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Subject: Impacts of Nutrients on Drinking Water Supplies

At the December 3, 1997, Parameter Assessment Team (PAT) meeting, the PAT considered a proposal to add phosphorus and nitrogen as environmental parameters of concern, and discussed the impacts of nutrients on beneficial uses in the Bay-Delta watershed. The PAT agreed to recommend addition of the following nutrient parameters to the CALFED list of parameters of concern: bioavailable phosphorus, nitrogen, and nitrite. These nutrient parameters are in addition to ammonia and nitrate, which are already on the parameters of concern list.

During the discussion on nutrients, members of the PAT requested additional information on the impacts of nutrients on drinking water quality and reservoir management. This paper provides additional information on the impacts of nutrients on drinking water supplies and specific examples of algae and macrophyte problems that are directly related to nutrients levels in source waters.

The direct relationship between nutrients and algal growth is very well known (Wetzel 1983, Reynolds 1984, Tilman et al. 1982, Cooke et al. 1993). Nitrogen, phosphorus and silica (for diatoms) are unquestionably the nutrients driving most algal growth. Some macrophytes, such as water hyacinth, derive their nutrients directly from the water column. Ultimately, nutrients are transported to the sediments by waterborne processes for use by rooted macrophytes.

Phosphorus, unlike nitrogen, does not have a gas phase to complicate cyclic processes. There are, however, numerous forms of phosphorus in the aquatic environment (see any edition of Standard Methods for the Examination of Water and Wastewater). Minimally, total P and some form of bioavailable P should be monitored to track changes in phosphorus loading to drinking water reservoirs. Total P consists of three broad components: (1) P associated with inorganic particulates, (2) organically bound P and (3) soluble reactive phosphorus (SRP) including ortho P and some forms of organically bound P that are readily available to algae. It is important to distinguish between phosphorus associated with inorganic particles and organic particles. The surfaces of inorganic particulates often have large amounts of phosphorus adsorbed to them that is not readily available to algae. With this situation, high P concentrations will not necessarily translate into algal biomass. However, it is common to have high P associated with cells (organic particles) with little or no SRP measurable within the water (Taylor et al. 1988). Under the latter conditions the cells are very effective scavengers and take up P as soon as it becomes available. Therefore, SRP alone is inadequate to interpret the significance of phosphorus as a driving variable for algae growth.

Nitrogen has a gas phase which, unlike phosphorus, makes it biologically available at all times to some algae. Often the algae that can fix atmospheric nitrogen are nuisance species. The important forms of nitrogen to monitor for potential algal growth include nitrite, nitrate, ammonia, and total organic nitrogen.

State Water Project (SWP) water has enough nitrogen and phosphorus to be classified as mesotrophic to eutrophic, i.e., exhibits moderate to high production potential (Table 1). Phosphorus concentrations between 10 and 20 micrograms per liter are considered mesotrophic in P-limited water (Vollenweider 1968, Larsen and Mercier 1968). Although nitrogen and phosphorus are both plentiful, SWP water tends to be nitrogen limited based on data from algal growth potential studies being conducted by Metropolitan. Metropolitan has two distinct sources of water, i.e., the Colorado River and the Bay Delta, that are blended for various operational reasons. The algae growth potential studies have made it abundantly clear that SWP water increases algal growth. There is a direct relationship between increased blends of SWP water and algal growth (Figure 1). Metropolitan's concerns for stimulation of algae by SWP water are great. Monitoring for changes in nutrient concentrations will have a direct bearing on algae management strategies for all water utilities supplied by SWP water, within SWP terminal reservoirs and Metropolitan reservoirs.

Metropolitan and other agencies have a history of algae mediated problems directly related to nutrients in SWP water. Algae have produced severe taste and odor problems, interfered with filter runs and caused physical blockage of conveyance systems requiring shutdowns and significant costs to manage the problems. Following are specific examples of algae problems directly related to nutrients in SWP water:

- Taste and odor production (geosmin and 2-methylisoborneol) in the California Aqueduct resulted in numerous complaints for a water agency receiving water directly from the aqueduct. They were forced to use more costly alternative sources (Izaguirre and Taylor 1995)
- There have been three severe algae generated taste and odor events in Castaic Lake since 1993 that required extensive operational changes and other management activities to avoid widespread public complaints (Taylor et al. 1994, Izaguirre and Taylor in press). These events were driven by continuous additions of nutrients to the surface of Castaic lake from the SWP.
- Massive diatom bloom in Castaic Lake during October 1997 resulted in failure of treatment plant filters and excessive turbidities in plant effluent at the Joseph Jensen Filtration Treatment Plant.
- A massive growth of the filamentous green algae *Cladophora* in Etiwanda Reservoir (100% State Project water) resulted in shut down of the facility to repair damage to the trash rack and remove approximately 106 tons of algae from the bottom of the reservoir.
- Clifton Court Forebay: DWR removes 32 cubic yards of aquatic vegetation per day from the Banks Pumping Plant trash racks.
- Tracy Pumping Plant: Bureau of Reclamation removes 300 truck loads per day of water hyacinth.

The Contra Costa Water District (CCWD) is also documenting nutrient and algae levels in their source waters and Mallard Reservoir. Following are problems CCWD has experienced related to nutrient levels in their source waters:

- Macrophyte development (< 7 feet) is a problem in shallow areas of CCWD's reservoir and is related to levels of nutrients in their source waters. Dense beds of macrophytes increase the attached populations of algae (various diatoms and algae) which, given the right conditions, can promote blooms in the reservoir. Macrophytes increase the levels of nutrients when they die off in the fall (recycling) and increases in odor levels have been noted during the fall die off.

- CCWD's main problems since the advent of GAC filtration has been filter run reductions due to filters being clogged by diatom and zooplankton blooms. Diatom blooms occur every year in the spring and fall and can be controlled by cutraine application to the reservoir. Zooplankton is not eliminated by cutraine and has presented a much more difficult problem to the CCWD treatment personnel. These blooms last for 3-4 weeks and reduce filter runs by as much as 50%. Low levels of chlorine at the headworks is the only thing that has been successful in reducing their populations (not good for THM production). Frequent and longer backwashing is also used to increase filter runs. While zooplankton blooms are not directly linked to nutrient levels, many of these critters graze on algae, and abundant levels of algae increase the length of their stay in the reservoir.

- CCWD's main reservoir, Mallard Reservoir, is a nitrogen limited system. With the high levels of phosphorus in CCWD's Delta source water, the reservoir experiences Cyanobacteria blooms about 75% of the year. With GAC, CCWD has reduced the taste and odor problems which they experienced in the past. In order to reduce the costs of cutraining the reservoir on a regular basis, CCWD now uses a combined process of algae enumeration and ID along with FPA to determine whether the odors from these blooms are getting through the GAC filters and affecting the finished product.

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