The Water Quality of the Transboundary Zarafshon River

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Abstract

- The transboundary Zarafshon river is one of the most polluted watercourses in Uzbekistan and it is only poorly analyzed. At the same time, it is the main source of drinking, agricultural and industrial water supply for three provinces of Uzbekistan. Long-term volume change trends of the Zarafshon water resources under the influence of anthropogenic and natural factors have been analyzed as well as the long-term trends of the pollution of the Zarafshon river. The concentrations of general mineralization, nitrites, phenol, mineral oil and copper have been investigated from 2002 to 2010. The discharge of collector-drainage water and treated waste water along the river watercourse and its influence to the river water quality were evaluated in a third step. The results show that the main sources of pollution in the Uzbek territory of the Zarafshon river water are the agricultural collector-drainage waters from the irrigation farming zones in the Samarkand and Navoi provinces as well as the waste water from the ore processing facilities in Tajikistan. Municipal and industrial waste waters on the other hand contribute to the pollution only in minor degrees. Based on these results, several steps towards a sustainable water resource management are proposed.

Keywords: Aquatic pollution; Pollutants; Transboundary river; Collector-drainage waters; Sewage disposal; Monitoring

1. Introduction

The Zarafshon river with its tributaries of Fandarya, Iskanderdarya, Kshtutdarya and Magiandarya is located in the territories of Tajikistan and Uzbekistan and is one of the largest rivers of the Aral Sea basin. It runs for more than 870 km with an average inclination of 2.8‰ between Oburdan in the upper part of the Zarafshon at 1765 m and the downstream city of Navoi at 335 m. It originates from the Zarafshon glacier in Tajikistan (39°30’31’’ N, 70°37’24’’ E) and then proceeds from the east to the west between the Turkestan and Zarafshon Ridges. Before the confluence with the Magiandarya it is called the Matcha. At the Chapanata heights, in the territory of Uzbekistan, it is split into the Akdarya and Karadarya, forming the Miankal Island. After the confluence of the two river branches, it is called Zarafshon again. While the Zarafshon reached the Amudarya until 1957, today the river ends close to Bukhara (40°4’26.8.’’ N, 64°46’47.9’’ E). The Zarafshon covers a catchment area of 12.3 thousand km² and has an average maximum annual discharge of 5.0 km³ (158.4 m³/s). It is basically fed by snow and glacial sources which defines the annual flow distribution: 50% of the runoff can be measured during the summer (July-September), which is up to 1.8 times the runoff during the spring (March-June).

As shown in Fig. 1, the Zarafshon river basin can be broken into three parts: the mainly mountainous eastern part, the mostly flat western part and the foothills in between. The flat part of the basin begins at the border of Uzbekistan and Tajikistan. In the west, most of the catchment is covered with sands from the Kyzylkum desert, mainly ridged and fixed by vegetation.

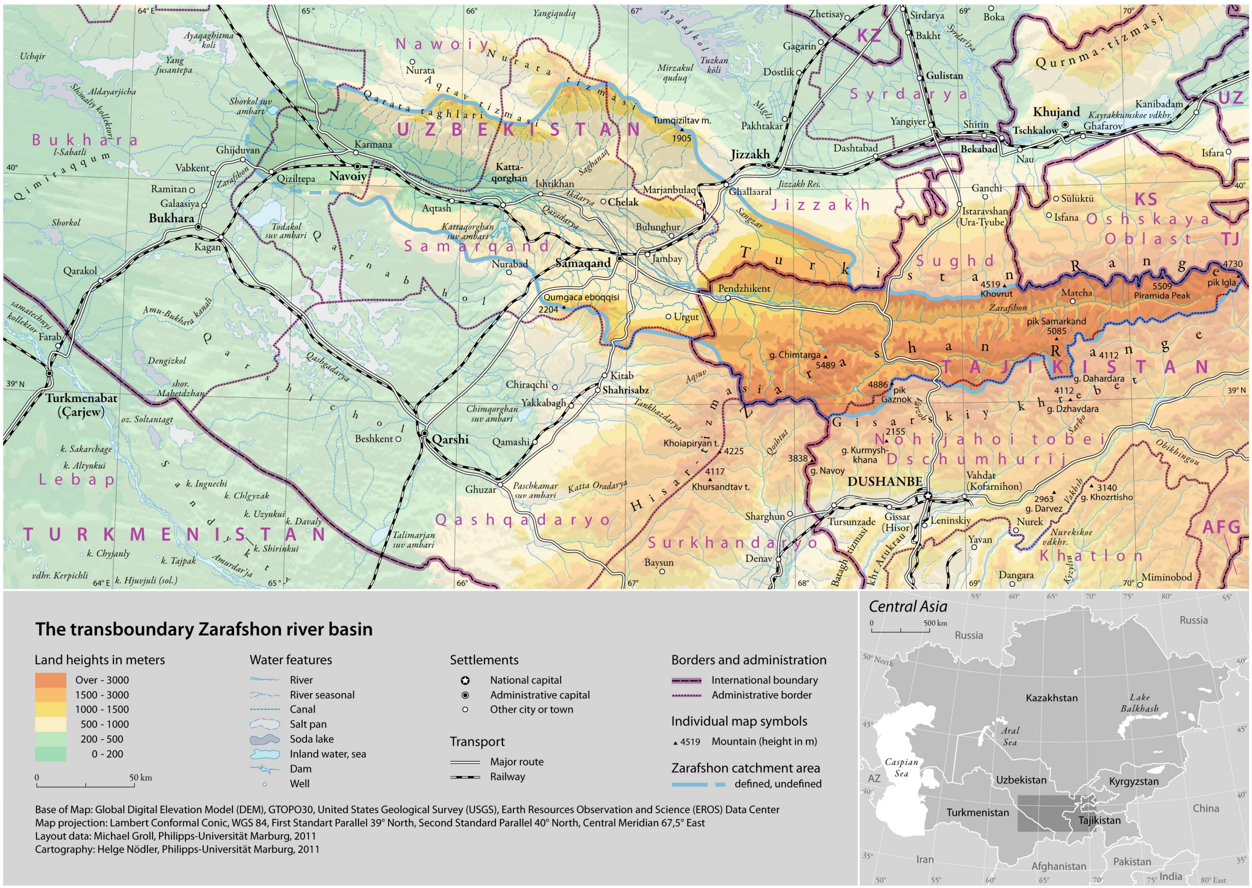

Fig. 1: The map of Zarafshon river basin

The water resources of the Zarafshon river basin are completely used for agricultural, industrial and household needs. More than 95% of the water resources are consumed in the territory of the Republic of Uzbekistan, while the remaining 5% are used in Tajikistan. More than six million people (27% of the inhabitants of Uzbekistan) and over 50 industries are located in the catchment (UNDP (EDS.) 2007) which leads to an annual water consumption of 6.6 km³, thus creating a 1.6 km³ water deficit (approximately 1 km³ during the vegetative period and 0.6 km³ during the non-vegetative period) that is covered by the reuse of untreated return flows.

