THE ELIMINATION OF INDUSTRIAL MERCURY POLLUTION IN KAZAKHSTAN UNDER THE PROJECT "CLEAN-UP OF THE "NURA" RIVER"

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The report discusses the results of work carried out under the Project "Clean-up of the "Nura" River". The Project included the stages of the cleanup of mercury from the riverbed, banks and floodplains and the industrial site of acetaldehyde production plant in Central Kazakhstan. The implementation of work was initiated by the Government of the Republic of Kazakhstan in cooperation with the World Bank. It was launched in 2007 by the Committee for Water Resources of the Ministry of Agriculture of the Republic of Kazakhstan, and carried out with participation from contractors from the People's Republic of China - "China Building" LLP and "CGC Overseas Construction Co., LTD" Kazakhstan Branch. The Project implemented under the Supervision Engineer, "Posch & Partners Consulting Engineers", www.pap.co.at a company from Austria. The Project was completed in 2011.

Source of Pollution

The activity of acetaldehyde production was the source of extensive anthropogenic mercury pollution in Temirtau city, Central Kazakhstan region, from 1950-1993 (Fig. 1).

The manufacturing method used for the production of acetaldehyde assumed the loss of mercury in various forms: atomic dispersed mercury in the products of production, metallic compact, atomic dispersed, ionic inorganic mercury and organic mercury in wastewater and gaseous mercury in vent emissions. Mercury emissions into the environment occurred during accidents, and also resulted from imperfections with the technology used for thermal regeneration of mercury from sludge. Waste water discharges into the "Nura" river also contributed to mercury pollution. The above practices resulted in the accumulation of mercury waste at the factory site and the adjacent areas. As a result, the soil was contaminated on the industrial area and surrounds, and the riverbed, banks, and floodplain for a distance of about 30 km downstream.

The sources of pollution was from the discharge of ash from the thermal power plant “TPP-2” into the river, and man-made sludge which contained the main concentration of mercury. The territory of the former acetaldehyde plant has become a potential source of secondary pollution due to the disrepair of the buildings, and lack of proper control and funds for targeted preventive measures. The occurrence of this kind of pollution sources has become a problem for the population of the cities Temirtau and Karaganda and for adjacent regions.

Fig. 1. General view of the former factory of acetaldehyde production.

Previous Studies and Research

1. From 1997 to 1998, the industrial area of the plant, and the banks, floodplain, and riverbed of the "Nura" river were examined as part of the international project - "INCO Copernicus".
2. A feasibility study for cleaning up the river basin and plant area was prepared in 2001-2002 in support of the project. Surveys were conducted by the company “BCEOM” to assess the location and thickness of the mercury-containing ash layers.
3. In 2002-2003 the company “Ramboll” conducted research on the former mercury-containing waste settler - "Zhaur" swamp.
4. In 2004, Posch and Partners conducted site visits, investigations, sampling, and laboratory analyses of the river banks, floodplains, and riverbeds, and "Zhaur" marshes. This was to evaluate the volume of excavation to remove the contaminated soils, and to verify the accuracy of the data used for preparation of the feasibility study. Posch and Partners also reviewed the results of previous studies.

Project Objectives

The main objectives of the project were to improve the living conditions of the population in the river basin, and to remove the source of mercury pollution. Additionally, providing a safe and inexpensive source of water supply for meeting the growing needs of water consumers was another requirement.

In order to improve the ecological situation in the suburb of Temirtau, the Government of the Republic of Kazakhstan in collaboration with the World Bank planned and carried out the environmental protection measures within the framework of the Project “Cleanup of the Nura River”. The stages included the construction and operation of a landfill for hazardous waste, the removal and transfer of mercury-contaminated materials, sludge, and soils from the territories of the industrial site of acetaldehyde plant and from the sewage treatment plant to the hazardous waste landfill. The stages also included clean-up of the river bed, banks, and floodplains, and the "Zhaur" swamp, by excavating and transporting materials to the landfill (Fig. 2).

