WHITE PAPER

A Conflicting Personality: Can Hyperaccumulating Plants like Cannabis and Hemp be Realistically Used as a Safe Source of Cannabinoids?

Robert Thomas
Scientific Solutions

Cannabis and hemp are known to be avid hyper-accumulators of contaminants in the soil. That is why they have been used to clean up toxic waste sites where other kinds of remediation attempts have failed. In the aftermath of the Chernobyl nuclear melt down in the Ukraine in 1986, industrial hemp was planted to clean up the radioactive isotopes that had leaked into the soil and ground waters **(1).** The phytoremediation properties of botanical species are well-recognized. It has been reported that close to 400 plants, shrubs, flowers and trees have the ability to absorb extremely high levels of metal contaminants out of the soil **(2).** Of course, Chernobyl is an extreme example of heavy metal and radionuclide contamination, but as a result of normal anthropogenic industrial activities over the past few decades, including mining, metal refining/smelting, power generation and use of fertilizers etc., heavy metal pollution has become one of the most serious environmental problems today.

Though much of farmland in the US is perfectly suitable for growing agricultural crops, even low levels of heavy metals can end up in the plant material. A recent report showed that popular infant food had unacceptably high levels of Pb, Cd, As and Hg derived from the vegetables used in the manufacturing process, which had escaped the scrutiny of the US FDA **(3).** And with all the diverse and varied soil conditions used for growing hemp for consumer products such as medicinal cannabinoids, edible seeds and industrial fibers, it will be very difficult to eliminate all these potential sources of pollution in order to reduce their impact on the plant's biology. So can hemp, which is predominantly grown outdoors – and one of the best plants for soil phytoremediation purposes be realistically and safely used as a source for all these wonderful products? Let's take a closer look.

Chernobyl Nuclear Disaster

On April 26, 1986, a sudden surge of power during a reactor systems test destroyed Unit 4 of the Chernobyl nuclear power plant in Pripyat, Ukraine, part of the former Soviet Union. The accident and the fire that followed released massive amounts of radioactive material into the environment and caused the worst nuclear disaster the world had ever seen. Thirty-one people perished as an immediate result of the accident, with a further 29 dying within weeks from horrific effects of radiation poisoning. Hundreds of thousands of people were affected by the long-term impact of the accident. The radioactive fallout was so serious that local farmers were deeply concerned that the soil would be irrevocably harmed by the toxic metals leaching into the soil. The site was left for a number of years to allow the radioactivity to subside. Then in the early 1990s scientists began growing industrial hemp around the abandoned Chernobyl nuclear power plant, and found it significantly reduced radionuclide soil toxicity **(4).** Fast forward 10 years to 2001 and a team of researchers in Germany confirmed the Chernobyl results by showing that hemp was able to extract lead, cadmium and nickel and other heavy metals from a plot of land contaminated with sewage sludge **(5).** All of a sudden industrial hemp became a viable option for cleaning up many industrial contaminated sites around the world as it offered many benefits over traditional remediation approaches.

Traditional Soil Remediation

Heavy metal accumulation in soil has been rapidly increasing due to various natural processes and industrial activities. As heavy metals are toxic and non-biodegradable, they persist in the environment, have potential to enter the food chain through crop plants, and eventually may

accumulate in the human body through long term exposure and biomagnification. As a result, heavy metal contamination has posed a serious threat to human health and the ecosystem. It is therefore necessary to take remediation measures to prevent heavy metals from entering into terrestrial, atmospheric, and aquatic environments, and to mitigate the contaminated land **(6).**

There are a variety of remediation approaches that have been developed to reclaim heavy metal-contaminated soil, which are mainly based on mechanical or physio-chemical techniques, such as soil incineration, excavation and landfill, soil washing, solidification, and electric field application. However, there are limitations to these approaches such as high cost, inefficient when contaminants are present at low concentrations, irreversible changes to the physicochemical and biological properties of soils, which lead to the deterioration of the soil ecosystem, and the introduction of secondary pollutants. Therefore, there is clearly a need to develop cost-effective, efficient, and environmentally-friendly remediation technologies to reclaim heavy metal-contaminated soil.