In the territory of Uzbekistan, about 85% of the water resources of the basin are used for irrigation, 11% for thermal power plant cooling purposes, 1% for communal services, 3% for industry and 1% for fishery.

The demand for water was constantly increasing over the last decades, as the population is still significantly growing. Fig. 2 shows the population development for the whole country as well as for the three provinces Samarkand, Navoi and Bukhara, which are composing the main part of the Uzbek Zarafshon catchment. The Uzbek population grew by 33% since the breakdown of the Soviet Union and the Zarafshon provinces showed a comparable development (+39% in Samarkand, +32% in Bukhara and +22% in Navoi) (WWW.UZ.STATICS.UZ, 2010). This puts an enormous pressure on the already limited water resources.

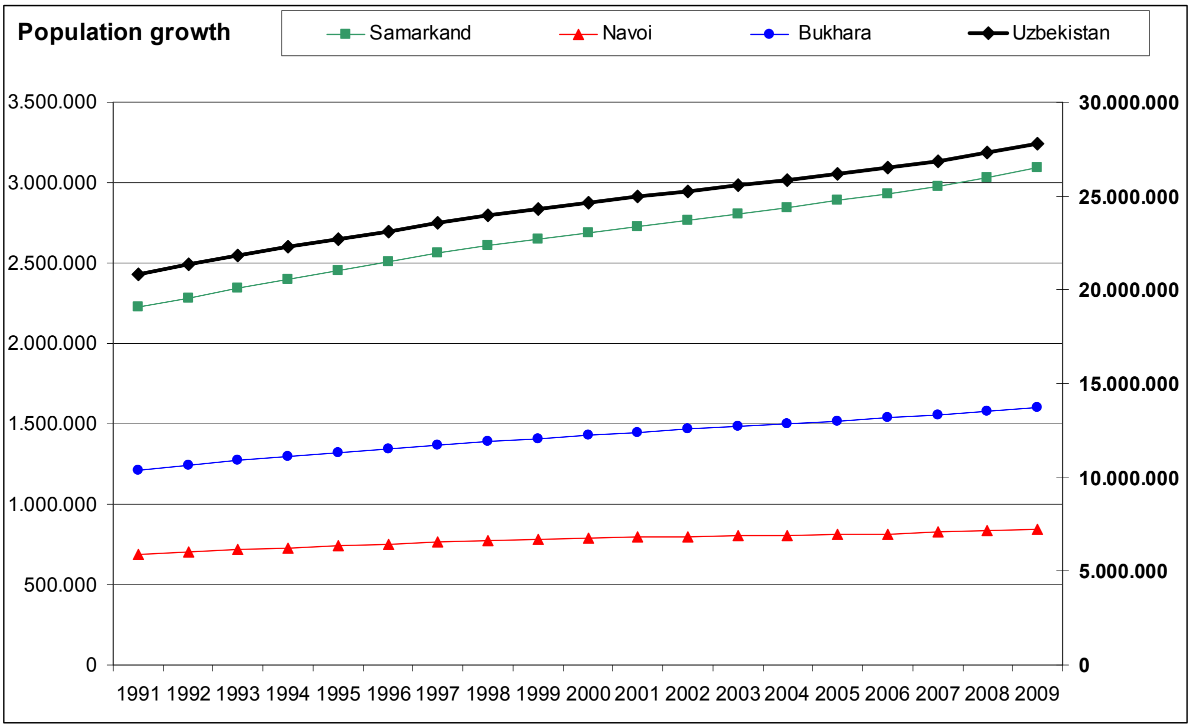

Fig. 2: Population growth in Uzbekistan and the Zarafshon river basin between 1991 and 2009 (data source: WWW. UZ.STATISTICS.UZ 2010; modified).

In addition to the population growth, the rapid development of the economy, that is observed in recent years along the Zarafshon increases the pressure on the water resources. Especially the heavy and chemical industry has developed fast. The various enterprises in the region produce spare parts for agricultural machinery, household refrigerators, conditioners, and different kind of lifts. Further important branches of the industrial sector include the light industry (with more than 50 enterprises) and the food-processing industry (canned food, wine, vegetable oil, tobacco, meat and confectionery products made of local raw materials) (UNDP (EDS.) 2007). The continued growths of the industrial and agricultural sector are the centerpieces of the strategy for the improvement of the living conditions in Uzbekistan that was declared in 2007. This strategy assumes a steady growth of the agriculture at an annual rate of 4,5-5,0 % up to 2015 while the share of the industrial sector is supposed to increase from 23,1 % in 2007 up to 28,2 % in 2015 (WWW.UZ.STATISTICS.UZ, 2010). This planned economic development will greatly increase the demand for usable water in the Zarafshon catchment within the next decade.

The largest proportion of water however is used for irrigation. The Zarafshon river basin has 551’910 ha of irrigated land: 376’700 ha in the Samarkand province (68%), 95’980 ha in the Navoi province (17%), 49’240 ha in the Dzhizak province (9%) and 29’990 ha in the Kashkadarya province (6%). In order to distribute the river water on to the fields, the Zarafshon system includes six diversion points and nine reservoirs with a total storage capacity of 1.2 km^3.
Agricultural crops, mainly cotton, occupy 30% of the irrigated areas of the basin. Other irrigation agriculture includes cereals (mostly wheat, covering 20% of the area), gardens and vineyards (10%) and household plots (10%). The rest of the irrigated area (30%) is used for vegetables, cucurbitaceous and forage crops (UNDP (EDS.) 2007).
Approximately 100’000 ha of the river basin are characterized by a ground water level of 2-3 m. In this area an extensive drainage and collector network is installed, that recovers 7-30% of the annual flow. To the greatest extent the drainage water is used for irrigation purposes in dry years when the run-off from the Zarafshon river decreases.

The deficit and the pollution of the Amudarya and Syrdarya river systems is one of the most important issues for the Aral Sea basin countries. The overuse of and the strong dependence on the water resources, the high degree of pollution, the disparate distribution and usage of the water resource between the two countries and the already noticeable impact of the climate change make especially the Zarafshon a most challenging river. However, while the big streams Amudarya and Syrdarya are thoroughly analyzed, only a few scientific studies deal with the pollution and protection of the Zarafshon river water. Based on the assessment of the anthropogenic pollution the reports indicate increases of intestinal infections and morbidity rates up to water-borne epidemic situations for typhoid fever and bacterial dysentery in the Samarkand, Navoi and Bukhara regions (FAYZIEVA ET AL. 2001, FAYZIEVA ET AL. 2008).

