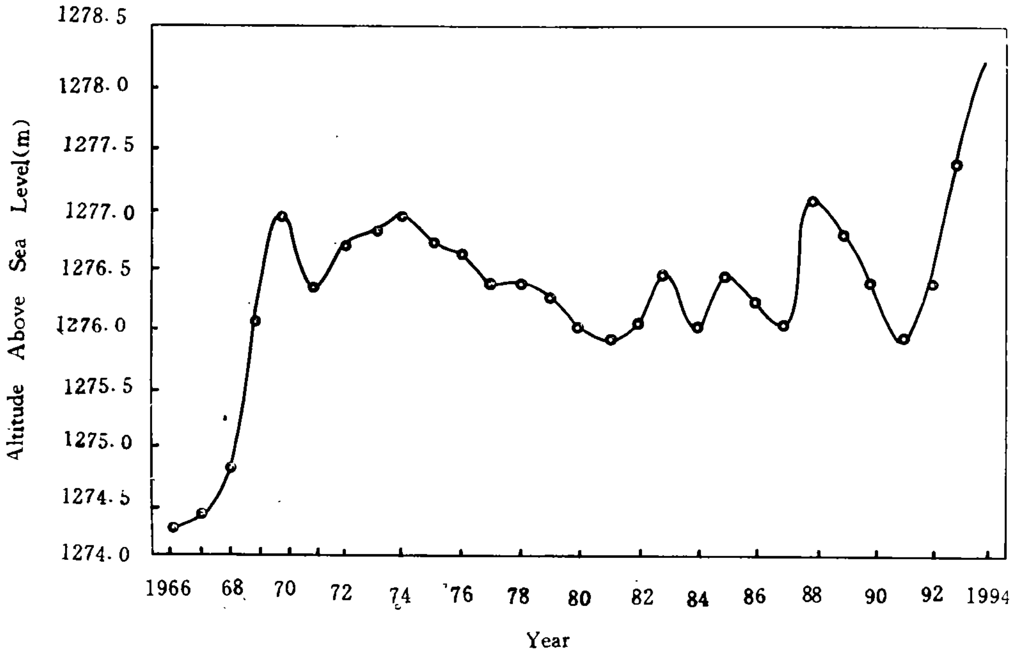


Figure2. Lake Level Fluctuation in the last 30 Years

(Data Aceording to Urmia. Sr. Citv)

Another way of producing K_2SO_4 in so large scale is to import KCl from abroad. The production of 50,000 tons of K_2SO_4 requires 130,000 tons of $Na_2SO_4 \cdot 10H_2O$ and 56,000 tons of KCl. Although Iran has huge sodium sulfate resources, there is no large—scale KCl industry in the country. Therefore, the feasibility for the production of K_2SO_4 depends on the price of imported KCl. The project can be performed if Iran can import KCl with lower purity in cheap price.

In the light of fully comprehensive utilization of Urmian Lake resources, the production scale of 200,000 tons of NaCl, 4000 tons of K_2SO_4 and 500 tons of Br_2 is reasonable. The production scale of 4000 tons of K_2SO_4 and 500 tons of Br_2 is too small and small—scale production gives poor economic benefits. Since the brine of Urmia Lake contains highly enriched bromine, in our opinion it is better to only extract bromine from original brine in the first stage of exploitation and a plant for the production of 2,000—5,000 tons of Br_2 should be built. In this way, investment will be lowered, and a high economic benefit will be attained. It is also reasonable to combine the scheme of fully utilization and large—scale extraction of bromine together to produce 200,000 tons of NaCl, 4000 tons of K_2SO_4 and 2,000—5,000 tons of Br_2.

