

Rival Eco-Anxieties: Legacy of Soviet Water Management in the Syr Darya Basin

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Abstract

This article focuses on the security and human rights implications of the water infrastructure legacy bequeathed to the Syr Darya river basin in the border area of the Ferghana Valley, by the Soviet period. Taking an environmental history approach, I consider the complex legacy of the system of ageing dams, irrigation canals, and reservoirs which for the most part were set in place between the 1950s and 1980s. Correcting the prevailing narrative that post-Soviet water tensions are often caused by the Soviet habit of disregarding borders and republican-level interests in designing water infrastructure, I show how Soviet water policy in the region fanned and exacerbated inter-republican tensions even while the national territorial divisions were ongoing. Current tensions are therefore not a response to a sudden and unexpected hardening of borders, but the fruit of much longer processes.

Keywords

Soviet policy – security – border security – ecology – environment – human rights – security nexus – post-Soviet – Central Asian

Introduction

Since the fall of the Soviet Union, simmering tensions over water management between the Central Asian nations, and occasional outbreaks of violence, have garnered significant international attention and coverage: Central Asia has repeatedly been flagged as the world region most likely to see conflict over

water.¹ The roots of the recent, and ongoing, tensions over water are to be found in the post-Second World War Soviet decades, when a vast infrastructure was put in place to manage, ration, and apportion the waters of the region's two main rivers, the Amu Darya and the Syr Darya, and their tributaries. In the mid decades of the twentieth century, both of these rivers flowed into the Aral Sea, one of the world's largest endorheic lakes. However, the root causes of current tensions, and their relationship to Soviet era water and energy distribution processes, are often misstated. My case study here focuses on the infrastructure built to regulate the flow of water from the Syr Darya and its tributaries within the Ferghana Valley, one of the most densely populated and economically strategic regions of Central Asia.

By taking a closer look at the rationale, priorities, and shortcomings of the water infrastructure erected in the Ferghana Valley between the 1950s and the 1980s, we can reach a better understanding of how these ageing structures have the capacity to foment significant security issues and human rights violations across the Ferghana Valley and beyond. Up until the dissolution of the Soviet Union, Moscow institutions tightly supervised the allocation of waters in the Syr Darya river basin: an economic priority in a predominantly agricultural region – much of it devoted to cotton, a strategic cash crop – characterised by low rainfall. The central archives of the Russian Federation (GARF) store thousands of pages of reports and correspondence documenting the minutiae of negotiations between water users in Central Asia, all directed to – or in any case via – Moscow, where these records remain today.

Commentators seeking to explain current tensions over water routinely gesture to the troubled Soviet legacy, but they misunderstand the nature of this legacy. It was not the sudden hardening of borders following the dissolution of the Soviet Union that generated tension in a system supposedly designed to maximise the irrigation and hydropower generation potential of rivers, by focusing on the topography and ignoring political boundaries. Quite to the contrary: many of the most persistent and acrimonious conflicts are caused by infrastructure located at the behest of agencies representing republican interests, disregarding engineering and hydraulic considerations in favour of national and sectoral priorities.

Intrarepublican tensions over the management of the waters of the Syr Darya and its tributaries ran high throughout much of the post-war decades, although thanks to Moscow's arbitration and control, they rather more rarely

1 See for example J. Rheinbay, S. Mayer, S. Wesch, K. Vinke, 'A Threat to Regional Stability: Water and Conflict in Central Asia,' *PeaceLab*, 20 April 2021; 'Water Wars in Central Asia,' *Foreign Affairs*, 24 August 2016.

entered the public eye. In the late 1980s, the archival folders documenting negotiations to share the waters of the Amu and the Syr are full of urgent telegrams requesting upstream reservoirs be all but drained to relieve downstream droughts, and grim forecasts of exceptionally low levels of water reaching the Aral.² In 1989, still, the stakeholders in these negotiations were not limited to the leaderships of the Central Asian republics, but extended to various All-Union institutions, including the Soviet Council of Ministers, the Ministry of Land and Water Management, the Ministry of Energy, and the State Planning Agency. Thus, local chairmen responsible for delivering certain quantities of fish, cotton, or rice tended to appeal to whichever All-Union agency seemed most likely to be responsive to their plight and to help them secure the additional quantities of water requested. Such requests routinely pitted one Soviet republic against its neighbours, and in this struggle for limited resources, political borders mattered very much indeed.