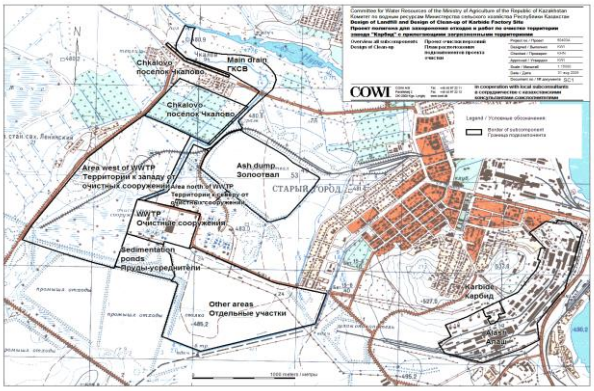


Fig. 2 Subcomponents of the upstream cleanup of the Nura River.

Results of the Project

In 2007, Contractors from the People's Republic of China- "China Building" LLP and "CGC Overseas Construction Co., LTD" of Kazakhstan Branch, as well as the Supervision Engineer "Posch & Partners Consulting Engineers" from Austria launched the Project.

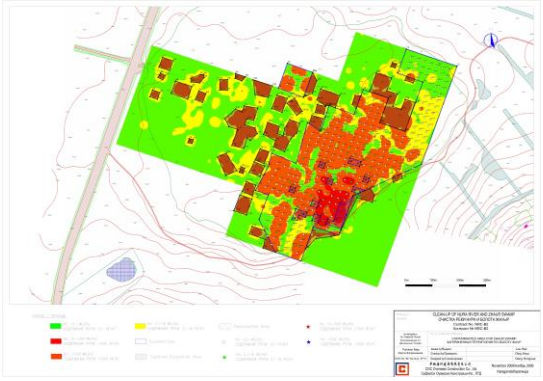
The following briefly discusses the results achieved on the type of activity and sub-components of the Project.

GIS Database

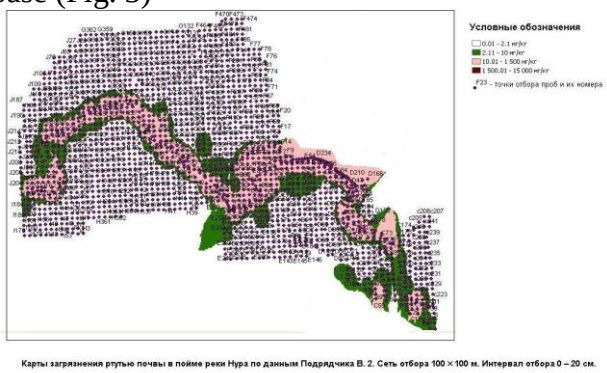
A GIS database of the cleanup area for project management has been created on the basis of geo-information systems. It includes cartographic, field, and laboratory data, creating a model for the distribution of mercury contamination in the soil in several layers, and calculating the volumes of contaminated soil.

Pre-excavation Surveys

For accurate determination of the volume of soil to be cleaned up, a total area about 11,000 hectares located on a 19 km long section of the Nura river, downstream of the city was surveyed. The width of the section was determined based on the 1% probability (once every 100 years) of flooding of the Nura River. This included settlements and adjacent territories (455 hectares); the river bank and bed itself, the Zhaur swamp (4,795 hectares) and remote floodplains (5,736 hectares). Different grid sizes and depth intervals were applied in this survey. 140,000 samples in total were taken and analysed. Pollution maps were prepared, highlighting the area of detailed surveys, and the data was entered into the GIS database (Fig. 3)



"Zhaur" swamp



Nura River floodplain

Fig. 3. Pre-excavation Survey Results

Clean-up criteria

On the basis of laboratory research completed in Germany, and in the "National Center of Labor Hygiene and Occupational Diseases" ("NCLHOD"), the clean-up criteria were determined which were approved by the relevant institutions of the Republic of Kazakhstan (Table 1).

Table 1- Project cleanup measures depending on the level of pollution

Mercury concentration, mg / kg	Cleaning activities
< 2.1 mg / kg	No action
2.1 - 10 mg / kg	Excavation of soil in areas used for agricultural purposes, settlements, etc.
10-1500 mg / kg	Excavation of sediments in the riverbed, banks and floodplains of the river and Zhaur swamps; isolation of the polluted ground at the place, creation of a new layer using clean materials.
> 1500 mg / kg	Excavation of polluted material and depositing it at the hazardous waste landfill in cells of class I hazard.
Metallic mercury	Collection and stabilisation in containers with subsequent depositing at the landfill.

