UDC 618.3.621.395 DOI: https://doi.org/10.64076/iedc250920.02

Prospective directions for the development of water treatment systems with surface water sources in the context of global climate, anthropogenic and socio-economic changes in Ukraine

Dmytro Charnyi
Ph.D. Head of the Department of Radioactive Waste Management Issues, Institute of Environmental Geochemistry, National Academy of Sciences of Ukraine, Kyiv
Dmytro Novytskyi
Deputy Director General for Strategic Policy, Kyivvodokanal Joint Stock Company, Kyiv
Volodymyr Kostyuk
First Deputy Director – Chief Engineer of the Water Supply Operations Department at Kyivvodokanal PJSC, Kyiv
Lada Podolina
Taras Shevchenko National University of Kyiv
Second year at the Institute of Philology, Kyiv

Abstract. *Traditional water treatment technologies in Ukraine, based on aluminium coagulants and chlorination, are effective for turbid waters but ineffective against organic pollutants, in particular phytoplankton (cyanobacteria) in the Dnieper reservoirs. Global climate change and anthropogenic factors (phosphates, pesticides) lead to water 'blooming', an increase in phytoplankton biomass to 10 million tonnes in the Kremenchuk reservoir, and the appearance of toxins (microcystins). Forecast for 5–7 years: phytoplankton concentration >200,000 cells/cm³. It is proposed to reconstruct facilities using chlorine dioxide (ClO_2) and methods of preliminary phytoplankton removal to ensure water quality for 70% of the population of Ukraine.*
Keywords: *water purification, phytoplankton, cyanobacteria.*

1. Introduction: Problems with traditional water treatment technologies

Surface water treatment technologies in Ukraine are based on developments from the 1950s–1970s: water intake, primary chlorination, coagulation with aluminium salts, sedimentation/filtration, chlorine disinfection. They are effective against inorganic suspensions and bacterial pathogens (dysentery, cholera), but limited for organic contaminants:

- Slightly turbid coloured waters (fulvates) cause problems with decolourisation and manganese, especially in winter.
- The growth of the organic component requires excessive doses of chlorine / coagulant, which leads to organochlorine compounds (chloroform), allergens, and carcinogens.
- Ineffective against chlorine-resistant pathogens (hepatitis, tuberculosis) and phytoplankton.

2. Factors affecting water quality in surface sources

2.1. Climate change

- Increase in average annual temperature, lengthening of the warm period (Fig. 1).

