IAEA-SM-362/20

Uranium production and the environment in Kazakhstan

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Abstract. The production of uranium from open-pit and underground mines in Kazakhstan has terminated. Currently, uranium is extracted in Kazakhstan only by the In Situ Leaching (ISL) method. This method has a number of economical and ecological advantages. During a short period in the 70s-80s, Kazakhstan created a firm basis for developing uranium extraction by the ISL method. Now more than half of the world's uranium reserves amenable to the ISL method are located in Kazakhstan. By 2005, a significant increase in uranium production is planned. Thereby, Kazakhstan has the ability to grow into a world leader in uranium extraction through a lower cost and low environmental impact operations using the ISL method.

1. INTRODUCTION

As an integral part of the former USSR, Kazakhstan was an important part of the nuclear complex and possessed significant nuclear cycle capacities. Kazakhstan extracted uranium, fabricated fuel pellets and generated atomic energy at the power plant in Aktau. Kazakhstan was one of the main uranium producing regions of the former USSR and the main fuel pellet producer. Before the collapse of the USSR, more than 70 000 t U was extracted and the Ulba Production Centre provided 80% of the fuel pellets used by the USSR.

Before the 90s, Kazakhstan produced uranium primarily from open pit and underground mines. In the 70s-80s, large uranium deposits were discovered in Kazakhstan including deposits amenable to the ISL method. Since Kazakhstan possesses these large uranium reserves amenable to low cost and low environmental impact extraction using the ISL method, it has the potential to maintain and stabilize a position as the world's largest ISL uranium producer.

2. HISTORY OF THE URANIUM INDUSTRY IN KAZAKHSTAN

2.1. Formation of ore basis for uranium industry

Two stages and two directions can be identified in the history of uranium exploration in Kazakhstan: the search for deposits suitable for mining and the search for deposits in the friable sediments that amenable to the ISL method.

Implementation of the first stage began in the early 50s and was addressed the search for deposits at outcrop areas, using airborne, vehicle-mounted, and hand-held gamma radiometric systems as well as mining and drilling equipment. It can be said that the territory of Kazakhstan has been adequately explored. As a result of these explorations between the 50s-80s, about 30 commercial uranium deposits containing more than 1000 t U each were discovered. These deposits were located in the following three regions: Kokshetau, Betpakdala-Ili, and Pricaspian (Fig. 1). The largest is the Kokshetau region in the north of Kazakhstan. These deposits are of the vein-stockwork type in Silurian-Devonian folded sedimentary complexes and volcanics with low uranium grade (0.1-0.3%). The exception is located in the Pricaspian region where uranium ores with very low content (0.03-0.05%) are hosted in Tertiary sediments with the fish bones. This unique type is called organic phosphate.

Productions centres: 1 - Ulba, 2 - Pricaspian, 3 - Tselinny, 4 - Kirghiz

Uranium regions: I - Kokshetau, II - Betpakdala -Ili, III - Chu-Syrdarya, IV - Ili, V - Pricaspian

FIG. 1. Map of uranium regions of Kazakhstan.

In the 60s, exploration began for uranium deposits in friable sediments of the depression structures in the South of Kazakhstan. As a result, several uranium occurrences and the Uvanas deposit were discovered, but work on the occurrences was soon discontinued due to low uranium contents.

