Does the “Fish Habitat Flows and Water Rights Project”, EIR (dated 8/19/16) adequately represent the threat of cyanotoxins in Russian River?

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Introduction:

In response to a National Marine Fisheries Service published Biological Opinion (BO) dated Sept. 24, 2008, the Sonoma County Water Agency (SCWA) has proposed changes to the regulation of Russian River water flow that are proposed to be enacted by 2017. The water agency released an environmental impact report (EIR) on Aug. 19th 2016 that describes the rationale and potential impacts of these river flow changes.

In section 4.2-4 of the EIR, SCWA states that “Changes to minimum instream flows could result in a violation of water quality standards or waste discharge requirements or otherwise degrade water quality relating to biostimulatory substances in the Russian River” that are “(Significant and Unavoidable)”. In addition, SCWA stated that “High concentrations of biostimulatory substances including nitrogen, phosphorus, and algae (chlorophyll-a) could have a negative effect on water quality in the Russian River, including the Estuary. High levels of nutrients can contribute to excessive algal growth in river and streams, causing nuisance conditions which can affect dissolved oxygen, pH, and temperature and the overall quality of aquatic habitat. Excessive algal growth can affect the aesthetics of the river negatively impacting contact and non-contact recreation. <u>Excessive algal growth can also contribute to the proliferation of blue-green algae, which in turn can pose a risk to contact recreation through the release of cyanotoxins into the water column.</u>” and that “There is no simulation model available for the Russian River that can adequately simulate algal biomass or nutrient and chlorophyll-a concentrations under a range of different flows.”

The purpose of this report is to challenge the assumption that the impact of lower flows on water quality and specifically to the prediction of the concentration of cyanotoxins as a function of river flow, water temperature, and high ambient air temperature cannot be predicted. This report describes a simulation model for 2015 and 2016 that accurately predicts the observed concentrations of anatoxin-a in the Russian River below the merge between Dry Creek and the Upper Russian River.

Biological Significance of Cyanotoxin Pollution:

“In August of 2009, a series of dog deaths occurred along the South Umpqua River in Douglas County, Oregon. One of those deaths was confirmed to be the result of exposure to a toxin produced by certain genera of photosynthetic cyanobacteria, also called blue-green algae. The deceased dog’s stomach contents contained 10 μg/L anatoxin-a. In August of 2010, another dog death was confirmed to be caused by exposure to anatoxin-a. This dog, a healthy six month old black Labrador retriever, was vomiting, staggering, and convulsing within 10 min of drinking and playing in water from an isolated pool along the banks of the same stretch of the South Umpqua River and was dead within an hour. The treating veterinarian reported that her hands were “burning” after handling the dog’s body [1].

On Aug. 29rd 2015 a dog died from anatoxin-a poisoning as a result of drinking water from the Russian River north of Wohler Bridge (Press Democrat Article 9/3/2016). Anatoxin-a is one of three types of cyanotoxin found in the Russian River during 2015 and 2016. It is produced by cyanobacteria associated with blooms of blue-green algae. Anatoxin-a is a neurotoxin that strongly inhibits the acetylcholine nicotinic receptor at the neuromuscular junction in skeletal muscle which is responsible for coordinated movement and breathing. Anatoxin-a poisoning is characterized by skin tingling, burning, and numbness, drowsiness, incoherent speech, and respiratory paralysis leading to death [2]. The other two types of cyanotoxin found in the Russian River and many other locations in California are known to be hepatotoxic. According to the California Department of Fish and Wildlife (CDFW) Water Pollution Control Lab (WPCL) report, these other two cyanotoxins are microcystin and cylindrospermopsin. This report will focus on the environmental factors along the Russian River that can be included in a simulation model to predict the daily concentrations of anatoxin-a.

Tolerable Daily Limits and Allowable Anatoxin-a concentrations

In the absence of federal criteria for cyanotoxins in recreational water, the Oregon Health Authority (OHA) developed guideline values for the four most common cyanotoxins in Oregon's fresh waters (anatoxin-a, cylindrospermopsin, microcystins, and saxitoxins). OHA developed three guideline values for each of the cyanotoxins found in Oregon. Each of the guideline values is for a specific use of cyanobacteria-affected water: drinking water, human recreational exposure and dog recreational exposure [1]. Table 2 was copied from the work of Farrer and lists the tolerable daily limits of several cyanotoxins.