Volumes of materials recoverable/used on each of the Project's subcomponents

Below table shows in the design volumes of material to be excavated (removed) or used by a component of the Project.

Table 2 – Design volumes of materials excavated/used on each of the subcomponents of the upstream river section

Subcomponent (site)	Volume of material (m^3)	
	Excavated	Backfill and isolation
1. "Carbide" Plant	110,000	70,000
2. Ponds - sumps	61,000	26,000
3. Sewage treatment plants	90,000	83,000
4. Ash dump	100,000	195,000
5. Main drainage ditch	50,000	82,500
6. Territories northwest from the Wastewater Treatment Plant (WWTP)	0	225,000
7. "Chkalovo" village and adjacent areas	17,500	17,500
8. Other sites	0	240,000
9. New sewer	30,000	20,000
Total:	458,500	959,000

Table 3 - Project volume of polluted materials extracted from each of the subcomponents of the downstream river section

Subcomponent (site)	Pollution area (hectares)
1. Area of contaminated soils	254.5
2. Area of contaminated banks	165.5
3. Area of contaminated river sediments	29.0
4. Area of Zhaur swamp contamination	60.0

Total	509.0
Subcomponent (site)	**Volumes of recoverable material with Hg concentration> 10 mg (m^3)**
1. River banks	1,418,000
2. River-bed	1,227,000
3. Zhaur swamp	54,137,000
Total	56,782,000

The territory of the "Carbide" plant

The plant site was the main source of mercury contamination and a priority subcomponent within the Project. The area was contaminated with mercury on the 3.5-hectare site, with concentrations up to several g/kg. In the area of underground utilities and in the upper layer of soil, drops of metallic mercury were found. The necessary site infrastructure was established before starting the clean-up works on the industrial site and preparatory work were carried out. As a result of the project implementation, all buildings technologically related to production and contaminated with mercury were dismantled (5 buildings, the septic tank, a former cooling tower, a reinforced concrete pipe, etc.). The water supply, drainage and sewage systems and other underground utilities were also disassembled (Fig. 4). The excavation of the contaminated soil was carried out to a depth of 2 m and 196,000 tons of material were removed to the landfill. For backfilling of the excavations, 62,000 m^3 of clay and soil was required. The soil cover an concrete slabs were removed from underground chambers which contained barrels with mercury (Building D-26a). The excavation of barrels was carried out after filling them with concrete. Then the concrete cavities and the concrete chamber itself was cleaned. After the excavation of contaminated soil, the areas were filled with a clean layer of clay material representing the impervious screen (Fig. 5). The backfill with clay was carried out in layers, with a maximum layer thickness of 0.25 m and appropriate compaction in order to avoid further settling of the layer. Re-cultivation of the earthworks area was carried out with greenery, and is now surrounded by a system for intercepting and draining drainage water and surface runoff.

Fig. 4. Excavation of soil from the base of industrial buildings.

Fig. 5. The territory of the industrial site of the plant after cleaning and remediation

The "Apan" landfill

The "Apan" hazardous waste landfill has been constructed in accordance with the requirements of SNiP RK 1.04-14-2003 and the EU Directive 1999/31 / EC on hazardous waste management of hazard classes I-IV, and it was provided with the necessary infrastructure for operation. The following criteria were set forth for the disposal of polluted materials: maximum humidity (soils, silts and channel sediments - 20%) and organic matter content (soil - less than 20%, silt and channel sediments - less than 25%, waste - less than 5%). Materials with a mercury content <1500 mg/kg were stored in the cells for class II- IV. Waste containing mercury > 1500 mg/kg or with the visible mercury was stored in a cell for I class waste. The upper impervious cover of the landfill cells was constructed from the following layers from top to bottom: 0.30 m fertile soil layer, 0.70 m near-surface soil layer, 0.30 m drainage layer, 1.5 mm

high density polyethylene sheet, 0.2 m compacted clay, and 0.5 m clay covering soils (fig. 6). This, the first hazardous waste landfill in Kazakhstan, was built with a total area of 160 hectares. A total of 2,142,457 tons of contaminated materials were placed at the landfill (273,548 tons in cell A2.1 for hazard class I and 1,868,909 tons in cells A1.1 - A1.3 for waste of classes II-IV). The landfill is filled to 29% and has the capacity for future placement of hazardous waste.

