Phytotechnologies

Contents

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Remaining Simulcast Questions and Answers from February 28, 2012

Question 1: How you can determine the maximun capacity of a plant can store a contaminat material? - International Participant; Ecuador

David Tsao: I would suggest conducting benchtop studies to determine this for your specific situation. If it is a volatile, you will need to have a setup that can capture volatile emissions (e.g. carbon traps) in order to get closer to a complete mass balance.

Question 2: Are any of the phytotechnology mechanisms listed on slide 20 employed on urban brownfield sites that are 1 acre or less in size? - State Government Participant; Saint Paul, MN, United States

David Tsao. yes, all of them. Actually, I think you mean applications rather than mechanisms. Area, of course, limits phyto-applications...just can't plant enough plants to do the containment or remediation needed in the small area. There are "pocket parks" that have been installed on small urban areas (Google or Bing it). these provide good phytostabilization covers; perhaps remediate residual organics (phytorem cover). There are landscape species that are better than others for remediation...we employed them at our retail sites for gasoline constituents. Generally, you are not going to get enough trees into a small area to do significant hydraulic control, but could be used to phytoremediate deeper soils.

Question 3: What is the potential for poplar trees to uptake groundwater with high concentrations of ammonia at the same time they hydraulically contain/control groundwater discharge to surface water? - Environmental Consultant; Ottawa, Canada

David Tsao: generally a decent potential. Will of course depend on concentration of ammonia, pH, other site-specific factors. I don't have direct experience with phytoremediating ammonia, but do know there has been some work done. I think Argonne National Lab (Dr. Negri) and U.Iowa (Dr. Schnoor) might have first hand knowledge.

Question 4: Slide 20: which is the fate of the wood, can be used as biomass in an incinerator under the states law or the US law? In Italy, that wood can't be considered as a resource in the sense that you have to pay the societies that incinerate biomass to take this wood (i am sorry but is what really happens and it is one of the major limit to this technology). - Regulator; Rome, Italy

David Tsao: agree that this can limit applicability. Do you have to harvest at all to make the remediation work? Or, is it simply an economics question. In the US it is state specific and depends on the contaminant (metals generally tend to be the issue more than organics). Generally it is the air emissions regulations that need to be considered.

Question 5: Slide 32: how can you evaluate if the "existing vegetation" is working properly in terms of reducing or immobilizing the contamination? I am referring particularly in the case that some vegetation is "sick" probably for the high concentration in a certain part of the site and some other is "health" because of low concentration in other part of the site (contaminated but not in the hot spot). - Regulator; Rome, Italy

David Tsao: depending on the contaminant, the target media/depth, etc., perhaps do tissue sampling looking for the contaminant or sample the rhizosphere. Ultimately you are trying to determine the phyto mechanism that is at play...phytoextraction, rhizodegradation, phytodegradation, etc. If you get confirmation that a specific

mechanism is at play, then you can determine whether that is causing the plant responses (e.g. contaminant toxicity) or something else (e.g. poor nutrients).

Question 6: How do you determiine a plant harvest frequency for phytoextraction (i.e., how long will a plant extract)? - Environmental Consultant; Grand Rapids, MI, United States

David Tsao: this depends on many factors: climate (how many cropping cycles you can get in a season), plant species, growth cycle (when does the extraction take place in the plant growth cycle), whether the plant is an annual, biennial, or perennial, where in the plant is the contaminant stored once extracted, etc. I would consider conducting benchtop studies to get some answers. This is just from the "plant" side; there are also operational issues to consider: how fast can you harvest, what equipment, waste handling, etc.

Question 7: In a situation where plants seasonally die back (for example with seeding-annual or herbaceous-perennial plants). Are there site examples where the dead plant matter needed to be collected so that they didn?t re-contaminate the soil and groundwater? If so, how was this achieved? - Environmental Consultant; Melbourne, Australia

David Tsao: Most phytoextraction applications (e.g. for metals) require harvesting plant materials and removing from the site. This is done just before or shortly after the end of the growing season. Since you are considering grasses or herbaceous species, the harvesting would be generally easier using standard farming equipment. You should also consider this (what equipment, how to harvest) when you select your species in the first place.

