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Water Quality and Public Health Monitoring of Surface Waters in the Kura-Araks River Basin of Armenia, Azerbaijan, and Georgia

Amy Ewing

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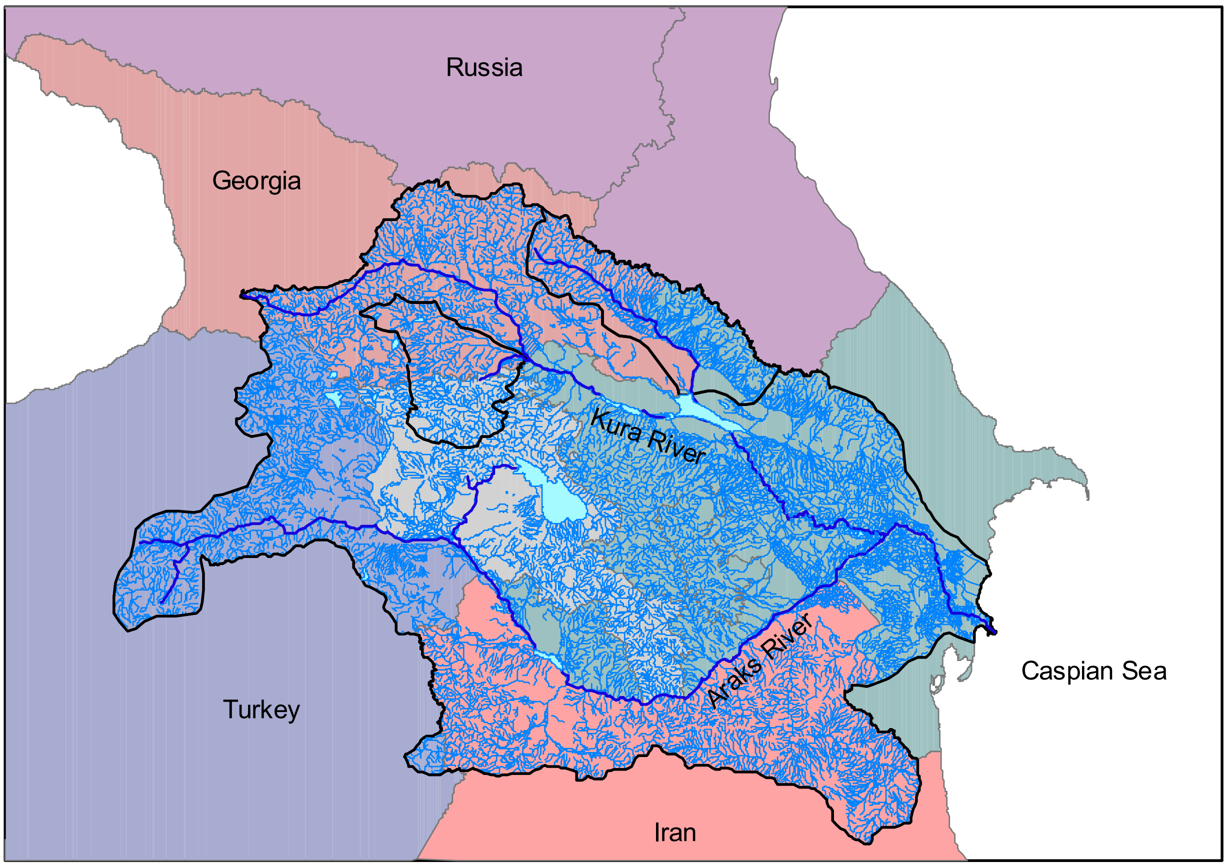

Water Resources Program

The University of New Mexico

Albuquerque, New Mexico 87131

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Abstract

The Kura-Araks (sometimes spelled Aras) River Basin is an international river basin located in the South Caucasus with five separate countries contributing area to the watershed. These countries are Turkey, Iran, Armenia, Georgia, and Azerbaijan. Surface water from the Kura and Araks Rivers is used for a variety of uses, including municipal, agricultural, industrial, and mining, and the waste products from each of these uses are discharged back into the rivers. Many of the resulting contaminants pose significant risks to human health, including exposure to organic pollution derived from municipal use, organochlorine pesticides and high nitrate from agriculture, chemical contamination from industry, and heavy metal contaminants from mining. The lack of existing data, and further limitations posed by the political situation and lack of regional economic stability make it necessary to involve international organizations in programs aimed at defining water quality baseline conditions. Although there are many water quality monitoring projects either existing or planned and international organization involvement in the basin is quite high, none of the current programs are approaching the problem of pollution in the Kura-Araks Basin from a public health perspective. A monitoring approach that targets those contaminants that pose the greatest risk to human health is proposed. Those contaminants are: nitrate, *E. coli*, 8 metals (arsenic, cadmium, chromium, cobalt, lead, manganese, nickel, and mercury), 10 organochlorine pesticides (aldrin, chlordane, DDT, endrin, dieldrin, heptachlor, hexachlorobenzene, mirex, toxaphene, and lindane), and PCBs, with laboratory costs expected to run $3,850.00 per sampling event. A community-based microbiological water quality monitoring program is also proposed. The annual cost of this program is $5,000.00 for monthly analyses by 100 communities, as well as an additional $55,000.00 the first year for the purchase of necessary equipment. Finally, a watershed planning committee including representatives from all 5 of the countries contributing area to the watershed, the international donor community, and other organizations involved with current water resource programs in the basin is proposed. This committee would be charged with keeping straight the progress, goals, coordination, and evolution of existing programs, as well as the need for additional programs in the basin.

Introduction

The focus of this project is the Kura-Araks River Basin, an international river basin located in the South Caucasus. The watershed includes Turkey, Iran, Armenia, Georgia, and Azerbaijan, although the analysis of this project will be constrained to the three lower basin states of Georgia, Armenia, and Azerbaijan (see Figure 1).

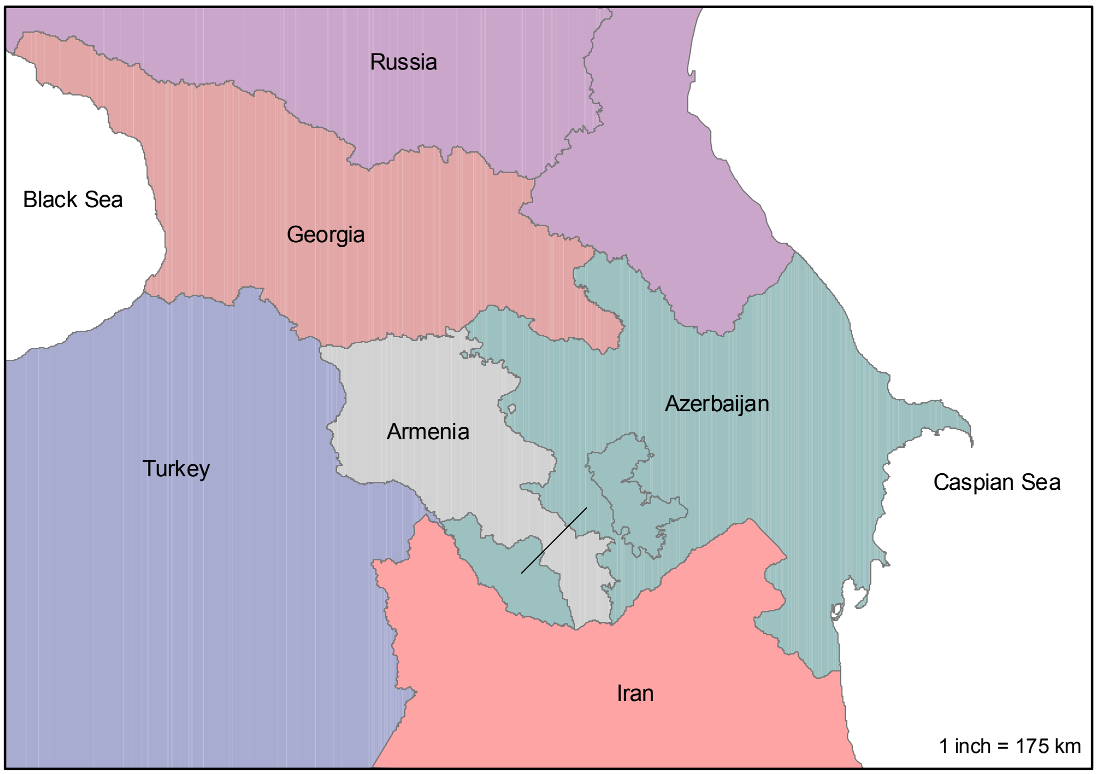

Figure 1. Study Area Location

The total area of the watershed is approximately 188,500 km^2, with the percent of total area for each of the countries as follows: 18% Georgia, 16% Armenia, 31% Azerbaijan, and 35% for Iran and Turkey combined (USAID, 2002). The Kura River originates in Turkey, and flows southeast through Georgia into Azerbaijan (USAID, 2002). Its length is approximately 1,364 kilometers (km), with an average discharge of 575 m^3/second (CEO, 2002). The headwaters of the Araks (sometimes spelled Aras) River are in Turkey, and it flows east through Turkey to the border with Armenia. The Araks marks the borders between Turkey and Armenia, and then Iran and Armenia, before flowing into Azerbaijan. The length of the Araks is approximately 1,364 km, with an average discharge of 210 m^3/second (CEO, 2002). The confluence of the Kura and Araks Rivers is in Azerbaijan, near the town of Sabirabad (USAID, 2002) (see Figure 2). The sub-watersheds shown in Figure 2 are for the Khrami-Debed, and Alazani Rivers. The majority of the flow in the basin is in the spring, with flow measuring up to 50% of the total yearly discharge (TACIS, 2003).

The population of the basin exceeds 11 million people (TACIS, 2003), with average population densities of 128 persons/km^2 in Armenia, 93 persons/km^2 in Azerbaijan, and 78 persons/km^2 in Georgia (CEO, 2002). There are three cities with an excess of 1 million inhabitants in the South Caucasus: Baku, Tbilisi, and Yerevan (CEO, 2002) (see Figure 3). There are currently no treaties among these countries concerning water rights or water quality in the basin (Wolf, 2003).