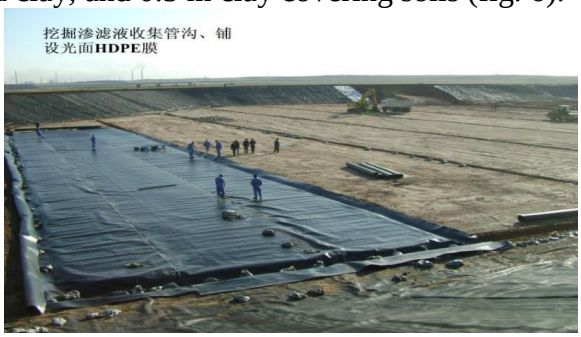


Figure 6. Insulation of the landfill bottom base.

The wastewater treatment plant (WWTP) and the surrounding area

The WWTP treated the wastewater of "Carbid" JSC with a high concentration of mercury, which arrived at the WWTP through the sewer system and the four ponds of the septic tank (Fig. 7). The station was commissioned in the 1950s and underwent modernisation. The stages of cleaning include: removal of coarse debris through screens, biological cleaning in aeration tanks, sedimentation, chlorination, and removal and drying of sludge on sludge beds. The territory of the station, settling ponds and adjacent areas with an area of 15 hectares was contaminated with mercury to a level of several g/kg. The mercury content in surface waters in ponds varies from less than 500 ng/l to 10,000 ng/l, and more than 1500 mg/kg in the bottom sediments. The content of mercury in soil samples from the greater part of the WWTP territory exceeded 1500 mg/kg. A pumping system and mercury removal plant was constructed for pumping the sludge from the ponds to mercury treatment plant to eliminated the mercury from the water. Works were carried out to excavate or isolate the bottom sediments, and with further reinstatement of the territory about 61,000 m^3 of polluted materials were removed from the area of the settling ponds. Works comprised excavation, drying and transportation of the dry sludge to the landfill, and excavation of the top soil layer of 0.5 m on the entire area of the WWTP and its disposal at the landfill.

The volume of waste handled of hazard class I is 23,000 m^3 (soils and silt) and of hazard classes II-IV is 67,000 m^3 (soils). The reclamation of all territories was carried out by the method of backfilling with uncontaminated material and re-cultivation. On the territory to the south and east of the WWTP, the mercury content exceeds 10 mg/kg. In some areas, mercury content varies from 665 mg/kg in the top layer of the soil to 6 mg/kg at a depth of 2 m. The total volume of insulation materials is 240,000 m^3.

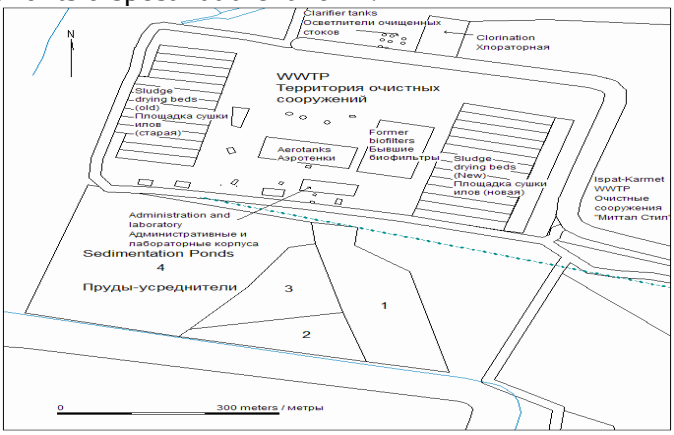


Figure 7. Layout of buildings and facilities of the wastewater treatment plant

Old ash dump of "KarGRES -1"

The total area of the ash dump was 65 hectares, of which 26 were contaminated with mercury concentrations over 10 mg/kg. The core area was about 2 hectares, and mercury content was more than 1500 mg/kg where the height of the ash dump was 5-6 m. Soil and ash were removed from the pollution site and transported, with a total volume of 100,000 m^3 of hazard class I. The formation of surface runoff of polluted water was reduced by covering the ash dump in areas contaminated over 10 mg/kg. A layer of unconsolidated soil and grass seeding was placed on the cover.