There has been a robust criticism of the appropriateness of continuing to use the post-socialist lens as a prism for interpreting everything that goes on in the Central Asian nation states, and for good reason.³ But when will post-socialism have run its course? It is hard to deny that the features of the security human rights nexus that I focus on here, pertaining to water management issues and environmental problems, are deeply bound up with the policies of the post-war Soviet decades. It was during the period between the 1950s and the 1980s that the Syr Darya river as it appears today, with its multitude of channels, embankments, dams, and reservoirs, took shape. Prior to the 1950s, and despite a long history of collectively maintained and hand dug irrigation channels, human capacity to affect the flow of the Syr or the Amu Darya was rather limited. Since 1989, no significant new water infrastructure projects have been undertaken in the Ferghana Valley portion of the Syr Darya – the most densely populated and agriculturally significant region in Central Asia. Thus, from the water management perspective at least, the shadow of the socialist legacy still looms large over the Ferghana Valley.

The water infrastructure on the Syr Darya was designed and built by supra-republican agencies, according to a logic dictated by a centralised All-Union government, and although the Union republics could and did compete fiercely amongst each other for resources and investment, the mechanisms to override objections and force cooperation were also strong. It is not surprising, therefore, that the demise of the centralised centre of power in Moscow

2 See for instance GARF (National Archive of the Russian Federation), Fond 5446, op.150, d.714, dealing with negotiations between the republics of Central Asia in 1989.

3 See, for example, M. Müller, 'Goodbye, Postsocialism!', *Europe-Asia Studies*, 2019, 71:4, 533–550.

has made the challenges and tensions between republics more overt and likely to lead to violence, even as the infrastructure itself ages, and teeters towards obsolescence.

While the present article focuses on the problems arising from the Ferghana Valley's ageing water infrastructure, and the similarly outdated mechanisms for negotiating and apportioning water fairly, this strategic water basin is also affected by other environmental problems. No other factor is more crucial than climate change, as a warming planet is melting the high mountain glaciers in the Tian Shan, Pamir, and Altai ranges that feed the region's rivers at an unprecedented rate.⁴ Increases in water flow from melting glaciers might sound positive in the short term, but retreating glaciers cause landslides and flash flooding, and portend sharply diminished water flows in the future. Central Asia's major rivers are severely polluted by agricultural runoff from pesticides and fertilisers, inadequately processed municipal waste, and the legacy of uranium mining in the Syr Darya basin. There are radioactive waste dumps and uranium tailings in the slopes immediately overlooking the river in both Kyrgyzstan and in Tajikistan, at mining and processing sites including Taboshar, Mailuu-Suu, and Chkalovsk. Several canals and tributaries of the Syr Darya pass close by these poorly monitored sites, and the area is known to be seismically active, with a powerful earthquake whose epicentre was not far from the Kairakkum dam in 1987.

Post-War Water Management in the Syr Darya River Basin

Historian Maya Peterson demonstrated in her recent book *Water and Empire* that the plans to exploit the waters of the Syr Darya on a 'more rational' basis began shortly after the Russian conquest of the river basin in the second half of the nineteenth century.⁵ Tsarist officials were inspired by the challenge of trying to prevent too much water from flowing 'uselessly' to the Aral Sea, diverting it instead to water the crops of locals and of Slavic settlers to the region.

Following the establishment of Soviet power over Central Asian territories, plans for apportioning the waters of the Syr Darya became far more ambitious, as projects for higher dams, bigger reservoirs, and longer irrigation channels were made. These projects made balancing the needs of agricultural irrigation

4 A. Sorg, T. Bolch, M. Stoffel, O. Solomina & M. Beniston, 'Climate change impacts on glaciers and runoff in Tien Shan (Central Asia)', *Nature Climate Change*, 2, 725–731, 2012.

5 M. Peterson, *Pipe Dreams: Water and Empire in Central Asia's Aral Sea Basin*, Cambridge University Press, 2019.

and of hydropower increasingly difficult (unlike other major rivers, navigation has not played a major role on the Syr Darya).