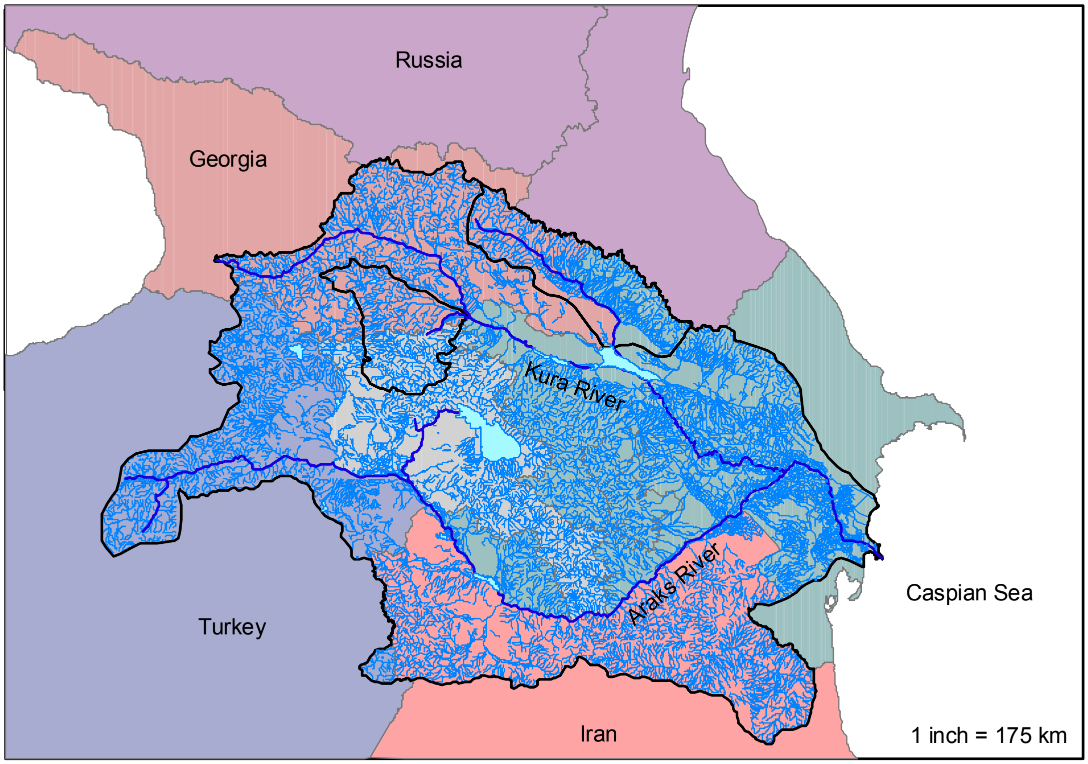

Figure 2. The Kura and Araks Rivers

Quantity of municipal, agricultural, industrial, and mining uses of water are fairly well defined along the river. In Georgia there is a surplus of water, and surface water from the Kura River is used primarily for agriculture. In Armenia, there are shortages some of the time, however, they are primarily induced by the water resource management methods (TACIS, 2002). In Armenia, the primary use of surface water from the Araks River is for agriculture and industry, while farther downstream in Azerbaijan, the Kura-Araks River is relied upon for drinking water as well as for agriculture and industry (TACIS, 2002). Azerbaijan is short on water, only allowing an average use of 1000 m^3 per person per year, which is one of the lowest rankings in the world (USAID, 2002). The shortage of water resources in Azerbaijan "is compounded by their inefficient use. Broken-down irrigation systems lead to water losses of up to 50%" (WHO, 2001b). In total there are more than 130 water reservoirs in the Kura Basin, used mostly for irrigation purposes. The “total effective capacity of these reservoirs is over 13 km^3” (TACIS, 2003). The South Caucasus has historically been a volatile region, and has gained significant international interest since the fall of the Soviet Union due to its known oil reserves. By 2020 it is estimated that the daily rate of oil extraction will reach approximately 3-5.5 million barrels in the Caspian region, through projects already developed (CEO, 2002).

Expected Contaminants and Exposure

Water resource abundance is not spread equally among the three South Caucasus countries, in fact both Armenia and Georgia “have abundant underground water reserves, which are used as a major source of drinking water”, while Azerbaijan relies almost entirely on the Kura River for all types of water uses (CEO, 2002). Over 70% of drinking water in Azerbaijan comes from the Kura River (CEO, 2002), and as Azerbaijan is the farthest country downstream, by the time the Kura enters Azerbaijan, it has flowed through both Armenia and Georgia.

Pollution in the Kura River includes organic pollution from untreated sewage, heavy metals from mining, hydrocarbons and PCBs from industry, nutrients and organochlorine pesticides from agriculture (TACIS, 2003), and high sediment load from deforestation and flood irrigation practices (TACIS, 2003). Cities and industrial centers are the main sources of pollution, with “low capacity of water treatment facilities or their absence in general” (CEO, 2002). Armenia, Azerbaijan, and Georgia all declared independence following the dissolution of the former Soviet Union in 1992, and since then, wastewater treatment facilities have either “ceased to function or work at very low levels of efficiency" (CEO, 2002). These facilities have not been updated or maintained since 1992, and as a result are both out of date and in disrepair (CEO, 2002). Effectively, the treatment capacity of the working wastewater treatment facilities does not go over 20% of the volume of water in need of treatment (TACIS, 2003). The impact of this is that larger quantities of water are discharged into the Kura River untreated. With a population of 11 million "this leaves a discharge load of 8.5 million inhabitant equivalent of organic pollution", with more than 35% of untreated wastewater concentrated around Yerevan and Tbilisi (TACIS, 2003) (see Figure 3).

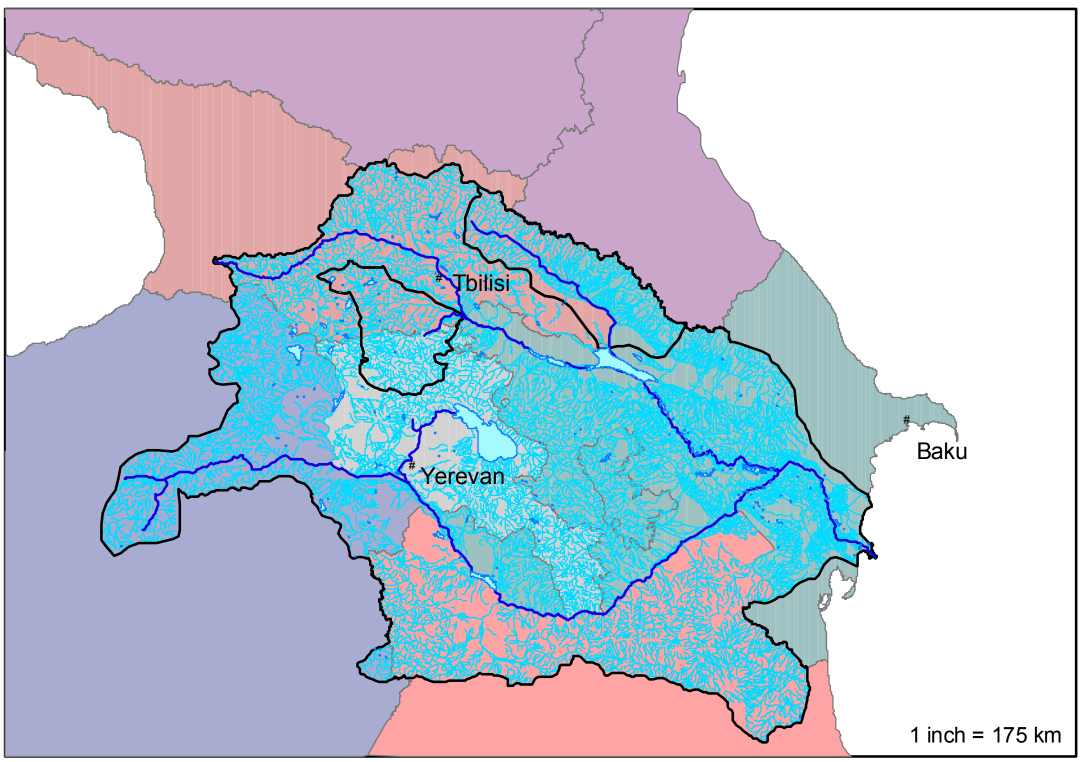

Figure 3. Major Population Centers of the South Caucasus

The state of water supply infrastructure in the South Caucasus mirrors that of wastewater infrastructure. Estimated losses in water supply pipelines fluctuate between 40 and 65%, and regular drops in water pressure cause "under pressure and therefore exchange of water between sewage and drinking water system" on a regular basis

(TACIS, 2003). In Georgia for example, where groundwater is the primary source of drinking water, "the water and sewage mains are close to one another and wastewater enters drinking water as a result" (WHO, 2001c). More than 80% of the population in Azerbaijan lives in districts where there are no modern water supply or sewage systems (WHO, 2001b). Thus, the exposure to organic pollution is very high in all three countries, and is not restricted to those who drink surface water.

During the Soviet period the region's economy was largely agriculture-based, and fertilizers and pesticides were used intensively (CEO, 2002). In Armenia in the 1980s, "average pesticide use was about nine kilograms per hectare (kg/ha) by public farms. In Azerbaijan, this figure amounted to about 33 kg/ha by that time" (CEO, 2002). In Georgia in the late 1980s, average fertilizer use was 240 kg/ha, with average pesticide use at 30 kg/ha (CEO, 2002). Although total use has declined dramatically since the break-up of the Soviet Union, the import and use of pesticides "is virtually uncontrolled, with standards and regulations flouted and no account being taken of concentrations or permissible loads per hectare" (WHO, 2001a). Unregistered pesticides "are smuggled into Georgia in a range and quantity over which there is no control" (WHO, 2001c). In fact, uncontrolled import and use of chemicals is a common phenomenon for the whole Caucasus. This includes the illegal use and import of pesticides including DDT (CEO, 2002). In addition to the past and present use of large quantities of chemicals, obsolete fertilizers and pesticides are stored in warehouses that do not meet environmental standards, increasing the levels of soil and water contamination (CEO, 2002).

