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THE NAVRUZ PROJECT:

Cooperative, transboundary monitoring, data sharing and modeling of water resources in Central Asia

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ABSTRACT

The Navruz Project engages scientists from nuclear physics research institutes and water science institutions in the Central Asia Republics of Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan, and Sandia National Laboratories. The project uses standardized methods to monitor basic water quality parameters, radionuclides, and metals in the Syr Darya and Amu Darya rivers. Phase I of the project was initiated in 2000 with 15 sampling points in each of the four countries with sample analysis performed for over 100 parameters. Phase II of the project began in 2003 and expanded sampling to include at least 30 points in each country in an effort to characterize "hot spots" and to identify sources. Phase III of the project began in 2006 and will integrate decision support modeling with the existing monitoring. Overall, the project addresses four main goals: to create collaboration among Central Asian scientists and countries; to help increase capabilities in Central Asian nations for sustainable water resources management; to provide a scientific basis for supporting nuclear transparency and non-proliferation in the region; and to help reduce the threat of conflict in Central Asia over water resources. Contamination of these rivers is a result of growing population, urbanization, and agricultural activities, as well as radioactive contamination from a legacy of uranium mining and related activities of the former Soviet Union. The project focuses on waterborne radionuclides and metals because of the importance of these contaminants to public health and political stability in Central Asia.

INTRODUCTION

Political, cultural, and economic stability in Central Asia requires a reliable and sustainable supply of high-quality fresh water for agriculture and direct human consumption. Fresh water in Central Asia is provided on the surface by an international, transboundary river system, and so the most effective management of the resource will result from a collaborative, international, transboundary approach. Freshwater resource management requires long-term, basin-wide data sets shared among all transboundary partners and integration with decision support systems that allow access by a wide range of users, including scientists, policy makers, and the public.

Central Asia's history of extensive uranium mining and fabrication highlights its high potential for radionuclide and metals pollution in regional river systems. Both radionuclides and metals pose a serious long-term public health risk in the region. Data collected as part of the first two phases of the Navruz Project (2000 – 2006) show significant radioactive contamination levels at localized points in the region, due primarily to the Soviet-era legacy of uranium mining and waste processing. These contaminants represent a significant threat to public health and regional security, since natural events (such as heavy rainfall and flooding) or terrorist activities could result in the accidental or intentional movement of radioactive materials into public water supply systems. Interestingly, results from across the basin do not indicate widespread, serious contamination problems as many researchers expected.

The monitoring and data sharing system developed in the Navruz Project provides both baseline data and the international scientific infrastructure for tracking and addressing waterborne radionuclide contamination, however it is propagated. Preliminary results from the Navruz Project demonstrate the need for expanded joint scientific studies to more completely understand fate and transport of all kinds of contaminants.

The data from the project, along with numerous documents describing the project and some publications that have come from the project, are available to all at the following website: https://waterportal.sandia.gov/centasia.

Founding partner institutions in the Navruz Project include the Institute of Nuclear Physics in Almaty, Kazakhstan; the Institute of Physics in Bishkek, Kyrgyzstan; the Atomic Energy Agency of the Academy of Sciences in Dushanbe, Tajikistan; the Institute of Nuclear Physics in Ulugbek, Uzbekistan; the Center for Non-proliferation Studies of the Monterey Institute of International Studies; and Sandia National Laboratories Cooperative Monitoring Center. Current efforts are aimed at engaging other institutions throughout Central Asia.

METHODS

One of the great obstacles in transboundary river studies and transboundary river management has been the different technical methods for sampling and data collection used by different riparian nations and institutions, often rendering the resulting data poorly comparable across transboundary basins. Planning for the Navruz Project began in 1999 and was quickly followed in 2000 with a meeting of project partners in Uzbekistan to standardize methods for field data collection, sampling, sample handling, sample analysis, and data sharing. Those efforts culminated in a collaboratively developed, transboundary sampling and analysis plan (Passell et al., 2002), which is available at the website shown above.