2. Comparison of methods and cost for the production of NaCl, K_2SO_4 and Br_2

NaCl: There are two current methods for the production of NaCl, Solar pond evaporation and vacuum evaporation by heating. The feed material for the production of NaCl is generally taken from seawater of brine of saline lake and underground brine water. Since the last decade some countries use electodialysis to concentrate the original seawater and then manufacture high—grade NaCl by vacuum evaporation. NaCl with a purity of about 95% can be produced from solar pond evaporation. Operation in the solar pond evaporation is seriously affected by climate and depends on the season. Utilization effciency of brine is commonly very low(about 50 percent) and the production period is very long. The production of NaCl by vacuum and heating evaporation can make high grade NaCl. The brine fed into a evaporator must be concentrated to saturation by NaCl, The concentration of seawater of saline lake water, at present, is attained by solar pond evaporation of electrodialysis concentration. The purity of sodium chloride from the process of vacuum evaporation can be generally attained to 99%. Utilization yields by vacuum evaporation can attain 90% for saline lake water and 70% for seawater respectively. The production period in vacuum evaporation is short, however, the energy consumption is high.

Table. 2 Main targets of different methods for production of NaCl①

Targets	Solar	Vacuum evaporation
Satureated NaCl(m^3/l)	5.00	2.50
Electric power(Kwhr/t)	30	200
Steam(t/t)		1.00
Purity(Wt%)	95.00	99.00
Making cost(U.S $/t)	1.2	31.00

K_2SO_4: There are many methods for the production of potassium sulfate. Based on different feed materials, the methods can be divided into two sorts: sulfuric acid method and sulfate salt transfer method.

The main method of K_2SO_4 production is sulfuric acid conversion method called Manhanms and improved manhams method. The major weaknesses of the method are higher reaction temperature (about 800 — 1000℃), heavy corrosion to equipment and high

① Sodium chloride with a purity of 99% can be attained from the process of vacuum evaporation.

consumption of power. The purity of KCl used in the process must exceeds.

In recent years, a manufacture technique with the reaction of KCl with sulfate salts has been rapidly developed to produce K_2SO_4. Depending on the local price of different sulfate salts such as $(NH_4)_2SO_4$, $MgSO_4$ and Na_2SO_4 in the different areas for the sulfate salt conversion process, these sulfate salts are used for the production of cheap K_2SO_4. The principle of complex salt conversion is make potassium—containing complex salt firstly to by the reaction of KCl with sulfate salts and then to decompose the complex salt and produce K_2SO_4.

Table. 3 Main consumption for production K_2SO_4 by different methods

	Manhams	Replacement	Extraction	Glauber	Potassium Mixture
KCl(95%)t	0.92	0.89	0.92	1.35	
H_2SO_4(95%)t	0.87	0.64	0.64		
Na_2SO_4(95%)t				1.30	0.97
K Mixture(KCl 14%)t					4.95
Coal t	0.70	0.20	0.20	0.40	0.15
Steam t		0.30	0.30	0.40	2.65
Electricity(kWh)	750	300	300	250	500
Purity(Wt%)	92	95	>98	92	96
Making Cost(U.S Dollar) $/t	118.00	168.00	168.00	151.00	120.00
Investment/10000T (Million U.S Dollar)	3.70	1.85	1.85	3.20	2.50

Br_2: Two popular methods, steam distillation and air blowing, have been used for the production of bromine in industry.

Bromine production by steam distillation: After extracting potassium, the mother liquor is preheated and fed into a distillation tower. In the distillation tower bromine ions are oxidized by chlorine and the molecular bromine is evaporated by steam and then condensed. The crude bromine is further distillated to obtain the bromine with high purity. The method is suitable for the bromine—containing liquor with high concentration of bromine (>5—7g/l). The method shows an advantage of high recovery yield of 95%, but energy consumption is also high.

Production of bromine by air—blowing method: The brine of concentrated sea water is acidified by H_2SO_4 and pumped into blowing tower. Br^- is oxidized by soda, and then disrobed by H_2SO_4. The crow bromine can be purified by distillation. The extraction yield of the process is low and large amount of feed material with a low concentration of bromine can be easily supplied for the processing.