Industry in the South Caucasus is "in severe crisis" (CEO, 2002), working at less than or equal to 20-25% capacity; however, "despite the overall reduction in environmental pressures from major economic sectors, per unit pollution increased relative to the 1970s and 1980s, due to the obsolescence or absence of pollution control technologies and the existence of poor compliance monitoring and control systems" (CEO, 2002). Although industry has been reduced greatly in the last 12 years, mining continues, and "prospects for future development of extensive mining are likely" (CEO, 2002).

Risk and Human Health Effects of Exposure

Microbiological Constituents

Of particular concern to human health in the Kura-Araks basin is the volume of raw sewage discharged into the river. A current estimate is that over 20% of the world's population lacks access to clean drinking water, and that "more than 5 million people die annually from illnesses associated with unsafe drinking water and adequate sanitation services" (Hunter et al., 2001). The South Caucasus is not the world's leading region for deaths due to the consumption of contaminated water; however, addressing the issue of microbiological contamination of the Kura-Araks River would save lives. Globally, with access to clean drinking water and sanitation services, it is estimated that "there would be 200 million fewer cases of diarrhea and 2.1 million fewer deaths caused by diarrheal illness each year" (Hunter et al., 2001). The Kura-Araks is not used solely as a drinking water source, and water quality standards clearly differ by use. The Kura-Araks does supply the majority of drinking water to Azerbaijan, and so decreasing the volume of raw sewage discharged upstream, causing a decrease in microbiological contamination, is of great importance along the full stretch of the river. Waterborne diseases include cholera, typhoid, dysentery, and other diarrheal diseases (Gleick, 2002). Outbreaks of dysentery and infectious disease (malaria and tuberculosis) are noted in all three South Caucasus countries, and mortality (primarily of children under 5 years old) due to diarrheal diseases is high, especially in Azerbaijan (WHO, 2001b).

While not a health threat in and of itself, the presence of coliform bacteria (fecal coliform and *E. coli*) in water indicates the presence of other potentially harmful bacteria (USEPA, 2002). Both fecal coliform and *E. coli* "only come from human and animal fecal waste" (USEPA, 2002), and the World Health Organization (WHO) drinking water quality guidelines specify that total coliforms "must not be detectable in any 100-ml sample" (WHO, 1998). Similarly, the level of turbidity is a good indicator of the presence of harmful bacteria, as "higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites, and some bacteria" (USEPA, 2002). The WHO lists turbidity of drinking water as one of the parameters that may give rise to complaints from consumers. The WHO turbidity guideline is for not greater than 5 nephelometric turbidity units (NTU) (for appearance) (WHO, 1998).

Inorganic Constituents

Many inorganic constituents including metals are expected to be present in the waters of the Kura-Araks, as a product of the mining operations as well as regional industrial operations. The effects of chronic exposure to high concentrations of these metals, as well as the human health effects of exposure to constituents such as chloride, nitrate, nitrite, and sulfate are discussed below.

Exposure to low levels of arsenic can cause skin discoloration, nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, a sensation of “pins and needles” in hands and feet (ATSDR, 2001a), and problems with the circulatory system (USEPA, 2002). Organic arsenic compounds are less toxic than inorganic arsenic compounds, and inorganic arsenic is a known human carcinogen (ATSDR, 2001a). At high levels, inorganic arsenic can cause death, and WHO has set a drinking water quality guideline for arsenic of “0.01 mg/l for excess skin cancer risk” (WHO, 1998).

Cadmium “damages the lungs, can cause kidney disease, and may irritate the digestive tract” (ATSDR, 1999a). In studies where animals were given cadmium in food or water, the animals developed high blood pressure, anemia, liver disease, and nerve or brain damage (ATSDR, 1999a). The United States Environmental Protection Agency (USEPA) lists kidney damage as the major effect of cadmium (USEPA, 2002), and both cadmium and cadmium compounds “may reasonably be anticipated to be human carcinogens” (ATSDR, 1999a). The WHO has set a drinking water quality guideline of 0.003 mg/l for cadmium (WHO, 1998).

Chloride is classified as a nuisance contaminant by the United States Environmental Protection Agency (USEPA, 2002). The World Health Organization (WHO) has identified a drinking water quality guideline of 250 mg/l for chloride, because it is a parameter on the list of those that may give rise to complaints from consumers. The standard is for taste and corrosion, and no adverse health effects from chloride were discussed (WHO, 1998).

Chromium is present in the environment in several different forms. The most common forms are chromium (0), chromium (III), and chromium (VI). Chromium (III) occurs naturally in the environment, and is an essential nutrient, while “chromium (VI) and chromium (0) are generally produced by industrial processes" (ATSDR, 2001b). The ingestion of large quantities of chromium (VI) can cause "stomach upsets, ulcers, convulsions, kidney and liver damage, and even death" (ATSDR, 2001b). The USEPA lists the most common effect of exposure to chromium as "allergic dermatitis" (USEPA, 2002), while the World Health Organization (WHO) has determined that chromium (VI) is a human carcinogen (ATSDR, 2001b). The WHO drinking water quality guideline for chromium is 0.05 mg/l (WHO, 1998).

Exposure to high levels of cobalt "can result in lung and heart effects and dermatitis", and in animal studies, liver and kidney effects have also been observed (ATSDR, 2001c). Cobalt and cobalt compounds are possibly carcinogenic to humans (ATSDR, 2001c); however, no WHO drinking water quality guideline for cobalt has been set (WHO, 1998).

Copper is classified by the USEPA as a nuisance contaminant (USEPA, 2002), and has determined that copper is not classifiable as to carcinogenicity (ATSDR, 2002a). The WHO drinking water quality guideline is 2 mg/l (WHO, 1998), with a lower guideline set at 1 mg/l because of its staining properties (WHO, 1998). Long term exposure to copper can cause "irritation of the nose, mouth and eyes, vomiting, diarrhea, stomach cramps, nausea" (ATSDR, 2002a), as well as kidney damage (USEPA, 2002).

Iron is another constituent that is classified as a nuisance contaminant by the USEPA (USEPA, 2002). A water quality guideline of 0.3 mg/l has been set for iron, because of its ability to stain "laundry and sanitary ware" (WHO, 1998).

Lead can affect almost every organ and system, with the central nervous system being the most sensitive, particularly in children (ATSDR, 1999b). There is inadequate evidence to clearly determine its carcinogenicity (ATSDR, 1999b); however, lead causes "delays in physical or mental development" in children, as well as kidney problems and high blood pressure in adults (USEPA, 2002). The WHO has set a drinking water quality guideline of 0.01 mg/l for lead (WHO, 1998).

At high levels, exposure to manganese can cause brain, liver, nervous system and kidney damage, as well as birth defects (ATSDR, 2001d). The EPA has determined that manganese is not classifiable as to human carcinogenicity (ATSDR, 2001d), and has classified it as a nuisance contaminant (USEPA, 2002). The WHO has set a health based water quality guideline for manganese at 0.5 mg/l, and also a lower guideline of 0.1 mg/l due to its staining properties (WHO, 1998).

Exposure to high levels of metallic, inorganic or organic mercury can cause brain damage and kidney damage, and birth defects (ATSDR, 1999c). Young children are more sensitive to mercury exposure than adults, and possible effects of exposure include "brain damage, mental retardation, incoordination, blindness, seizures, and inability to speak" (ATSDR, 1999c). The EPA has determined that mercuric chloride and methylmercury are possible human carcinogens (ATSDR, 1999c), and WHO has developed a drinking water quality guideline of 0.001 mg/l for mercury (WHO, 1998).

While the most common adverse health effect of nickel in humans is an allergic reaction (ATSDR, 1997), in addition to skin effects, exposure to nickel can also cause lung and nasal sinus cancers (ATSDR, 1997). Nickel and certain nickel compounds "may reasonably be anticipated to be human carcinogens" (ATSDR, 1997), and WHO has established a drinking water quality standard of 0.02 mg/l for nickel (WHO, 1998).

The exposure effects of nitrogen as nitrate (NO_3^-) and nitrite (NO_2^-) are greatest on children who are less than 6 months of age. Symptoms include shortness of breath and blue-baby syndrome (USEPA, 2002). The World Health Organization (WHO) has set drinking water quality guidelines of 50 mg/l for nitrate, 3 mg/l for acute and 0.2 mg/l for chronic nitrite exposure (WHO, 1998).

Selenium and selenium compounds are not classifiable as to their carcinogenicity to humans (ATSDR, 2001e), although chronic exposure to high concentrations of selenium can cause hair loss, nail brittleness, and neurological abnormalities (selenosis) (ATSDR, 2001e). The WHO has set a drinking water quality guideline of 0.01 mg/l (WHO, 1998).

Silver is classified by the U.S. Environmental Protection Agency as a nuisance contaminant (USEPA, 2002), while WHO has determined that "it is unnecessary to recommend a health-based guideline value for this compound because it is not hazardous to human health at concentrations normally found in drinking water" (WHO, 1998). The EPA has determined that silver is not classifiable as to human carcinogenicity (ATSDR, 1999d). At very high levels, exposure to silver "may cause argyria, a blue-gray discoloration of the skin and other organs", which is a permanent effect that "appears to be a cosmetic problem that may not be otherwise harmful to health" (ATSDR, 1999d).

Sulfate is classified by the U.S. Environmental Protection Agency as a nuisance contaminant (USEPA, 2002), and WHO has classified sulfate as a parameter that may give rise to complaints from consumers. The WHO drinking water quality guideline has been set at 250 mg/l for taste and corrosion (WHO, 1998).

