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**Water Quality, Cropping and Small Ruminants:
A Challenge for the Future Agriculture in Dry Areas of Uzbekistan**

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Summary

Water samples taken along Zerafshan River and its tributaries (canals and collectors) were analyzed by ion chromatography and inductively coupled plasma mass spectrometer (ICP-MS). The dissolved solids in Zerafshan River water include major cations, major anions, trace elements, and radionuclides. The analysis demonstrated that water quality in the river and canals in the area of alluvial fan around Samarkand is significantly different than that in the lower reaches in Kyzylkum Desert. These differences are in the concentrations of almost all ions, dissolved metals and salinity. It is presumed that pollutants are released mostly to the lower part of Zerafshan River from numerous sources. Typical sources are municipal wastewater, manufacturing industries, mining, and rural irrigation and agricultural cultivation. IN the created environments there is need to carefully optimize the grain production and the meat production from small ruminants and to balance available natural resources for a sustainable future of agriculture in Uzbekistan. Research activities in this case are also to be focused on monitoring of water quality and effectively management of scares water resources in the arid/semiarid zones.

Keywords:

Water quality, ICP-MS, heavy metals, salinization, Biosaline agriculture, wheat production, small ruminants, monitoring, Zerafshan River, Kyzylkum desert, Central Asia.

Introduction

Zerafshan River basin is the most ancient heart of agricultural and urban civilization of Central Asia. The basin is densely populated after Fergana and North-Eastern Uzbekistan. Population density of the basin is 80-100 per km². The basin is located in the center of Zerafshan inter-mountainous depression bordered with Nurata Mountains in the Northeast, Zerafshan ridge in the Southwest.

Nowadays there is a potential for increasing productivity of irrigated agriculture in the Zerafshan Valley and Kyzylkum deserts. Due to the difficulties of the transition period, however, numbers of negative factors are common for most irrigated farming system of this region. Among them more acute are: the declining of soil fertility, expanding areas of saline soil and that prone to salinization with rising level of groundwater of various salinity rate; growing of deficit of irrigation water and setting up limits on its use during and between vegetation periods; rising salinity level of river runoff and eventual water quality deterioration; decline in the environmental status.

Besides, the process of decreasing irrigation land productivity has been observed due to contamination of irrigation water source with salts, organic pollutants and traces metals at various parts both in soil, water and vegetation (Goltstein, 1997, Toderich et al., 2002). This has brought a high environmental risk in the whole South-western region of the Republic of Uzbekistan.

Large-scale industrial development of Kyzylkum Desert in combination with technoerosion, overgrazing, deficit of winter feeds and consequent deforestation of shrubs for fuel resulted in the sharp reduction of productivity of rangeland phytocenosis. This entire industrial and natural pressing renders sufficient influence on the environmental situation of dry irrigated areas of Zerafshan basin that was 557 thousand ha as of 1990.

After the fall of the soviet system, the major problem faced by the new Central Asian republics is to produce their own crops (Nordblom et al. 1997) mainly obtained under rainfed and irrigated condition in the country.

The present investigations were focused on monitoring of Zerafshan Valley and Kyzylkum deserts main streams and canals water quality in relation with appropriate management of irrigated cropping and small ruminants systems.

Objectives of this study are summarized as follows, 1) to assess the current ecological state of Zerafshan river basin; 2) to identify the water quality of main streams and canals which are providing irrigation and collector-drainage system; 3) to improve the methods of sampling of surface water streams; 4) to master new methods for field quality assessment of water streams, vegetation, range productivity; and 5) to adjust analytical data derived by joint Uzbek-Japanese-French Scientific Joint Research Programs.

Material and methods

The area for water sampled was along the watercourse of Zerafshan river from the settlement of Rahmatabad, through Kattakurgan and Navoi, to the Bukhara into Karakul plateau (south-east part of Kyzylkum desert)... In Samarkand area, typical inflow to Zerafshan was to be sampled at Karadarya, Akdarya, and Kattakurgan Reservoir. From Ishtykhan to Navoi, typical inflow from Karatau Mountain was to be taken as to show the additional water resource to Zerafshan basin. By setting up the traverse perpendicular to each basin flow especially at Navoi, Northern Bukhara, Central Bukhara, and at the lowest part of Zerafshan, almost all flow were to be sampled. Along the traverse near 40.00-north latitude, and along the traverse from Karaulbazar-Bukhara- (40N, 64E), almost all water from river, canal and collector would be analysed.

