

COEH PROJECT FINAL REPORT:
Public Health Impacts of the Three Gorges Dam:
A Preliminary Survey of Cyanobacteria in the Three Gorges Dam Reservoir
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ABSTRACT

Water quality monitoring was initiated during the summer of 2005 to evaluate the presence of cyanobacteria and their associated toxins in the Three Gorges Dam Reservoir in Central China. We conducted sampling at seven locations along the 700-kilometer reservoir during an initial reconnaissance tour. Samples were analyzed for algae, nutrients, temperature, nutrient concentrations, dissolved oxygen, transparency, pH, turbidity, and conductivity. Later two locations were identified for intensive sampling. These locations in Wanxian and Yunyang became our long-term sampling sites, which we continue to monitor for temporal and spatial changes in water quality. Although the cyanobacterium, *oscillatoria*, was identified in the reservoir, its population is low and no visible scums or blooms of blue-green algae were seen. It was therefore deemed unnecessary to measure toxin concentrations, however the project documented numerous pathways for human exposure in the communities that would pose health risks if cyanobacteria proliferate in this water that is used for recreation, fishing, and drinking. Measured water quality parameters were typical of a eutrophic lake where cyanobacteria have a competitive advantage. The fact that these organisms are not yet creating nuisance blooms may indicate the presence of other water quality contaminants, which may also be of human health concern.

PROBLEM DESCRIPTION

The construction of the Three Gorges Dam is altering the hydrology and ecology of the Yangtze River basin in a myriad of ways. Many of these impacts pose potential threats to public health, yet minimal attention has been given to monitoring, quantifying or remediating these health impacts. The World Health Organization has recommended that Health Impact Assessments be conducted for all new dams, yet only a few hydropower development projects have incorporated this into their planning phase. The creation of the Three Gorges Dam reservoir will prevent the dilution of contaminants that were traditionally washed downstream and into the sea. Their pooling and concentration in the reservoir could highly contaminate fish as well as drinking water. Elevation of nutrients (e.g. nitrogen and phosphorous), reduction in stream flow, and elevation in water temperature are all consequences of dam construction and all contribute to eutrophication and the enhanced growth of cyanobacteria.

Cyanobacteria or blue-green algae produce toxic compounds referred to collectively as cyanotoxins. For humans, exposure to cyanotoxins via drinking water, contact, inhalation and consumption of fish result in liver damage, gastro-intestinal disorders, and neurological impacts [1, 2]. Cyanotoxins include hundreds of variants of nine main toxin groups (see Appendix A, Table A-1) produced by cyanobacteria (also called blue-green algae). Both epidemiologic and toxicological studies have also linked chronic low dose exposures to cyanotoxins with the promotion of liver tumors [3-5]. Although cyanotoxins occur naturally, their prevalence and abundance are, to a large extent, influenced and increased by human action. Anthropogenic modification of the natural environment can cause tremendous changes to the hydrology and water quality of a river, which in turn can lead to eutrophication and proliferation of cyanobacteria. In China's Yangtze River watershed changes precipitated by the construction of the Three Gorges Dam have the potential to promote cyanobacterial growth and induce public

exposure to their toxins. This pilot project collected water samples in China's Three Gorges Dam reservoir to provide baseline data on the presence of cyanobacteria and cyanotoxins in the water and the water quality parameters that affect their growth. Continued evaluation of temporal changes in human health exposure to these contaminants as a result of the dam is ongoing.

Historically the strong stream flow in the Yangtze River has mediated the impacts of extensive water pollution [6]. The completion of the Three Gorges Dam, however, has reduced the river's water velocity. The resulting elevation in water temperature and increased concentrations of organic material and nutrients in the growing reservoir are important variables in the promotion of cyanobacterial growth. Concomitant land use shifts may also result in new agricultural development, which could further raise nutrient levels in the water due to fertilizer input.