Table 4. **Main economic targets for production of bromine by different methods**

Materials	unit	Steam Distillation	Air blowing
High concentrated brine(5—7g Br_2/lit)	m^3/t	140—150	
Seawater or Brine (50—70mg Br_2/lit)	m^3/t		20000—30000
Liquid Chlorine (100%)	t/t	0.50—0.53	0.8—1.0
H_2SO_4(100%)	t/t		3.4—4.0
Soda(95%)	t/t		1.0—1.2
Power	Kwh	80—100	7500
Coal	t/t	4—4.5	2.0
Making Cost(U.S. doolar) $/t		750	
Investment/1000 tons million $		1500000	1900000

3. Technical route for the comprehensive utilization of Urmia lake resources

Based on the chemical composition of Urmia Lake brine and local climatic conditions, we have compared the economic targets for the extraction of valuable elements by different chemical processing methods. Obviously, the most valuable elements in Urmia Lake are Br_2, NaCl and potassium salt. We consider that there are two possible technical routes for the utilization of Urmia Lake resources, that is, the comprehensive utilization of Na, K and Br, and the single extraction of bromine.

3.1 The comprehensive utilization of Na, K and Br_2:

We can build solar pond in the west or southwest area. The original brine of Urmia Lake can be concentrated to obtain raw NaCl. After the extraction of sodium chloride, the mother liquor can be continuously concentrated to get the mixture of potassium salts in solar pond. Passing through heating solution, cooling decomposition and a series of conversion processes, the mixture of potassium salts can be converted into K_2SO_4. Then, bromine can be extracted from the residual mother liquid by acidification, chlorine—oxidization, blowing—out, absorb and distillation. The mother liquid after the extraction of bromine can be used to produce $MgCl_2 \cdot 6H_2O$. The technical diagram and the equilibrium of materials for the technical route are shown in figure 3.

3.2 Single extraction of bromine from Urmia brine

Since the concentration of Br_2 in the brine of Urmia Lake is generally about 80—150 ppm, it is possible to directly extract bromine from Urmia Lake using air blowing method. The technical flow chart is shown as follows.

4. Environmental evaluation of the processing

In the technical scheme proposed for the comprehensive utilization of resource of Urmia

Lake, we just use the lake water as the main feed materials. In the evaporation process by solar