Zinc is an essential element in our diet, with harmful health effects generally beginning "at levels from 10-15 times the RDA (in the 100 to 250 mg/day range)" (ATSDR, 1995). Exposure to high concentrations of zinc "can cause anemia, pancreas damage, and lower levels of high density lipoprotein cholesterol (the good form of cholesterol)" (ATSDR, 1995). Zinc is classified by the U. S. Environmental Protection Agency as a nuisance contaminant (USEPA, 2002), and has not been classified for carcinogenicity (ATSDR, 1995). WHO has set a water quality guideline of 3 mg/l for appearance and taste (WHO, 1998).

Organic Constituents

The human health effects of exposure to organic chemicals are even worse than exposure to inorganic compounds including metals. A subset of organic chemicals "noted for their environmental persistence, long half-lives and their potential to bioaccumulate and biomagnify in organisms once dispersed into the environment" (IPCS, 1995) have been classified as Persistent Organic Pollutants by the United Nations Stockholm Convention (UNEP, 2002b). Of the first 12 chemicals to be classified as POPs, 9 are organochlorine pesticides, and 3 are other chemicals (PCBs, dioxins, and furans). These chemicals "are used in or arise from industry, agriculture and disease vector control" (IPCS, 1995), and the Stockholm Convention aims to minimize their use and concentration in the environment (UNEP, 2002b). Although they are highly toxic, organophosphorus pesticides "are readily hydrolysed in water, adsorbed on sediments, or readily degraded in soil. As a result, they are seldom if ever found in drinking water" (WHO, 2000). This, combined with known historic heavy use of organochlorine pesticides in the South Caucasus countries, constrains our discussion away from the effects of organophosphorus pesticides. The 12 POPs are the organic chemicals with the greatest impact on human and environmental health, and their use, risks, and exposure effects are discussed below. Lindane, another organochlorine pesticide that has not been classified as a POP, has been included in this discussion because of its wide current and historic use in the Kura-Araks region (Bodo, 1998).

Aldrin is an organochlorine pesticide that is "applied to soils to kill termites, grasshoppers, corn rootworm, and other insect pests" (UNEP, 2002c). Aldrin is readily metabolized to dieldrin, another organochlorine pesticide, such that "the levels of dieldrin detected likely reflect the total concentrations of both compounds" (IPCS, 1995). Dieldrin is used principally to control termites and textile pests, but has also "been used to control insect-borne diseases and insects living in agricultural soils" (UNEP, 2002c). There is inadequate evidence for the classification of carcinogenicity of aldrin and dieldrin, due to limited evidence in laboratory animal studies (IPCS, 1995), although they are known to decrease immune system function, reduce reproductive success, cause kidney damage, and may cause birth defects (USEPA, 2003a). The WHO has set a drinking water quality guideline of 0.03 μg/l (WHO, 1998) for aldrin/dieldrin.

Chlordane is an organochlorine pesticide "used extensively to control termites and as a broad-spectrum insecticide on a range of agricultural crops" (UNEP, 2002c). Chlordane causes nervous system problems, harms the endocrine system, nervous system, digestive system, liver, and likely causes cancer (USEPA, 2003b). Chlordane is classified as a possible human carcinogen (IPCS, 1995). The World Health Organization (WHO) has set a drinking water quality guideline of 0.2 μg/l (WHO, 1998) for chlordane.

Dichlorodiphenyltrichloroethane (DDT) is an organochlorine pesticide "widely used during World War II to protect soldiers and civilians from malaria, typhus, and other diseases spread by insects. It continues to be applied against mosquitoes in several countries to control malaria" (UNEP, 2002c). DDT and related compounds are very persistent in the environment, with as much as 50% remaining in the soil 10-15 years after application (IPCS, 1995). DDD and DDE are breakdown products of DDT and "are also present virtually everywhere in the environment and are more persistent than the parent compound" (IPCS, 1995). DDT affects the nervous system, with symptoms of large doses including tremors and seizures (ATSDR, 2002b). Exposure to high concentrations of DDT damages the reproductive system, and reduces reproductive success (USEPA, 2003c). Studies in rats have shown that DDT and DDE can mimic the action of natural hormones and in this way affect the development of the reproductive and nervous systems (ATSDR, 2002b). There is limited evidence of carcinogenicity of DDT in humans (as studies have not been performed on humans); however, there is sufficient evidence in experimental animals. DDT is classified as a possible human carcinogen (IPCS, 1995). There is limited evidence that "suggest a possible association between organochlorines, such as DDT and its metabolite DDE, and risk of breast cancer" (IPCS, 1995). It is illegal to use DDT in the United States, although it can still legally be manufactured here "but it can only be sold to, or used by, foreign countries" (NPTN, 1999). The WHO has set a drinking water quality guideline of 2 μg/l (WHO, 1998) for DDT.

Polychlorinated dibenzoparadioxins (dioxins) and polychlorinated dibenzofurans (furans) are organic chemicals that are produced unintentionally as byproducts resulting from the production of other chemicals (UNEP, 2002c). Both are produced due to incomplete combustion, and in the manufacture of certain pesticides, while furans are also "found in commercial mixtures of PCBs" (UNEP, 2002c). Dioxin exposures "are associated with increased risk of severe skin lesions, altered liver function and lipid metabolism, general weakness due to drastic weight loss, depression of the immune system, and endocrine and nervous system abnormalities" (UNEP, 1999). Exposure to dioxins and furans lead to reproductive difficulties and an increased risk of cancer (USEPA, 2002).

Endrin is an organochlorine pesticide that is sprayed on the leaves of crops such as cotton and grains, and also used to control mice, voles, and other rodents (UNEP, 2002c). Endrin is not classifiable as to carcinogenicity in humans (IPCS, 1995). Long-term exposure effects include convulsions and damage to liver tissue (USEPA, 2003d).

Heptachlor is an organochlorine pesticide used "to kill soil insects and termites… cotton insects, grasshoppers, crop pests, and malaria-carrying mosquitoes" (UNEP, 2002c). Effects of exposure to heptachlor and heptachlor epoxide (a breakdown product of heptachlor) include damage to the central nervous system and the liver, with symptoms including tremors and convulsions (IPCS, 1995). The WHO has set a drinking water quality guideline of 0.03 μg/l (WHO, 1998) for heptachlor.

Hexachlorobenzene (HCB) is an organochlorine pesticide that kills fungi. It is also released as a byproduct along with dioxins and furans during the manufacture of certain chemicals (UNEP, 2002c). Exposure effects include damage to bones, kidneys, blood cells, the immune, endocrine, and nervous systems, and exposure lowers survival rates of young children (USEPA, 2003e). Hexachlorobenzene is considered to be carcinogenic (WHO, 2000), and the WHO has set a drinking water quality guideline of 1 μg/l (WHO, 1998) for it.

Lindane (gamma isomer of hexachlorocyclohexane) is an organochlorine pesticide that has not yet been classified as a POP (UNEP, 2002b). Short term exposure effects include high body temperature and pulmonary edema (USEPA, 2003i), and long term exposure effects include heart disorders, blood disorders, seizures, changes in sex hormones, and in rats, liver cancer (USEPA, 2003h). Lindane is classified as a possible human carcinogen (WHO, 1993). The WHO has set a drinking water quality guideline of 2 μg/l (WHO, 1998) for lindane.

Mirex is an organochlorine pesticide that is "applied mainly to combat fire ants and other types of ants and termites. It has also been used as a fire retardant in plastics, rubber, and electrical goods" (UNEP, 2002c). Mirex is known to damage the liver and kidneys, cause damage to the nervous and reproductive systems, and it may be the cause of increased miscarriages (USEPA, 2003f). Mirex is classified as a possible human carcinogen (IPCS, 1995).

Polychlorinated biphenyls (PCBs) are organic compounds "employed in industry as heat exchange fluids, in electric transformers and capacitors, and as additives in paint, carbonless copy paper, sealants and plastics" (UNEP, 2002c). PCBs cause adverse effects on the immune, reproductive, nervous, and endocrine systems (USEPA, 2002), and are classified as probable human carcinogens (IPCS, 1995).

Toxaphene (also called camphechlor) is an organochlorine pesticide used to control insects on "cotton, cereal grains, fruits, nuts, and vegetables. It has also been used to control ticks and mites in livestock" (UNEP, 2002c). Toxaphene "damages the immune system, kidneys, liver, harms the adrenal gland, causes changes in the development of fetuses, damages the lungs and nervous system, and may cause cancer" (USEPA, 2003g). Toxaphene is classified as a possible human carcinogen (IPCS, 1995).

While exposure to high concentrations of metals can yield adverse health effects, it takes high doses, often over long periods of time. This is not the case with POPs. Unlike with exposure to metals, adverse effects have been associated with chronic low level exposure to POPs (IPCS, 1995). Laboratory investigations and environmental impact studies in the wild "have implicated POPs in endocrine disruption, reproductive and immune dysfunction, neurobehavioural disorders and cancer" (IPCS, 1995). Endocrine disruptors are compounds which are "agents which interfere with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development and/or behavior" (Snyder et al., 2003). In a *Science* article in 2000, Jocelyn Kaiser wrote that "given mounting evidence of human reproductive and developmental problems… these findings regarding low doses in lab animals suggest that environmental factors, including exposure to endocrine-disrupting chemicals, may be to blame in causing such problems in people" (Kaiser, 2000). Examples of problems that are being seen in people include decreases in human sperm quality and quantity over the last 50 years which has been attributed to the presence of endocrine disrupting compounds in the environment (Snyder et al., 2003), and the consideration of POPs as a potentially important risk factor in the etiology (cause) of human breast cancer (IPCS, 1995). The fact that these compounds persist in the environment, and bioconcentrate by factors of up to 70,000 fold (IPCS, 1995) magnifies the problem.

Public Health in the South Caucasus

Life expectancy is quite high in all three of the South Caucasus countries; however, the real figures could well be somewhat lower as deaths may be "under-recorded especially in the rural areas" (WHO, 2001a). During the Soviet era, "morbidity and mortality rates due to neoplasm and birth defects were traditionally high among the rural population of the Caucasus, mainly due to unsustainable use of pesticides" (CEO, 2002). Magnifying the quantity of pesticides used, "many individual farmers are not aware of health and environmental requirements for pesticide use" (CEO, 2002). In addition, miscarriages and premature births reached 30-45% among women dealing with pesticides, and "high morbidity for gynaecological diseases" was also seen in these women (CEO, 2002). Average pesticide use in Armenia exceeded the Soviet Union average value by 20-25 times in 1989, and general morbidity among children under age 6 was 4.6 times higher than that among children living in regions with minimum pesticide loads also in 1989 (CEO, 2002).