Sampling bottles of 60 ml HDPE were newly procured from Nalgene and soaked in 12.5 % HNO₃ for 24 hours and four times Milli-Q-water rinsed. All samples were in the field filtered with a combination of JMS 100 ml syringe and Advantec cellulose acetate 0.45 µm disk filter. For each sampling a new syringe and filter, bottle was used. HNO₃ is a product of Kanto Kagaku of UGR 1.42.

At each sampling site, following field data were collected: global position by SONY GPS; pH, electronic conductivity, turbidity, dissolved oxygen, water temperature and salinity by Horiba multiple water quality monitoring system LMO or U-20.

Following ion concentrations by Shimadzu ion chromatographic analyzer HIC-6A: Na^+ , K^+ , Mg^{2+} , Ca^{2+} , Cl^- and SO_4^{2-} . Measurement of dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP) was by Technicon Instruments Corporation Auto Analyzer II. Standard for NH_4 , NO_2 and NO_3 were special grade reagents of $(\text{NH}_4)_2\text{SO}_4$, NaNO_2 and KNO_3 from Wako Pure Chemical Industries, Ltd. These reagents were first dried for one hour at a temperature of 110°C , and adjusted to each concentration after cooled in desiccators. Standard PC'4 from Wako Pure Chemical Industries, Ltd. was also used. Table 4 shows the results of DIN, DIP, NEU^+ , and NCV . Note that the unit of DIN and DIP is the amount of simple elements of nitrogen and phosphorus, while that of NH_4^+ and NO_3^- is the amount of molecular weight of each ion.

Analysis and Results

Zerafshan River, by the source, is of glacier-snow type. According to V.M. Shultz's data only 31% of river's total flow has underground source, the rest comes from glacier and mountain snow. The stream of the river from Tadjik border to Navoi is plain, flowing along alluvial bottom with big-size fractured sediments. Sometimes it splits into branches. From Navoi to the end - Bukhara and Karakul oasis - the stream of Zerafshan becomes of collector-drainage system type. Surface of water there is 4-6 meter deeper from surface of soils formed by fine-fractured material. Within the investigated area of the basin from Tajikistan border to Bukhara oasis the river has no significant inflows and the water is used for intensive irrigation. Running toward Bukhara, it reduces its water volume because of the irrigation and runs through this vast irrigation land with increasing minerals and metal content, diminishes in the neighborhood of Karakul trying in vain to reach Amu-Darya.

Results of reduced chemical analysis of these materials indicate that mineralization of river's water changes within surveyed area from 0.3 to 2.7 g/l. Down the stream from mountains to Navoi meridian mineralization increases from 0.3 to 1 g/l and then up to Bukhara oasis it reaches 2.6 g/l. In the same direction the chemical composition of water changes - hydrocarbonate ion decreases and sulphate ion increases. Mineralization level of collector-and-drainage water, broadly used within Bukhara oasis, is higher making 2.5-4 g/l. Lower mineralization (0.6 - 0.7 g/l) occurs in canals water taken from Amudarya River and used for irrigation and partially for potable water supply.

According to the results of atomic absorption method the chemical contents of Zerafshan waters is closely related to the collecting points and varies extensively (mg.eqv/%) : HCO_3^- :15.0-28.0; Cl^- : 11.74-27.0; SO_4^{2-} : 55.0-69.72; Ca^{2+} :27.0-36.79; Mg^{2+} :24.0-45.00; $\text{Na}+\text{K}$:28.0-36.82. It was defined that the HCO_3^- content is decreasing and the Cl^- and SO_4^{2-} are generally increasing from Navoi to Buchara.

Discussion

Table 1 shows correlation coefficients with each other that are supposed to be of normal distribution. The most significant relation is seen between electric conductivity (EC) and salinity ($r=0.998$). This is because electric conductivity is converted into salinity from the empirical formula composed of EC. Sulfate ion well correlates with salinity and with other cations and chloric ion. Salinity also well reflects the water quality in such an arid area as Zerafshan basin. The river keeps the lowest salinity up to Kattakurgan, lower salinity between Kattakurgan and Navoi except an inflow from Karatau Mountain. Remarkable feature of saline distribution is at many tributaries after passing Navoi towards Buchara into Karakul plateau, which is characterized by sandy-clayey conglomerates, sandy hills and saline lakes. Maximum value of salinity was of 6.4 g/l in sampled water from various

collectors in the Karakul plateau and Kuimazar canal (near Buchara) to which there was a discharge from cotton field. EC also showed the highest value at the same site.