Table 2. Summary of Oregon's tolerable daily intakes and guideline values for four cyanotoxins for use in acute or short-term exposures.

Guideline value	Anatoxin-a	Cylindrospermopsin	Microcystin	Saxitoxin
Human TDI (μg/kg-day)	0.1	0.03	0.05	0.05
Dog TDI (μg/kg-day)	None—used human TDI	None—used human TDI	None—used human TDI	0.005
Drinking Water (μg/L)	3.0	1.0	1.0	1.0
Recreational Water (μg/L)	20.0	6.0	10.0	10.0
Dog-specific (μg/L)	0.4	0.1	0.2	0.02

Since the molecular target of these environmental toxins is common to all mammals the toxic effect will depend on the dose (what volume of water is consumed and at what concentration of toxin) and the physiology of the animal or human (body weight, etc .). According to OHA and the Farrer article, the tolerable daily intake (TDI) for humans (and dogs) is 0.1 ug/Kg body weight per day. A bloom of blue-green algae resulting in anatoxin-a concentration of 48.9 μg/L (as occurred at Steele Beach on Sept. 21st 2015), then a typical glass of water (250 mL or 1/4 of a liter) would have 12 μg of anatoxin-a. If the TDI is 0.1 μg/Kg then a human (70 Kg) would tolerate 7 μg but a dog (10 Kg) would only tolerate 1 μg. So the dog dose would be 10 times the tolerable limit set by the Oregon Health Authority. In the case of a small river otter (body weight = 5 Kg) then the tolerable limit would only be 0.5 μg. So on Sept. 21, 2015 it would be recommended that the otter should not to drink more than 0.01 L (~ 2 teaspoons) of river water.

Environmental Factors that Influence the Production and Degradation of Cyanotoxins

Basic research on cyanobacteria suggests that they will thrive under the conditions predicted for global climate change [3]. Anatoxin-a was first detected in the Russian River in August of 2015 and as such represents a newer subject of environmental concern that may not have been adequately studied in the EIR. The subject of cyanotoxins is only mentioned twice in the entire 3602 pages of the EIR and anatoxin-a is never once mentioned. This is a serious deficiency in the EIR and represents an important reason to immediately halt the implementation of lower flow recommendations until these issues can be mediated.

Cyanotoxin production is thought to be influenced by a number of different physical and environmental parameters, including nitrogen, phosphorous, trace metals, growth temperature, light and pH [4]. Conditions that can contribute to blue-green algae blooms, include decreased water flow and decreased water mixing, elevated water temperature, and the presence of excess nutrients (Draft Voluntary Statewide Guidance for Blue-Green Algae Blooms – July 2010 from the Blue Green Algae Work Group of the State Water Resources Control Board (SWRCB), the California Department of Public Health (CDPH), and Office of Environmental Health and Hazard Assessment (OEHHA)). As water temperatures approach and exceed 70 deg. F, the growth rates of normal freshwater algae generally stabilize or decrease while growth rates of many cyanobacteria increase, providing a competitive advantage [3]. It only makes sense that increased river flow will result in dilution of any cyanotoxins produced resulting in lower concentrations than would be found at lower flows. The SCWA concluded that appropriate models to predict cyanotoxin concentration are not available and therefore the impact might be significant but cannot be avoided. Finally, anatoxin-a degrades readily, especially in sunlight and at high pH, to nontoxic degradation products such as the stable alkaloid dihydroanatoxin-a [5].

Development of a Simulation Model for Anatoxin-a in Russian River

Data for daily flow in cubic feet per second (cfs) along the Russian River at Hacienda (HAC) was obtained for the years 2012 to 2016 from the California Department of Water Resources, California Data Exchange Center (http://cdec.water.ca.gov). There was missing data for some days due to flow being below the lower limit of the flow gauge range. In those cases the flow was averaged from data one day before and one day after the missing values. In August of 2015, several days in a row had missing flow data and in those cases the model assumed 50 cfs. Data for ambient air temperature was collected from historical values found at the web site "Weather Underground" (https://www.wunderground.com). Data for Russian River water temperature measured near Guerneville, CA was collected from the United States Geological Survey National Water Survey Information System (http://nwis.waterdata.usgs.gov). Data for the measured concentrations of anatoxin-a during 2015 and 2016 was obtained from multiple sources. First, a web site developed by Stephanie K. Baer (a reporter for many Southern California news outlets) in June of 2016 (http://projects.sgvtribune.com/blue-green-algae/) provides an interactive map of California with geographical locations and cyanotoxin levels for many lakes and streams. In addition, the author of this report obtained the original source data for cyanotoxin locations and levels measured by the California Department of Fish and Wildlife (CDFW) Water Pollution Control Lab (WPCL) and the US EPA. Finally, the cyanotoxin concentrations measured in 2016 were obtained from the Sonoma County Department of Health Services blue-green algae information website (http://www.sonoma-county.org/health/services/bluegreen.asp).