Drainage ditch

Contaminated soils with a maximum mercury content of up to 187 mg/kg associated with dredging in a drainage ditch were identified on the territory. The total volume of excavated soil to a depth of 1 m was 36,000 tons. After cleaning works, the bottom of the ditch was laid with a 0.5 m thick clay layer. Insulation was carried out in all contaminated areas with a clean layer of soil. On the garden plots and fields, the areas of excavation of polluted soils were covered with a clean layer of soil at the request of the owners of the plots.

The "Chkalovo" village and surrounding areas

The territory is used by the population as land pots for dachas (houses of local style) and other economic purposes. In samples taken from the 0–0.5 m layer, mercury contents higher than 2.1 mg/kg were detected. The territory of the garden plots to the north of the road was 2 hectares. The total volume of excavation was 17,500 m^3 of soils belonging to hazard classes II-IV.

The territory of the plant "Alash"

The industrial site of the "Carbid" plant is surrounded by the industrial territory of the Alash plant, which produces ferromanganese alloys and other products (Fig. 8). To assess the extent of pollution, surveys of atmospheric air (792 points), building materials (300 samples), soil (300 wells, 1698 samples, 1868 analyses), groundwater (10 wells up to 8 m deep were drilled, 50 soil samples and 10 groundwater samples; 55 soil analyses and 11 water analyses) and surface waters (30 wells, 30 samples from 30 wells) were taken. It has been established that in the C-14 building the content of mercury vapor varies from 2,619 to 27,133 mg/m^3, and in the building D-17 it reached 1,961 mg / m^3. In the C-14 building the floors and walls were also contaminated with a maximum mercury content of 11,700 and 12,900 mg/kg. The second highest concentration of contamination was recorded in building D-17. The detected concentration of mercury was 292 mg/kg.

The soil on the industrial site was contaminated everywhere (concentrations ranging from less than 2.1 mg/kg to more than 1500 mg/kg). In this case, there was a tendency of reducing mercury concentration with increased depth of sampling. Contamination of deep soil layers with a mercury content of more than 10 mg/kg (depth of 1.5–2.0 m) was observed in individual segments of industrial drainage sewage. The mercury concentrations at a depth of 6 m and 8 m were 11,700 mg/kg and 1,520 mg/kg respectively. At a depth of 2 m and 4 m, concentrations varied from 29.9 mg/kg to 51.2 mg/kg.

The mercury content in the wells was estimated to be 0.00132 mg/l and 0.08899 mg/l which corresponded to a PDK index 174.24 and 177.98 respectively. The increased mercury concentrations in the wells were confined to areas where contamination was found during the study of soil profile and groundwater samples. On the industrial site the soils in a small localised area of high pollution were subjected to material excavation and removal. This area was near to C-14 workshop, where the mercury content was more than 1500 mg/kg.

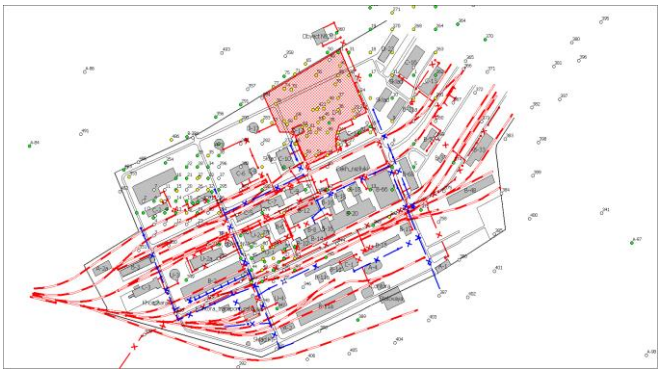


Fig. 8. Industrial site of the "Alash" plant

Main sewage ditch

A temporary sewage ditch was built then cleared of mercury-containing silts. After that the Main ditch of sewage waters of Temirtau city was put into operation. 36,000 tons of contaminated sediments were buried at the hazardous landfill. The banks of the ditch were isolated with clean soil.

The Transfer Stations

Transfer Stations for the temporary storage of excavated soil and other materials, as well as the separation of “black zones” from “white zones” were constructed on the industrial site of the "Carbide" plant near Gagarinskoe village, "Zhaur" bog, "Tegiz-Zhol" village, and others.

The “Zhaur” Swamp

The excavation work was carried out on the area of 60 hectares, with burial of 344,000 tons of contaminated soil for hazard classes I and II-IV.