Remaining Simulcast Questions and Answers from September 15, 2011

Question 1: If you're using phytotechnology and intend to use a specific technology (ex. rhizodegradation) to what extent do you have to account for another phytotechnology coming into play? - Community Stakeholder; Port Washington, NY, United States

David Tsao: The mechanisms such as rhizodegradation are generally inherent in any application of phyto as long as the specific contaminant can be influenced by the mechanism. For example, if you want to rhizodegrade a contaminant, but that contaminant can also enter into the plant (phytoextraction), then you will have to deal with both. However, the mechanisms occurring in the root zone (rhizodegradation) will occur first and could degrade sufficient contaminant that entry into the plant is negligible.

Question 2: Is there a reference that IDs which plants are good for which contaminants? - Environmental Consultant; Vernon Hills, IL, United States

David Tsao: check the slide I presented with the various databases. One of those is Appendix B in the PHYTO-3 document. It's dated, but it's a place to start. Unfortunately, there is no single comprehensive phyto database available although I had recent discussions with those working in the field to develop one. Also US EPA has developed some guidance documents with specific focus (i.e. phyto of chlorinateds) which contain selected species.

Question 3: Do you control the technology used by plant selection and contaminant at issue only or are there other factors? How often does a secondary technology (planned or not) come into play? - Community Stakeholder; Port Washington, NY, United States

David Tsao: Not sure I understand this question completely, but there are many factors that "control" the technology. Some are within actual human control (irrigation, fertilization, weed control, use of boreholes to access deeper, etc.) and some outside of our control (i.e. weather, predation, infestation, etc). We can try to address some of the outside factors, but usually only in reactive mode. Another ability to "control" is species selection...appropriate depth, growth rate, biomass production, suitable to the climate/altitude, etc. The second part of the question is probably a "depends" answers (depends on the specific situation at your site). Based on my portfolio of sites where phyto has been applied (several dozen), only a handful (count on one hand) have switched from phyto to some other technology at a later date or added something to supplement.

Remaining Simulcast Questions and Answers from May 10, 2011

Question 1: At a project site, a fungus claimed the life of almost all hybrid poplar trees planted as part of a phyto-remediation project. When selecting trees for hydraulic control/remediation purposes, do you recommend a diversity of species to reduce the likelihood of such devastation? - Environmental Consultant; Laramie, WY, United States

DTsao: yes, 2 to 3 species within the Salicaceae Family such as a mix of poplars and willows can be enough diversity. I have some sites with up to a dozen species including climax (oaks, cypresses, etc.)

Question 2: Have these species of plants used ever become invasive species in the larger area beyond the site ? - Participant; Milwaukee, WI, United States

DTsao: I will never say never, but typically the hybrids that are available commercially are sterile clones. Commercial growers don't want their stock replicated. If that is a potential issue, then incorporate that into the species selection process and also consult local ag extension service for advice on noxious/invasive species.

Question 3: Slide 59; Can mechanical barriers be used to keep animals like the beavers out? ? Participant; Milwaukee, WI, United States

DTsao: Not 100% sure what is meant by a "mechanical barriers". Fencing can be considered a mechanical barrier. So can a gun (that's a quote from a wildlife specialist I once received - also known as acute lead poisoning at military cleanup sites). Individual trunk guards around trees need to be flexible to allow the trunk to expand, need to also allow some sunlight and moisture to pass through (trapped moisture will rot the tree and promotes fungal infections - see Q1). Some have suggested trapping and relocating larger animals such as beavers.

Remaining Simulcast Questions and Answers from January 27, 2011

Question 1: How is the identification and mapping used with this remedial option? - Environmental Consultant; Taylorsville, KY, United States

- David Tsao - If you are refering to mapping GW plumes, then trunk coring existing trees is one possibility. See Section 2.5.3.3. Generally looking for VOCs. If you are refering to mapping hotspots in soil, then first pass look for barren zones vs. vegetated zones, then in vegetated zones, look for dominant species differences between zones. Cross reference to database on species/contaminant.