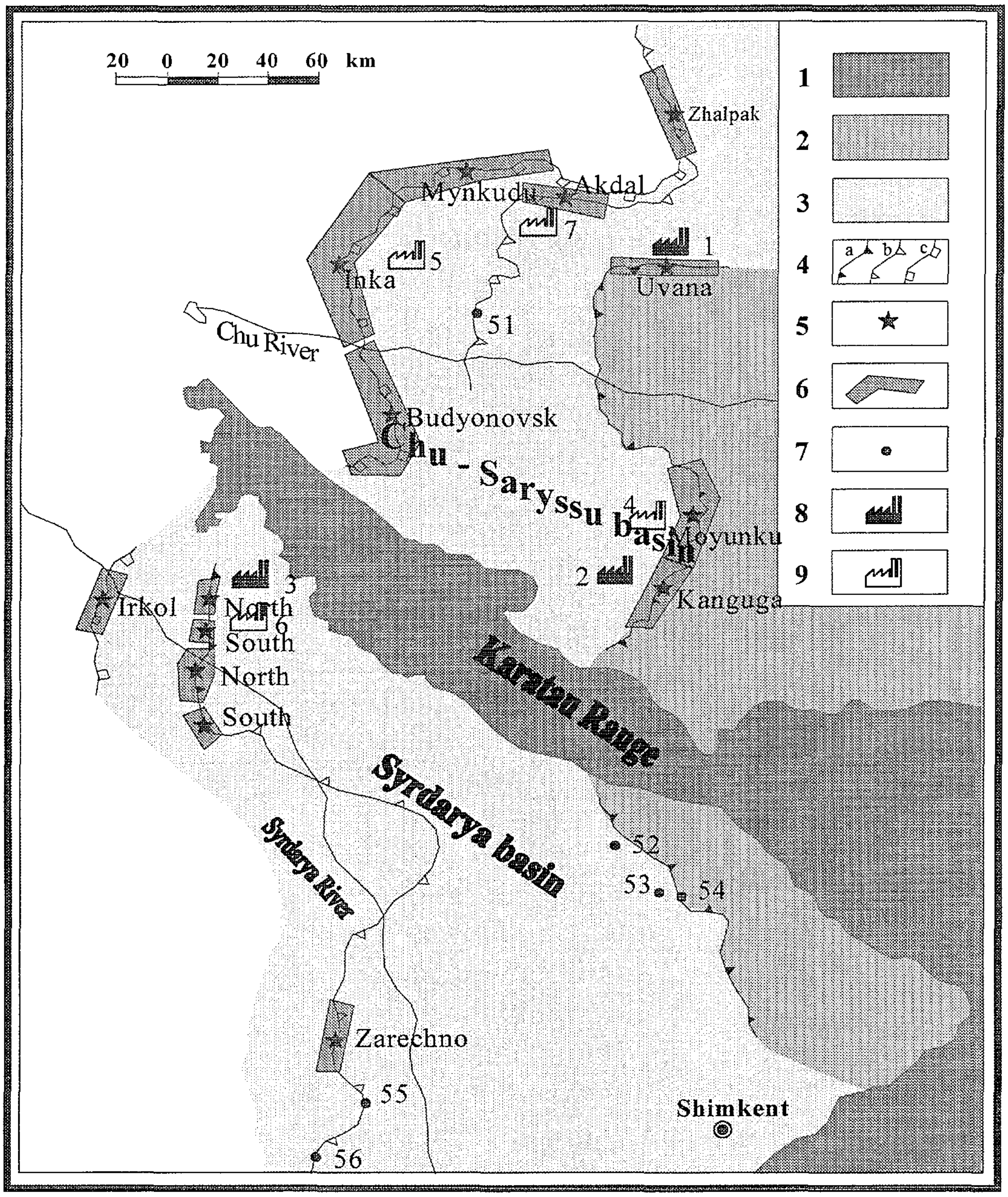
After the industrial use of the ISL method was proven and a successful ISL test at the Uvanas deposit was carried out in 1971, intensive search work was done by drilling in depression structures in the South of Kazakhstan. As a result, two ore regions were discovered: Ili and Chu-Syrdarya (Fig. 1). The Ili region located near Balkhash Lake includes mainly coal-uranium deposits and it is not of commercial interest for a number of reasons, mainly ecological ones. The Chu-Syrdarya region (ChSR) is now the most important uranium region in Kazakhstan (Fig. 2).