At such sampling sites as Kanimekh, Kyzyltepa, Galasiya, Kuyuchukurak, Kuymazar canal, Karaulbazar, Yamanzhar Aktepa, Shaikhan, as well as some waterways that flows through Shafrican district and others sites of Karakul plateau where salinity was comparatively high, EC and other anions and cations correspond with their high concentration. This might be caused both by the usage of some chemicals at the agricultural field in harvest season and/or by the discharge of some technogenic chemicals from industry, which are especially concentrated in lower reaches of Zerafshan and in the south-eastern part of Kyzylkum deserts.

Table 1. Correlation Coefficients between Each Item

item	NH ₄ ⁺	K ⁺	Mg ⁺	Ca ²⁺	Cl ⁻	N-NO ₃ ⁻	SO ₄ ²⁻	pH	EC	salinity	alkalinity
Na ⁺	-0.114	0.786	0.843	0.941	0.963	0.201	0.932	-0.379	0.964	0.971	0.281
NH ₄ ⁺		-0.010	0.003	-0.053	-0.083	0.231	0.028	-0.180	-0.096	-0.107	0.127
K ⁺			0.938	0.837	0.660	0.300	0.822	-0.588	0.843	0.830	0.596
Mg ⁺				0.900	0.705	0.457	0.896	-0.683	0.908	0.894	0.672
Ca ²⁺					0.848	0.358	0.958	-0.500	0.945	0.941	0.381
Cl ⁻						0.088	0.881	-0.258	0.896	0.912	0.109
N-NO ₃ ⁻							0.409	-0.503	0.322	0.294	0.689
SO ₄ ²⁻								-0.540	0.947	0.946	0.415
pH									-0.510	-0.488	-0.691
EC										0.998	0.451
salinity											0.420

However, the inflows into Bukhara along with flows of Amu-Bukarskiy canal are of comparatively low salinity. This, perhaps, is the result of wise artificial water management in the arid area.

Microcomponent content of surface water in Zerafshan basin includes higher level of iron, manganese, potassium, cadmium, copper, nickel, and selenium in unfiltered samples. When filtered, content of most of the heavy metals in water do not exceed various guidelines from WHO, EEC and others. That means heavy metals in water directly related to mechanical suspension. Electronic microscope study of mechanical suspension of Zerafshan River indicated contrast size of fractured material. Prevailing size of fractures is from 5 to 10 - 15 μ m. Mechanical suspension near Samarkand has significant sizes, poor roundness, and rich content of quartz, feldspar, and micaceous minerals. In ore and sulfate minerals some indications of pyrite, magnetite, hematite, barite, celestine, sphene, and antimonite are found. Size of ore minerals varies from 0.5 - 1.3 μ m.

Water samples taken from eastern part of Zerafshan shows higher concentration of antimony up to 0.5 LPC. This is probably resulted by the operation of mining kombinat in Ayni town (39°23' N, 68°32' E: 80 km east of Pendjikent), Tajikistan which runs Jijakrut mercury-antimony deposit. Microprobe analysis of suspension on filters detected frequent traces of antimonite of 1- 3 μ m in size. Sampling for pesticides and organic compounds showed presence of butifos exceeding LPC, which is not allowed to use in Uzbekistan.

Traces of some metals were found also in the underground mass of different crops and in some wild desert species. The most frequent are as follows (mg/kg): Va (0.5-13.9); Cu (1.40=5.40);

Zn (8.1-72.0); Mn(11.8-91.0); Cd(0.01-0.50); Ni(0.22-12.4); Cr (0.4-43.6), Sb(0.01-0.48) Fe (110-5020); Se (0,1-3.2); Co (0.12-2.65); Sr (21-980); Mo (0.1-9.3).

From the viewpoint of the health of people living in Zerafshan River Basin, Table 2 shows maximum and minimum concentration of some metals that frequently occurred in the surface analyzed by us water samples. They are compared with various guidelines for drinking water and irrigation water proposed by WHO, EEC, FAO.