The public health care system has dramatically changed since the break-up of the Soviet Union, as "the post-Soviet economic crisis has resulted in the deterioration of existing infrastructure" (CEO, 2002). The effect of this deterioration has been a decrease in water quality, "whereas in the early 1980s about 10-12% of samples did not meet water quality standards for toxicity, in 1991 the figure reached 74%. The figure was about 15-16% for bacteriological contamination in the 80s and it became about 53% in 1991" (CEO, 2002). All without exception urban treatment installations fail to provide an adequate level of treatment and disinfection of wastewater, with the result that "in

Georgia 16% of the drinking water is not satisfactory, in Azerbaijan this in certain regions goes up to 80%" (TACIS, 2003).

Since 1990, "sanitary-hygenic conditions have been worsening in the region" with outbreaks of infectious diseases, especially gastrointestinal ones becoming common (CEO, 2002). High morbidity due to infectious diseases is traced to poor living conditions, and low food and water quality (CEO, 2002). Even in Armenia where the majority of drinking water is from a groundwater source, "water supplied through the centralized network frequently does not comply with microbiological standards" (WHO, 2001a). The pattern of hospital admissions is somewhat different in the South Caucasus from Europe. In Armenia, hospitalization due to infectious and parasitic diseases was 6.6% (WHO, 2001a), 6.1% in Azerbaijan (WHO, 2001b), and 8.1% in Georgia (WHO, 2001c) as compared to 3.4% for the European average. In rural areas, gastrointestinal diseases and poliomyelitis caused morbidity figures of higher than average values" (CEO, 2002), and in Georgia, "the incidence of tuberculosis rose to become the highest in the European Region" in the 1990s (WHO, 2001c). Malaria and tuberculosis are serious problems in Azerbaijan, and although the incidence is less than in Azerbaijan, malaria is also a problem in Armenia. Premature mortality due to breast cancer in Armenia is the highest among the newly independent states (NIS) (WHO, 2001a), and while the rate in Georgia is slightly lower than in Armenia, it is still high (WHO, 2001b). The rate in Azerbaijan is just below average (WHO, 2001c). In addition to issues of quality, "water is supplied according to a timetable, people receiving water for 2-6 hours a day (in Armenia), despite adequate supplies of water at the source" due to the high cost of electric power (WHO, 2001a).

By 1993 gross domestic product (GDP) had fallen to 60% of the 1989 figure (WHO, 2001a). Health care expenditure as a percentage of GDP is quite low in the South Caucasus, with expenditure values of 1.3% in Armenia (WHO, 2001a), 1.6% in Azerbaijan (WHO, 2001b), and 0.6% in Georgia (WHO, 2001c), compared to a European average of 6.0%. Since the dissolution of the Soviet Union, "health-care systems have lost their ability to practice preventative medicine and usually treat people in advanced stages of disease…Although qualified professionals in the system still exist, they too lag behind in their knowledge of recent tools and methods used in contemporary toxicology and epidemiology" (CEO, 2002). Overall, much of the public has little or no access to health care services. Hospital bed occupancy and the quality of health care have dramatically dropped during due to the low level of public financing (CEO, 2002). The lack of access to good health care only exacerbates the issue of poor water quality in the region.

Also worth noting are the effects of natural disasters and armed conflict on public health in the region. In 1988 the Spitak earthquake in Armenia "caused 25,000 deaths and led some hundreds of thousands of people to leave the earthquake area, moving mainly to Yerevan" (WHO, 2001a). As a result of the conflict in Nagorno-Karabakh, approximately 320,000 refugees entered Armenia, mainly from urban areas in Azerbaijan, while ethnic Azerbaijanis fled the rural areas of Armenia (WHO, 2001a). Recent ethnic conflicts in some parts of the region "have destroyed the sanitation infrastructure in some areas, aggravating the sanitary-hygenic conditions there. Military actions have resulted in the displacement of local populations and the establishment of refugee camps where sanitary-hygenic conditions are extremely poor" (CEO, 2002).

International Toxics Treaties and their Applicability

Armenia, Azerbaijan, and Georgia are all member states of the United Nations (UN, 2003). There are three international conventions developed under the United Nations Environment Programme (UNEP) that together "provide an international framework governing the environmentally sound management of hazardous chemicals throughout their lifecycles" (UNEP, 2002a), and these conventions were used in the identification of those chemicals that should be monitored in the Kura-Araks River Basin. Each of these conventions will bind their list of signatories to their respective convention upon taking effect. Of the three toxic treaties, the Stockholm Convention is most pertinent to the discussion of water quality and human health; however, all three conventions are summarized here for completeness.

The Basal Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in 1989 "in response to concerns about toxic waste from industrialized countries being dumped in developing countries, and countries with economies in transition" (UNEP, 2002a). This convention aims to control the transboundary movement of hazardous wastes, the development of criteria for environmentally sound management of the wastes, and minimization of hazardous waste generation (UNEP, 2002a). This convention has been ratified by all but three of its 156 signatories including Armenia, Azerbaijan, and Georgia (it has not yet been ratified by Afghanistan, Haiti, or the United States), and it is in effect (UNEP, 2003a).

The Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade was adopted in 1998. Forty-one parties have ratified the convention and it will enter into force after the 50th

ratification (UNEP, 2003b). Armenia is a signatory to the Rotterdam Convention, although they have yet to ratify, while neither Azerbaijan nor Georgia are signatories. This convention "will take voluntary codes of conduct and information exchange, and replace them with a mandatory PIC procedure" (UNEP, 2002a).

The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted in 2001 "in response to the urgent need for global action to protect human health and the environment from POPs" (UNEP, 2002a). POPs are defined as chemicals "that are highly toxic, persistent, bioaccumulate and move long distances in the environment" (UNEP, 2002a). In implementing the Stockholm Convention, "governments will take measures to eliminate or reduce the release of POPs into the environment" (UNEP, 2002b). Of 151 signatories (which include both Armenia and Georgia, but not Azerbaijan), 30 have ratified so far (UNEP, 2003c). This convention will take effect following the 50th ratification (UNEP, 2002b). Twelve countries have been chosen by the Global Environment Facility (GEF) / United Nations Environment Program (UNEP) for the development of national implementation plans for the management of persistent organic pollutants (POPs); the South Caucasus countries are not included as a part of this pilot study (UNEP, 2003d).

The goals of the Stockholm Convention include "eliminating dangerous POPs, supporting the transition to safer alternatives, targeting additional POPs for action, clean-up of old stockpiles and equipment containing POPs, and working together for a POP free future" (UNEP, 2002c). The first 12 persistent organic pollutants have been identified. These include 9 organochlorine pesticides (aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex, and toxaphene), as well as dioxins, furans, and polychlorinated biphenols (PCBs) (UNEP, 2002c). Following its 50th ratification, both Armenia and Georgia will be obligated to take action in support of achieving the goals of the Stockholm Convention.

Together, the WHO and the United Nations Economic Commission for Europe (UN/ECE) have proposed yet another international treaty that pertains to water quality. The Protocol on Water and Health has been signed by 36 European governments (including Armenia, Azerbaijan, and Georgia), and it needs 16 ratifications in order to become legally binding (WHO, 2001d). So far, 8 countries have ratified the Protocol on Water and Health, and Azerbaijan is one of those 8 (UN/ECE, 2003). Major provisions of the Protocol on Water and Health include providing "adequate supplies of wholesome drinking water which is free from any micro-organisms, parasites and substances which, owing to their numbers or concentration, constitute a potential danger to human health" (UN/ECE, 2000). In addition, under the Protocol on Water and Health, "effective systems for monitoring and assessing situations likely to result in outbreaks or incidents of water-related diseases and for responding to them or preventing them are to be established" (UN/ECE, 2000).

Existing Data and Limitations

During the Soviet era, water resource monitoring data was collected by region, and forwarded to Moscow at the end of each year. This practice stopped in 1989 (USAID, 2002). Little reliable information is available on the Kura and Araks, as after 1992 "most monitoring was stopped or slowly died under political and economic pressure (TACIS, 2003). The quality of monitoring is low due to lack of reagents, old or malfunctioning equipment, and the fact that quality assessment and quality control are completely lacking (TACIS, 2003). For the South Caucasus countries, data for the last ten-year period are often lacking or entirely absent, especially for Georgia, where environmental data collection has diminished the most dramatically (CEO, 2002). Disrupted power in Georgia has further eroded willingness to even attempt analysis since the lights go out without warning all the time, many times for days; "having power is the exception for many organizations and people" in the region (Fischer, 2003). Regionally, water laboratories are reported to be inoperative due to financial constraints (TACIS, 2003).

As a part of the European Union's Technical Assistance to the Commonwealth of Independent States (TACIS) Joint River Management Programme, a review of all existing water quality data was performed. Data sources included in the review were State Department of Hydrometeorology of Georgia, U.S.S.R. Academy of Science Monitoring Centre, and World Bank Water Programme for Armenia. The data review yielded the following results:

> "These data in most cases have been reported as annual average figures, however this gives no indication of the number of samples from which the average results have been derived";
>
> "Where data are available over some years there are variations between years and source and month for which it seems doubtful that the reason is environmental changes, but is more likely to result from analytical errors";
>
> The trend in results for ammonia and BOD in the 1980s "appears to be a marked decrease… suggesting that either the sources of pollution have been removed or that the analytical methodology has been changed" (TACIS, 2003).

Currently “hardly any water quality monitoring takes place, let alone transboundary monitoring”, and all efforts taken are incidental samples with low reliability (TACIS, 2003).

