The Tiete, Sao Paulo State's main river, is filtered by dam reservoirs

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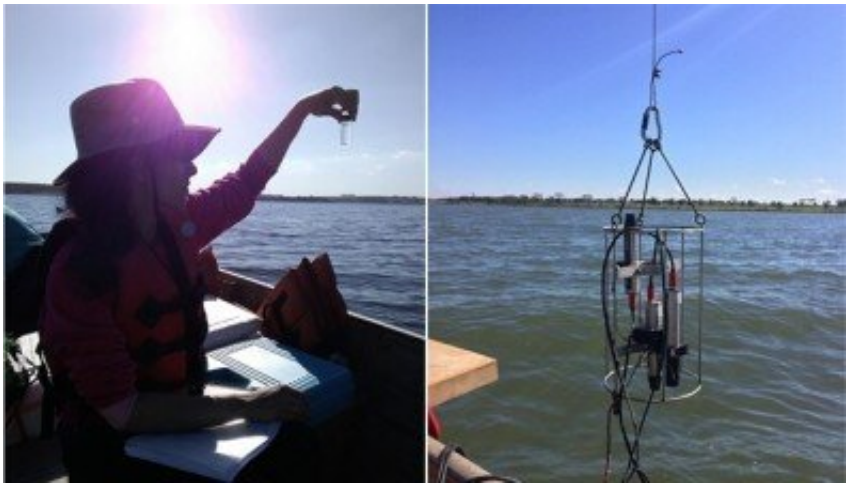

Scientist Naiane Bernardo [left] in fieldwork; equipment used to measure radiances and irradiances [right]. Reservoir cascade steadily improves water transparency by retaining matter in suspension that affects light absorption
Credit: Naiane Bernardo

In São Paulo City, Brazil, the Tietê River is polluted by a vast amount of waste, mainly domestic sewage, but the farther it runs into the interior, the better the quality of its water becomes. It is much less murky at Barra Bonita, 294 km from São Paulo, and transparent at Buritama (546 km).

A study by Brazilian researchers at São Paulo State University (UNESP) in Presidente Prudente and São José dos Campos shows that this change

in water quality as the river crosses the state is due to filtration by a series of dams along the way. The 1,100 km Tietê rises near the coast, passes through the state capital and flows on to São Paulo's western border, where it joins the Paraná, a tributary of the Plata. The Barra Bonita reservoir retains part of the algae that feed on nitrogen and phosphorus in the sewage. With fewer of these organisms, the river flows through the turbines and on to the next set of dams, where it is filtered again.

As the study shows, filtration of the Tietê by this series of dams allows more light into the water, which is oxygenated and converts more organic matter from pollutants into inorganic matter, eventually becoming transparent. The results were published in the journal *Water*.

"We demonstrate that Tietê water quality steadily improves thanks to this reservoir cascade, with exposure to pollution from domestic sewage decreasing as the river flows away from the state capital," said Enner Herênio de Alcântara, a professor at UNESP in São José dos Campos and one of the authors of the study.

"From one reservoir to the next, the composition of the organic and inorganic matter in the river changes. This affects light absorption in each reservoir," Alcântara told.

The researchers analyzed the light absorption characteristics of the water in four of the six reservoirs that comprise the Tietê dam cascade: Barra Bonita, Bariri, Ibitinga and Nova-Avanhandava. These reservoirs account for more than 90 percent of the hydropower generated by the cascade.

Chemical composition and turbidity vary in accordance with the type of contamination. Barra Bonita and Bariri are eutrophic—full of algae, hypoxic and murky. Ibitinga (349 km from São Paulo City) is

mesotrophic, hosting a medium amount of vegetation and with moderately clear water. Nova-Avanhandava reservoir at Buritama is oligotrophic, with low algal production and transparent water.

The researchers analyzed water samples collected during fieldwork to measure the levels of organic and inorganic particulate matter.

Their findings show that Barra Bonita reservoir contains a large volume of algae (phytoplankton), while high levels of dissolved organic carbon are characteristic of Bariri and Ibitinga. These two reservoirs also displayed high variability of particle composition between organic and inorganic within any given year, depending on the period, in accordance with changes in light absorption measured during the analysis. Inorganic matter—minerals and non-carbonated compounds—predominates in the downstream portion of Nova Avanhandava.

These materials absorb light at different wavelengths. Absorption varies in intensity depending on the concentration of optically active components present in the water. As well as absorbing light, they also scatter it. The balance between the amount of light absorbed and the amount scattered by these materials is reflected in the variations in the color of the Tietê's water.

Phytoplankton, for example, absorb more energy in the blue and red wavelengths, and much less in the green, causing more scattering at this wavelength. This is why the water in reservoirs with large amounts of phytoplankton is dark green, the researchers explained.

"We found that the reservoirs' total light absorption capacity reflected the level of pollution fairly accurately. The vigorous phytoplankton growth due to intense eutrophication interfered most with light absorption in the reservoirs closest to São Paulo, for example," Alcântara said.

Satellite monitoring

The results of the study will contribute to the development of new mathematical and statistical models that can be used to estimate and monitor water quality in the Tietê cascading reservoir system via satellite imaging, Alcântara added.

Because of the variability of light absorption in these reservoirs, a mathematical model has yet to be developed to assure precise measurement of water quality parameters for the entire system.

"The reservoirs contain high levels of pollution, with large amounts of aquatic plants, for example, so the signals recorded by the sensor on Landsat-8 in space become saturated. As a result, the model eventually falters and supplies incorrect information," he explained.

Landsat-8 is the eighth satellite in the NASA-USGS Landsat Earth observation program, and the seventh to reach orbit successfully. The on-board sensor for its Operational Land Imager (OLI) enables it to record images at different wavelengths.

The organic and inorganic materials present on or near the reservoir surface reflect solar radiation back to the sensor at specific wavelengths. As a result, their distribution in the reservoir can be estimated using these images.

When the mathematical model for variations in light absorption is applied to the surface reflectance parameters obtained from the images, it is possible to estimate the levels of organic and inorganic matter in the water, and hence its transparency.

"The Landsat program has produced images since the 1970s. Once we've validated the mathematical model developed by our group, we'll be able

to obtain water quality indicators for the entire Tietê reservoir system in the past 40 years or so," Alcântara said.

"On this basis it will be possible to understand the process of deterioration in the Tietê's water quality during recent decades."

More information: Nariane Bernardo et al, Light Absorption Budget in a Reservoir Cascade System with Widely Differing Optical Properties, *Water* (2019). DOI: 10.3390/w11020229

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