Application of GIS allows complex studies to be conducted on epidemiological conditions of the investigated area. TODERICH ET AL. (2004) studied the water quality in the Aral Sea area (Zarafshon river) and high concentrations of some toxic metals have been reported. Dangerous concentrations of various salts (nitrates, sulfates, oxalates and chlorides) and trace metals in the soils, the water resources and the vegetation of the Bukhara oasis and the central Kyzylkum region indicate severe environmental problems. As pioneers, KULMATOV & HOSHIMHODJAEV (1992) investigated the concentrations and speciation of heavy metals (Hg, Zn, Co, Cr, Sb, etc.) in the Zarafshon river water by applying neutron activation analysis and through experimental modeling using appropriate radionuclides. The obtained data are important for the assessment of the migration and distribution of heavy metals in the river waters and may be used for the treatment of drinking water. Similar studies about the quantity and quality of the water resources, water usage and pollution characteristics were done for the Amudarya river by FEDOROV ET. AL. (1988).

Recently, results about the usage, protection and management of water and land resources of the Aral Sea basin were reported by KULMATOV (2008). The main problems of the deficiency and pollution of water and irrigated land resources in the Aral Sea basin countries were discussed. The implication of return waters on the Amudarya water quality were investigated by GIUSEPPA ET AL. (2006). The case-study suggested that to fully understand the longitudinal increase of the Amudarya salinity, there is a need for mass-balance models with an evaluation of the cumulative effects of the loads from the main agricultural areas. The problems of the formation, distribution and usage of water resources of the Aral Sea basin have been discussed by KIPSHAKBAYEV & SOKOLOV (2002).

The necessity for cooperation on the usage of the transboundary Amudarya and Syrdarya river water resources in regard to the challenges of the climate change and the reduction of glacier volume was emphasized by DUKHOVNY & SOKOLOV (EDS.) (2007). In order to do so, it is essential to assess the meteorological and hydrological long-term development of the quality and the quantity of the water resources in Central Asia (CHUB, 2002).

This paper is contributing to this important field of research by presenting the results of an evaluation of the quality and quantity of the Zarafshon river water resources carried out in the years from 2002 to 2010.

2. Materials and methods

For this study, the following four water sampling points in the Zarafshon river watercourse in the territory of Uzbekistan were chosen:

P1 – Ravathodja (on the Tajik-Uzbek border);
P2 – 0.5 km downstream of Samarkand;
P3 – 0.8 km downstream of Kattakurgan;
P4 – 0.8 km downstream of Navoi.

Long term discharge data was available only for the sampling point P1, close to the Uzbek-Tajik border, while monthly water quality data (2002-2010) were provided by the Uzbek Hydromet service for all four stations. In addition to these four sampling sites, data about the most important drainage water collectors and several waste water treatment plants was collected and analyzed. The specific locations of the sampling points and the collectors are shown in Fig. 3.

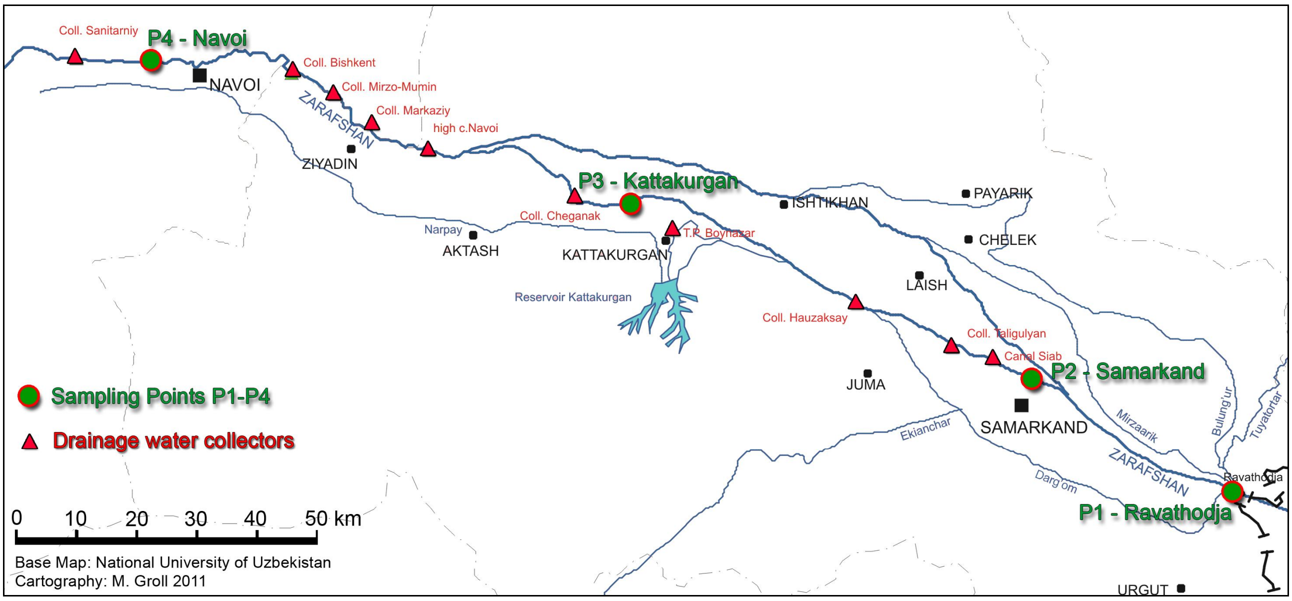

Fig. 3: Water sampling points and drainage water collectors in the Uzbek part of the Zarafshon river system

Most of the techniques used were standard laboratory methods for the examination of water and wastewaters. The analytical procedures applied to analyze the water samples have been described by the UZGIDROMET (EDS.) (2010). The concentrations of the following parameters were determined: mineralization, nitrites, phenols, oil products and copper. Long term data have been statistically processed, transformed and analyzed.

As the provinces Dzhizak is hydrological only loosely connected to the Zarafshon and the provinces Kashkadarya and Bukhara nowadays hardly contribute to the catchment of the river, the following analysis concentrates on the provinces Samarkand and Navoi.

3. Results and Discussion

3.1 Long-term development of the discharge

The first parameter presented here is the long-term development of the discharge at the sampling point Ravathodja (P1 – at the Tajik-Uzbek border). The minimum discharge was recorded in 2001 (108.0 m³/s), the maximum discharge was observed in 1942 (213.2 m³/s) and the average discharge during the 96 years observation period was 158.3 m³/s (Fig. 4). The change of the average annual discharge from one year to the following year was up to 77.1% (from 1972 to 1973), but there were also years with almost no change at all (0.3% from 1934 to 1935). The average yearly fluctuation of the discharge during the 96 observed years was 17.7%.