METHODS

The size of the Three Gorges Dam Reservoir (700 km in length when flooding is completed) prevents our ability to fully characterize it. Initially we traveled from its western end in Chongqing (~700 km west of the Three Gorges Dam) to just east of the dam in Yichang (located just east of the dam). Water samples were collected and analyzed from seven different locations as we evaluated variability in nutrient levels, turbidity, conductivity, pH, transparency, water temperature, water uses, and water access in order to choose a long term sampling location. Visual inspections for discoloration and scum formation, and for transparency with the use of a Secchi disc were also carried out along the course of this tour. The only visible algae scum was identified at the actual dam as well as in Yunyang. Based on these data from the reconnaissance site tour, we selected two longer-term sampling locations: Yuyang and Wanxian.

We collected samples from 12 and 15 sites respectively at Yunyang and Wanxian that were approximately 100 meters apart in distance. In Yunyang, these sampling sites occurred on either side of the drinking water withdraw pump. Figure 1 shows these sites overlaid on a Landsat TM satellite image from 2000.³ The sampling sites included both shores as well as the middle of the reservoir. At each location (Yunyang and Wanxian) the sites are spread out over a section of the reservoir that is roughly 500x200 m².

For all samples, temperature, dissolved oxygen, turbidity, pH and conductivity were measured. Cyanobacteria were identified and quantified (cells/volume) under a microscope (400x) after preservation with Lugol's solution. Samples were also analyzed for reactive phosphorus, nitrate, and chlorophyll-a. The analytical methods are described briefly below. If cyanobacterial surface blooms were visible or if cyanobacteria cell counts exceeded 10,000 cells/ml⁴, a sample would also have been analyzed for microcystin. Since these conditions were not met, microcystin analysis was not conducted.

³ As this image is from before the construction of the dam, the full extent of the water is not reflected. This is the most recent satellite image available for free, but continued funding of this project will allow the purchase of current images from the dates when sampling occurs.

⁴ This cell concentration was chosen to fall below the current WHO guideline levels for health hazard alerts under which 100,000 cells per milliliter constitutes a moderate risk level (WHO 2003).

Sample Handling and Storage

All samples were kept in a cooler until they reached the lab, where they were transferred to a refrigerator. Sampling bottles/whirl-pak bags were kept in black plastic bags to prevent exposure to sunlight.

Phosphorus Analysis

Reactive phosphorus was measured spectrometrically by digesting the soluble phosphorus to orthophosphate and then inducing the reaction to form the strongly colored blue molybdenum complex. A handheld field spectrophotometer (HACH colorimeter 890) was used to measure the absorbance of distilled water blanks, calibration solutions, and the sampled water.

Nitrate Analysis

Similar to the phosphorus analysis, nitrate was measured spectrometrically by reacting sulphosalicylic acid with the nitrate to form a yellow compound.

Chlorophyll a Analysis

Measurement of the concentration of chlorophyll *a* can be used as an estimate of phytoplankton biomass. It overestimates the biomass of cyanobacteria when other phytoplankton populations are also present. The cells were first separated from the water by filtration. They were then ground and left in ethanol for 24-48 hours, the cellular material was separated by centrifugation, and the absorbance of the supernatant was read with a spectrophotometer.

Multiple measurements were run for all samples to attain the mean values, thus minimizing variance due to measurement error.