Sampling and data collection began in 2000. Three sampling events occurred as part of Navruz 1, in the fall, spring and fall of 2000-2001. The monitoring occurred at 15 sampling sites in each country (for a total of 60 across the basin) on the main stems and the major tributaries of the Amu Darya and Syr Darya rivers. A map showing the approximate locations of the original 15 sampling locations is shown in Figure 1. Actual sampling locations are shown in the Appendix, and are recorded in Passell et al. (2002). Basic water quality parameters (Table 1) were collected using identical water quality data collection instruments manufactured by Hydrolab, Inc. Radionuclide and metals data (Tables 2 & 3) were generated using a variety of radioanalytical methods, quality assurance and control approaches, and other collaborative efforts described elsewhere (Passell et al. 2002, Barber et al., 2003). Analytical instruments included alpha & beta counters, gamma spectrometers, activation analysis (AA), and atom emission spectrometry with inductive-coupled plasma (AES-ICP). Sampling media included water,

water dissolve, bottom sediments, aquatic vegetation, and nearby soils. Data were collected on more than 100 parameters over those 5 environmental media.

One of the goals of the Navruz Project has been to develop a long-term data set for rivers of the Aral Sea Basin. In Navruz 2, seasonal data and sample collection and analysis continued at the original 15 locations in each country and was expanded to include a second 15 locations in each country. The second 15 locations were chosen by each partner institution to help characterize "hot spots", or areas of high radioactivities, and to help identify the sources of those hot spots.

In Navruz 3, data and sample collection and analysis continued at the original 15 locations as a way of continuing the development of the long-term data set. Sampling and data collection also continued at the second 15 locations, although some of those locations changed as understanding of the hot spots and sources evolved.

Navruz 3 also initiated transboundary collaboration among the partners on system dynamics decision support modeling in the Aral Sea Basin. This modeling approach, tested in various settings in the U.S. and Asia (Passell et al., 2002; Tidwell et al., 2004), employs system dynamics models with an interactive interface. The interactive capability – meaning that users can change variables, run the model, and view output in real time – makes this approach applicable to resource management, public education, policy making, and legislation, by both scientists and non-scientists. Models are built and run on laptops, variables can be set and reset by users, and output can be generated in seconds to minutes, allowing real time assessment of different management strategies and scenarios. Modeling efforts as part of Navruz 3 are just beginning as this writing takes place.

A weakness in the existing Navruz Project has been the absence of consistent river discharge data. This absence has been due to the physical difficulties and expenses associated with collecting these data. Gidromet agencies in each of the Central Asian countries once collected regular discharge data and still have much of the capability to do so, but since the collapse of the Soviet Union the capabilities and activities of these agencies have decreased. Navruz 3 will also broaden the current Central Asia collaboration to include Gidromet agencies in each of the countries.

Table 1. Basic Water Quality Parameters

Time	Discharge (m^3/s)	Water Temp. (deg C)	Dissolved Oxygen (% saturation)	Dissolved Oxygen (mg/L)	Specific Conductivity (□S/cm)	Salinity (g/L)	TDS (g/L)	Depth (m)	pH	Redox Potential (mV)

Table 2. Radionuclide Parameters

Alpha activity	Beta activity								
Be-7	Na-22	Na-24	K-40	Cr-51	Mn-52	Mn-54	Co-56	Co-57	Ni-57
Co-58	Fe-59	Co-60	Zn-65	Sr-85	Y-88	Zr-95	Mo-99	Ru-103	Ru-106
Ag-108	Ag-110	Sn-113	Cd-115	Sb-122	Sb-124	Sb-125	I-131	Ba-133	Cs-134
Cs-137	Ce-139	Ce-141	Ce-144	Nd-147	Eu-152	Gd-153	Eu-154	Eu-155	Ta-182
Ta-183	Ir-192	Tl-201	Hg-203	Tl-207	Tl-208	Pb-210	Pb-211	Bi-212	Pb-212
Bi-214	Pb-214	Rn-219	Ra-223	Ra-224	Ra-226	Th-227	Ac-228	Ra-228	Th-228
Th-229	Pa-231	Th-231	Th-232	Pa-233	U-235	Np-237	U-238	Pu-239	Am-241
Cm-243									

Alpha and beta activity reported in Becquerel/kilogram (Bq/kg)
Water (dissolved) and water (suspended) reported in Becquerel/liter (Bq/L).
Sediments, vegetation, and soils reported in Bq/kg.