Question 2: I am in region 2 (Orange County, NY) and am looking for types of plants or trees known to absorb lead. We are in the city of Newburgh and the children I work with are interested in community gardening around an old armory. - Local government participant; Newburgh, NY, United States

- David Tsao - There were a lot of studies on the phytoextraction of lead in the mid- to late 90's. See Appendix B in the document. Despite the initial reports of success, phyto for lead is dubious and I recommend CAUTION. Most of the applications required some chelant or acid applied at the appropriate stage of plant growth in order for the extraction to occur. The chelant or acid is detrimental to the plant and in the "last gasp" of the plant to survive, it pulls everything in, including lead. You must harvest, and time the harvest for optimal extraction...not easy. This has significant risks since these chelants/acid could also leach the lead deeper or into groundwater.

- Training Program Support - ITRC has a document and training about small arms firing ranges: Characterization and Remediation of Soils at Closed Small Arms Firing Ranges (SMART-1, 2003) document is available from http://www.itrcweb.org/guidancedocument.asp?TID=35 and an archive of the associated Internet-based training course is available at http://www.clu-in.org/conf/itrc/smart_061003/

Question 3: Just for clarification, the goal of hydraulic control is to direct groundwater flow and not to directly remove the contaminant? - Student; Hampton, VA, United States

- David Tsao - From a terminology standpoint, that is correct. Hydraulic control is simply managing water. However, it you are planting downgradient of the plume, and the contaminant can enter into the plant, then phytoextraction is still possible. Again, the rhizosphere is a great buffer/barrier to contaminants getting into the plant. Also, if the contaminant does get into the plant, the plant may be able to remediate it once inside.

Question 4: Are soil amendments or soil augmentation needed for any of these options? - Participant

- David Tsao - Amendments yes...for the plant, and oftentimes for the microbes in the rhizosphere (i.e. rhizo/bioremediation). There is a competition for nutrients by both, so fertilization needs to compensate for both. Augmentation generally may not be needed; however, the effect of composting is often seeding microbes into a stressed soil that has little organic matter. there is a lot of research determining the role of mycorrhizal fungi and there are "root dips" commercially available which is basically ectomycorrhizal fungi.

Question 5: Is the depth of bedrock, 5-10 feet below ground surface, be a limiting factor in the effectiveness of phytoremediation in treating impacted groundwater? - Participant

- David Tsao - depends. If the GW is below a competent bedrock, then yes. If the bedrock is fractured,

there have been some applications where the roots have entered the fractures.

Question 6: For the arsenic phyto using ferns, you indicated the plant matter caused the arsenic to be in a more toxic form. Do they have to handle that material as Haz waste? The data indicates reduction to about 100 or 150 ppm, do you know if it has been able to reduce levels to near background levels (5 ppm)? - Environmental Consultant; Plymouth, WI, United States

- David Tsao - Once the fern was harvested, the As in the plant material began to convert from As(III) to As(V). It was the decomposition process, not the plant itself. Note that the 2.2% was on a dry wgt basis. Harvesting is usually done on material with wet wgt. Handling as haz waste is a discussion with the regulator. I do not know if they achieved background; nor what the background concentrations were for the test sites. They were not my sites.

Question 7: Is there any evidence that a phytotechnology might alter groundwater chemistry such that it affects pre-existing natural biodegradation? For example, could tree roots exude sufficient oxygen to increase oxygen levels in groundwater such that pre-existing anaerobic biodegradation is reduced or aerobic biodegradation is enhanced? - Environmental Consultant; Manchester, NH, United States

- David Tsao - yes. I am aware of different TCE sites where both redox changes have been observed. Trees (plants) are aerobic, so their cells need oxygen environments. Previous anaerobic environments were switched to aerobic due to the oxygenation by the plants but resulted in phytoextraction/phytodegradation of the TCE becoming the dominant breakdown mechanism. Another site changed an aerobic aquifer to anaerobic by exuding/sloughing sufficient carbon from the root systems to drive the redox change and promoted reductive dechlorination.

Question 8: Resources for case studies? - Environmental Consultant; Portland, OR, United States

- David Tsao - see Appendix C. There are also EPA resources (check resource links)

Question 9: What is time frame for cleanup using phyto? - Environmental Consultant; Portland, OR, United States

- David Tsao - Depends, but generally on the scale of years rather than months.