Table 2. Comparison of Guidelines with Zerafshan Water Quality

	B	Al	Cr	Mn	Fe	Ni	Cu	Zn	As	Se	Mo	Cd	Sb	Pb	U
drinking water	5,000	200	50	100	200	50	1,000	5,000	50	10		5	10	50	10
irrigation water	5,000	5,000	100	200	5,000	200	200	2,000	100	20	10	10			
max	1,109	91	47	86	847	15	455	179	17	181	25	5	26	72	75
min	71	38	14	7	374	6	9	15	3	37	5	2	1	3	2

Unit: ppb

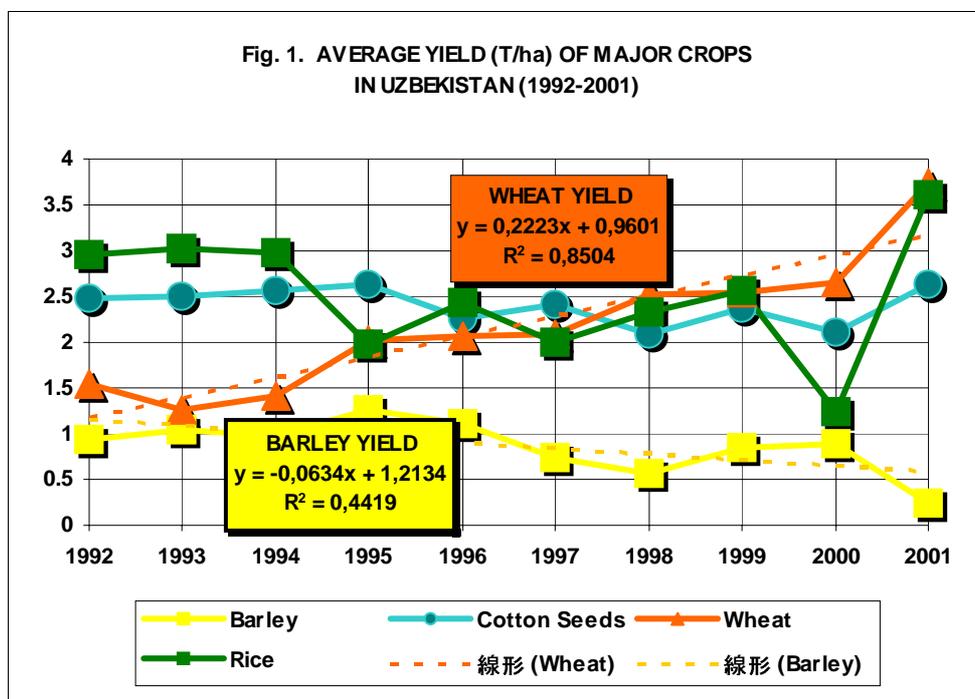
Those metals that exceed guidelines are of iron for drinking water, selenium both for drinking and irrigation water, molybdenum for irrigation water, antimony for drinking water and uranium for drinking water. Other metals are far below the guidelines. Distribution of boron showed a strong correlation with those of arsenic and antimony. Aluminum has a significant correlation with arsenic and lead distribution. Antimony correlates significantly with zinc and arsenic, while copper and iron (Fe^{57}) also well correlate with each other. Because these metals rarely exist in natural environment, it is presumed that they are from some industries along Zerafshan River.

The radiological impact to the local residents should be more fully investigated, especially in the transfer mechanism of heavy metals through various chains of foodstuffs including agricultural systems, freshwater ecosystems, and natural ecosystems.

Thus, works completed by authors give necessary data to make preliminary assessment of environment of Zerafshan Basin, and enables to point out objects for further monitoring, and to elaborate a program of detailed ecological and agricultural research in Zerafshan River Valley and Kyzylkum deserts. In such condition agricultural production in dry areas requires regular account of surface and underground water quality used for irrigation, water-salt regime on irrigated lands with an appropriate management of cropping and small ruminants feeding systems.

However, during the last 11 years, despite of significant changes in agricultural sector, the majority of local farmers and pastoralists, mainly in arid zones of Uzbekistan are facing lot difficulties affecting their income and eventually the living standard.

One of the most important changes as is shown on the figure 1 some of the cotton, barley and possibly rice areas, as well as new rainfed cropping zones through range clearing were assigned to wheat production. Increasing the wheat grain production was possible by increasing yield and the wheat acreage both on irrigated and rainfed territories. From 1992 onward, the area sown