The Chu-Syrdarya uranium ore region was discovered and explored during the years 1971-1991. Exploration work in this region was carried out very intensively by three expeditions. Exploratory drilling efforts achieved up to 800 000 m per year. As a result, 15 large and unique uranium deposits in the permeable Paleogene-Cretaceous sand sediments were discovered and explored. The largest of them is the Inkay deposit, which contains 350 000 t U [1].

Exploration was accompanied by field tests for ore quality and different conditions of ore occurrence. In this case, the main emphasis focused on the following:

(a) uranium content in the ore;
(b) ore permeability;
(c) depth of the ore occurrence;
(d) existence of the confinement beds (especially in ecological importance in connection with solution excursion).

Primarily, the tests were carried out using sulphuric acid technology. Good results were obtained in practically every case. Uranium extraction reached more than 80% with acid consumptions of 50-80 kg per kgU. Several tests carried out using the alkaline method and various oxidants, showed significantly lower results on both extraction and solution productivity.



1 - Outcrop of Pre-Mesozoic rocks, 2 - Area of the bed oxidation zone development on whole thickness of Cretaceous-Paleogene sediments, 3 - Area of the bed oxidation zone development in Cretaceous sediments only, 4 - Redox-front a) in Paleogene sediments, b) in Zhalpak horizon of the top upper Cretaceous, c) in Mynkuduk-Inkuduk horizon of middle part of upper Cretaceous, 5- Commercial uranium deposits amenable for ISL, 6 - Ore-fields of the commercial uranium deposits, 7 - Unprofitable uranium deposits, 8 - Operating production centres (1-Stepnoe, 2-Tsentralnoe, 3-№6), 9 - Planned production centres (4-Katko, 5-Inkay, 6-South Karamurun, 7-Akdala)
Unprofitable deposits: 51 - Sholak-Espe, 52 - Kyzylkol, 53 - Lunnoe, 54 - Chayan, 55 - Zhautkan, 56 - Asarchik

FIG. 2. Distribution of uranium deposits in the Chu-Syrdarya ore region.

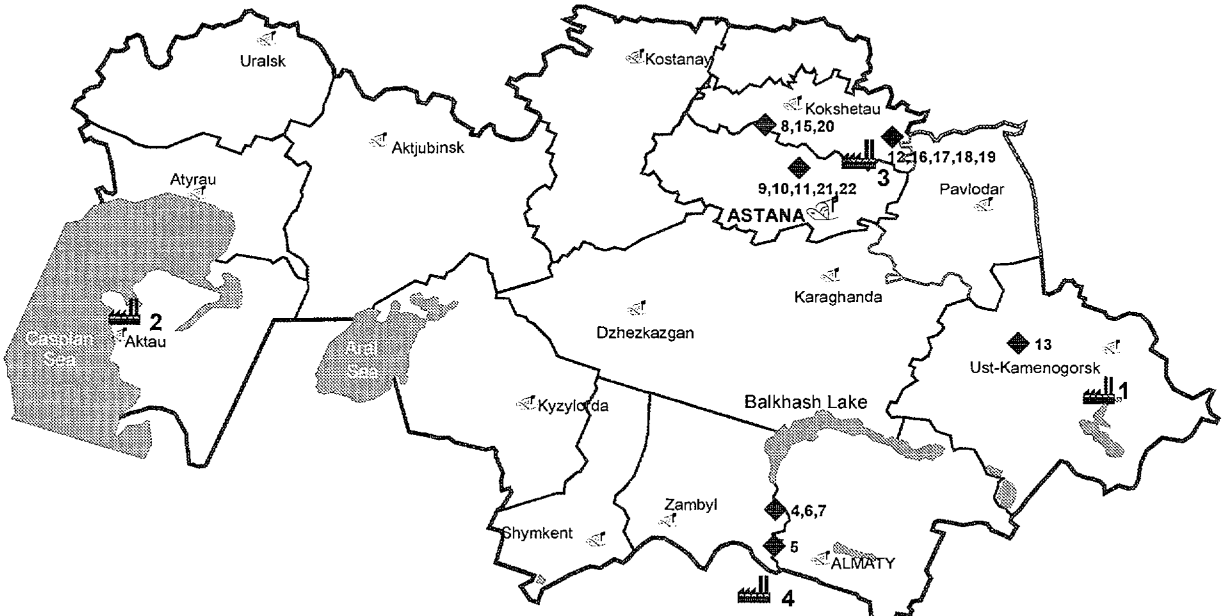
Therefore, acid technology of the ISL was selected as the main extraction method for practically of all deposits in the region. The low carbonate content of the uranium ores in Kazakhstan favoured such a decision. Thus, the unique Chu-Syrdarya uranium region, which has 15 commercial deposits with the reserves from 20 000 to 350 000 t U each, was discovered and developed for extraction within two decades as a result intensive exploration works in the South of Kazakhstan. Total resources of the region are estimated at 1.3 million t U, including about 0.6 million t U in proven and probable reserves. Although the uranium content is relatively low (up to 0.07-0.08%), ores in the ChSR are characterized by quite considerable ore body thickness and favourable permeability coefficients (average of 6-8 m/day). In this case, the square productivity of the ore bodies reaches 7-10 kg/m^2 and solution concentrations of more than 150 mg/l are achieved. These circumstances show the strong possibility for the ChSR region of Kazakhstan to be an area for successful development in uranium production in the future.