Other sources do provide some qualitative data. It is estimated that the “millions of tons of untreated sewage and industrial waste (discharged into the Kura-Araks) regularly push the level of water pollution to 10 to 100 times international standards” (Postel and Wolf, 2001). In general heavy metal content in the soils of Azerbaijan exceed world standards by 8 times for lead, 3 times for cadmium, 2 times for nickel, 50-60 times for zinc, and 10 times for copper (UNEP, 1998). Organochlorine pesticide residues in the soil are expected to be high, as during the Soviet era pesticide use in the South Caucasus was many times greater than average (UNEP, 1998). The unregulated use of pesticides in the previous years has lead to the high residual quantities of poisonous chemicals in soil, and in addition, “thousands of tonnes of outdated and prohibited pesticides and mineral fertilizers are stored in semi-destroyed and non-operating warehouses” (UNEP, 1998). The haphazard storage of surplus chemicals provides a source for continued environmental contamination while posing a threat to public health. Other sources include current use of organochlorine pesticides in agriculture. There is evidence that “lindane usage may be increasing”, and that DDT continues to be used (Bodo, 1998). Also, PCBs are still widely used in industry (UNEP, 1998).

Poverty levels in Georgia and Armenia have been stable for the past several years at 50-55%. In Azerbaijan, this number is higher at 61.5% of the total population (CEO, 2002). These levels are very high, “considering that these countries had some of the highest standards of living in Soviet times" (CEO, 2002). Currently, "environmental concerns are over-shadowed by the more pressing problems of poverty and insecurity that are considered the leading causes of vulnerability in the region" (CEO, 2002). It is for this reason that the involvement of international organizations is so vital in order for progress on environmental issues to be made.

Design of a Monitoring Program

When developing an effective monitoring program, one must first clearly define the problem, goals, and objectives (Brooks et al., 1997). In the case of the South Caucasus, inventory monitoring, where existing water conditions are defined, is needed. While background monitoring itself does not improve the water quality, by thoroughly defining present conditions with the aim to prevent and reduce pollution, "further steps can be taken and incentives developed to reduce the pollution level" (TACIS, 2003), and the progress of such steps can then be monitored. The ultimate goal of monitoring is to provide the information needed to answer specific questions in decision-making (UN/ECE, 2000). The questions most pressing to the South Caucasus are, what are the priority contaminants, and what can be done to reduce exposure to them within the basin.

My objective is to recommend the monitoring of surface waters used as a source of drinking supply. However, it should be noted that this is not the only mode of exposure to contaminants. Crops that are irrigated using contaminated water and then eaten (as well as animals who feed on the crops and are eaten) biomagnify exposure to certain contaminants, mainly pesticides. For this basin, the information objectives should really be the assessment of the actual status for water quantity and a series of water quality parameters, and also through obtaining those data, the recognition and understanding of the major issues.

The number of points to be included in transboundary monitoring should be limited in number, and "depending on the nature of the transboundary situation should be no more than 10 in each country" (TACIS, 2003). Selection of monitoring points should be based on the purpose for which data are being collected (UN/ECE, 2000), as well as location and accessibility of the site. Monitoring points should include sites near border crossings between countries, and "intra-country sampling points should be linked to significant changes in water quality as a result of major discharges or the confluence with major tributaries, particularly where these are known to carry significant pollution loads" (TACIS, 2003). The World Health Organization recommends the following parameter list for physical and chemical quality of drinking water: pH, conductivity, turbidity, dissolved oxygen, temperature, biochemical oxygen demand (5 days, 20° C), ammonia, nitrate, nitrite, phosphate, chloride, bicarbonate, sulfate, sodium, potassium, cadmium, chromium, lead, nickel, zinc, copper, arsenic, selenium, mercury, oil in water, organochlorine pesticides and PCBs (TACIS, 2003). Frequency of analysis as recommended by the European Commission, is once per month (TACIS, 2003).

Existing or Planned Monitoring Programs

There are many existing and planned water resource projects in the Kura-Araks Basin. My interest in this area stems from a NATO proposal entitled the South Caucasus River Monitoring Project, for which Michael Campana is the NATO Project Director. This NATO funded project, also supported by OSCE and the Swedish government through the intercession of OSCE, aims to set in place a monitoring program developed and maintained by these countries, and will collect water discharge and quality parameter data monthly and quarterly, analyzing for a score of contaminants. Parameters to be monitored monthly include discharge, specific conductivity, total dissolved solids, salinity, pH, temperature, dissolved oxygen, redox potential, copper, lead, zinc, mercury, chromium, nickel, manganese, cadmium (NATO, 2002). In addition to the monthly analyses, the following parameters will be added quarterly to the list of contaminants monitored: sulfate, chloride, carbonate, bicarbonate, sodium, potassium, magnesium, calcium, phosphorus, and total nitrogen (NATO, 2002). NATO/OSCE monitoring is scheduled to begin in the fall of 2003, and the project is planned to operate for a period of 3 years (NATO, 2002). This NATO/OSCE project is exciting because scientists from Armenia, Azerbaijan, and Georgia are coming together in an effort to document a baseline of current conditions, with a look into the future at how best to manage the shared water resource. The governments are aware of this project, but they are not officially involved in it. Scientists will brainstorm a transboundary management plan as a part of this project, with possible future implementation by governments who have historically been in conflict.

The main purpose of the European Union's TACIS project in the basin is to characterize the transboundary river (TACIS, 2003). Eight river basins (including the Kura) were chosen as pilot studies for testing the United Nations Economic Commission for Europe (UN/ECE) Guidelines on Monitoring and Assessment of Trans-boundary Rivers (1992 Helsinki Convention), and TACIS (2003) is the result of the pilot study. TACIS aims to establish a monitoring network among the three South Caucasus countries. They have been providing training, intend to establish viable water quality laboratories in each country to do QA/QC sample analyses, and have discussed the establishment of water quality standards in each country (Fischer, 2003). Rieks Bosch, team leader for the Kura Basin TACIS Joint River Management Program states "we are close to agreement with the countries on a system of guidelines to be aimed for in relation with the major functions of the rivers and tributaries" (Bosch, 2003). In addition to water quality monitoring and guideline development, TACIS is looking at "driving forces and options for response basin wide", including discussion of issues such as hot spots, response times, import of pesticides, and illegal selling of DDT" (Bosch, 2003).

Analyses for the TACIS program will be performed monthly at the borders between countries, and at other monitoring stations once or twice per year, with an estimated preliminary cost of "around U.S. $4,000 – 5,000 per country" (TACIS, 2003). The parameter list for TACIS monitoring is broken into two priorities, with the order of priority "determined by the ability of the laboratories to carry out this work" (TACIS, 2003). Parameters to be sampled for priority 1 include: conductivity, turbidity, dissolved oxygen, temperature, biochemical oxygen demand (5 days, 20°C), ammonia, nitrite, nitrate, phosphate, chloride, bicarbonate, sulfate, sodium, and potassium (TACIS, 2003). The remaining parameters to be sampled for (priority 2) are: cadmium, chromium, lead, nickel, zinc, copper, arsenic, selenium, mercury, oil in water, organochlorine pesticides, and PCBs (TACIS, 2003). Microbiological parameters are not included in the parameter list for the TACIS project, and sampling is expected to begin in June 2003 (Bosch, 2003).

The United States Agency for International Development (USAID) has two major water resource programs in the South Caucasus. The first of these is the Strengthening

Water Management in the South Caucasus Program, where USAID acts through their consultant Development Associates, Inc. (DAI). The goal of the project is to increase the dialogue for sustainable water management in the South Caucasus, and work has already involved renovating water and meteorological stations, developing a mapping capability (GIS based), and promoting a watershed decision-making approach (USAID, 2002). DAI has developed a water quality data management program to be used to maintain and exchange information among the three countries, and is involved with assembling the information needed to pursue other funding for water infrastructure in a couple of communities (Fischer, 2003). Project objectives include providing frameworks for increased cooperation and collaboration, integrated river basin planning, and bilateral agreements in the management of water resources (Hasanov, 2003). The water quality data management database will be implemented by each of the Hydromets in the region, as well as by the European Union TACIS Joint River Management Program, and the ARD Sustainable Water Management Project (USAID, 2003).

The second major USAID project is the Armenian Sustainable Water Resource Management Program, which is being implemented by Associates in Rural Development (ARD) (USAID, 2003). The goal of this project is “to develop Armenia’s capacity to promote sustainable management of a critical natural resource to support enhanced environmental quality and economic growth” (USAID, 2003). Specific objectives include strengthening the policy and institutional framework for improved management of water resources, and rehabilitating selected water quality and quantity monitoring stations (USAID, 2003).

The Eurasia Fund (EURASIA) is an independent grant organization operating under funds provided by the United States Government, and is currently supporting 3 separate partnership grants, each of which is approximately $100,000 (Fischer, 2003). The objectives of the three projects are to set up regional information centers, work on legislation and policy, and look at infrastructure (Fischer, 2003). Each EURASIA partnership project must have one indigenous non-governmental organization in collaboration (Fischer, 2003).

The United Nations Development Program (UNDP) has a project called the Regional Partnership for Prevention of Transboundary Degradation of the Kura-Aras River Basin. This project "aims at maximizing impacts by facilitating and supporting dialogues among riparian countries and strengthening existing institutional mechanisms" with the overall objective "to ensure that the quality of the water throughout the Kura-Aras river system meets the short and long term needs of the ecosystem and of the communities using the ecosystem" (UNDP, 2003). The project has a total budget of $4.7 million, and the expected outcomes include "a transboundary diagnostic analysis of pollution sources and hot spots in the Kura-Aras Basin; structured and developed Regional Strategic Action Plan that will further translate into national strategic action plans for each country of the basin; structured and established trans-boundary river basin authorities functioning for the region; built regional capacity for transboundary water management; increased harmonization of legislation, standards, and monitoring; structured and developed policy framework of Integrated Water Resource Management for the basin; and strengthened and operational Kura-Aras NGO network" (UNDP, 2003). UNDP is also developing a Global Environmental Facility (GEF) International

Waters project, intended “to assist the riparian countries of the basin in the integrated sustainable development of the basin’s water resources”; this project is currently at an early conceptual stage (Hudson, 2003).

