Phytoremediation of Ionic and Methylmercury Pollution

Richard B. Meagher, Department of Genetics, University of Georgia, Athens, GA 30602.
Tel: 706-549-0914, Fax: 706-542-1387, Email: meagher@uga.edu

Our long-term goal is to enable highly productive plant species to extract, resist, detoxify, and/or sequester the toxic heavy metal mercury and other toxic pollutants (1-3) in a process called phytoremediation. Mercury pollution is a serious, world-wide problem affecting the health of human and wildlife populations, primarily due to the production of methylmercury (MeHg, CH_3Hg^+) by native bacteria at wetland sites. MeHg is inherently more toxic than metallic Hg(0) or ionic Hg(II) mercury, and because MeHg is efficiently biomagnified up the food chain. Our current working hypothesis is that transgenic plants controlling the transport, chemical species, electrochemical state, and aboveground binding of mercury will efficiently remediate mercury. As part of earlier DOE EMSP funded research we successfully engineered several plant species to use the bacterial *merB* gene, methylmercury lyase, to convert MeHg to less toxic Hg(II), and a highly modified bacterial mercuric ion reductase gene, *merA*, to further detoxify Hg(II), electrochemically reducing it to the least toxic metallic form Hg(0), which is volatilized from plant tissues. Plants expressing both MerA and MerB proteins detoxify MeHg in two steps to Hg(0). All these plants germinate, grow, and set seed at normal growth rates on levels of MeHg or Hg(II) that are lethal to normal plants. During the last four years grant period we met several other Specific Aims including: 1) Developing a strong root-specific gene expression system (4); 2) Increasing the above-ground accumulation of mercury three-fold using enzymes that synthesize low-molecular weight chelating agents (5-8); 3) Developing a system of complete female- and male-sterility to contain genetically modified plants (In preparation); 4) Quantifying the abilities of transgenic cottonwood and rice to tolerate and process mercury (9-11); 5) Initiating the first field testing of transgenic cottonwood on a mercury contaminated site (12); and 6) Devising novel assays to study the phytoremedaition of mercury (13). Although this previous research has achieved significant gains in methyl and ionic mercury tolerance beyond what is at needed at most field sites, the rates of mercury volatilization and/or hyperaccumulation are still low. For the next two years we will focus on the goal of engineering plants that can accumulate 1000 ppm dw (0.1%) mercury aboveground. We are currently pursuing the following Specific Aims: 1) Increasing the transport of mercury into roots and to aboveground shoots; 2) Enhancing biochemical sinks for mercury in leaves; 3) Increasing leaf cell vacuolar transport and storage; and 4) Testing the ability of multiple transgenes, when functioning in concert, to enhance mercury resistance and hyperaccumulation.

Bibliography: 1. Meagher, R. B. & Heaton, A. C. (2005) *J Ind Microbiol Biotechnol* 32, 502-13. **2**. Meagher, R. B. (2006) *Nat Biotechnol* 24, 161-3. **3**. Meagher, R. B., Kim, T., Smith, A. P., & Heaton, A. C. P. (2006) in *Designing plants for the remediation mercury- and arsenic-polluted soils and water,* eds. McKeon, T. and Jiann-Tsyh, L. (American Chemical Society Books, pp. 272. **4**. Kim, T., Balish, R. S., Heaton, A. C. P., McKinney, E. C., & Meagher, R. B. (2005) *Plant Biotech* 3, 571-582. **5**. Li, Y., Heaton, A. C. P., Dhankher, O. P., & Meagher, R. B. (2006) *Physiol Plantarum* In Press. **6**. Li, Y., Dhankher, O., Carreira, L., Balish, R., & Meagher, R. (2005) *Env Tox & Chem* 24, 1376-1386. **7**. Li, Y., Dhankher, O., Carreira, L., Lee, D., Chen, A., Schroeder, J., Balish, R., & Meagher, R. (2004) *Plant & Cell Physiol.* 45, 1787-1797. **8**. Li, Y., Dhankher, O., Carreira, L., Cobbett, C., & Meagher, R. (2006) *Plant Physiol* In Press. **9**. Che, D. S., Meagher, R. B., Kim, R., Heaton, A. C. P., Lima, A., Rugh, C. L., & Merkle, S. A. (2006) *In Vitro Cellular and Developmental Biology- Plant* In Press. **10**. Che, D. S., Meagher, R. B., Heaton, A. C. P., Lima, A., Rugh, C. L., & Merkle, S. A. (2003) *Plant Biotech* 1, 311-319. **11**. Heaton, A. C. P., Rugh, C. L., Kim, T., Wang, N. J., & Meagher, R. B. (2003) *Env Tox & Chem* 22, 2940-2947. **12**. Ivry, B. (2004) *Popular Sci.* 264, 41-44. **13**. Heaton, A., Rugh, C., & Meagher, R. (2005) *Water, Air, Soil Pollu.* In Press.