2.2. Uranium mining and processing in Kazakhstan

2.2.1. Mining method

As uranium deposits were discovered in Kazakhstan during the 1950s, the mining complexes and the uranium ore processing centres were constructed. In 1956, the Kirghiz Production Centre was constructed for processing the first ore discovered in Kazakhstan in 1954 at the Kurday deposit (Fig. 3).

The Kirghiz Centre is located in territory of Kirghizstan. Through 1990, this centre also processed uranium ores of the Betpakdala-Ili region. In 1957 the Tselinny Production Centre in Stepnogorsk came into production, supported by the resources of the large Kokshetau ore region in the north of Kazakhstan. The unique ores of the Pricaspian region were processed at the Pricaspian Production Centre that came into production in 1959 in the West of Kazakhstan. In the East of Kazakhstan the Ulba Production Centre was constructed. Currently, fuel pellets are fabricated at this Centre. Thus, for short time the Kazakhstan power industry was created for extraction and processing of uranium ores and the uranium product fabrication. This industry included four large Production Centres. Before the USSR collapsed in 1991, these centres produced more than 70 000 t U from nine deposits using underground mines and open pits. The activities of the uranium Production Centres positively impacted the economies of the regions in which they were located. New settlements were built near the mines. Production Centres were accompanied by new town building.



Productions centres (tailings): 1 - Ulba, 2 - Pricaspian, 3 - Tselinny, 4 - Kirghiz
Worked out uranium deposits (exploration and exploitation dumps) - numbering on the map corresponds to numbering of the Table 1

FIG.3 Distribution of Radwaste storages in Kazakhstan.

So Aktau city appeared on the map of Western Kazakhstan together with construction of the Pricaspian Production Centre. In the North of Kazakhstan the Tselinny Production Centre helped build Ctepnogorsk city. Ulba Production Centre was constructed near the existing city of Ust-Kamenogorsk. In the new cities with the uranium production other industries were created, such as oil industry in Aktau and biological and the other industries in Stepnogorsk. New roads and electrical lines were built. New regions of Kazakhstan were involved in this industrial activity.

Uranium production from underground and open-pit mining in Kazakhstan started to decline after the collapse of USSR. Several reasons caused this decline, such as the low uranium content of the Kazakhstan ores, falling prices in the world uranium market and the possibility to extract uranium by the more profitable ISL method. Currently, uranium production by conventional mining in Kazakhstan is practically non-existent.