Principles of Phytoremediation

Phytoremediation is a plant-based clean-up approach, which involves the use of plants to extract and remove elemental pollutants or lower their bioavailability in soil. Plants have the abilities to absorb ionic compounds in the soil even at low concentrations by extending their root system into the soil matrix and establishing rhizosphere ecosystem to accumulate heavy metals and modulate their bioavailability, thereby reclaiming the polluted soil and stabilizing soil fertility. There are many advantages of using phytoremediation, which include **(2)**:

- Economically feasible, requiring only a source of carbon, nitrogen and solar energy for metabolic synthesis, therefore is simple to manage, with low cost of installation and maintenance
- Environmentally-friendly—it can reduce exposure of the pollutants to the environment and ecosystem
- Prevents erosion and metal leaching through stabilizing heavy metals, reducing the risk of spreading of contaminants
- Improves soil fertility by releasing various organic matter into the soil
- Extremely efficient for many contaminants
- Applicability over large areas and the plants easily be disposed of

Phytoremediation Efficiency

A great deal of research has gone into molecular mechanisms to understand heavy metal tolerance and uptake by plants. It has been well-studied and as result the process of phytoremediation is optimized and extremely efficient. It has been reported that there are over 400 plants that can be called hyper accumulators, many with properties that are metal specific. For example, alfalfa is an excellent remediator for the classic heavy metals and studies have shown it can extract up to 43,000 mg of Pb per kg of the plant and still remain healthy. While other plants such as alpine pennygrass will work better for transition metals and studies have reported it can remove up to 51,000 mg/kg Zn from the soil **(2).** Hemp is not as efficient as other metal-specific phytoremediators but appears to be a plant that has good hyperaccumulation properties for a broad range of contaminants including heavy metals, transition metals and radionuclides. A recent study showed that industrial hemp could absorb up 1000 mg/kg of cadmium without affecting the strength of its fibers **(7).** Its very long root system and high biomass, means the metals are absorbed quickly and reside in many different parts of the plant, including roots, shoots, stems, leaves, flowers etc. As a result, it is widely used to clean up contamination from areas such as coal mining waste, metal refining effluent, power plant ashes, sewage sludges, and polluted nuclear reactor sites such as Chernobyl. It's also worth noting that after the Fukushima nuclear meltdown in Japan in 2011, hemp together with sunflowers were used to clean up cesium-137 and Strontium-90 from the soil. Sunflowers are another hyperaccumulator plant with the added benefit of growing very tall for maximum absorption of the contaminant. In addition, they are inexpensive, plentiful in Japan, and perfectly suited for the local climate **(8).**

In conventional phytoremediation, once the plants have absorbed the maximum level of contaminants, they are usually destroyed (typically incinerated). However, in some applications the extracted material is then processed to remove the metal. This is a relatively new science called phytomining, which is phytoextraction applied to the extraction of various metals from waste sites using various plants, including hemp **(9).** For example, rare earth metals are being extracted from acid drainage sites which contain waste effluents left over from the refining of rare earth minerals. This is attracting a great deal of attention, particularly from China and South Africa, where most of the rare earth mining is carried out today. It is a way of both cleaning up the waste site and

also extracting the rare earth metals, which would otherwise have been treated and dumped **(10).**

Hemp as a Source of CBD

It is a very important point to emphasize, that cannabis and hemp have found a commercial use as a source of cannabinoids for medicinal and adult recreational use. When used for this purpose, they are strictly regulated by individual states **(11)**, so there is a robust regulatory process with maximum allowable heavy metal limits (Pb, Cd, As, Hg), which is supported by vigorous third-party testing procedures to ensure the safety of consumers. In addition, hemp is also grown as a source of edible seeds as well as for industrial purposes including biofuels, building materials, plastics, fabrics and much more. Currently there are very few regulations with regard to heavy metals limits in these products, so they could contain extremely high levels of heavy metals, depending on the source of the hemp and where it's grown.