In contrasting water management practices in the Syr Darya river basin during the Soviet decades with those that have prevailed since independence, the hardening of international borders is often emphasised. Indeed, it is true that tensions over water allocations between neighbouring republics, driven by asymmetrical needs between upstream and downstream countries, led to a level of sabre-rattling and outright violence in border regions that exceeds Soviet-era tensions in severity. However, the claim that administrative borders were purely notional or did not matter in the Soviet Union is amply disproved by the archival record. Border disputes between republican leaderships occurred regularly, and were sparked on several occasions precisely by the construction of large water infrastructure projects. Adjustments to republican borders continued to be made in Central Asia long after the official process of national-territorial delimitation had wrapped up in the 1930s. Any suggestion that a neighbouring republic might obtain the upper hand in accessing a shared resource or infrastructure caused great consternation, and triggered volleys of concerned letters from republican officials to Moscow.⁶

Between the 1940s and the 1960s, water infrastructure projects initiated at the behest of one republic caused intra-republican tensions and border disputes. In the cases of both the Farhad and Kairakkum dams, the sites were chosen on the basis of pre-existing infrastructure and republican agendas, which overrode to some extent the stated goals of power generation and water storage, which would have been achieved more efficiently, and possibly at lower cost, elsewhere. In other words, considerations of the local environment, climate, and topography, were subordinated to republic-level economic agendas, which conferred real meaning to administrative borders.

The very first dam built on the Syr Darya, begun in 1943 on the Tajik-Uzbek border at the western end of the Ferghana Valley, caused the Tajik authorities great consternation. The first of a suite of dams designed to meet artificially twinned needs of irrigation and power generation, the Farhad project had originally been mooted in a lengthy planning report submitted in 1940 to the Ministry of Finance, but was hastily approved following the outbreak of the Second World.⁷ The Farhad dam was built to supply both hydropower to

6 F. Roberts, 'A controversial dam in Stalinist Central Asia: Rivalry and "fraternal cooperation" on the Syr Darya,' *Ab imperio* 2/2018.

7 J. F. de la Croix and F. Roberts, 'Big Dam Biographies in Central Asia: Tracing Goals, Actors, and Impacts from World War II to the Present Day,' in Ștefan Dorondel and Stelu Șerban, *A New Ecological Order: Development and the Transformation of Nature in Eastern Europe*, University of Pittsburgh Press (forthcoming, 2022).

the factories evacuated to the region, and irrigation water, so that the ‘Hungry Steppe’ might grow more grain, and – above all – more cotton.⁸ The leadership of the Tajik Communist Party objected to the dam at the Farhad site because the dam would be managed by their Uzbek counterparts, who would use the electricity and most of the irrigation water diverted from the river, but the dam’s reservoir would flood mostly Tajik territory.⁹ The submerged fields and lost orchards would, of course, affect the balance sheet of the Tajik republic and hinder them in meeting their quotas of cotton. Dam construction went ahead, but mediation from Moscow brokered a deal whereby the Uzbeks would lease the territory occupied by the dam from the Tajiks for an initial period of four decades. The forty-year lease elapsed even as the Soviet Union was falling apart, and the Uzbek military pre-empted any trouble by occupying the site in 1991.¹⁰ Tajikistan was soon embroiled in civil war, but by 2002 had ‘recaptured’ the dam from Uzbekistan following a surprise strike, allegedly on the initiative of a local general. Only since 2018 has a new joint agreement been in place on the dam’s management and maintenance.

It did not take long after completion of the first dam on the Syr Darya to realise that the needs of irrigation and hydropower were far from easy to reconcile, as seasonal water withdrawals for agriculture affected electricity generation. It was decided by the early 1950s that a far larger reservoir would be needed upstream, in order to regulate the flow to the hydropower station at Farhad, and compensate for seasonal variations.¹¹

The location proposed for a second dam again caused consternation among the Tajik party leadership. This second dam – designed to regulate the flow of water at Farhad – was also to be located in the Ferghana Valley, just a short distance upstream from Leninabad, the Tajik republic’s second city, and would flood a far larger area of agricultural land than the earlier dam had. Again, beginning in 1944, the Tajiks objected to the chosen location, and again, the dam project went ahead. This time, however, the Tajiks were compensated, when an amount of territory roughly equivalent in size to the land flooded by the Kairakkum reservoir was ceded by the Uzbek republic, and the border amended in 1958. The value of the land ceded by the Uzbek to the Tajik SSR would be negligible, in strictly economic terms, absent a significant investment

8 On the wartime evacuations to Central Asia, see Rebecca Manley, *To the Tashkent Station: Evacuation and Survival in the Soviet Union at War*, Cambridge University Press, 2009.