2.2.2. ISL method

The discovery in ChSR of deposits amenable for the ISL method in the 70s, lead to the initial uranium production by this method at the Uvanas deposit (Stepnoe mine) in 1976. An additional two mines were put into operation very quickly: Tsentralnoe mine at the Moynkum deposit and Mine No. 6 at the North Karamurun deposit (Fig. 2). These mines are part of the National Atomic Company Kazatomprom and are producing more than 1500 t U per year. Kazatomprom is one of the world's largest producers of uranium by the ISL method. The company plans to increase uranium production. For this purpose, two satellite operations at the South Karamurun deposit (Mine No. 6) and at the Akdala deposit (Stepnoe mine) are being put into operation. In addition, two joint ventures: Inkay (together with Comeco) and Katco (together with Cogema) have received licences and have begun construction of their own ISL uranium operations. It is planned by 2005 to bring the uranium extraction in Kazakhstan up to 4500 t U per year. The reality of this plan certainly depends on the world uranium market.

The ISL operations are located in a semi-desert region, which is generally unsuitable for agricultural use and subsist through unique astrakhan farming. Activity of ISL mines as well as mining production has positively impacted the economy of this semi-desert region. Two small towns near Stepnoe and Tsentralnoe mines were built, new roads, electrical lines and water-pipe were constructed. At the same time, both mining production and ISL mines have had a detrimental impact on the environment.

3. ECOLOGICAL PROBLEMS CONNECTED WITH URANIUM PRODUCTION

3.1. Mining production

Uranium mining has had negative impacts on the environment. These impacts are seen in contamination of the soil and vegetation, hydrogeological and hydrochemical changes in surface and underground waters, and the formation of radioactive wastes. Due to the comparatively low uranium content of the uranium ore in Kazakhstan (especially in the Pricaspian region), a large quantity of Radwaste (about 235 mln. t) was formed during uranium extraction. The storage sites for this Radwaste have not yet treated for various reasons. One of the main reasons is the collapse of uranium enterprises after the USSR disbanded.

In 1996-98, special work was carried out on the inventory and characterization of the Radwaste storage sites in Kazakhstan [2]. As a result, about 100 storage sites were located but only 22 of these sites contained nearly 98% of all Radwaste. These sites are shown in Table 1 and Fig. 3. It has been determined that the dumps do not significantly impact the environment due to natural conditions in Kazakhstan (dry climate and limited population). The danger is primarily the uncontrolled use of dump material for construction purposes.

TABLE I. DISTRIBUTION OF THE WASTE ROCK DUMPS AND TAILINGS IMPOUNDMENT IN KAZAKHSTAN

№	Name of deposit or Productian Centre	Region	Type of waste	Volume (1×10^3t)	Nearest settlement (km)
1.	Ulba Centre	East Kazakhstan	Tailings	420	0.5
2.	Pricaspian Centre	West Kazakhstan	Tailings	120 000	6
3.	Tselinny Centre	North Kazakhstan	Tailings	88 330	5
4.	Deposit Botaburum	South Kazakhstan	Dumps	3 681	1.5
5.	Deposit Kurday	South Kazakhstan	Dumps	6 280	3
6.	Deposits Sections 2 and 4	South Kazakhstan	Dumps	2 130	6
7.	Deposits Sections 7 and 11	South Kazakhstan	Dumps	396	20
8.	Deposit Chaglinskoe	North Kazakhstan	Dumps	1 772	12
9.	Deposit Balkashinskoe	North Kazakhstan	Dumps	576	5
10.	Deposit Shokpakskoe	North Kazakhstan	Dumps	866	3
11.	Deposit Ishimskoe	North Kazakhstan	Dumps	568	6
12.	Deposit Manybay	North Kazakhstan	Dumps	6 340	0.5
13.	Deposit Ulken-Akzhal	East Kazakhstan	Dumps	19	27
14.	Deposit Panfilovskoe	South Kazakhstan	Dumps	13	0.1
15.	Deposit Kosachinoe	North Kazakhstan	Dumps	290	1.5
16.	Deposit Glubinnoe	North Kazakhstan	Dumps	123	0.5
17.	Deposit Zaozyornoe	North Kazakhstan	Dumps	568	6
18.	Deposit Shatskoe	North Kazakhstan	Dumps	430	2
19.	Deposit Tastykol	North Kazakhstan	Dumps	638	6
20.	Deposit Grachyovskoe	North Kazakhstan	Dumps	448	2
21.	Deposit Agashskoe	North Kazakhstan	Dumps	131	2
22.	Deposit Viktorovskoe	North Kazakhstan	Dumps	100	2