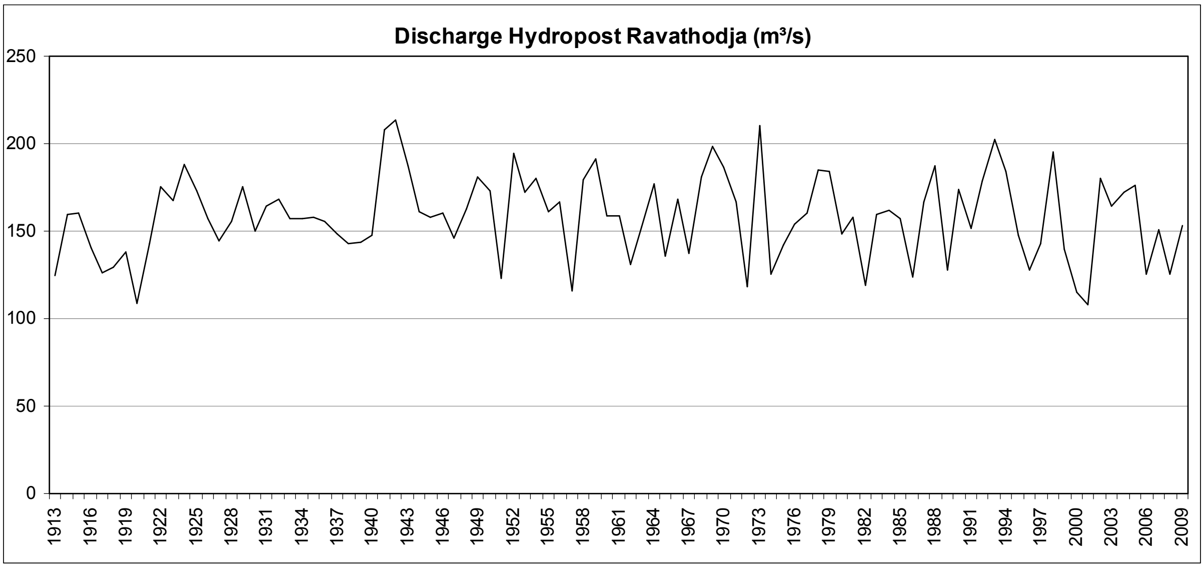

Fig. 4: Average annual runoff of the Zarafshon river at the sampling point Ravathodja (1913-2009)

This high dynamic of the Zarafshons discharge reveals no overall trend on a yearly basis. If however the data is grouped into 30-years-periods, a general development becomes obvious (Fig. 5). There was a significant increase in the rivers discharge from the 1940s to the 1970s of 4.3%. Since the 1970s, the discharge was constantly decreasing and this trend seems to be continuing until today.

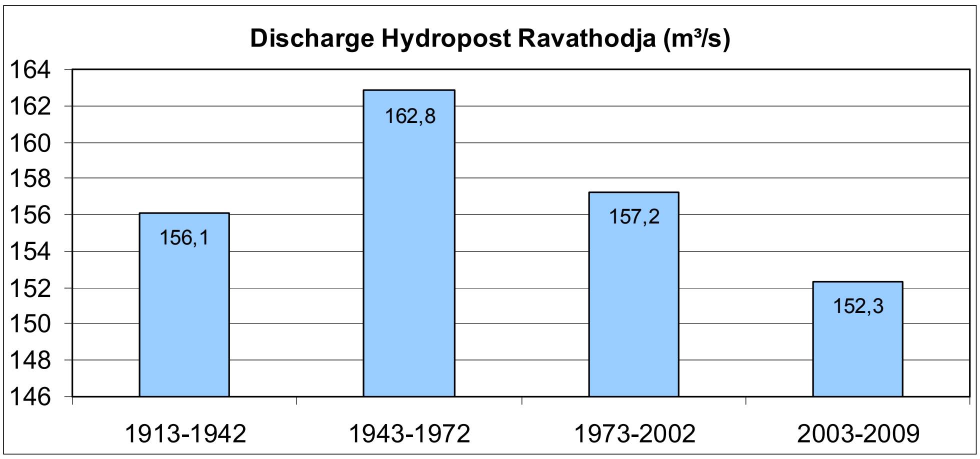

Fig. 5: Long-term trend of the average annual runoff of the Zarafshon river at the sampling point Ravathodja (1913-2009).

This decrease of the discharge since the 1970s is most likely connected to anthropogenic influences and regional effects of the global warming as described by CHUB & OSOKOVA

(EDS.) (2008) and thus contradicts the expected increase of the discharge due to an accelerated glacier meltdown. The reason for this might be that most glaciers already reached their transition point at which an even higher temperature cannot lead to an increase of glacier melt water (AGALSEVA, 2008). The data from the Zarafshon also confirm the findings of AIZEN ET AL. (2006), who already observed a glacier retreat in the Central Asian region.
An additional loss of discharge can be contributed to the increasing water withdrawals in the Tajik part of the catchment.
In the long term, the glacier retreat, the evaporation and the water usage will further increase and the discharge of the Zarafshon will continue to decrease, resulting in a worsening of the water resource supply guarantee.

3.2 Long-term development of the pollution

For an estimation of the pollution level of the Zarafshon river water, it is convenient to compare the data with the maximum allowable concentrations (MAC) as they were defined by the UZGIDROMET (EDS.) (2010). Table 1 shows the MAC values of the analyzed pollutants for drinking water and for the fishery industry.

Tab. 1: Maximum Allowable Concentrations (MAC) of pollutants for drinking water and fishery in Uzbekistan (in mg/l)

Pollutants	for fishery	for drinking water
Mineralization	1000.0	1000.0
Nitrite	0.05	0.02
Phenol	0.001	0.001
Oil products	0.05	0.1
Copper	-	0.001

The results of the laboratory analysis are shown in Figures 4 to 10 in comparison to the MAC (values larger than 1.0 meaning, that the maximum allowable concentration was exceeded).

3.2.1 Mineralization

The mineralization is one of the most important parameters for the pollution of the Zarafshon river (Fig. 6). At the Tajik-Uzbek border (sampling point P1 - Ravathodja), an annual average of 284 mg/l was observed for the mineralization. Near the cities of Samarkand (P2) and Kattakurgan (P3), the mineralization increases to average values of 411 and 488 mg/l which are still below the MAC of 1000 mg/l but already shows the impact of the anthropogenic water usage. At the downstream sampling point Navoi (P4) however, the sewage and drainage water inflow into the Zarafshon lead to a continuously increasing mineralization that exceeds the MAC since 2004 and reached a preliminary maximum of 1680 mg/l in 2010. The Navoi sampling point also showed the highest fluctuation of the mineralization with a span of 985 mg/l between the lowest and the highest results.