This data was compiled in a MS-Excel spreadsheet and plotted in order to observe the basic trends and relationships in river flow, water temperature, high air temperature, and anatoxin-a concentrations. It was hypothesized that anatoxin-a levels would increase as river water temperature increased, decrease as river flow increased, and would decrease as sunlight and UV radiation increased. The influence of sunlight was represented by the daily high ambient air temperature. A simple ordinary differential equation (Eqn. 1) for the rate of anatoxin-a concentration as a function of time was developed.

$$\frac{dAnatoxin}{dt} = +(Kform * WaterTemp) - (Kdeg * HighAirTemp) - (Kflow * HACFlow)^{N} \qquad \text{Eqn. 1}$$

Where:

Kform = rate constant for formation of anatoxin-a

WaterTemp = Russian River water temperature (deg. F) near Guerneville, CA

Kdeg = rate constant for degradation of anatoxin-a
HighAirTemp = daily high ambient air temperature (deg. F) near Rio Nido, CA
KFlow = rate constant for the influence of river flow at Hacienda (HAC)
HACFlow = Russian River flow (cfs) at Hacienda (HAC)
N = exponent for the relationship of *KFlow* time river flow.

Parameter estimates used for the following figures are:
Kform = 0.17 day^{-1}
Kdeg = 0.022 day^{-1}
Kflow = 4900 day^{-1}
N = 0.1815

Results:

Figure 1 shows the variables assumed to be important in predicting the anatoxin-a concentrations along with bars for the sparse data available for the observed levels of anatoxin-a during 2015 and 2016. In addition, a solid line for the simulation model predictions for daily anatoxin-a concentration is shown.

