СУЧАСНІ ПРОБЛЕМИ УРБОЕКОЛОГІЇ

APPLICATION OF WATER STABLE ISOTOPES IN STUDIES OF URBAN WATER CYCLE

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Urban hydrological cycle is highly changed due to intensive anthropogenic pressure from densely populated areas what increases the risks of water contamination and depletion. The main issue is associated with overexploitation, leakages from water supply and sewerage infrastructures that change water balance and drinking water quality. These impacts cannot be appropriately evaluated using hydrochemical or traditional hydrological parameters and often require application of expensive techniques that cannot be used by many developing countries. To address this issue, environmental stable isotopes can provide important information to water managers to assess sources and interactions between water bodies on the urban area where the water of different origin is mixing. The unique isotopic signatures of water sources can be used to better define sources, pathways and interactions of water bodies in urban environments and evaluate the water sources availability and fluctuation. This study aims to develop, test and integrate new methodologies and capabilities using environmental isotopes to better assess, map and manage water resources used for domestic water supply in a large water scarce city of Kharkiv (1.4 M inhabitants) in East Ukraine.

The city of Kharkiv is located in a semi-humid (forest-steppe) climate zone with a limited local runoff that cannot satisfy water needs of economic sectors and population. Therefore, water is supplied from adjacent areas – 75% from the transboundary Siversky Donets river (as far as 30 km from the city) and 25% from the canal Dnipro-Donbas (130 km away from the city). Total water consumption through centralized system is around 570 000 m^3 per day, from which 430 000 m^3 per day are taken from Siversky Donets river and 140 000 m^3 per day is supplied from

Krasnopavlivske reservoir located on the Dnipro-Donets canal. Treated water is discharged to the Lopan river (~ 70%) and Udy (~30%) river, which are tributaries of the Siversky Donets.

Shallow groundwater that outflows on the surface in a form of springs is widely used as an alternative drinking water source for the population. The number of people who use urban springs in the city of Kharkiv as major drinking water source is growing annually caused by deterioration of centralized tap water quality. Several opinion polls done in the city have shown that the majority of city inhabitants prefer bottled artesian water and spring water for drinking purposes instead of water from centralized supply system. The latter covers 84 % of the city, but the distribution networks are increasingly degrading (water losses may reach more than 25%) and need renovation (official data from KP Vodokanal 2017). At present time, water losses from the distribution network could be the principal source of recharge of urban springs that accounts up to 70% of the total groundwater recharge according to our previous investigation. As estimated, water supply leakages, that recharge shallow aquifer, reach up to 3% of the total water supply and strongly correlate with spatial distribution of failures on the water infrastructure. Sewage leakages to the aquifer appear to be less in amount than water supply leakages, but induce nitrate and associated contaminants pollution risk of urban groundwater [1].

Two water systems have been found to have quite distinct isotopic signature of water stable isotopes. Water from Siversky Donets river is relatively depleted while water from Krasnopavlivske reservoir is much more enriched with ^{2}H and ^{18}O. This may be clearly explained by initial water sources conditions. Water from Krasnopavlivske reservoir undergoes evaporation during storage in the reservoir, while the Siversky Donets water is taken directly from the river and inflows to the relatively isolated pipeline system where there are no conditions for intensive evaporation exist. Additionally, Krasnopavlivske reservoir is located 100 km southward where climatic conditions slightly differ in terms of overall higher temperature and evaporation.

Nowadays, about 30 groundwater-driven equipped springs are located within the city of Kharkiv accounting for a total discharge of 1700 m^3 per day. Almost all springs belong to a semi-confined shallow aquifer and are vulnerable to pollution. Our previous study has shown that isotope composition of the springs is very close to local precipitation in rural areas where mainly natural recharge occurs [2]. However, in urban area, groundwater quality is highly impacted by sewage leakages from wastewater collectors, septic tanks and pit latrines [3]. Therefore, the complexity of urban groundwater recharge and quality conditions is provided by combination of regional surface water sources, trans-basin water transfers, inputs of leakages from water supply, central heating and sewage systems, polluted runoff infiltration.

Investigation of shallow groundwater was done through the springs located in urban and suburban areas and equipped for decentralized water consumption. In total 20 springs have been studied, from which 11 have been sampled monthly and 9 springs quarterly. From these 20 springs 12 are located on urban areas, 5 on suburban areas and 3 in forested areas outside the city representing natural background groundwater composition.

Isotopic samples of urban springs are mostly plotted along local evaporation line, which is built on local river water isotopic composition. This clearly indicates anthropogenic recharge by mixing groundwater with tap water leaks bringing more evaporated water and thus enriched with heavy isotopes. Furthermore, comparison of isotopic signature of urban springs between each other has shown that springs are grouping in separate clusters by $\delta^{18}O$-$\delta^{2}H$ signature indicating specific and often even unique conditions of recharge for almost each of the springs.

Springs of 1st group have $\delta^{2}H$ range from -83 to -77‰, 2nd group has the range from -78 to -73.5‰, while 3rd group is characterized with the range from -75 to 69‰. Ranges of $\delta^{18}O$ values for the three groups were respectively -11,6 to -10,6‰, -11,2 to -10‰ and -10,4 to -9,0‰. Springs of 3rd group are the most enriched with heavy isotopes due to more intensive input of leaks from tap water and centralized hot water mains. For certain springs this is confirmed also by elevated values of water temperature and concentration of anthropogenic tracers – Cl^{-}, SO_4^{2-}.

Thus, urban water cycle of Kharkiv city area undergoes noticeable anthropogenic impact, namely through decrease of infiltration on built-up areas, increase of evaporation and recharge of shallow aquifer by leaks from tap water supply systems. Isotopic composition of groundwater from equipped springs located within the city has elevated concentrations of heavy water isotopes clearly indicating mixing this water with tap water enriched with ^{18}O and ^{2}H due to its origin from rivers.

References

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