Table 3. Metals Parameters

Al	Ag	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	Hg
K	Mg	Mn	Mo	Na	Ni	Pb	Se	Si	Tl	V	Zn	

Water (dissolved) and water (suspended) reported in micrograms/liter (μg/L). Sediments, vegetation, and soils reported in μg/g.

Fig. 1. Map of Central Asia. Orange dots represent approximate locations of original sampling locations for the Navruz Project

RESULTS

Data collected as part of the Navruz Project are available to partner scientists and to the public at this website: https://waterportal.sandia.gov/centasia.

Several publications have described the results of sample and data analysis from Navruz 1 (Passell et al., 2002; Passell et al., 2003; Barber et al., 2003; Barber et al., 2005; Kadyrhzanov et al., 2005; Vasiliev et al., 2005; Yuldashev et al., 2005). Detailed graphs, tables, and other analyses of early data can be found in those publications. Results from work under Navruz 2 are described in subsequent chapters in this volume.

In general, early results showed elevated levels of some naturally occurring and anthropogenic radionuclides at some locations throughout the Aral Sea basin. However, the widespread occurrence of high concentrations of radionuclide contamination throughout the basin has not appeared as expected by many workers. These high concentrations were expected because of the Soviet-era legacy of mining and fabrication of radionuclides and nuclear weapons testing in the former Soviet republics of Central Asia. Numerous metals concentrations across the basin did show elevated levels, likely as a result of extensive historic and current mining operations in the basin.

The largest concentration of natural radionuclides in bottom sediments occurred in the eastern part of the Chardarya reservoir of eastern Kazakhstan. Increased concentrations of all natural radionuclides and uranium also occur near the city of Shieli, Kazakhstan.

In Uzbekistan, the highest concentrations of natural radionuclides in soil and bottom sediments were found in samples from the Akhangaran River near the cities of Yangiabad, Angren, and Tuyabuguz. The Akhangaran River is a tributary of the Syr Darya in the Ferghana Valley, not far from Tashkent. In these samples, the concentration of the radionuclides of the ^{238}U and ^{232}Th families frequently exceeded 100 Bq/kg. Alpha and beta measurements from vegetation also showed significantly increased activity in those locations.

In Tajikistan, the highest concentration of natural radionuclides in the ^{238}U and ^{232}Th families is found on the Syr Darya near Khudzhand, also in the Ferghana Valley. Additionally, the highest contamination by ^{137}Cs in the region was found in the rivers that are tributaries to the Amu Darya and that are fed from the glaciers from the Pamir Mountains. The sources of this contamination require further investigation.

As an upstream country on the Syr Darya, Kyrgyzstan enjoys relatively low levels of contamination by radionuclides and metals compared with its downstream neighbors. However, considerably higher levels of radionuclide contamination were found downstream from the Mailuu Su uranium tailings, compared to levels immediately upstream. The Mailuu-Su River is a tributary to the Syr Darya near the Ferghana Valley.

The basic water quality data indicated a number of notable trends. There was a strong upward trend in the mean specific conductivity of the river water. These levels increased from less than 500 uS/cm in the upper reaches to over 1500 uS/cm in the lower reaches. The highest specific conductivity occured at Chinaz in Uzbekistan. The pH content of the river was between 7.5 and 8.3 throughout the length of the river. There were notable increases in pH at the Toktogul Reservoir and at Chyily in Kazakhstan.

Several interesting trends for metals emerged from the data. Results reported indicate all sampling seasons unless specifically noted. Results show high concentrations of selenium at TJ-13, UZ 06, KZ 08, and KZ 12 see Appendix for actual sampling code locations.**)** These concentrations exceeded 0.05 ug/L, the United States Environmental Protection Agency (EPA) drinking water safety standard.

The copper content of the river increased steadily from KG 03 through KZ 15 KZ 08, 09 and 12 had copper levels in excess of 1300 ug/l**,** the maximum permissable level according to the EPA. KZ 8 and 12, also had high concentrations of chromium and arsenic.