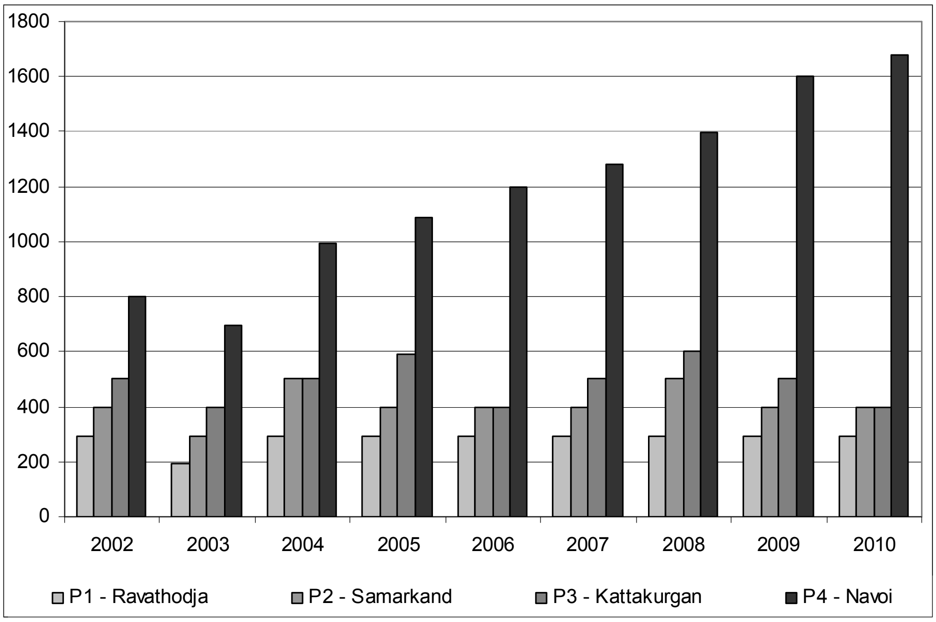

Fig. 6: Development of the mineralization of the Zarafshon river water (in mg/l)

During the nine years covered by this analysis, the mineralization at the upstream sampling point Ravathodja was very stable, while the results from the station Navoi show a significant linear increase (R^2=0.96).

3.2.2 Nitrite

The dynamics of the long-term pollution of the Zarafshon river water by nitrite are given in Fig. 7. At the Ravathodja sampling point nitrite concentrations between 0.0026 mg/l (in 2006) and 0.0528 mg/l (in 2003) were measured with an average concentration of 0.0152 mg/l. The Maximum Allowable Concentration was exceeded in 2003 (by the factor 2.64) and 2010 (by 1.45) and almost reached in 2005. The yearly transported amount of nitrite in those years was up to 274 tons, while in years without excessive nitrite pollution less than 100 tons are dissolved in the Zarafshon river water close to the Tajik-Uzbek border. At the city of Samarkand (P2), the concentration of nitrite was the highest and showed strong fluctuations (between 0.019 and 0.14 mg/l). The threshold was exceeded by the factor seven in 2010 and by the factor six in 2004 and 2009. In other years however (2005 and 2007) the concentrations were much lower and in 2005 the nitrite pollution stayed below the MAC. Further downstream, at the sampling point P3 (Kattakurgan), the nitrite pollution is comparable to the one at P1 (0.0174 mg/l in average), but the fluctuations were smaller. At the sampling point P4 (Navoi), the nitrite concentrations were higher again (0.0412 mg/l in average) and a steady increase of the pollution can be observed since 2005 (R^2=0.95 for a polynomial trend).

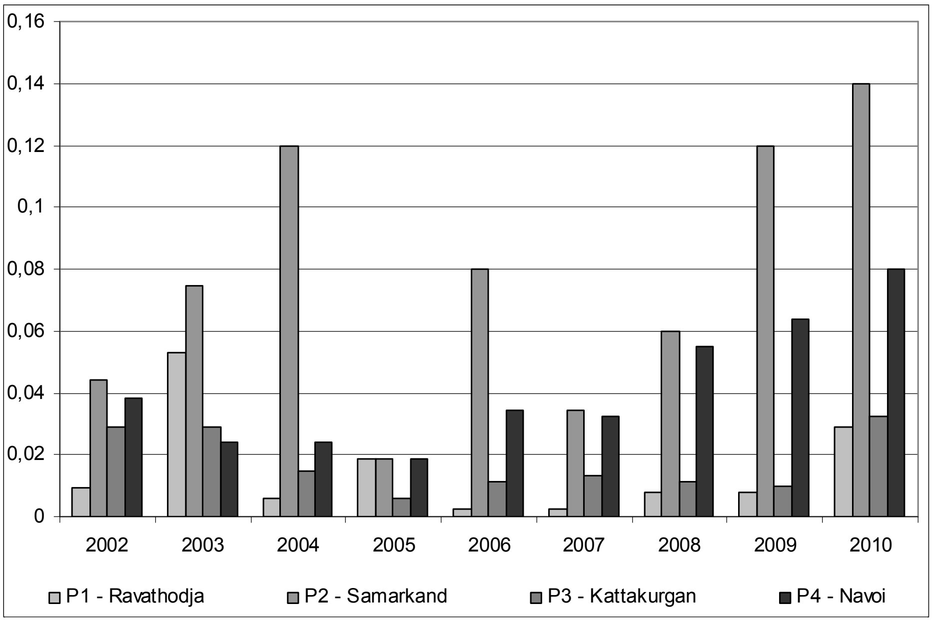

Fig. 7: Development of the nitrite pollution (in mg/l)

3.2.3 Phenols

At the Tajik-Uzbek border (sampling point P1 – Ravathodja), the pollution with phenols ranged between 0.08 µg/l (0.08 times the MAC) in 2009 and 1.7 µg/l (1.7 times the MAC value) in 2010 (Fig. 8). These concentrations result in phenol fluxes of up to 5.9 tons per year (in 2006) at the border. The concentrations at the sampling point P2 (Samarkand) showed a general decrease between 2002 (2.2 µg/l) and 2010 (0.7 µg/l) and since 2005, the MAC value was not exceeded here. The highest overall phenol concentrations were observed near the city of Kattakurgan (P3) with up to 3.4 times the MAC value in 2003. Since then, the concentrations were lower (not more than 1.7 times the MAC), but still much higher than at the upstream sampling point P2, resulting in the highest average phenol concentrations of all four sampling points (1.19 µg/l). The second highest overall phenol concentration was detected at sampling point P4 (Navoi) in 2006 (2.9 times the MAC value), but during most years, the pollution did not exceed the threshold.

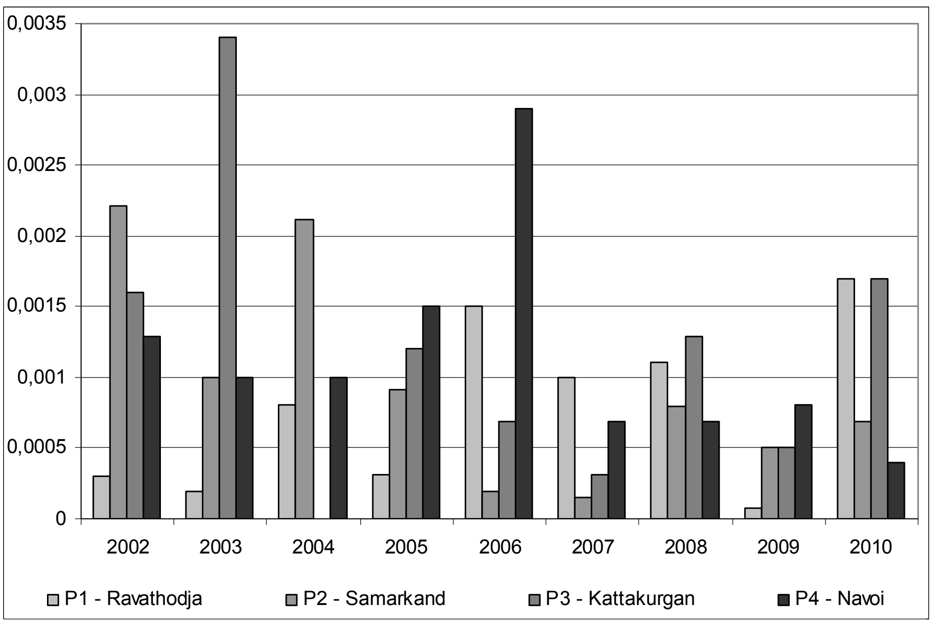

Fig. 8: Development of the phenol pollution (in mg/l)