The tailings from uranium ore processing at the Pricaspian and Tselinny Production Centres became a significant danger due to the formation of dusting beaches after uranium production ceased. Tailings of Ulba Production Centre are also a significant danger due to infiltration of radionuclides into the ground water, which is used by the population of the Ust-Kanenogorsk. Currently, a programme for remediation of all the Radwaste storage sites, including the Ulba Centre, is being developed for approval by the government of Kazakhstan.

3.2. ISL method

Currently, an active interest is being paid to the ISL method by world uranium producers. Uranium extraction is already successfully carried out in several countries. Uranium production by the ISL method has considerable economic and ecological advantages. The main ecological advantages compared to conventional mining method are as follows:

(a) less surface damage,
(b) less Radwaste formation and radionuclide contamination,
(c) lower remediation costs.

Uranium extraction without surface damage is a very important factor for restoration of the land after cessation of ISL extraction. Large volumes of Radwaste are formed by conventional mining. The quantity of Radwaste depends on the uranium content in the ore and often reaches 1000-3000 kg per one kg of extracted uranium. With the ISL method, the amount of Radwaste does not exceed one kg per one kg U. By improving production techniques, there is a possibility that in the future, waste formation can be further reduced to 0.1 kg/kg U.

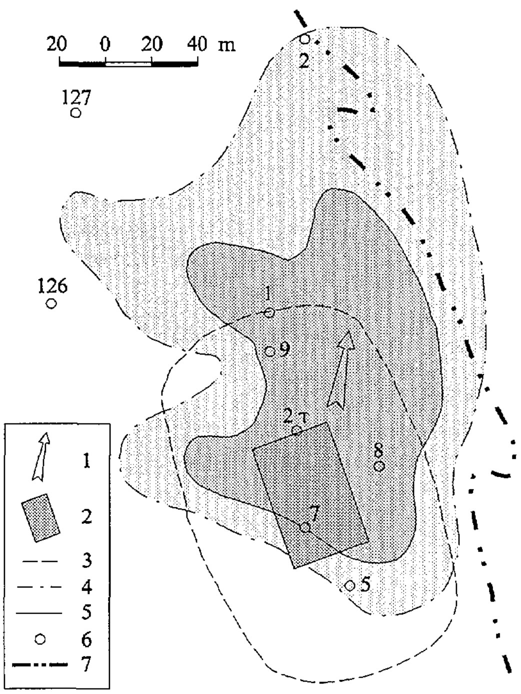
Remediation of the Radwaste storage sites after ISL operations includes surface rehabilitation and treatment of the ore bearing aquifer. Surface rehabilitation has no special problems. The problem of aquifer treatment costs deserves special consideration. We emphasize that there are now some data, which dispute a myth of the first years of ISL use about the economic impossibility of treating an aquifer contaminated by the ISL process using sulphuric acid.