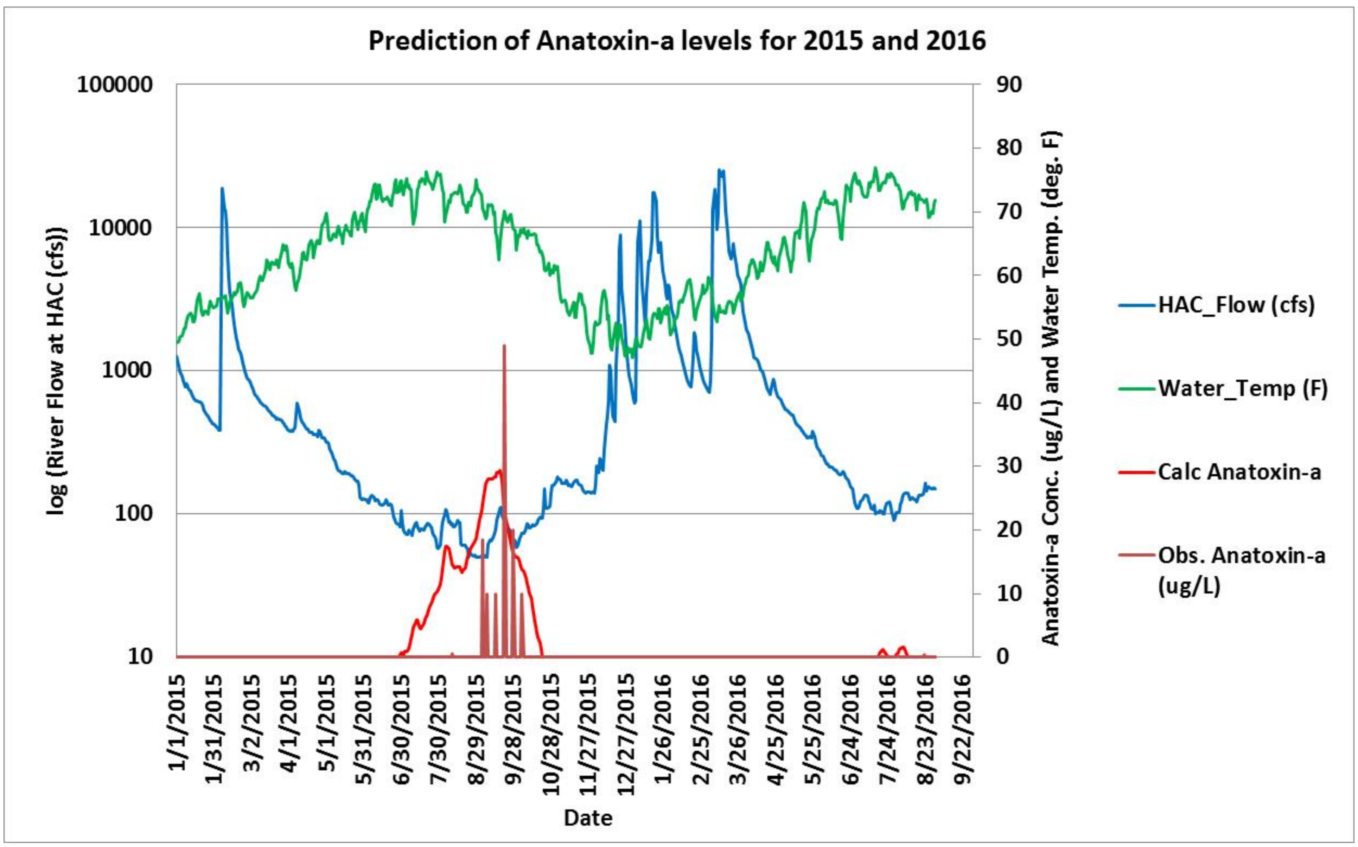

Figure 1. Daily predicted and observed anatoxin-a concentrations for 2015 to 2016. The right hand axis represents the log of the river flow at HAC (cfs) and is shown as the blue line. The left hand axis is tied to both anatoxin-a concentration and water temp. The observed anatoxin-a concentrations (μg/L) for 2015 and 2016 are shown as brown spikes along with observed water temperature (solid green line, in deg. F). The simulation model predicts anatoxin-a concentration (μg/L) (shown as a solid red line) for 2015 and 2016.

One can easily see from Fig. 1 that the combination of high water temperature and low river flow results in a bloom of blue-green algae and production of higher levels of anatoxin-a in the Russian River. A low level of anatoxin-a was measured in an algal-mat collected near Rio Nido on August 10th 2015. The predicted concentrations for that time period exceed that measured value by a wide margin. However, since this was the earliest date that anatoxin-a was detected and a regular program of sampling was not in place it is possible that higher concentrations were in the river but just not detected.

Figure 2 shows the results of a simulation for the years from 2012 to 2014 indicating that much lower levels of anatoxin-a would have been expected to be formed due to the higher river lows during that time. It's impossible to know if those levels were in the river at that time since no data was collected in those years and the predicted levels are low enough that toxic effects on animals and humans may not have been detected.