9 GARF F. P5723, op.65, d.172, l. 1.

10 A. Murzakulova, ‘The Soviet Water Legacy in Central Asia,’ *The Diplomat*, September 01, 2021.

11 J. F. de la Croix and F. Roberts, ‘Big Dam Biographies in Central Asia: Tracing Goals, Actors, and Impacts from World War II to the Present Day,’ in Ștefan Dorondel and Stelu Șerban,

in artificial irrigation, which succeeded for a few years in supplying new fields for Tajik cotton, although the area of Zafarobod – like other areas of ‘reclaimed’ steppe, has since been plagued by secondary salinisation and steadily declining yields.¹²

Farhad and Kairakkum were not the only examples of water infrastructure built at the behest of the Uzbek republic, but located or partially located across a republican border.¹³ Another large reservoir was built at the eastern end of the Ferghana Valley, not far from the Uzbek city of Andijan, after which it is named. The Andijan dam, begun in 1969, is in Uzbekistan, but its large reservoir formed largely on Kyrgyz territory, which thereby lost some sixty square kilometres of its scarce agricultural land, in a predominantly mountainous country. The Andijan project, too, resulted in a modification of those supposedly notional borders.

It should be clear by now that the narrative, common among contemporary observers of water tensions in the region, that borders were effectively non-existent or irrelevant before the dissolution of the Soviet Union is inaccurate.¹⁴ The novelty ushered in by the disintegration of the USSR was *not* political tensions between upstream and downstream republics, or difficulties in reconciling the needs of agriculture and energy production, but rather the depletion of mechanisms for enforcing compliance with agreements brokered between stakeholders.¹⁵ Even the narrative that describes the interests of upstream countries pitted against those of downstream countries is not wholly accurate in the case of Uzbekistan, which with respect to the Syr Darya is both upstream and downstream of Tajikistan, thanks to the convoluted borders of the Ferghana Valley. Impulses towards both competition and cooperation remain, and new institutions have arisen to broker agreements, but compliance is weak.

A New Ecological Order: Development and the Transformation of Nature in Eastern Europe, University of Pittsburgh Press (forthcoming, 2022).

- 12 F. Roberts, ‘A controversial dam in Stalinist Central Asia: Rivalry and “fraternal cooperation” on the Syr Darya,’ *Ab imperio* 2/2018.
- 13 Moritz Florin, ‘Emptying lakes and filling up seas. Hydroelectric dams and the ambivalences of development in late Soviet Central Asia,’ *Central Asian Survey* 38 (2) (2019): 237–254, <https://doi.org/10.1080/02634937.2019.1584604>.
- 14 A. Murzakulova, ‘The Soviet Water Legacy in Central Asia,’ *The Diplomat*, September 01, 2021.
- 15 J. Sevring, ‘Masculinity and water diplomacy in Central Asia,’ in Matthias Schmidt, Rune Steenberg, Michael Spies, Henryk Alff (eds), *Beyond Post-Soviet: Layered Legacies and Transformations in Central Asia*, Augsburg, 2021.

Post-Soviet Security and Human Rights Concerns

Since the collapse of the Soviet Union and collectivised agriculture, enduring tensions over their shared water infrastructure have taken a far heavier toll on local inhabitants, many of whom are subsistence farmers, and are far more likely to lead to violence. The agricultural sector remains the largest consumer of water in the region by far, and in each of the Central Asian nations, per capita water consumption far exceeds that in Europe – despite millions of rural households lacking access to clean water.¹⁶

The steadily ageing infrastructure, which there is little appetite to update absent significant external investment, brings with it heightened risks of seasonal and catastrophic flooding, particularly in this seismically active area. Of perhaps greater concern is the dilapidated state of much of the water distribution network, which leads to unacceptably high losses – more than half of irrigation water diverted from the Syr and Amu Darya water basins never reaches the fields.¹⁷ Many of the over 1,200 dams across Central Asia are reaching the end of their natural life, but plans to replace or remove them are not being made systematically.¹⁸ There is little willingness in the upstream countries in particular, who benefit most heavily from hydropower, to consider the advantages of removing dams, and shifting to more sustainable forms of energy production. While often presented as green sources of energy, dams are a major contributor to global carbon emissions, warming water to the point that riverine ecosystems are severely disrupted, and biodiversity depleted.