Riverbed and floodplain deposits

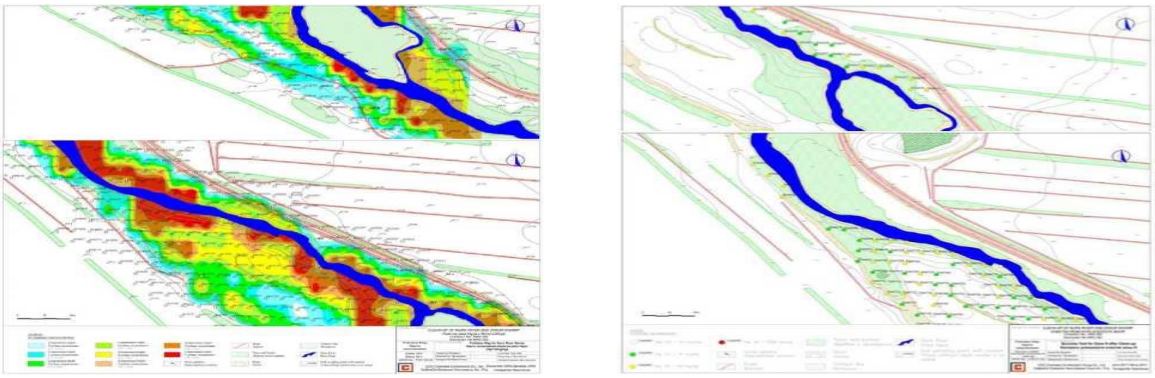
In total 1,428,854 tons of bed and floodplain deposits were removed. In order to avoid turbulence of polluted river sediments and their movement over the course of water during excavation, sediment traps and silt curtains were constructed.

Stabilization of the river bank near the village of “Gagarinskoe”

Some of the houses adjacent to the river bank were in danger of collapsing due to erosion of the river bank. The opposite bank was contaminated and needed to be excavated. Therefore, a new river section of approx. 500 m in length was constructed, and the bank on the village side was stabilised with gabions.

Monitoring of the clean-up success

This was done in all areas (industrial site of the plant, wastewater treatment plant and the surrounding areas, the ash dump, "Chkalov" village and the surrounding areas, the "Zhaur" swamp, channel, banks and floodplains of the river, and others). Evaluated the success of the treatment with the selection of control samples (Fig. 9). Restoration of the landscape and work on the restoration of vegetation and sowing of grass in the plots was carried out after approval by the Supervision Engineer.



A B

Fig. 9. Zones of mercury pollution before (A) and after (B) cleaning.

Monitoring of the environment

Environmental monitoring was conducted before the start of the rehabilitation process and continued until completion of the project. Monitoring of the mercury vapor content of air (as well as dust, noise, surface and ground water) was carried out at seven locations: at the Apan landfill site, the production site of the carbide plant, and at transfer stations.

Social and Environmental Benefits of the Project

In the course of project implementation, more than 2 million tons of contaminated material has been removed. The content of mercury vapours in the industrial site of "Carbid" JSC decreased from 140,000 ng/m^3 to 300 ng/m3. The concentration of mercury in the air decreased from 416.5 to 10.8 ng/m3 in the area of the village of Chkalovo, and from 257.4 to 21.28 ng/m^3 (PDK 300 ng/m^3) in the

"Zhaur" swamps. The concentration of mercury in the soil decreased from a range of 100 to 1500 mg/kg, down to a range of 10 to 50 mg/kg. At the end of 2011, the concentration of mercury in the surface waters dropped below the PDK index (500 ng/l) and in the underground drinking water in the villages in 2008–2010 it decreased to a level of 70 to 300 ng/l. About 6,234 hectares of land became available for agricultural and pasture purposes. More than 60 hectares of industrial territory and 18 km - more than 3,500 hectares - along the banks and floodplain of Nura river was transformed into an area “safe for human and animal life”. Safe water supply was provided to nine villages upstream (7,600 inhabitants) and downstream (12,000 inhabitants) of the "Yntumak" reservoir, as well to the cities of Temirtau (170,000 inhabitants) and Nur-Sultan (785,000 inhabitants). Now there is also the possibility of irrigation of land along the river up to 600 km downstream of the Yntumak reservoir. There is the potential to expand irrigated land from currently 3,500 hectares to 20,000 hectares in 2020.

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