3.2.4 Oil products

The dynamic of the pollution of the Zarafshon river water by oil products is shown in Fig. 9. As a whole, the level of pollution by oil products is not high. The MAC values were exceeded at the sampling point P2 (Samarkand) in 2003 and 2004 and at the sampling point P3 (Kattakurgan) in 2003, but in general, the oil concentrations stay well below the threshold. All sampling points show a decrease of the oil concentrations since 2003 and in 2010 no oil products were detected in Ravathodja and Navoi. These results suggest, that the primary sources of the pollution with oil products are the industrial enterprises located in the city of Samarkand.

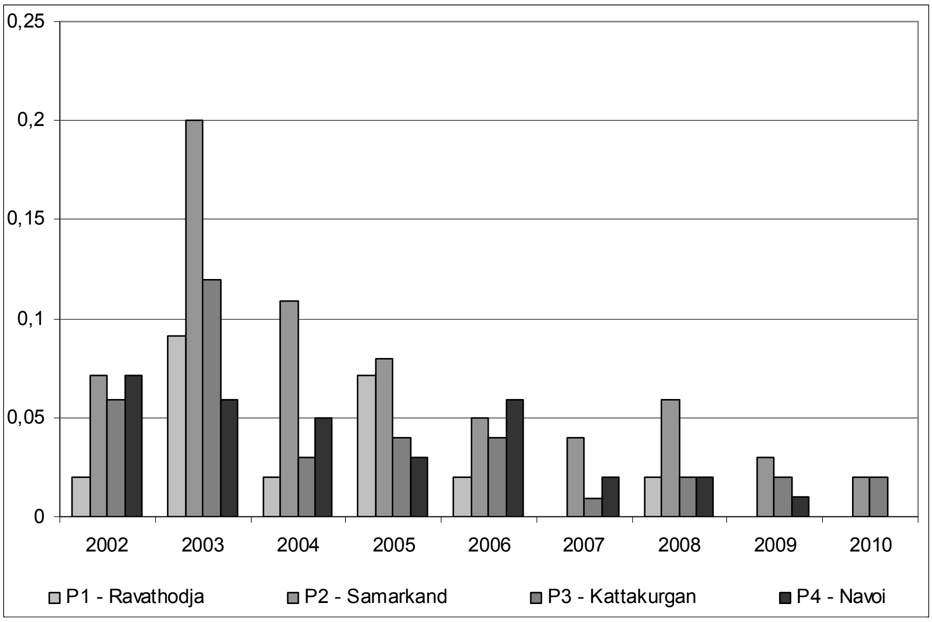

Fig. 9: Development of the oil product pollution (in mg/l)

3.2.4 Copper

The pollutant copper showed a long-term increase at all sampling points. The lowest concentrations were observed in 2002 and 2003, where the MAC value was reached at the sampling point P4 (0.011 mg/l) but stayed below the threshold at the other points (Fig. 10). In 2004, the threshold was reached at the Kattakurgan station as well and was exceeded in Navoi. In the following years, the copper concentration increased at all sampling points from average concentrations of 0.62 µg/l in 2002 to 3.07 µg/l in 2010, so that the MAC value was exceeded area-wide. The highest concentrations were detected in 2009 and exceeded the threshold up to 3.9 times. The data from individual month of that year showed an excess of up to 7 times the MAC value. A likely source of this pollution is the Anzob ore processing facility, which is located upstream in Tajikistan and discharges waste waters polluted with heavy metals directly into the Zarafshon. The yearly copper flux at the Tajik-Uzbek border ranged between 1.65 tons in 2002 and 13.55 tons in 2009. The increase of the copper concentration in the Uzbek part of the Zarafshon catchment can be explained with the decrease of runoff (irrigation, evaporation), which leads to a higher concentration of the remaining pollutants. Between 2002 and 2010 all four stations registered a similar linear increase of the copper pollution (R^2 between 0.6 in Kattakurgan and 0.82 in Ravathodja).

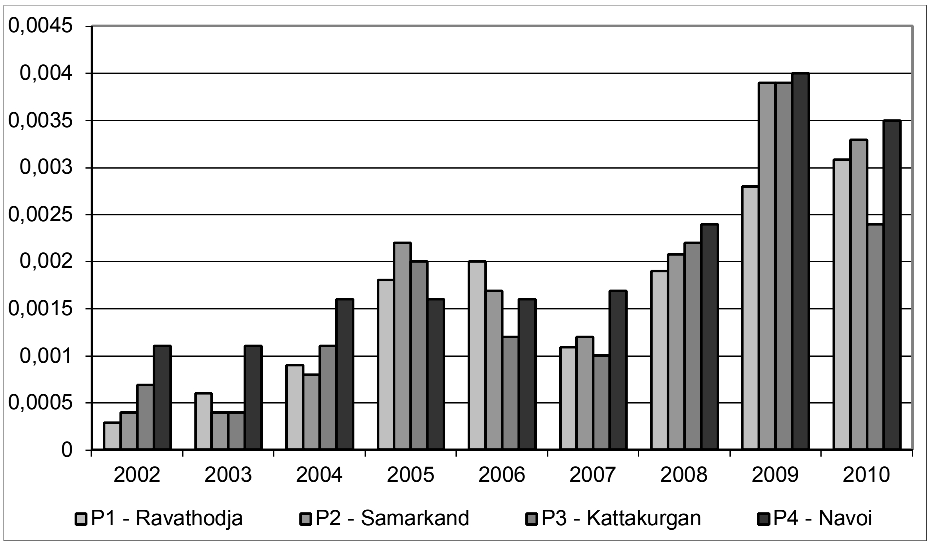

Fig. 10: Development of the copper pollution (in mg/l)