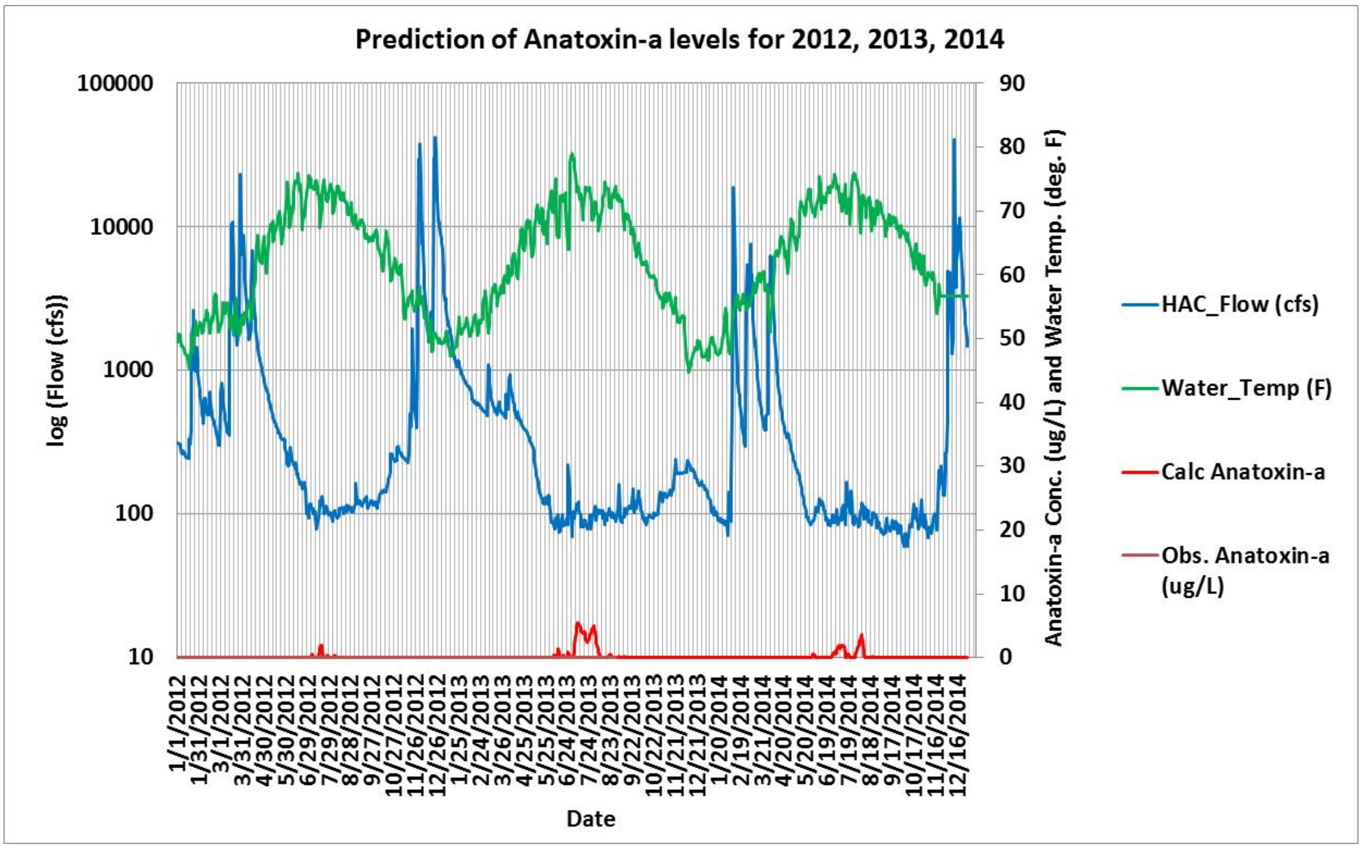

Figure 2. Daily predicted and observed anatoxin-a concentrations for 2012 to 2014. The right hand axis represents the log of the river flow at HAC (cfs) and is shown as the blue line. The left hand axis is tied to both predicted anatoxin-a concentration and water temp. Anatoxin-a was not measured in 2012 to 2014. Water temperature is shown as a solid green line, in deg. F. The simulation model predicts anatoxin-a concentration ($\mu g/L$) (shown as a solid red line) for 2012 to 2014.

As seen in Fig. 2, the river flows from 2012 through 2014 rarely went below 100 cfs and the predicted anatoxin-a concentrations are quite low and would not be expected to produce toxic effects in animals or humans.

Figures 3, 4, and 5 show the 2015 and 2016 predicted anatoxin-a levels if we keep all the same water temperature and air temperature data but simply substitute the proposed lower "Fish Flow" proposals from May 1st through October 15th for levels 1to 3, 4, and 5 of hydrological drought categories.