Question 10: In temperate climates, does inactivity during the winter (4 months?) prevent regulatory consideration and approval of phytoremediation as a groundwater containment method? I imagine it depends on the hydrogeologic situation. - Environmental Consultant; Plymouth, WI, United States

- David Tsao - yes it does depend on hydrogeo. You can design a system to account for winter assuming sufficient planting area and/or soil storage capacity when the vegetation is not pumping. Over plant the area. Many of my phyto sites are in upper northern climates, even Canada.

Remaining Simulcast Questions and Answers from November 16, 2010

Question 1: Are the plant databases listed on slide 38 available publicly? - Participant from private sector; Milwaukee, WI, United States

- *David Tsao:* All are publicly available except the BP Landscape database which I can provide upon request. If one has trouble locating any of the publicly available databases, I can also send those.
  Remaining Simulcast Questions and Answers from September 16, 2010 ***Question 1:*** *Is there a list of plants that work best for some of the phytotechnologies? - Participant from US EPA; Kansas City, KS, United States*
  David Tsao:
  check the database references discussed in the training, on the slides, and look through Appendix B in the ITRC document ***Question 2:*** *What are the considerations regarding the potential for the transport of COCs through plant tissues? ex. shed leaves, consumers feeding on plant tissues, etc? - Consultant; Houston, TX, United States*
  David Tsao:
  not really an issue for organics, but more for inorganic COCs. If in doubt sample/analyze the tissues. Also could consider the ecological cycle (plant and consumer) and adjust harvesting if needed.
  Question 3: *Does evidence exist that photo-degradation occurs in above-ground plant tissues? If so, could the presenters offer references regarding this issue? Asking specifically about PHOTODEGRADATION (degradation by light). - Consultant; Houston, TX, United States*

David Tsao:
Photoox is well documented in the atmosphere. Check OECD SIDS and PBT Profiler Pollution Prevention Considerations (Google these) for typical photoox (photodeg) and related attenuation rates (i.e. atm ozone reactions). Photoox in plants is indirect through the oxidation/reduction cycle that occurs in association with photosynthesis. The redox potentials reached range from +1,100 to -1,300 mV. Most organic chemicals that can even get into the plant are also the most rhizodegradable so often don't get to this level in the soil-plant-atmosphere continuum. Best demonstration of photoox in plants has been done on RDX. ***Question 4:*** *Do you have any information on Native Species that work for Phytoremediation? - Participant from US EPA; Kansas City, KS, United States*

David Tsao:
The BP database for landscaping around retail sites (Phytoscaping) incldued about 60 native prairie species. I assume this is what you mean. The term 'native' depends on your definition. ***Question 5:*** *Question about how to sell this as a partial solution when no in place allowed due to a recent federal agreement. No in place allowed meaning that the recent historic agreement for the Santa Susana Field Lab here stipulates presumptive remedy approach skipping risk assessment where no in place treatment is specifically on the agreement. That was there due to the effort by RPs to potentially create onsite landfill solution. But we want to use these technologies so we don't just fill other landfills. It's a landmark deal here in California that just happened last friday. - Participant; West hills, CA, United States*

David Tsao:
Still not 100% sure I understand the context of this question. Possible solutions include fortuitous remediation by landscaping the site. Basically what the phytoscaping concept is...landscape, but select species that could do the remediation. Also could look at ecological land reuse as an option (see ITRC ECO-1 and -2 documents). ***Question 6:*** *What must be considered regarding the lifetime of a phytosequestration remedy? I.e. If persistent COCs are locked into the rhizosphere during the life of the plant, what happens at the end of the plant's life? - Consultant; Houston, TX, United States*

David Tsao:
Hard question to answer without specifics. Depends on the type of phytosequestration, plant species, COC, and transformations that might occur to the phytosequestered moiety (whether in/on the root or soil; with/out an organic component, etc.) Another consideration is whether the COC accumulates in the rhizo such that the resulting mass if periodically removed is better than removing the mass when the COC is left diffuse in the subsurface. ***Question 7:*** *Do any of the presenters have experience implementing phytotechnology for remediation of PCB impacted soil? - Consultant; E. Brunswick, NJ, United States*