3.2.5 Pollutants - Summary

The analysis of the pollution dynamics of the Zarafshon river water for the period from 2002 to 2010 revealed significant exceeding of the MAC values for the mineralization, nitrite and for copper. The pollution with oil products and phenols was less severe, as the concentrations of both parameters stayed below the threshold during most years. For the oil products, which are mainly car traffic related pollutants, a long-term decrease of the pollution was observed, probably due to the effects of nature protection measures in the Samarkand region. The mineralization on the other hand was steadily increasing in the lower Zarafshon. At the sampling point Navoi, the total amount of dissolved matter more than doubled during the analysed ten year period. The same holds true for nitrite, but this parameter was also characterized by strong fluctuations between stations and years, due to the fact, that nitrite is quickly transformed into nitrate and it is thus hard to detect stable concentrations. Another reason for the fluctuations in the measured concentrations of nitrite (and phenol as well) lies in the sampling programme, that cannot detect the overall pollution of the river water, but only records the concentrations once per month. Especially point sources (agricultural waste water dumps and industrial sewage water) are not operated steadily but discharge their waste water depending on production cycles. Within the limitations of the measurement programme, the MAC for nitrite was exceeded at at least one station in all but one years. Both parameters – the mineralization and the nitrite – show, that the agricultural drainage water is the main source for the pollution of the lower Zarafshon.
The high pollution with copper indicates a second important input path of pollutants into the Zarafshon, located at the Anzob ore processing facilities in Tajikistan. The copper concentration at the border station Ravathodja showed a strong increase during the ten year period. Other heavy metals were not analysed, but it is likely, that their concentration follows the trend shown for copper.

In order to assess the possible long term development of the five analyzed parameters, the trends were calculated for the ten year period (Fig. 11). Copper showed a very strong exponential increase (R^2=0.83) that can be expected to continue in the future. A slightly weaker trend (R^2=0.79) was found for the mineralization. As this trend is linear, the expected increase in the next years could be less pronounced as for the copper.
The oil products showed a strong negative exponential trend (R^2=0.80) and thus can be expected to further decrease in their importance as pollutant of the Zarafshon.

The trends for nitrite and phenol were both weaker (R^2=0.65 and R^2=0.32), so that no clear indications for the future pollution can be made.

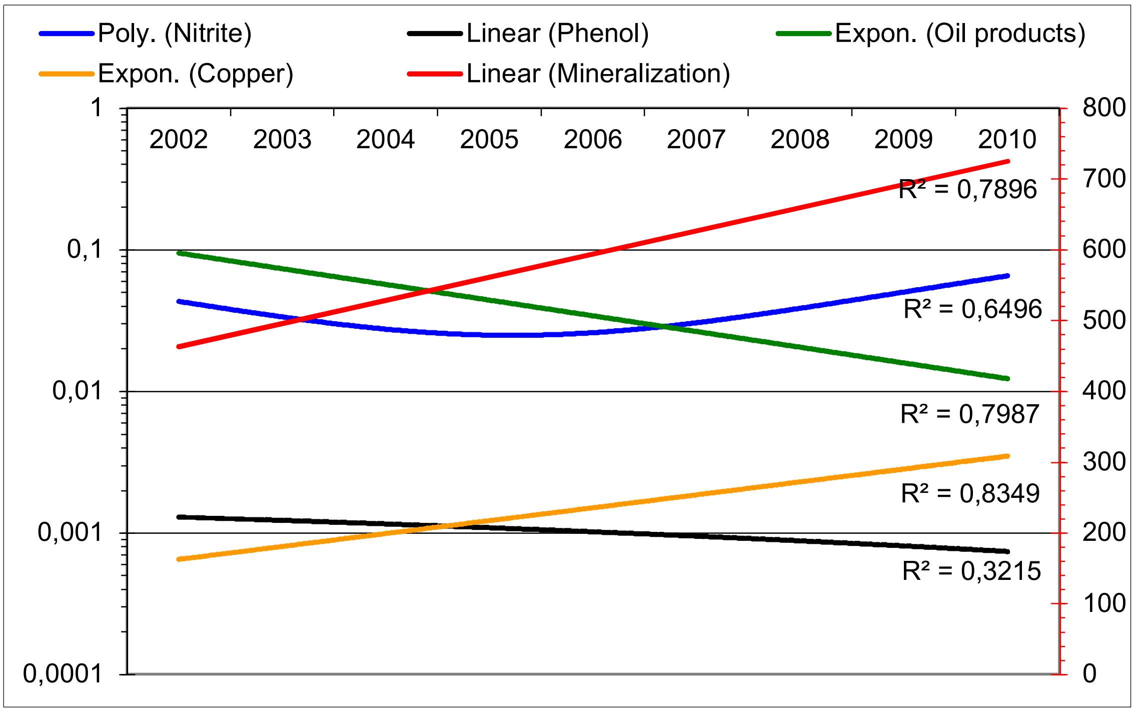

Fig. 11: Trends for the pollution with Nitrite, Phenol, Oil products, Copper and for the Mineralization in the Uzbek part of the Zarafshon (in mg/l, the mineralization is displayed on the secondary axis)

This trend analysis shows, that the two most important pollution sources of the Zarafshon – agrochemicals from the drainage water channels and heavy metals from the ore processing industry – are very likely to increase the level of pollution during the next years and will make it more difficult to provide clean water for growing population and economy of the region.

3.3 Drainage water and waste water treatment

Unlike the Zarafshon river water itself, the agricultural drainage water from the collectors is only poorly investigated as a regular monitoring of these water bodies is still lacking. Effects of the drainage water on the main river can be seen in the mineralization and the nitrite pollution, but currently, there are almost no direct measurements taken in the vast network of irrigation and drainage channels.

68% of the irrigated land in the Uzbek part of the catchment is located in the Samarkand province and more than 48% of all the irrigation water (2.4-2.5 km³ per year, ALIHANOV (EDS.) 2008) is used here. 57% of that water is collected as highly contaminated drainage water (1.25-1.55 km³ per year). The average mineralization of the collected drainage water (CDW) ranged between 0.66 and 1.1 g/l (ALIHANOV (EDS.) 2008), though this data is based on only a few measurements and individual collectors might show a different pollution. The largest channel in the Samarkand province is the Siyob collector with a discharge of 123-137 mln. m³ per year. Other important collectors are the Hayzaksay collector, the Taligulyan collector and the Cheganak collector. Together, these four collectors transport 27.7% of the drainage water in the Samarkand province.

The mineralization of the CDW is clearly linked to the vegetative period, as the example of the Cheganak collector for 2003 shows (Fig. 12). The highest values of more than 1.8 g/l were measured in June, while the lowest values were registered after the harvest in the

last summer and early autumn month. Analysis from CHEMBARISOV & SHODIEV (2007) revealed that the CDW in the Zarafshon river basin contains mainly nitrates, chlorides, ammonium, and sodium and in lower concentrations phosphates, the insoluble parts of mineral fertilizers and traces of pesticides. The pollution of the collector water is so high, that even in the month with the lowest mineralization values, the MAC is clearly exceeded.
The collectors discharge shows a different, more leveled annual dynamic than the pollution with the highest discharge in August, when the water consumption of the irrigated crops is already recessed and the fields are drained of the anthropogenic water input. In the late autumn and early winter, when there is no irrigation, the discharge of the collector reaches its minimum.
These two different dynamics show, that the irrigation and the fertilization are two separate processes that are not directly linked (R^2=0.002), though the data from more years would be needed to investigate this further.