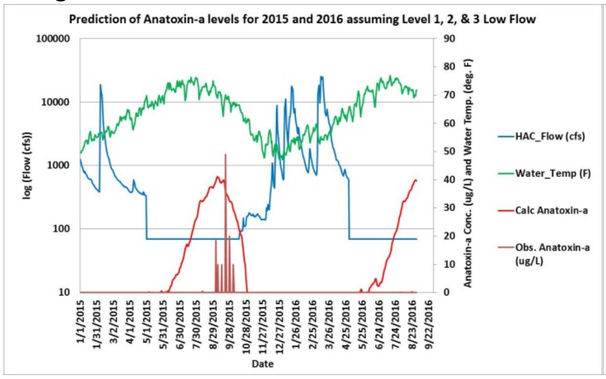

Figure 3

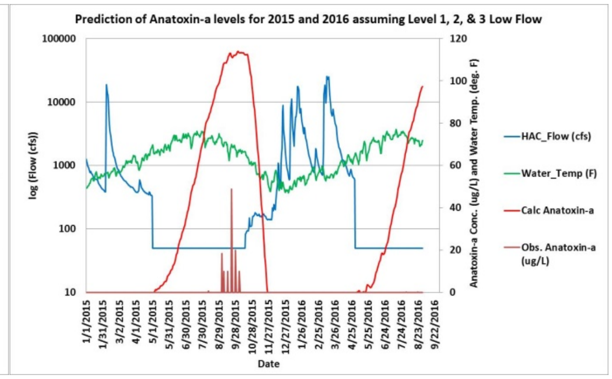

Figure 4.

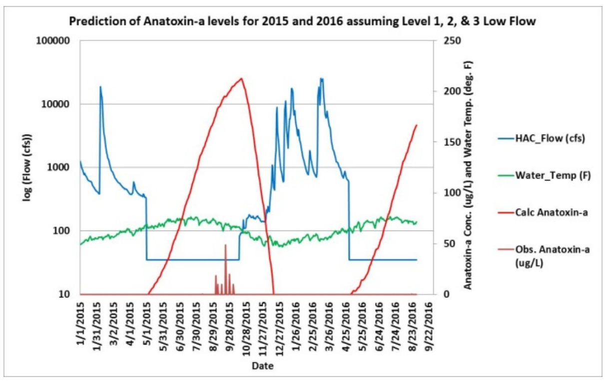

Figure 5.

Of course these predictions would be the worst possible scenario if the recommendations in the EIR are enacted since the river flows in May and June are usually higher than the minimum flows represented by Level 1,2, and 3 (70 cfs), Level 4 (50 cfs), and Level 5 (35 cfs). However, it is clear from this simulation model that the SCWA should consider this type of scientific simulation tool in conjunction with their recommendations for lower river flows to prevent the harmful effects in animals and humans.

Summary and Conclusions:

This study reveals a glaring deficiency in the SCWA draft EIR with regard to the prediction of cyanotoxin levels due to the proposed lower Russian River flows. The SCWA has neglected to discuss the growing problem and significance of this type of water quality degradation. The physiological consequences of exposure to high levels of cyanotoxins in river water cannot be ignored. Data was collected and used to build a simulation model to predict the concentration of anatoxin-a as a function of river flow, water temperature, and ambient air temperature. The simulation model was able to accurately estimate the observed anatoxin-a levels measured in 2015 and 2016. Finally, the consequences of implementation of the recommendations in the Biological Opinion to lower the minimum river flows were simulated and show alarming high predicted anatoxin-a concentrations. It is recommended that the Sonoma County Board of Supervisors **do not proceed to implement the lower**

flow recommendations until the impact of this new toxic threat can be mitigated. I'd be pleased to meet with SCWA scientists on the development of this model.

References:

1. Farrer, D., Counter, M., Hillwig, R., and Cude, C. Health-based cyanotoxin guideline values allow for cyanotoxin-based monitoring and efficient public health response to cyanobacterial blooms, Toxins (Basel), *7:* 457-477, 2015.
2. Boopathi, T. and Ki, J. S. Impact of environmental factors on the regulation of cyanotoxin production, Toxins (Basel), *6:* 1951-1978, 2014.
3. O'Neil, J. M., Davis, T. W., Burford, M. A., and Gobler, C. J. The rise of harmful cyanobacteria blooms: The potential roles of eutrophication and climate change, Harmful Algae, *14:* 313-334, 2012.
4. Neilan, B. A., Pearson, L. A., Muenchhoff, J., Moffitt, M. C., and Dittmann, E. Environmental conditions that influence toxin biosynthesis in cyanobacteria, Environ Microbiol, *15:* 1239-1253, 2013.
5. Osswald, J., Rellan, S., Gago, A., and Vasconcelos, V. Toxicology and detection methods of the alkaloid neurotoxin produced by cyanobacteria, anatoxin-a, Environ Int, *33:* 1070-1089, 2007.