Because of the lack of regulatory procedures, clearly hemp used for phytoremediation purposes cannot be used in the production of cannabinoids or for growing seeds. However, it has been mentioned in a number of Internet discussion groups that it could be possibly used to make other products including biofuels, textiles, plastics or hempcrete (a building material made from hemp). Although this could be a very attractive option, the industry should proceed with caution. Depending on the element, it has been shown that hemp and other hyperaccumulator plants can extract up to 50,000 mg/kg of metallic contaminant out of the soil and still remain healthy. If the contaminant levels are at the low end of this range, I think the risks are relatively low, but if they are at the high end, would the marketplace embrace a product that could potentially have these levels of toxic contaminants, particularly for a consumer product like hemp seeds?

One could argue that hempcrete might not be such a serious problem, particularly if it's used for outdoor building construction purposes. However, wearing clothes using textiles made from contaminated hemp might not be such a good idea. Moreover, I would strongly suggest that heavily contaminated hemp should not be used in the production of biofuels either, especially if the contaminant is a heavy metal. For example, if there are high levels of Pb in the hemp, significant amounts are likely to be extracted into the biofuel. When the fuel goes through engine combustion, the vaporized Pb particles will eventually be emitted out of the vehicle's tail pipe, as it's well-accepted that catalytic converters do not remove lead compounds **(12).** All of a sudden this environmentally-friendly biofuel becomes a toxic polluter of lead. The US banned the use of tetra ethyl lead as a gasoline additive in the mid-1990s....didn't we learn our lesson then!

So clearly, robust hemp regulations are critical to ensuring consumer safety. Let's take a brief historical look at the regulatory process for hemp.

Current Regulations for Hemp

The challenges of regulating the hemp industry were compounded when CBD products derived from hemp begin to hit the marketplace in 2020. Up until then, much of the cannabis grown in the US was cultivated in greenhouses where the growing environment is controlled. However, when the growing of hemp for research purposes was legalized in the Agricultural Act of 2014 (also known as the 2014 Farm Bill) **(13),** the majority of it was being grown outdoors with much less control over growing conditions and a higher risk of heavy metal contamination from the soil.

So, it's worth taking the time to summarize current status of regulations for hemp in the US **(14).** In the revamped Hemp Farming Act of 2018 (also known as the 2018 Farm Bill), the federal government has made it legal to grow hemp (defined as cannabis containing less than 0.3 % THC) by removing it from the controlled substance list. As a result, growers do not need a permit from the Drug Enforcement Administration (DEA). This adds a new twist to the state-based regulations for cannabis, because the bill directed the U.S. Department of Agriculture (USDA) to issue regulations and guidance to implement a program for the commercial production of hemp which could either be used for a variety of industrial processes (inc. fuels, textiles, concrete, fibers, plastics, etc.), as a health food supplement (eg. hemp seeds) or as a source of CBD products from the hemp flowers (oils, supplements, edibles etc.)

USDA has already begun the process to gather information for rulemaking. Once complete, this information will be used to formulate regulations that will include specific details for both federally regulated hemp production and a process for how individual states should submit their plans to the USDA. In the short term it is likely that the USDA will look to the states' departments of agriculture who will assisted by specialized

hemp analytical testing laboratories which were originally required to be registered with the DEA, but in a recent update, this has been relaxed as long as the lab has the necessary accreditation according to ISO (International Organization of Standards) 17025:2017. Currently, potency is the most important requirement because hemp is not allowed to have more than 0.3% THC, but it is likely they will be guided by state cannabis commissions for maximum levels of contaminants such as pesticides and heavy metals. And as previously mentioned, it could potentially be more complicated to regulate hemp grown for CBD products, because the vast majority of hemp plants will be grown outdoors where there is less control over the growing environment.