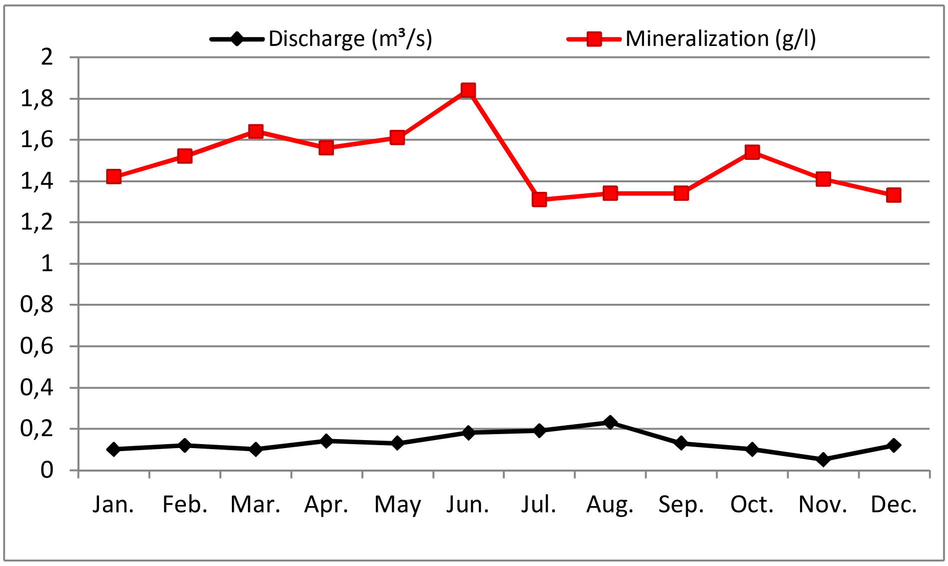

Fig. 12: Discharge (m^3/s) and mineralization (g/l) of the collector Cheganak in 2003

In the Navoi province, which is located downstream of Samarkand, 1.7 to 1.9 km^3 of water are used for irrigation every year (ALIHANOV (EDS.) 2008). This is more than 35% of the irrigation water of the complete Zarafshon catchment and only 13% less than in the Samarkand province. The irrigated area however is with 96’000 ha much smaller than in Samarkand. This means, that in Navoi three times as much water per hectare is used for irrigation than in Samarkand (18’750 m^3/ha and year). The reason for this is the proximity of the Navoi province to the Kyzylkum, resulting in arid conditions, higher demands for irrigation and a smaller return rate of drainage water. 45.3% (0.75-0.88 km^3 per year) of the irrigation water are collected as CDW. This water is characterized by a mineralization of 1.66 to 3.0 g/l (UNDP (EDS.) 2007; UZGIDROMET (EDS.) 2010). The most important collectors are the Markaziy, Mirzo-mumin, Bishkent and Sanitarniy collectors.

The southernmost part of the Zarafshon river is located in the Bukhara province. The arable land of this province is irrigated by the Zarafshon river and water from Amu-Bukhara channel. 0.5-1.1 km^3 of Zarafshon water are used for irrigation purposes every year. The Akaltin-2, Central and Narpay collectors transport a part of the drainage water back to the river with a total volume of 95.4 mln. m^3 (11.9% of the irrigation water) and a mineralization of 1.66-2.53 g/l. The larger part of the drainage water however is collected in several large depressions which function as sinks for the highly polluted water.

The analysis shows, that the irrigation farming leads to a serious contamination of the Zarafshon. The results differ from province to province. While the irrigation in the Samarkand province withdraws the largest proportion of river water, the conditions for this kind of agriculture are much worse in the Navoi and Bukhara provinces, leading to higher losses and thus to reduced return rates and higher pollutant concentrations.

A second point source for the pollution of the Zarafshon is the inflow of water from the municipal waste water treatment plants. Only 57% of the waste water in the provinces Samarkand and Navoi is treated and the efficiency of the treatment plants is very poor, ranging between 42.3 and 57.9% for the 15 analyzed facilities (UZGIDROMET (EDS.) 2010). The reduction rates differ greatly for the various pollutants in both provinces. While the BOD, COD and the suspended matter showed reductions of the pollution level of up to 86.4%, nitrite and nitrate concentrations are reduced by only 45 to 56%.
The low efficiency of the waste water treatment plants is causing a further pollution of the Zarafshon, but in comparison to the importance of the agricultural drainage water, it is almost negligible. The capacity of the five treatment plants in the Navoi province for instance is with approximately 90 m³ per day almost 25’000 times smaller than the drainage water volume in the same province. This clearly shows the paramount relevance of the drainage water for the quality of the Zarafshon river.

4. Conclusions

More than six million people live in the Uzbek part of the Zarafshon catchment. They depend on the river’s water resources for their household needs, the intensive agriculture and the diverse industry. The present state of the water resources in the catchment is characterized by a deterioration of the water caused by the excessive extraction of river water, the unregulated dumping of waste water from the irrigated fields and industrial complexes and the poor overall efficiency of urban waste water treatment plants.

The analysis of the data from four Hydroposts revealed two main pollution sources in the Zarafshon catchment. The biggest negative impact on the overall water quality of the Zarafshon river has the drainage water from irrigation farming in the Uzbek part of the catchment. The second important source can be found in the mining industry which concentrates in the antimony-mercury belt in the Zarafshon-Gissar mountains in Tajikistan and leads to a pollution of the river water with heavy metals. The pollution caused by municipal and industrial waste waters is secondary by far, but as the population and the economy grow, the importance of these sources will increase in the future.

The expected growth of the population and economy in the Zarafshon river basin will further increase the pressure on the already overused water resources. The regional effects of the global warming might not lead to an immediate decrease of the discharge, but a significant reduction of the available water resources has to be expected in the long term.

5. Recommendations

The results emphasize the importance of a sustainable water resource management that has to be developed today in order to deal with the challenges of the future. The following improvements of the status quo should be first steps of such a management concept and are highly recommended:

1. In order to assess the contamination with agrochemicals correctly, a water monitoring program has to be installed, that not only covers the Zarafshon itself, but also the irrigation channel, water reservoirs and drainage collectors in the Samarkand and Navoi provinces, because these are the primary pollution sources.
2. The already existing monthly analysis at the Hydropost stations (especially at the Ravathodja station) should include a wider range of toxic heavy metals, such as Hg, Sb, As, Cr and Cu, which greatly contribute to the pollution of the Zarafshon.
3. Based on the results of a thorough status quo analysis of the pollution, guidelines, thresholds and restrictions for the extraction of river water, the usage of agrochemicals and the purification of municipal and industrial (including mining) waste water have to be developed as centerpieces of a transboundary water management plan between Tajikistan and Uzbekistan.

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