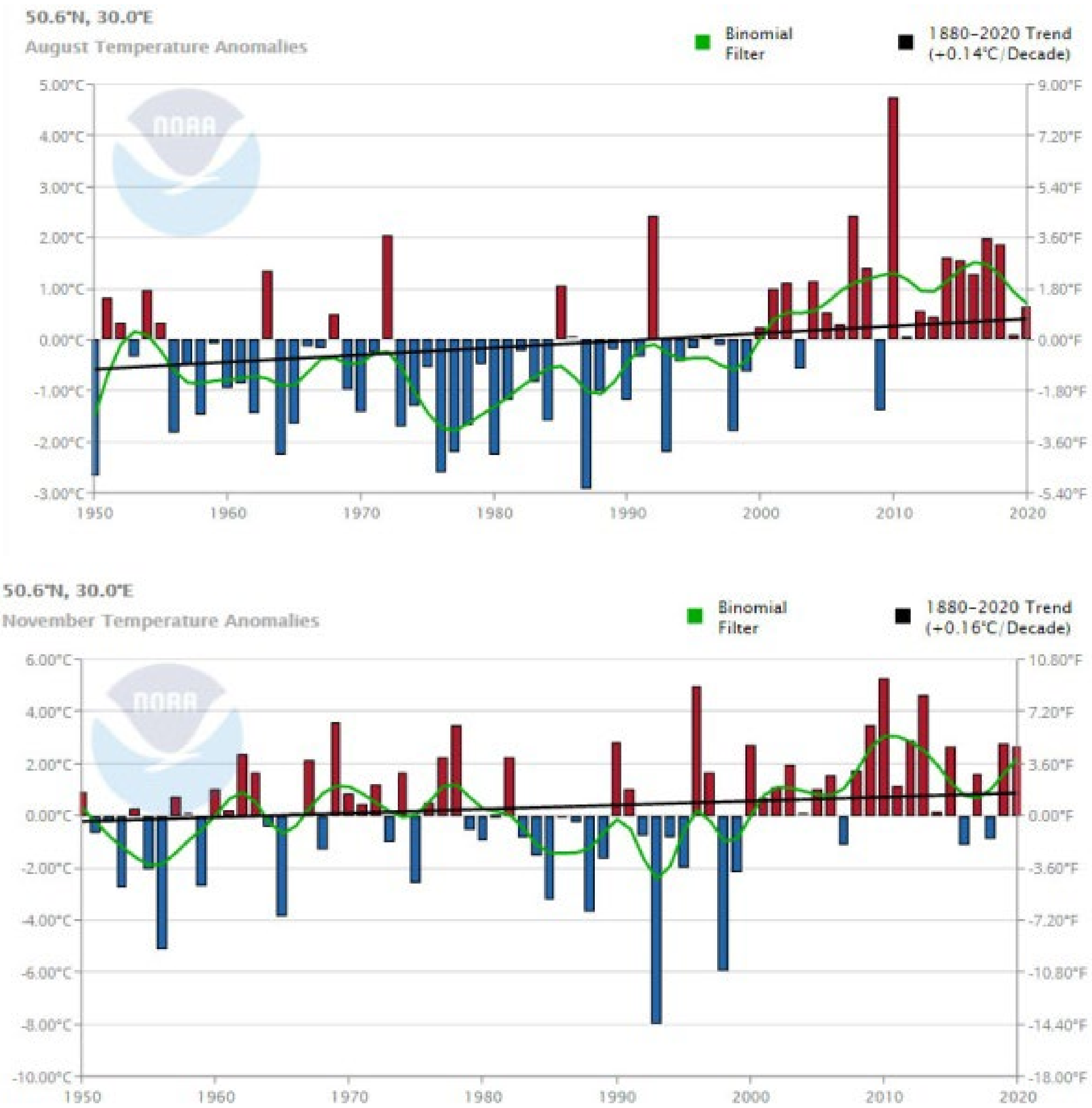

Fig. 1. Surface temperature anomalies for August and November from 1950 to 2020, according to data from NOAA's National Centre for Environmental Information (NCEI) https://www.ncdc.noaa.gov/cag/global/time-series/50.56791997,30.4902792/land_ocean/1/11/1950-2020?trend=true&trend_base=10&begtrendyear=1880&endtrendyear=2021&filter=true&filterType=binomial.

- Decrease in precipitation, droughts (5–7 years), desertification spreading towards Kyiv.
- Decrease in river water content, drying up of wells; catastrophic rainstorms.
- Dnipro reservoirs as water accumulators, but with deterioration in quality (silting, anoxia)

2.2. Anthropogenic factors

- Reduction in wastewater discharges, but increase in biogenic substances (phosphates) from fertilisers, detergents, and sewage treatment plants.

- Screening monitoring of the Dnipro basin (2020): exceedance of MPCs for herbicides (terbuthylazine, nicosulfuron), fungicides (carbendazim), pharmaceuticals (carbamazepine, lopinavir).

- Microplastics as centres of cyanobacterial aggregation.

2.3. Phytoplankton bloom

- Exponential growth of biomass (Fig. 1): from 3 million tonnes (2013) to >10 million tonnes in the Kremenchuk Reservoir.

- Dominance of cyanobacteria (blue-green algae): 80–90% of phytoplankton.

- Extension of the activity period: June–November.

- Cyclicality: peaks every 4–5 years (Fourier spectral analysis), growth of 10–49%.

- Forecast: 78,328–99,327 cells/cm³ (average), peaks up to 175,874 cells/cm³.

Water quality formation scheme: consumption of biogens, accumulation of toxins, post-mortem decomposition → anoxia, metal leaching, silting.

3. Health and water supply implications

- Increase in cyanobacterial species diversity → competition → microcystins (hepatotoxins, allergens).

- Microcystins are resistant to chlorination; exceedance of standards (EPA: 0.3–1.6 μg/dm³ for children).

- Symptoms: skin rashes, gastrointestinal disorders, liver damage, respiratory problems (example: Toledo, USA, 2014 – water shut-off for 500,000 people).

- Risk for 70% of Ukraine's population (Dnipro and tributaries).

4. Promising areas for the development of water treatment systems

Structures need to be renovated (they have reached the end of their service life, and reducing water consumption by 60–70% allows physical, chemical and biological methods to be combined).

4.1. New reagents

- Chlorine dioxide (ClO_2): oxidation without organochlorine compounds, effective against phenols, microcystins, chlorine-resistant microbiota; prolonged action.

- Mechanism: atomic oxygen (analogue of ozone, hydrogen peroxide), but with an aftereffect.

- Limitations: growth of chlorites at high organic content (>0.2 mg/dm³ according to DSanPiN).

- Application: after phytoplankton removal to avoid excessive costs.

4.2. Phytoplankton removal methods

- Monitoring and selective water sampling (variable concentration by depth/area).

- Flotation, membrane filtration or biological treatment at existing facilities.

- Combination with slow filtration for biocenosis.

4.3. Recommendations

- Integration of ClO_2 into the chain after preliminary treatment.

- Research on microplastics and pharmaceuticals.
- Forecast: implementation within 5–7 years to avoid a water supply crisis.

Conclusions Global changes are transforming phytoplankton into a key factor in water quality in Ukraine. Traditional technologies need to be modernised with a focus on removing organic matter and toxins. The use of ClO_2 and the reconstruction of facilities will ensure sustainable water security.

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