Regulations for states who submit plans will include procedures and information collections regarding land to be used for planting; testing; effective disposal of plants and products; compliance with law enforcement; annual inspections; submission of information to USDA; and certification that resources and personnel are available to carry out these procedures. States do not need to submit plans for approval until regulations are in place. However, should a state submit a plan, USDA will hold that submission until regulations have been implemented, which is expected in late 2021.

The Farm Bill allowed states and institutions of higher education (universities, research organizations), to continue operating under authorities of the hemp research program for the 2019 planting season. The 2018 Farm Bill also extended the 2014 Farm Bill authority for one year. States were allowed to continue operating pilot programs until Oct. 31, 2020. The USDA also established a plan to monitor and regulate the production of hemp in those states that do not have an approved plan, as well as issuing regulations to accommodate the 2021 planting season. Note: the U.S. Domestic Hemp Production Program extended its comment period to allow stakeholders time to provide feedback, and the USDA has indicated it will give itself until Nov. 1, 2021, to issue final regulations. As soon as the regulations have been approved, they will be published in the Federal Register, when it will be legal to grow hemp anywhere in the US for the production of CBD-based products. So, it will be interesting to see how the Department of Agriculture regulates the industry at the federal level, particularly with regard to heavy metals when cannabis is currently regulated by the individual states.

It's also worth pointing out that the 2018 Farm Bill also explicitly preserved the authority of the U.S. Food and Drug Administration (FDA) to regulate hemp products under the Federal Food, Drug, and Cosmetic Act, which states that products containing cannabinoid-derived compounds are subject to the same authorities and requirements as FDA-regulated drug products containing any other substance. In fact, this has already come into play, as there have been a number of product recalls for heavy metal limits being exceeded in hemp-derived CBD products **(15).**

(Note: After more than a year of negotiating, in early October 2021 Colorado has finally been given approval by the USDA to implement a fully-regulated hemp program to include testing for contaminants such as pesticides and heavy metals **(16).** It's only a matter of time before other states will be following Colorado's lead.)

Final Thoughts

Hemp is a very flexible plant. It has shown itself to be a prolific phytoremediator which can thrive anywhere, including in contaminated soil. In this role it clearly has unique capabilities to clean up toxic pollutants where other approaches have failed. In addition, it can be turned into novel fabrics for clothes, make durable plastic materials, as well as producing hempcrete for building materials. However, its role in the manufacture of cannabinoid products is creating the most excitement because of its ability to treat multiple ailments including pain management, stress, anxiety, depression, seizures, epilepsy etc. However, it should be strongly emphasized that because hemp can be used for such a wide range of applications it is critically important that the growing conditions are carefully monitored. When grown outdoors, it will avidly accumulate contaminants from the soil, so if it is going to be used for CBD production, it's imperative to make sure the soil chemistry is well-characterized before planting **(17).** Alternatively, if it's going to be used for phytoremediation purposes, its final end use should be carefully considered, particularly if it is being used for human consumption.

A final word of caution! The insatiable consumer appetite for cannabis products in the US is being fulfilled from outside the country. Yunnan Province in southern China is now producing CBD-products for the US market **(18).** This should not be surprising, considering we cannot produce enough to supply the huge demand. However, what is more disturbing is that the metal refining for the electronics industry in China has produced some

of the most contaminated waste sites in the world **(19).** Experience has warned us that consumer products coming from China aren't always of the highest quality. So, it's imperative that no matter where the products are sourced, especially if it is from outside the US, testing the hemp and CBD products for a comprehensive suite of elemental contaminants is critically important. Our love of the cannabis and hemp plant for their cannabinoid properties is never going to diminish so we are always going to have to balance that with its heavy metal content. Hopefully we will not be tempted to sacrifice one for the other and jeopardize consumer safety!

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