Many disputes over water management have been documented in the last decades, and by some measures these are increasing in both frequency and severity.¹⁹ This comes in spite of some positive developments, such as the improvement in relations between Uzbekistan and Tajikistan, following the death of President Islam Karimov in 2016 and the succession of Shavkat Mirziyoyev. Under Mirziyoyev, a fresh agreement over the management of the Farhad dam was brokered in 2018, according to which the territory on which

16 J. A. Peña-Ramos, P. Bagus and D. Fursova, 'Water Conflicts in Central Asia: Some Recommendations on the Non-Conflictual Use of Water', *Sustainability*, 13, 3479, p. 6, 2021.

17 I. V. Severskiy, 'Water-Related Problems of Central Asia: Some Results of the (GIWA) International Water Assessment Program', *Ambio*, 33, No. 1/2, *Transboundary Issues in Shared Waters*, pp. 52–62, 2004.

18 CAWater-Info. Safety of Large Hydraulic Structures (Dams, HPP, Reservoirs).

19 Nick Megoran, *Nationalism in Central Asia: a Biography of the Uzbekistan-Kyrgyzstan Border*. University of Pittsburgh Press, 2017.

the infrastructure is located was recognised as Tajik, but the power plant will be run and maintained by Uzbek engineers.²⁰

The large number of dams constructed throughout the Syr Darya watershed have not alleviated persistent seasonal water shortages or flooding events, and local anxiety over access to water has continued to lead to violence. In late April 2021, violent clashes broke out over a critical piece of water infrastructure near the Tajik-Kyrgyz border, towards the south-eastern end of the Ferghana Valley, which Uzbekistan also shares with Kyrgyzstan and Tajikistan. At least 36 Kyrgyz nationals and 20 Tajik nationals lost their lives in these clashes, which saw mortar fire exchanged between military forces, as well as rocks and other improvised weapons wielded by civilians.²¹ More than one hundred properties – including schools, businesses and petrol stations – were set on fire, causing many thousands of Kyrgyz citizens to flee their homes.²²

As of 2021, *Eurasianet* was reporting that almost half of the largely mountainous border between Kyrgyzstan and Tajikistan, 450 out of 970 kilometres, had yet to be fully defined, leading to uncertainty and local tensions. The two governments have recently recommitted to resolving the border issues, but – though important – such initiatives fail to tackle the central cause of many tensions in the surrounding communities, which is the difficulty of sharing water resources.

While agriculture continues to play a dominant role in the regional economies of each of the three countries that share the Ferghana Valley, the climate is dry, with average annual rainfall of about 300 mm yearly. Thus, agricultural practices are highly dependent on access to irrigation water, particularly at certain times of the year, when interruptions in the water supply can spell ruin for subsistence farmers living from harvest to harvest.²³

According to official Kyrgyz statistics, Batken province, where the clashes of April 2021 occurred, is the poorest and most remittance-dependent of Kyrgyzstan's seven regions.²⁴ The Ak-Suu/Isfara river, a left tributary of the Syr Darya, has its source in the mountains of Batken, and flows southward over

20 'Tajikistan, Uzbekistan Reach Visa Deal, Settle Border Dispute,' *Eurasianet*, 11 January 2018. Retrieved <https://eurasianet.org/tajikistan-uzbekistan-reach-visa-deal-settle-border-dispute>.

21 A. Imanaliyeva, 'Kyrgyzstan: MPs pursue special status for conflict-stricken region,' *Eurasianet*, 28 May 2021. Retrieved <https://eurasianet.org/kyrgyzstan-mps-pursue-special-status-for-conflict-stricken-region>.

22 'Kyrgyzstan-Tajikistan: Images of destruction after border clashes,' *BBC*, 02 May 2021. Retrieved <https://www.bbc.com/news/world-asia-56963998>.