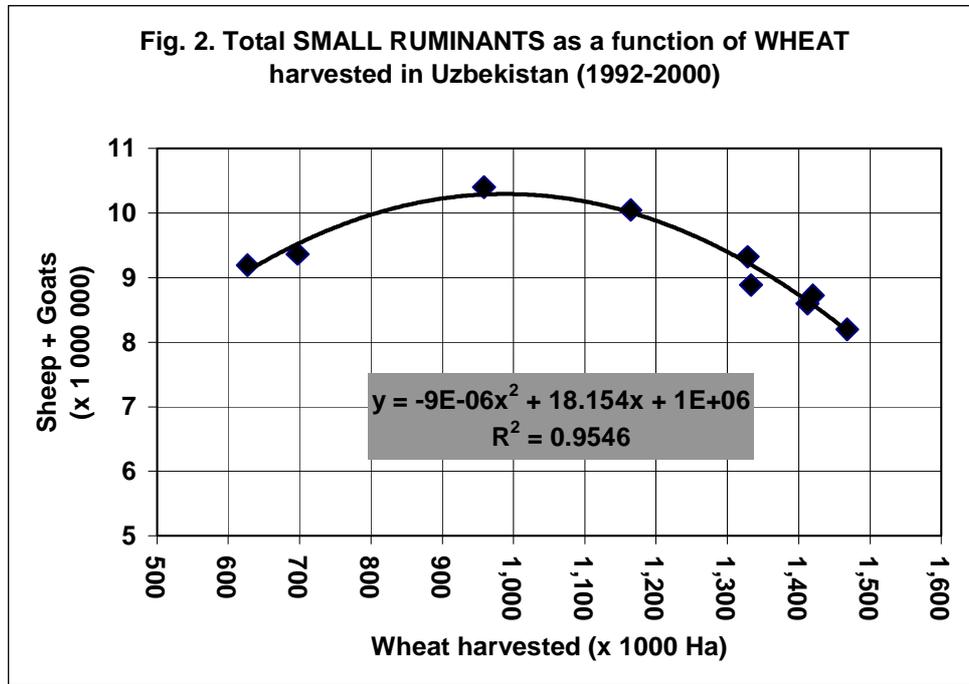


with wheat more than doubled (Fig. 1) from a mere 600 000 ha to nearly 1.5 M ha in 1997, then retreated again to 1 M ha in 2001 (FAO Stat 2001). The wheat yield raised from 1.4 t/ha (st.dev=0.14, n=3; 1992-1994), then to 2.3 t/ha (st.dev=0.28, n= 6; 1995-2000) and to a record yield of 3.7 t/ha in 2001.

During the same period, however, the cotton area, absolutely under irrigation, gradually declined from approximately 1.7 M ha in 1992 to 1.4 M ha in 2001, but maintained a stable yield of 2.4 t/ha (st.dev= 0.19, n=10) from 1992 to 2001. This purpose has frequently achieved at the expense of the best rangelands in the best rainfall zones on the adyr and also in the pre-desert environments where extra runoff and water resources could be secured. This new burden on Uzbekistan, particularly in Zerafshan River basin and Kyzylkum deserts, added to the current poor water quality and rangeland productivity

We found out that there is a positive linear relationship between barley grain and sheep number ($R^2 = 0.490$; data not shown here) or total number of sheep and goats ($R^2 = 0.497$), substantiating that barley in Uzbekistan is important for sheep and small ruminants complementary feeding, i.e. the less barley cropped, the less sheep and goats population in Uzbekistan. It is also clear from the statistical data available and estimating that 80 % of the barley produced is fed to small ruminants, the daily supply of barley grain to small ruminants has steadily and linearly decreased (Fig. 6 ?, $R^2 = 0.899$) between 1992 to 2001, from 720 g/head small ruminant/day (1992-1995), to 436 (1996-1997), 206 (1998-2000) and to low 49 g/head small ruminant/day available in 2001. In term of animal feeding, this may indicate a higher pressure on the feed resources coming from rangeland in Uzbekistan, as barley grain is no more available. This should raise the alarm amongst decision-makers with regards to increased the rangeland degradation and new desertification trends in the country

Looking at the quadratic relationship between small ruminants and wheat area harvested between 1992 and 2000, on can see that the more wheat cropped i.e. over 1 M ha, the less sheep and small ruminant population in Uzbekistan. If we consider that new wheat areas are extended to the best rangeland and to the best barley producing areas, the result is not surprising.



Summarizing the material given in this paper one could conclude that if the new challenge for Uzbekistan is to produce more wheat for its population this has to be carefully balanced in terms of expanding new wheat cropping areas onto irrigated land, on the best rainfed areas, on the best rangeland, as this has a direct bearing on the small ruminant flocks producing the much needed meat and derived milk products. More small ruminants mean more sheep, hence potential increase of range degradation. There is a need to carefully optimize the grain production and the meat production from small ruminants and to balance available natural resources for a sustainable future of agriculture in Uzbekistan. Research activities in this case are also to be focused on monitoring of water quality and effectively management of scarce water resources in the arid/semiarid zones of the country.

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