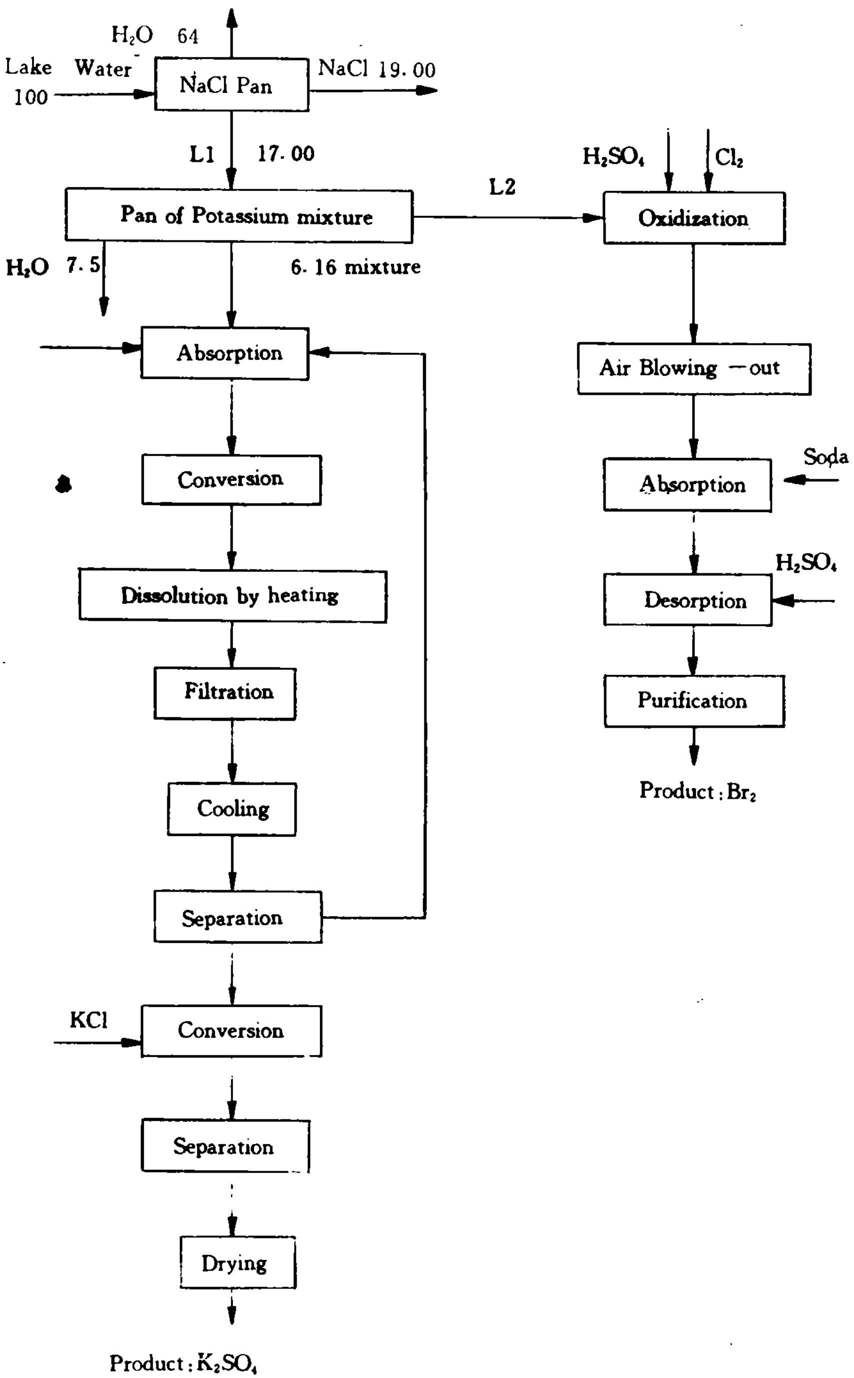


Fig. 3 Technical route for the comprehensive utilization of Urmia lake resources

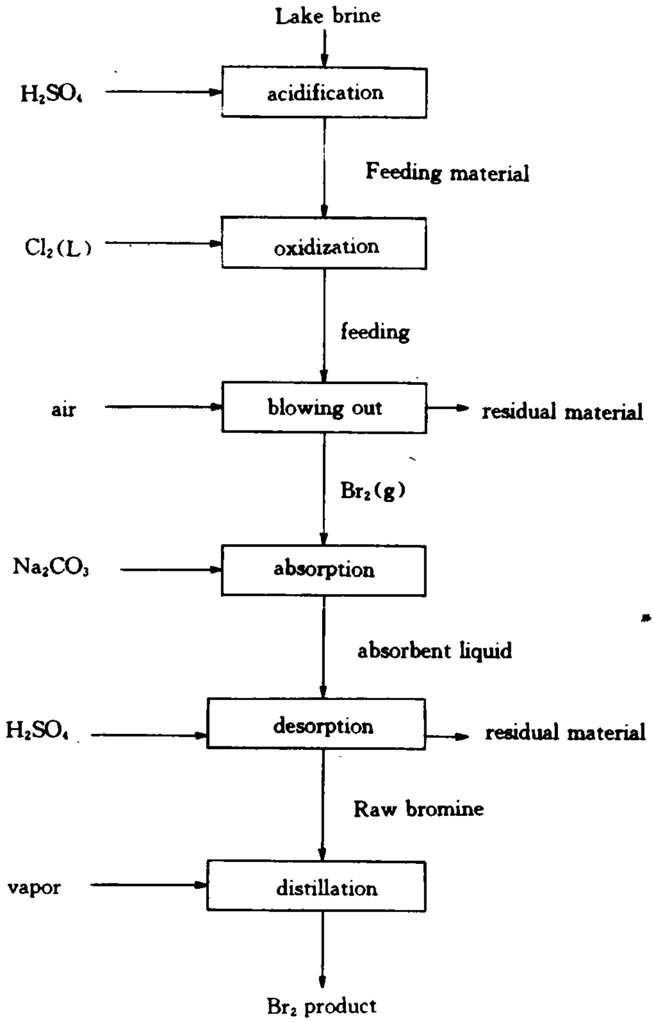


Fig. 4. Technical flow chart for the preparation of Br_2 by air blowing

pond and chemical conversion, only water is drained from the system. After production of K_2SO_4, highly concentrated bittern can be used to extract bromine. the mother liquor after the extraction of bromine mainly contains $MgCl_2$. Because the local climate is generally dry, it is possible to concentrate the liquor and obtain crystal $MgCl_2 \cdot 6H_2O$ by natural evaporation in a solar pond. In the process of the extraction of bromine, small amout of Na_2SO_4 can be produced. We can convert Na_2SO_4 into K_2SO_4 to increase the yield of K_2SO_4. So, if we use the proposed technical scheme for the utilization of Urmia Lake resources, the chemical process will not give bad influence on the natural and ecological environment.

5. The choice of place for building factory

It is necessary for the project to build large—scale solar ponds. The place for building large—scale solar ponds must be smooth terrains (generally slope$<$10 percent)and the soil must be of anti — seepage property. According to the seepage data supplied by Azebaijor Mineral & Research Co. the seepage of the soil was about 4mm/hour in a solar pond which has been build by the company. Therefore, we must treat the soil for the anti—seepage if the solar pond will be built in the area. Moreover, there should be convenient common facilities and installations such as water, energy source and transport road in the solar pond area.