Chromium data were inconsistent. Chromium content average over all sampling events decreased along the length of the river in the water dissolved medium. Chromium concentrations measured during spring sampling events alone increased from upstream to downstream in the water dissolved medium.

Chromium content increased from the 1-2 ug/L in upstream reaches to roughly 4-6 ug/L in downstream reaches. There was also a slight increase in the chromium content in the soils and bottom sediments data from upstream to downstream.

The site most consistently contaminated with heavy metals along the river basins occurred downstream of Kyzyl-Orda in Kazakhstan. The site had high levels of arsenic, chromium, copper, lead and mercury. The site showed a distinct increase across most of the metals from the sampling location located upstream of Kyzyl-Orda.

CONCLUSIONS

The Navruz Project is a collaborative, international, transboundary data and sample collection, data sharing, and data analysis project engaging institutes of nuclear physics and other institutions in Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan, in the Syr Darya and Amu Darya basins of Central Asia. Overall findings show some high concentrations of some radionuclides in sites across the basin, but generally lower concentrations than were expected based upon the nuclear legacy of the region. Some metals concentrations increase from upstream to downstream, as expected as a result of mining past and current mining operations in the basin. Salinity increases from upstream to downstream, as expected.

The project represents a strong example of international, transboundary cooperation on water resources, complete with standardized approaches, mechanisms for data sharing, and collaborative transboundary data analysis. This project can be a model for transboundary water resource collaboration in other regions of the world.

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Appendix: Sampling codes and actual locations

Kyrgyzstan
KG-01, **Kichi-Naryn River before the confluence with the Chong-Naryn River, Kyrgyzstan**
KG-02, **Chong-Naryn River before the confluence with the Kichi-Naryn River, Kyrgyzstan**
KG-03, **Naryn River before the confluence of the Kichi-Naryn, Kyrgyzstan**
KG-04, **At-Bashy River before its confluence into the Naryn River, Kyrgyzstan**
KG-05, **Naryn River after the confluence of the At-Bashy tributary, Kyrgyzstan**
KG-06, **Chychkan River before the confluence into the Toktogul water pool, Kyrgyzstan**
KG-07, **Naryn River before its confluence in the Toktogul reservoir (hydrological post Uch-Terek), Kyrgyzstan**
KG-08, **Toktogul reservoir, Kyrgyzstan**
KG-09, **Naryn River after the Toktogul reservoir (region of Kara-Kul town), Kyrgyzstan**
KG-10, **Naryn River, southeast part of the town of Tashkumyr, Kyrgyzstan**
KG-11, **Mailuu-Su River, on the bridge (boundary with Uzbekistan), Kyrgyzstan**
KG-12, **Mailuu-Su River at the departure from Mailuu-Su town, Kyrgyzstan**
KG-13, **Mailuu-Su River near the transformer factory, Kyrgyzstan**
KG-14, **Mailuu-Su River, right tributary, Kyrgyzstan**
KG-15, **Mailuu-Su River 200 meters from the tributary, Kyrgyzstan**

Kazakhstan
KZ-01, **Chardarya reservoir, southeastern coast between the Keles and Kurukkeles Rivers, Kazakhstan**
KZ-02, **Chardarya reservoir, northeastern coast near Chardarya, Kazakhstan**
KZ-03, **Keles River, Saryagash town (upstream), Kazakhstan**
KZ-04, **Keles River, Saryagash town, (downstream), Kazakhstan**
KZ-05, **Badam River, Chymkent (upstream), Kazakhstan**
KZ-06, **Arys River before the confluence with the Badam River, Chymkent (downstream), near Obruchevka, Kazakhstan**
KZ-07, **Syrdarya, Chernak village (below Turkestan town), Kazakhstan**
KZ-08, **Syrdarya, Chyily (upstream), Tomlnaryk village, Kazakhstan**
KZ-09, **Syrdarya, Chyily, Kazakhstan**
KZ-10, **Syrdarya, Chyily (downstream), Zhulek village, Kazakhstan**
KZ-11, **Syrdarya, Kyzyl-Orda (upstream), Belkul village, Kazakhstan**
KZ-12, **Syrdarya, Kyzyl-Orda (downstream), Abaj village, Kazakhstan**
KZ-13, **Syrdarya, Korkyt village, below Zhusa town, Kazakhstan**
KZ-14, **Syrdarya, Bajkonur town, below Torwtam village, near Bay-Kozha, Kazakhstan**
KZ-15, **Syrdarya, Kazalinsk, Kazakhstan**