Other projects include a World Bank Integrated Water Resources Management Plan, which has “made loans for irrigation rehabilitation and dam safety projects, and is planning further water supply sector infrastructure rehabilitation lending” (USAID, 2003). The European Union has supported transboundary water management on the Kura River, and is considering options to support wastewater management (USAID, 2002). Still other donors include Germany (focusing on local water distribution systems), the Netherlands, Norway, France (all small-scale water infrastructure projects) (USAID, 2003), and the Danish Corporation for Environment in Eastern Europe (DANCE) together with the Danish Environmental Protection Agency (DEPA) (Fischer, 2003).

Proposed Public Health Based Water Quality Monitoring Program

My first plan of attack for designing a water quality monitoring program was to take the existing programs and add additional parameters to them, but then I realized that such an approach would be backward. The need for and feasibility of water quality monitoring in the South Caucasus varies from that in the United States, and it is the application of western monitoring ideology elsewhere that has created many monitoring programs that are “data rich, but information poor” (UN/ECE, 2000). Many existing water quality programs “collect the wrong parameters, from the wrong places, using the wrong substrates and at inappropriate sampling frequencies”, and operate with an inertia that is independent of what data is actually needed (Ongley, 2000). And so I took a step back with a commitment to keeping this simple, while designing a public health based water quality monitoring program that could provide information that, if acted upon, would make a significant impact on the health of the people in the Kura-Araks Basin.

Following its 50th ratification, those who signed the Stockholm Convention will be obligated to take measures to eliminate or reduce the release of persistent organic pollutants into the environment (UNEP, 2002b). Both Armenia and Georgia are signatories to the Convention (Azerbaijan is not), and so both countries will need to monitor for all POPs following its taking effect while also taking measures to eliminate their release. Early monitoring for POPs will put Armenia and Georgia at an advantage for adopting policy in line with the goals of the Convention as it takes effect.

As classified in State of the World 2002, the most persistent and toxic industrial materials are dioxins and furans, halogenated aromatic hydrocarbons (including PCBs and DDT), cadmium, cobalt, mercury, and lead (McGinn, 2002). This information was combined with the research on human health risk of exposure presented earlier; a list of those parameters to be monitored for in the proposed program follows (see Table 1).

▪ nitrate
▪ *E. coli*
▪ arsenic, cadmium, chromium, cobalt, lead, manganese, nickel, mercury
▪ 9 organochlorine pesticides classified as POPs: aldrin, chlordane, DDT, endrin, dieldrin, heptachlor, hexachlorobenzene, mirex, and toxaphene
▪ lindane
▪ PCBs

Table 1. Proposed Monitoring Program Parameters

The proposed frequency for this program is once per year for all parameters with the annual sampling event taking place in the springtime, when runoff is at its maximum. *E. coli* should be sampled for at a frequency of at least once per month. Annual sampling of the full list of parameters will satisfy this program's goal of defining existing water quality, and it will also track any changes in water quality that occur as a result of changes in policy. As sampling when runoff is at its maximum may mask higher average contaminant concentrations by dilution, a second sampling event taking place during the low flow period might be considered.

The estimated cost for metal analyses is $50.00 for the first metal plus $5.00 for each additional metal, per sample (Sellers, 2003). The metal analyses that are a priority include cadmium, cobalt, mercury, and lead; however, arsenic, chromium, manganese, and nickel have been added because they also pose health risks and the cost to add their analyses is small. Nitrate analysis runs $20.00 per sample, and *E. coli* $30.00 (Sellers, 2003). Organochlorine pesticide analyses run approximately $150.00 per sample for all 10 pesticides (Sellers, 2003). PCB analysis costs approximately $100.00 per sample, while testing for the group of 17 most common and toxic dioxins and furans costs approximately $950.00 per sample (Sellers, 2003). For this reason, dioxin and furan analyses have been left out of the proposed program, and a policy approach to their control is suggested instead. It is assumed that the presence of dioxins and furans can be inferred and acted upon by location of present and historic industry, instead of tracking them through resulting surface water contamination. The total anticipated cost of laboratory analyses per sample is $385.00, or a total of $3,850.00 per year for all samples. Should two sampling events be carried out per year, the annual laboratory costs would be $7,700.00. As the Joint River Monitoring Programme (TACIS) is working with one laboratory per country in the development of necessary equipment and training, use of the same laboratories is recommended. These laboratories are the National Monitoring Center in Armenia, the Hydromet Environmental Laboratory in Georgia, and in Azerbaijan, the National Monitoring Center for all analyses except for heavy metals and organochlorine pesticides, which will be analyzed by the Caspian Pollution Monitoring Center until the National Monitoring Center is prepared to run these analyses (TACIS, 2003).

As a part of the USAID Strengthening Water Management in the South Caucasus Program, USAID consultant DAI has developed mapping capabilities for the Kura-Araks Basin using GIS, and these files were made available for my use. There are scores of existing and preexisting water quality monitoring stations in the basin; however, only 19 are functional in Armenia, 33 in Azerbaijan, and 6 in Georgia (USAID, 2002) (see Figure 4). The following stations have been chosen as monitoring points for this program (see Figure 5):

Country	Station Number	Location
Georgia	station 75	Kura River at Gori
	station 65	Kura River downstream of Tbilisi, at Rustavi
Armenia	station 35	Araks River at border between Armenia and Turkey
	station 59	Hrazdan River downstream of Yerevan, drains to Araks
	station 56	Araks downstream of confluence with Hrazdan River
Azerbaijan	station 6	Confluence of Debed and Kura Rivers
	station 25	Alazani River upstream of Mingechauer Reservoir
	station 26	Kura River at Zardob, downstream of Mingechauer Reservoir
	station 12	Kura-Araks River downstream of confluence at Sabirabad
	station 29	Araks River at Julpa, on Iranian border