4. ESTIMATION OF ENVIRONMENTAL IMPACT OF THE ISL URANIUM EXTRACTION IN KAZAKHSTAN

As mentioned previously, ISL uranium extraction in Kazakhstan is carried out using sulphuric acid. Uranium deposits are located in permeable Paleogene-Cretacious sand sediments. Ore bodies occur at depths from 100 to 800 m. Uranium extraction is mainly carried out in the sparsely populated semi-desert areas. Of course, during uranium extraction, there is radionuclide contamination of the aquifer, which has a detrimental effect on the environment. Kazakhstan Laws require reclaimation of the aquifer to pre-leach conditions after cessation of ISL extraction. Currently, there are effective methods of treatment. Treatment is commonly carried out during 2-3 years and incurs significant costs (up to $4 per one kg extracted uranium). Is it needed for Kazakhstan? The following facts should be kept in mind when considering this problem:

First, deposits of the Chu-Syrdarya region are largely located in areas of high salt content in the ore-bearing aquifers and where the underground water is unsuitable for use. Secondly, natural contamination occurs in these areas when radionuclides, heavy metal salts, and sometimes selenium form at the redox front (geochemical barrier) in the aquifer where there are uranium ore deposits. This natural occurrence renders the water unsuitable for technical uses and is undrinkable.

Further, enough evidence has been gathered from experience in Kazakhstan and Uzbekistan to assure that restoration of the groundwater to pre-leach conditions after ISL is possible. After cessation of ISL extraction, self-treatment and demineralization can offset the pollution formed in the aquifer during uranium extraction. This fact is convincingly shown by M. Fazlullin based on his observation of results at the uranium deposits worked out by the ISL method in Uzbekistan [3].



1 – movement direction of underground waters; 2 – test area; 3–5 – acid solution excursion boundaries: 3 – December, 1976; 4 – December, 1978; 5 – May, 1982; 6 – drill holes; 7 – redox front

FIG.4. Aquifer self-treatment at the Kanzhugan deposit for 6 years after the ISL completion.

Observations at the Kanzhugan test area in Kazakhstan [4], which were terminated due to commercial extraction beginning, also show a clear tendency of the acid solution halo decrease for six years (Fig. 4).

Currently, in connection with the licensing of uranium ISL projects, NAC Kazatomprom has been conducting investigations on the environmental impact of ISL extraction at four deposits in the Chu-Syrdarya region. The result of these studies will be presented in a special report, which will contain new data from these sites. This report will form the foundation for an official decision by the ecological authorities as to whether it is possible to leave the sites which have had uranium extracted by ISL method to natural restorative processes rather than treating the aquifer through other means.

5. FUTURE OF THE URANIUM PRODUCTION IN KAZAKHSTAN

The impact of extraneous influence on the uranium industry in Kazakhstan is reflected in the fact that Kazakhstan today produces only about 4% of world's uranium production although it has more than 20% of the world's uranium reserves. For comparison, Canada has about 11% of the world's reserves and about 32% of the production. In addition, Kazakhstan has more than half of the world's uranium resources amenable to extraction by the ISL method. This allows for NAC Kazatomprom to discontinue conventional uranium mining and, since 2000, to completely produce uranium by the ISL method.

Sulphuric acid ISL technology in Kazakhstan produces uranium with low costs and low environmental impact. NAC Kazatomprom has extensive experience using this technology in areas with various conditions of deposit occurrence, ore body thickness and ore body depths up to 750 m. These facts allow Kazatomprom to prepare plans for increasing uranium production up to 4500 t U per year by 2005. In the future, production could be even higher under favourable conditions in the world uranium market.

Main tasks for the future development of the uranium industry in Kazakhstan are as follows:
(a) updating and construction of new ISL operations to increase the production capacity;
(b) perfecting techniques and leaching technology, using new geotechnological systems and oxidants;
(c) completion of investigations for comprehensive estimation of the environmental impacts from ISL extraction and the approval by the government of aquifer self-treatment as the method of aquifer remediation after cessation of ISL extraction.

Thus, with the availability of a practically unlimited uranium base suitable for the ISL method, the use of this method instead of mining, will allow Kazakhstan to develop a successful uranium industry in the 21st Century with negligible negative environmental impact.

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