Tajikistan
TJ-01, **Varzob River, 18 kilometers above Dushanbe city, Tajikistan**
TJ-02, **Varzob River, 9 kilometers below Dushanbe city, Tajikistan**
TJ-03, **Kafirinigan River, 1 kilometer above the confluence with the Varzob River, Tajikistan**
TJ-04, **Kafirnigan River, 3 kilometers below its confluence with the Elok River, Tajikistan**
TJ-05, **Kafirnigan River, at the Shaartuz railway bridge, Tajikistan**
TJ-06, **Elok River, 1 kilometer above its flow into the Kafirnigan River, Tajikistan**
TJ-07, **Vakhsh River, at the Dzhilikul bridge.**
TJ-08, **Vakhsh River, "Chiluchor chashma," the spring, Tajikistan**
TJ-09, **Vakhsh River, 1 kilometer below Norak City, Tajikistan**
TJ-10, **Yekhsu River, at hydrological post "Vose", the settlement Vose, Tajikistan**
TJ-11, **Kyzylsu River, 5 kilometers from the settlement Vose, before its confluence with the Yekhsu River, Tajikistan**
TJ-12, **Kyzylsu River, Gulistan Village, Tajikistan**
TJ-13, **Syrdarya, 60 kilometers above the Kayrakkum reservoir, (unfinished frontier bridge), settlement Bulok, Tajikistan**
TJ-14, **Syrdarya, the bridge on the entrance of Khudzhand city, Tajikistan**
TJ-15, **Isfara River, the settlement Yangiobod between Rabot city and Nefteobod city, Tajikistan**

Uzbekistan
UZ-01, **Amudarya, Kyzyldzhar village, Karakalpakstan, 1 km above the terminating range of the Amudarya River (the nearest town is Kungrad), Uzbekistan**
UZ-02, **Amudarya, Kipchak town, Karakalpakstan, 0.5 km above the town, Uzbekistan**
UZ-03, **Amudarya, Tuyamuyun site, 8 km below the dam (Khorezm region), Uzbekistan**
UZ-04, **Karadarya, Namangan region, 20 km southwest from Namangan, at Kol' village, Uzbekistan**
UZ-05, **Syrdarya, Bekabad, Tashkent region, 0.9 km below the dump of drainage waters of "Vodokanal" enterprise, Uzbekistan**

UZ-06, **Syrdarya, Chinaz town, Tashkent region, 3.5 km SSW from Chinaz, Uzbekistan**
UZ-07, **Ankangaran River, Yangiabad town, Tashkent region, 5.5 km below Dukant village, Uzbekistan**
UZ-08, **Akhangaran River, Angren town, Tashkent region, 5.5 km below the Angren dam, Uzbekistan**
UZ-09, **Akhangaran River, Tuyabuguz, Tashkent region, Soldatskoe village, 0.5 km above the outfall of the Akhangaran River, Uzbekistan**
UZ-10, **Chirchik River, Gazalkent town, Tashkent region, 3.5 km below the town, Uzbekistan**
UZ-11, **Chirchik River, Kibraj village, Tashkent region, 3 km below the UZKTZhM enterprise sewage effluent, Uzbekistan**
UZ-12, **Chirchik River, Tashkent City, Tashkent region, 3 km below the sewage effluent from the Segeli KSM plant,**
UZ-13, **Zaravshan River, Ravatkhodzha, Samarkand region, 3.7 km below the outfall of the Taligulyan dump, Uzbekistan**
UZ-14, **Zaravshan River, Kattakurgan, Samarkand region, 0.8 km below the outfall of the Chegonak collector, Uzbekistan**
UZ-15, **Zaravshan River, Navoi City, Navoi region, 0.8 km below the sewage effluent from "NavoiAzot" enterprise, Uzbekistan**