FINDINGS AND RECOMMENDATIONS

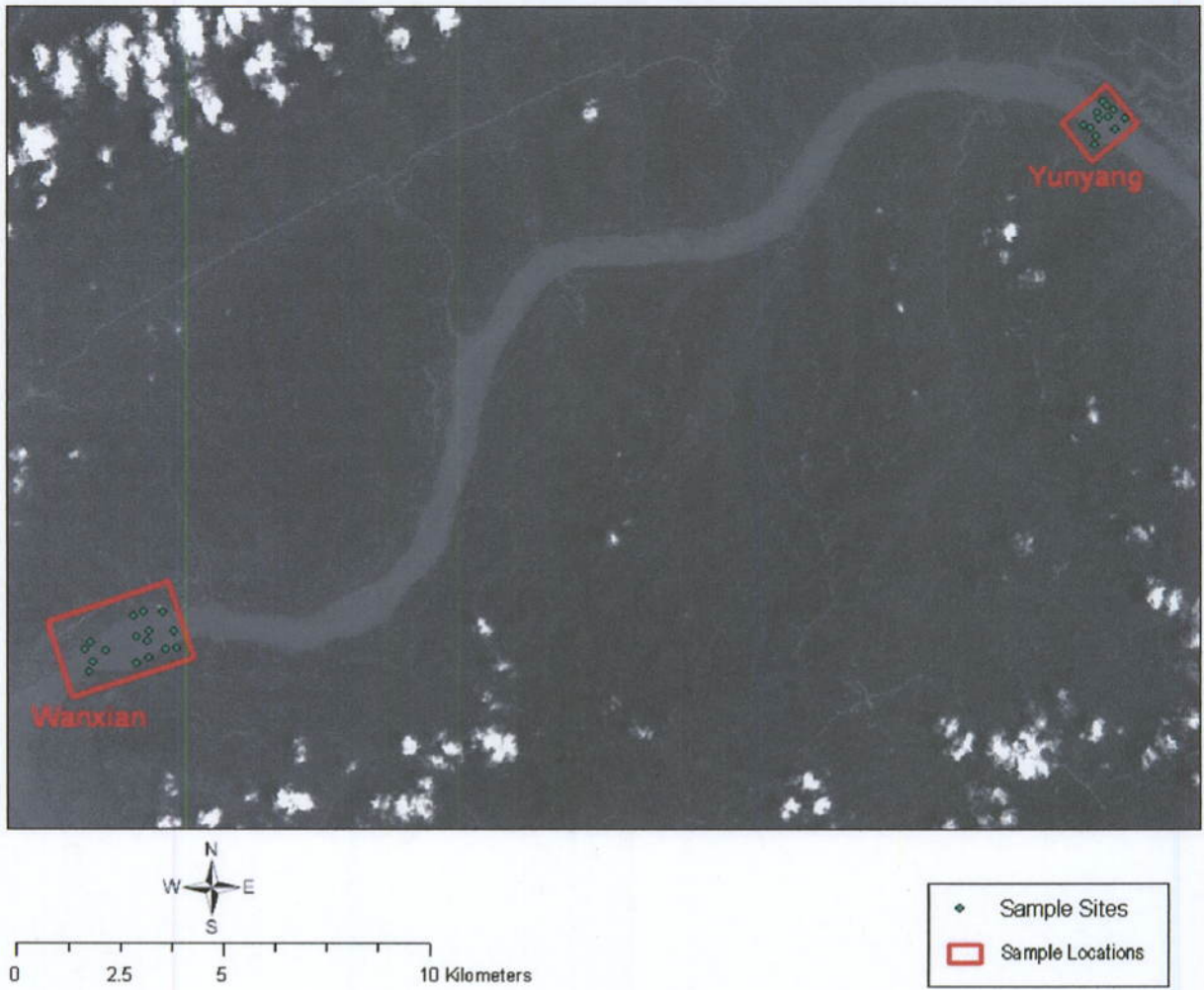
Yunyang County has one of largest land areas being submerged in the region. It has a population of 1.23 million of which approximately 120,000 have been relocated. Currently the entire population of Yunyang County receives its drinking water from the Yangtze River. In addition the water is used for swimming most of the year, for washing clothes and for fishing, all of which result in water contact and thus potential exposure to cyanotoxins. In addition to drinking water and contact, fish consumption may also result in exposure to cyanotoxins if and when they are present. This project was initiated with the hypothesis that exposure to cyanotoxins in the reservoir would be one of the many potential human health risks resulting from the construction of the Three Gorges Dam.

This pilot project confirmed the potential for health risks from cyanotoxins and has generated new hypotheses regarding water quality trends in the reservoir. The Pacific Rim Research Program and the C.C. Chen Fellowship have funded this project to continue monitoring through the summer of 2007. Publication of detailed data and findings is hoped to be forthcoming.

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Figure 1: Sample Sites at each Sample Location



On board fishing boats rented to collect samples in reservoir



Scenic vistas in the Three Gorges area