David Tsao:
not directly myself, but check the work by Barbara Zeeb from the Royal Military College of Canada (Google her). Remaining Simulcast Questions and Answers from June 15, 2010 ***Question 1:*** *What relevance, if any, does phytoremediation have to DNAPL cleanup? - Participant from U.S. EPA; Crystal City, VA, United States*

David Tsao:
if the target depth of the DNAPL is still within the range of phyto (10-15 ft typical altho 35 ft has been achieved in the field), then there are strategies to case off shallower GW sources with impermeable materials emplaced into the borehole (patented). The DNAPL (as a separate phase) may be toxic altho we have determined some species able to withstand LNAPL. ***Question 2:*** *Have any of the speakers worked directly with perchlorate remediation or other phytotechnologies? - Environmental Consultant; Hockessin, DE, United States*

TP Support:
For additional information from ITRC, the ITRC Perchlorate team has documents available at http://www.itrcweb.org/guidancedocument.asp?TID=32 and Internet-based training at http://www.clu-in.org/conf/itrc/perremtech/ ***Question 3:*** *Is there any evidence that when trees drop their leaves in winter, the surface soil could potentially become re-contaminated with the targeted analyte which has now become stored in the plant tissue? thanks - Environmental Consultant; Hockessin, DE, United States*

David Tsao:
this depends on the contaminant and the site conditions that can lead to accumulation of leaves. If a humus layer is formed, the COC will likely be retained there as an organo-metallic complex. Less likely to have any organic COC accumulate at all. Some plants take up and exude salts from their leaves to establish a niche against competition. ***Question 4:*** *As for shallow groundwater, how to determine the groundwater flow rate is suitable for phytoremediation? And how to determine the optimal distance for tree planting? - Environmental Consultant; Athens, GA, United States*

David Tsao:
I would point you to Section 2.4.1.2, equation 2-7, and the example calc on p.75 of the document. PHYTO-3 document is available at http://www.itrcweb.org/guidancedocument.asp?TID=63 Also, the 1 day training course offered at SETAC in Portland in November 2010 will go through this calculation in detail. More information available at http://portland.setac.org/node/17 ***Question 5:*** *Would the speakers*

recommend working alongside a landscaping company to ensure good plant selection, longevity and develop a maintenance plan? - Environmental Consultant; Hockessin, DE, United States
David Tsao:
Yes. Also recommend an arborist. Only caution is to keep the focus on remediation vs. plant health/appearance (which is what they will focus on). ***Question 6:*** *If we know that groundwater is at 3 feet, can we plant cottonwood whip in a 9 foot hole and have the roots grow at that depth without rotting?*