According to the information about wind power, wind dircetion and concentration distribution of Urmia brine supplied by Azebaijor Mineral Research Co. , we consider that the proper terrain for building solar ponds should be southwest or west district of Uramia Lake. This is based on : 1) the concentration of lake water in the district is high, 2) rivers in the district are not so many and there may be not so much underground water, 3) wind direction in the district generally is western or southwestern and this is favorable for the evaporation in solar ponds.

References:

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乌尔米耶盐湖的综合利用

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摘要 伊朗乌尔米耶盐湖是中东地区最大的盐湖之一。本文针对该湖卤水的和当地自然地理条件，对其卤水中钾，钠，溴，镁等资源综合利用的可能性，合理的开发规模，可行的化学加工路线，未来建厂的选址，环境问题及技术经济可行性等问题进行了研究。结果表明，该湖的溴和钠资源具有重要的开发价值。

关键词 乌尔米耶盐湖，盐湖资源，综合利用

"硼酸铝晶须新材料研制"项目通过验收鉴定

由中国科学院青海盐湖研究所承担并完成的"硼酸铝晶须新材料研制"项目验收鉴定会，于一九九八年十二月三日由青海省科委组织并主持在西宁召开。经专家验收鉴定组认真讨论评审，一致同意通过验收鉴定。

硼酸铝晶须是一种用途极其广泛的新兴材料，可广泛用于铝基合金、工程塑料、高强水泥、防碎玻璃等。晶须用作铝基合金和工程塑料的添加剂，能提高复合材料的抗压、抗拉、粘结和抗磨性能，还可以开发机械滑动部件、航空部件。用作玻璃添加剂，可明显改善玻璃的裂碎性能，以替代进口防碎挡风玻璃。用作高性能水泥添加剂，可提高水泥的防裂和抗震性，可满足于拦河大坝和大型工程对高性能水泥的要求。

中国科学院青海盐湖研究所在国内外技术成果的基础上完成的该研制项目，利用我国丰富的盐湖资源硼酸和矾矿资源产品明矾，采用现代高温合成和晶体生长技术，制备特定需要的高产值硼酸铝晶须材料，同时副产国内短线产品硫酸钾，在小试和中试的基础上取得成功。目前该项目的理论生产能力已达年产硼酸铝晶须万吨左右，并可通过选择不同的条件控制晶须的生长，从而达到生产不同用途的晶须产品之目的。产品经部门多种应用试验证明性能良好，质量达到了同类进口产品标准。

以该技术生产硼酸铝晶须产品的经济指标如下。每吨硼酸铝晶须产品需耗电 2.8 万度，耗去离子水 30 吨，需用原料明矾 10 吨，硼酸 0.28 吨，总生产成本低于 3.5 万元/吨。

此外，该项目已较好地解决了其关键技术——高温连续化生产问题。

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