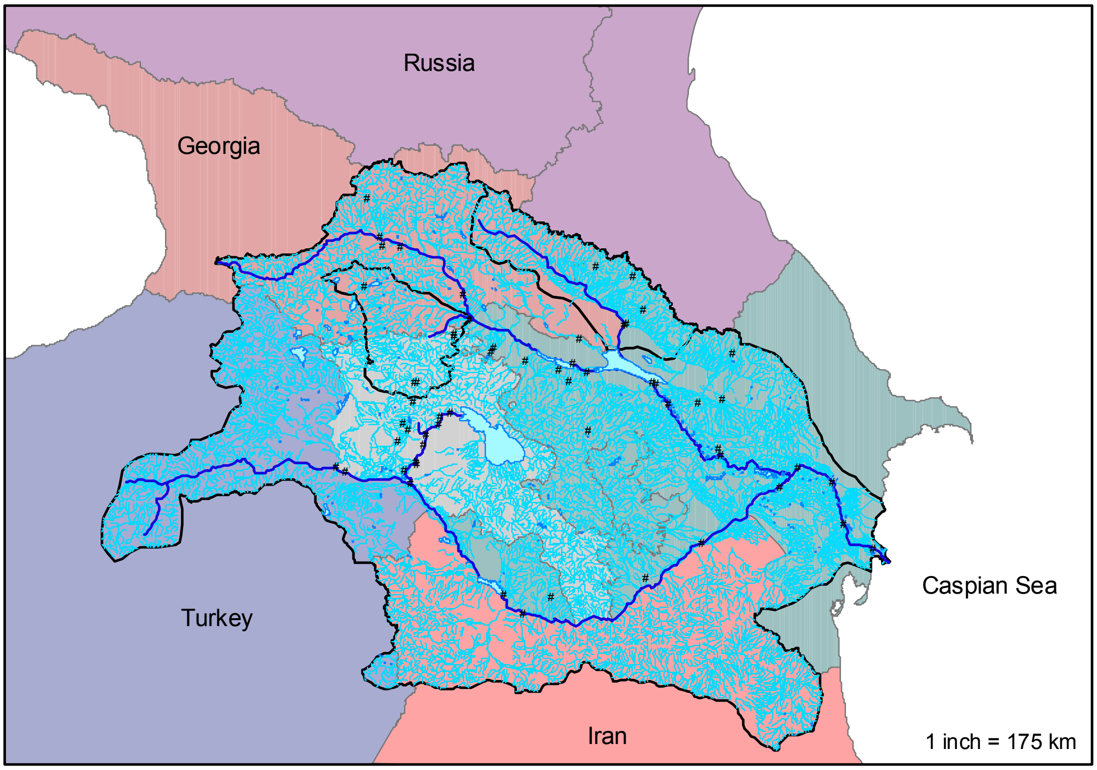

Figure 4. Functional Water Quality Monitoring Stations

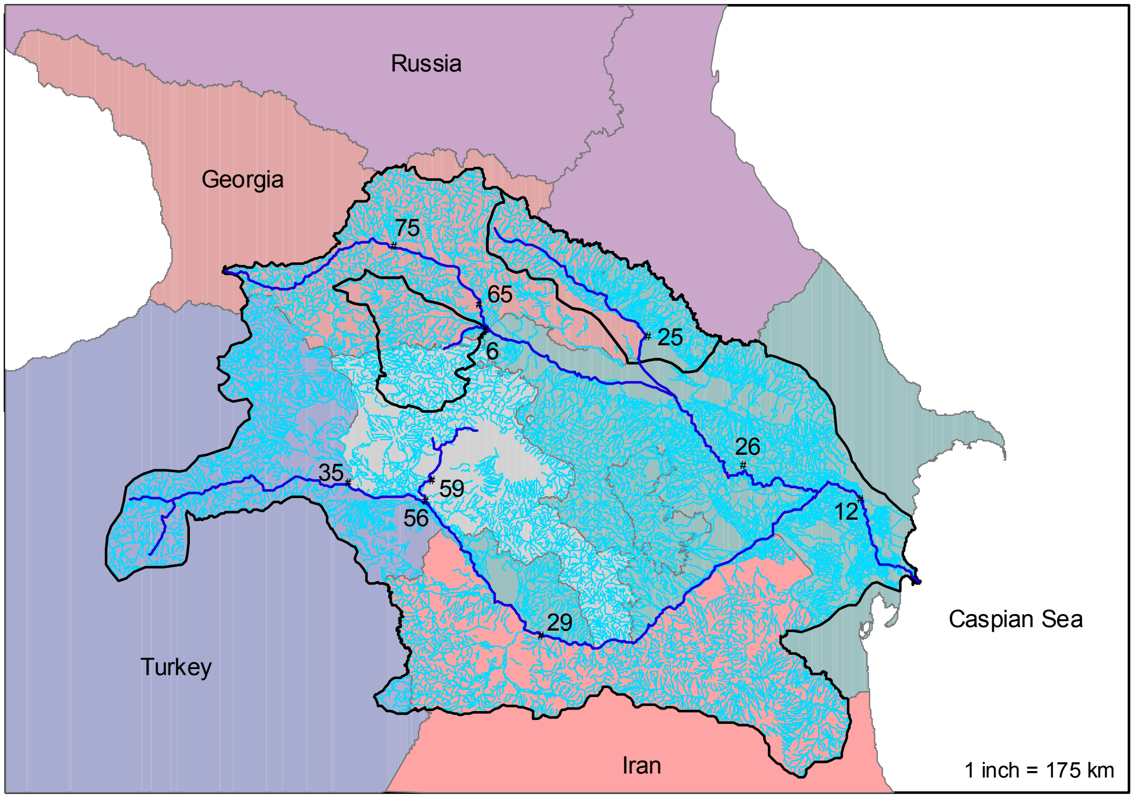

Figure 5. Public Health Based Water Quality Monitoring Stations

Microbiological sampling is an important aspect of monitoring in the Kura-Araks Basin, as there is such a large discharge of untreated water (and therefore, organic pollution) into the rivers. Early microbiological monitoring will give Azerbaijan an advantage for compliance and action within the Protocol for Water and Health goals when it becomes legally binding. One constraint on laboratory analysis of microbiological parameters is that analysis must be performed within 24 hours of sample collection (Gray, 2003). Microbiological testing should be carried out more frequently than the bulk of analyses. Considering the sample holding time constraint, along with the fact that laboratory results of microbiological contamination are "rarely disseminated to those who drink the water" (Ongley, 2000), field testing for microbiological parameters in addition to laboratory analysis is suggested. Field testing for microbiological contamination is most beneficial when carried out on the community level, by community-based group who take responsibility for their own water quality (Ongley, 2000).

For the community-based microbiological water quality monitoring, I recommend the E*Colite Test by Charm Sciences Inc. This test is simple to perform, and comes with all of the equipment necessary except for an ultraviolet light and incubator. The E*Colite test is a presence/absence type test, which "is based on the detection of two enzymes: β-galactosidase and β-glucuronidase", which are characteristic of total coliforms and *E. coli* respectively (Charm Sciences, 1999). Each sample requires 28 hours of incubation at 35˚ C; the sample color changes from yellow-clear to blue if total coliforms are present, and will also fluoresce if *E. coli* bacteria are present among the total coliforms (Charm Sciences, 1999). The cost is $395.00 for 100 tests (Charm Sciences, 2003), and a bactericide is included that can be added to each sample after each test is complete, which will eliminate the grown bacteria by "7 logs" within 2-3 hours, minimizing the risk to human health following disposal (Charm Sciences, 1999). Field based microbiological testing should be performed at least monthly, with communities in high risk regions who are interested in participating to be identified after the initial laboratory results have been obtained. If 100 communities were to perform monthly analyses, the annual cost of this program would be $5,000.00. In the first year, it would be necessary to purchase both a portable incubator ($400) and a basic ultraviolet light ($150) for each community, bringing the total cost for the first year up to $60,000.00 (Charm Sciences, 2003).

In addition to water quality monitoring, public health monitoring is an important aspect of defining baseline water quality. The WHO is monitoring public health by country, and those data have been very useful. One aspect of monitoring that they have not done is to monitor any neurological effects present as a result of exposure to heavy metals. The short list of parameters that I have chosen to focus on for the proposed public health based water quality monitoring plan are in fact those parameters that are need to be addressed as the priority in basin water quality and its effect on public health (particularly organochlorine pesticide use). Addressing these priority parameters and developing a baseline through monitoring could lead to addressing policy and source issues in an effort to reduce parameter concentration in the water of the Kura-Araks. This approach would yield the greatest impact on the betterment of the public health in the basin. Not only can this approach be taken in the Kura-Araks Basin, but also it could be applied to other basins around the world.

Summary and Conclusions

A large portion of the pollution in the Kura-Araks River Basin is a result of former Soviet policies, and the remainder has stemmed from the economic collapse of these countries following the dissolution of the Soviet Union in 1992. The list of expected and known contaminants is diverse, including organic pollution from the lack of municipal wastewater treatment, organochlorine pesticide and high nitrate concentrations from agriculture, chemical contamination from industry, and heavy metal contamination from mining. The issue of water quality is compounded with water use by country. While Georgia and Armenia rely almost exclusively on groundwater for drinking, further downstream the untreated Kura-Araks River supplies almost all of the drinking water for the people of Azerbaijan.

A monitoring approach that targets those contaminants that pose the greatest risk to human health is proposed, with the hope that such a program would lead to policy aimed at reducing the concentration of these contaminants in drinking water. Such an approach would yield the greatest impact on the betterment of public health in the basin. The contaminants to be monitored are: nitrate, *E. coli*, 8 metals (arsenic, cadmium, chromium, cobalt, lead, manganese, nickel, and mercury), 10 organochlorine pesticides (aldrin, chlordane, DDT, endrin, dieldrin, heptachlor, hexachlorobenzene, mirex, toxaphene, and lindane), and PCBs. Laboratory costs are expected to run $3,850.00 per sampling event. A community-based microbiological water quality monitoring program has also been proposed, with a start-up cost of $60,000.00 and an annual cost of $5,000.00 for monthly analyses by 100 communities.

The human health effects of exposure to the score of contaminants present in this basin are well defined, and while many international organizations are involved in the basin water resource issues of quality and supply, the existing programs are moving forward without making significant attempts to coordinate with and complement one another. Efforts of the many programs seem to be aimed solely on the collection of data, rather than on collecting data for those contaminants with the most significant impacts on human health, followed by implementing policy aimed at reducing and eliminating exposure. Limits to the collection of necessary data, such as funding for laboratory equipment and training, would be most effectively addressed by multiple funding sources acting together to achieve a common goal. It is with such an approach, as is proposed here, that the greatest positive impact can be made.

Recommendations

I have proposed yet another water resource project for the Kura-Araks Basin in this paper, this one with the goal of monitoring parameters in surface water with the greatest impact on human health. In addition to the public health based water quality project, what is needed in the Kura-Araks Basin is a committee charged with keeping straight the progress, goals, coordination and evolution of existing programs (i.e. a watershed planning committee).

The Organization for Security and Cooperation in Europe (OSCE) presented a joint seminar on Transboundary Water Issues in the South Caucasus in Tbilisi in November 2002. Other seminar sponsors included the Carnegie Foundation, Pacific Institute, Development Alternatives, Inc., and the Universities Partnership for Transboundary Waters (Oregon State University and the University of New Mexico) (OSCE, 2002). Delegations from Armenia, Azerbaijan, and Georgia "included representatives of relevant ministries, parliamentary committees, water committees, Academies of Science, Hydromets, and Universities" (OSCE, 2002). The meeting outlined each of the water projects currently underway in the South Caucasus, and a need for a Water Management Coordination Group was identified. A proposal for such a group was developed by the OSCE, defining that the Water Management Coordination Group would be "an advisory body consisting of representatives from the Governments of Armenia, Azerbaijan, and Georgia, the international donor community, international organizations and implementing partners" (OSCE, 2002) currently working on projects in the South Caucasus. The role and functions of the Water Management Coordination Group were also defined. These are as follows:

a. ensure timely and smooth flow of information on completed, ongoing, and planned programmes and projects between the members of the Group;

b. facilitate the coordination of donor initiatives in the sector with an objective to ensure complementary and synergy of effort and avoid duplication;

c. formulate recommendations to the respective donors agencies and/or government representatives for priority action in areas in need within the water sector" (OSCE, 2002).

The first meeting was to be called, possibly before the summer 2003, however, as no leader has stepped forward, no such meeting has yet been planned. Although the OSCE Joint Seminar took place over 6 months ago, people are still not clear about the full number of water projects underway (or of their progress or goals) in the South Caucasus. Southern DataStream (SDS) hosts a variety of international students in Florida each year, and during his internship, Iman Hasanov did a lot of background research into Kura-Araks Basin projects, and has posted his results online (Hasanov, 2003). Marshall Fischer of DAI has been researching the list of projects as well, indicating that the information from the OSCE Joint Seminar has not yet been broadly disseminated, as a result of the fact that the Water Management Coordination Group has yet to be formed. Each international aid agency is encouraging these countries, which are harboring both current and historic conflicts with one another, to work together in a basin wide approach to management. It is vital for these agencies to work together as well.

Glossary of Terms

ARD	Associates in Rural Development, consultant to USAID
ATSDR	Agency for Toxic Substances and Disease Registry
CEO	Caucasus Environmental Outlook
DAI	Development Alternatives, Inc., consultant to USAID
DANCE	Danish Corporation for Environment in Eastern Europe
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DEPA	Danish Environmental Protection Agency
EU	European Union
GDP	Gross Domestic Product
GIS	Geographic Information System
HCB	Hexachlorobenzene
NATO	North Atlantic Treaty Organization
NGO	Non-governmental Organization
NIS	Newly Independent State (former Soviet republics)
NTU	Nephelometric Turbidity Units
OSCE	Organization for Security and Cooperation in Europe
PCBs	Polychlorinated Biphenyls
POPs	Persistent Organic Pollutants
QA/QC	Quality Assurance/Quality Control
SDS	Southern DataStream

TACIS	Technical Assistance to the Commonwealth of Independent States (EU)
UN	United Nations
UNDP	United Nations Development Programme
UNDP/GEF	United Nations Development Programme/ Global Environment Facility
UN/ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

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