David Tsao:
roots will likely rot. Over time the static water level may be lowered as the bulk root mass grows deeper, but initially, the portion planted below the sat zone will rot and slough off. Would not plant significantly into the sat zone so that the plant reserves are retained and can be used to produce a healthy plant ***Question 7:*** *Any experience with the beneficial affects of shallow ponds with cat tails created by determined and pesky beavers?*
David Tsao:
not sure what the quesiton is here, but cattails are a common phyto species used in wetlands (broad remedial capability) Could be good for surface water, NPS runoff, etc.
Ellie Wehner:
Worked with the State of PA on several projects planting cattails in shallow ponds to assist improving water quality discharge from abandoned coal mines/tailings (acid mine drainage/metal contamination issues)...proved very effective. These sites proved inhospitable to all forms of wildlife (no beaver visitations, etc.). ***Question 8:*** *If we are using phytotechnologies to control the shallow groundwater gradient, what type of information do we need to collect to construct a water balance equation? - Environmental Consultant; Houston, TX, United States*
David Tsao:
see answer to Q4. Attend the ITRC Phyto classroom course provided at SETAC in Portland in November ***Question 9:*** *In your opinion how applicable is phytotechnology to Alaska where a cold climate and muskeg conditions exist? Is a constructed wetland treatment system or some other form of phytotechnology viable if these conditions exist at a mine where tailings and waste rock can produce acid mine drainage and at closure leachate will contain high concentrations of zinc, lead, cadmium and other metals? - Alaska State Regulator; Juneau, AK, United States*
David Tsao:
my only experiences in AK are with organics; mentioned the 14dioxane project during the training. Also found North Slope species able to remediate diesel on tundra. For metals, likely limited by short season, slow growth (biomass/yr), and low uptake concentrations (phytoextraction mech), particularly lead. Can use to stabilize (phytosequester).
TP Support:
For additional information from ITRC, the ITRC Mining Waste team is working on a Technical and Regulatory Guidance that includes decision trees and case studies. The guidance and associated Internet-based training will be available in Fall 2010. ***Question 10:*** *What plants species are able to take up zinc, lead and cadmium in Alaskan conditions? If possible can you point to any studies where phytotechnology has been used in Alaska. - Alaska State Regulator; Juneau, AK, United States*
David Tsao:
All plants take up small quantities of zinc (essential plant nutrient - see table 1-1). Lead, not many if any in reasonable quantities. The PHYTOREM dbase has 37 species that take up Cd, but not sure of suitability to AK climate/ecology. Check Appendix B of ITRC doc as well. Remaining Simulcast Questions and Answers from February 25, 2010 ***Question 1:*** *Does Ele have any more examples of phyto projects implemented as part of the VCP here in Texas -- Environmental Consultant; Austin, TX, United States*
Ellie Wehner:
I've received limited feedback regarding the application of phytotechnologies in via the VCP program. Only 1 active VCP case was noted and the project is only in the preliminary stage (pilot scale). Feel free to contact the TCEQ Project Manager of the case (Joe Bell @ 512-239-6753). ***Question 2:*** *what volume of groundwater can the average tree "pull up"? Is it species dependent? -- New York State Regulator; Avon, NY, United States*
David Tsao:
Short answers are that it depends on surface-available water, method of planting (restricting access to surface-available water), maturity, climate, and species. See Figures 1-4a-c, Table B-7 in Appendix B, and the example on p.75 of the PHYTO-3 document. PHYTO-3 document is available at http://www.itrcweb.org/guidancedocument.asp?TID=63 ***Question 3:*** *For the assessment phase, is there a plant-selection reference available that cross-references plants to USDA plant-hardiness zone maps? -- Private Sector Participant; Houston, TX, United States*
David Tsao:
Best resource is to check out the PLANTS National database: http://plants.usda.gov While I don't think it necessarily has the hardiness zone map per species, it does provide whether a species is present in a state (even county level). You can "overlay" a hardiness zone map onto that map if needed. ***Question***

4: *Do you know any successful story to tell about removal of cadmium and zinc from vadose soil with phyto? thanks -- Environmental Consultant; Milan, Italy*
David Tsao:
I would look at Appendix B Table B-5...it's rather dated though. Also, zinc is an essential nutrient, so all plants can take it up to some degree. Table B-4 covers nutrient elements. The Phyto REM database (Terry Mc Intyre, Environment Canada; terry.mcintyre@ec.gc.ca) lists 37 records of species that can extract Cd, and 48 for Zn. I am not involved in any case studies / sites dealing with those, so can't provide real-world success stories. PHYTO-3 document is available at *http://www.itrcweb.org/guidancedocument.asp?TID=63* ***Question 5:*** *Will regulators allow the use of contaminated groundwater to irrigate the remediation plantings in areas with insufficient precipitation. Are there concentrations that will stress the plant sufficiently to prevent remediation -- Private Sector Participant; Wilsonville, OR, United States*
Kris Geller:
While I have not had any situations as you describe them I think that this could be allowed, particularly if the contaminated ground water was being applied within the plume area, was not at levels toxic to plants (answer to your second q, use greenhouse or field studies to determine toxicity levels), would not run off onto uncontaminated area, would not result in residual levels in soils that required remediation
David Tsao:" It has been done for landfill leachate. Some require the GW to remain in the pipe only, no spray irrigation. Yes, but this depends on the contaminants, composition, and species. Also, there is usually a difference in response depending on if the plant is already growing and then impacted or planted into the impact. The influence that the plant has on building a rhizosphere from the start vs. after the fact can also lead to building a rhizosphere that can protect (remediate) the contamination before it impacts the plant. This is basic acclimation to the environment.