23 BSk according to the Köppen and Geiger system of climate classification.

24 'Уровень бедности в Кыргызской Республике' [The level of poverty in the Kyrgyz Republic], *National Statistical Committee of the Kyrgyz Republic*. Retrieved <http://www.stat.kg/ru/publications/uroven-bednosti-v-kyrgyzskoj-respublike/>.

about ninety kilometres. In the 1970s, a system of locks and a canal was built, known as the the Golovnoi system and the Friendship canal. Through this system, the waters of the river are divided into two branches: while a portion of the river continues its natural course through Batken province (Kyrgyzstan) into Tajikistan, and on into Uzbekistan, where it joins the Syr Darya, another portion of the river is diverted into a sixteen kilometre-long channel (The Friendship canal – the name should not surprise us by now), which feeds an artificial reservoir vital to Kyrgyz farmers, the Tortkul reservoir.²⁵

The system for shared use of the waters of the Ak-Suu/Isfara river has not been substantially revised since it was established in 1980. Bishkek claims that the Golovnoi system was an initiative of the Kyrgyz SSR, and that independent Kyrgyzstan has borne the maintenance costs ever since. Tajikistan, where hundreds of farmers rely on the Golovnoi system to apportion the river water according to this long-established pattern, has claimed that no repairs have been carried out by the Kyrgyz for over a decade, but at the same time seem nervous about any substantial maintenance plans, which may be read as a claim to sole ownership on the part of Kyrgyzstan.

Apparently intending to monitor the maintenance plans, Tajiks installed surveillance cameras at Golovnoi on April 28, 2021.²⁶ This action, seems to have triggered the hostile reaction from the Kyrgyz side that evolved into violence on both sides of the border, which spread to several other locations along the border, some over twenty kilometres from the Ak-Suu. While the Golovnoi infrastructure, like most of the other water management objects we have considered here, lies within the border zone, resolving the border delimitation issues alone will fail to ease tensions, absent renewed negotiations about water allocations. Given the justified concerns about overuse and scarcity, no water allocation plan that does not also commit all parties to radically reduce the amount of water used by the agricultural sector (and the mining sector, in the Kyrgyz case), is likely to succeed.

25 A. Imanaliyeva, K. Ibragimova, 'Kyrgyzstan, Tajikistan: Solving water puzzle key to preventing fresh fighting', *Eurasianet*, 19 May 2021. Retrieved <https://eurasianet.org/kyrgyzstan-tajikistan-solving-water-puzzle-key-to-preventing-fresh-fighting>.

26 A. Imanaliyeva, K. Ibragimova, 'Kyrgyzstan, Tajikistan: Solving water puzzle key to preventing fresh fighting', *Eurasianet*, 19 May 2021. Retrieved <https://eurasianet.org/kyrgyzstan-tajikistan-solving-water-puzzle-key-to-preventing-fresh-fighting>.

Conclusion

Across the Central Asian region, agricultural water use has reached critically unsustainable levels, due to a combination of an excessive focus on thirsty cotton crops (where a more diversified fibre crop range including flax, hemp, and linen would be more sustainable), and continued reliance on a dilapidated network of leaky pipes and channels. In the context of retreating glaciers and continuing population growth, reducing water consumption in agriculture by means of improved irrigation techniques and crop diversification is an urgent priority.

Too little progress has been made towards meeting the UN's Sustainable Development Goals, particularly indicator 6.5.2 on Transboundary water cooperation, relating to the 'Proportion of transboundary basin area with an operational arrangement for water cooperation.'²⁷ Many thousands of small scale and subsistence farmers across the Ferghana Valley, and in its foothills in Batken province, depend for their livelihoods on obsolete infrastructure designed for a far different political, economic, and climate reality, and it is small wonder that these communities are on edge.

Perhaps, as Martin Muller suggests, it really is time to close the chapter of 'post-socialism' for Central Asian water management, as while there can be no doubt as to the vintage of the major constituent parts of the system, the degree of disruption caused by the fall of the Soviet Union and the 'hardening of borders' has been greatly overstated. The tensions between stakeholders across republican boundaries, present since the projects' inception, are still largely caused by a reckless overuse of a finite resource, and an overreliance on outdated technology and an ill-considered commitment to cotton.

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²⁷ On the Transboundary water cooperation metric, see <https://sdg6data.org/indicator/6.5.2>. See also: Peña-Ramos José Antonio, Philipp Bagus and Daria Fursova. Water Conflicts in Central Asia: Some Recommendations on the Non-Conflictual Use of Water. Sustainability 2021, 13, 3479. <https://doi.org/10.3390/su13063479>.

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