Modified Plants to Save our Earth

Term Paper by
Ana Elisa Galery Käser
& Hester van den Bold

Biology Class 4F/E Patrick Ruggle

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PREFACE

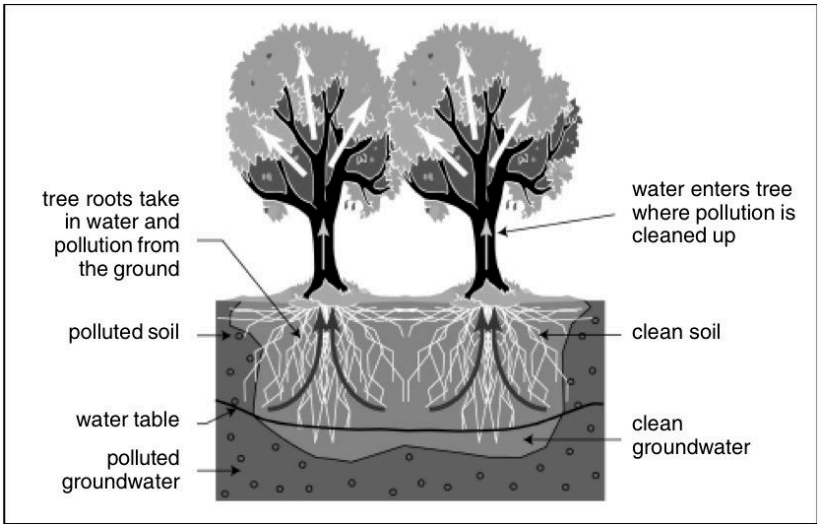
Our topic in the present term paper is pollution-combatting plants. We chose this topic because it seemed to be very interesting. It has to do with cleaning up the environment und getting rid of pollution, which we find very important. Our planet is suffering a lot under the carelessness of people who are polluting it, so we need to clean up and fight pollution to keep the fragile ecosystem of our earth alive and intact. We stumbled across the topic of pollution-combatting plants while doing some research on the topic “genetic engineering,” and we thought that it was a great idea to try to clear up pollution with plants instead of machines. We found it very interesting that someone had the idea of cleaning up nature with nature.
After reading some articles about this topic we asked ourselves some questions, which especially interested us:

1. How does combatting pollution with plants work? Does it really work?
2. Does it change a lot in the polluted environment? Can it get rid of significant amounts of pollution?
3. Is it effective enough to be worth investing in?
4. Where can this technique be used? In what kind of areas is it effective?
5. What kind of contamination or impurities can be eliminated with pollution-combatting plants?
6. Are there other ways in which plants can be used specifically to protect the environment apart from pollution-combatting plants?

INTRODUCTION

Scientists have seen the potential of growing plants that are able to take up groundwater pollutants through their roots in order to clean up contaminated areas since the 90's. In the process of phytoremediation (the use of plants to remove or reduce contaminants from the environment – see picture) there are many different examples. We decided to focus on one that interested us in particular: The use of poplar trees to eliminate pollutants and clean up contaminated sites.
Poplar trees are capable of breaking down Trichloroethylene (TCE) as well as a variety of other environment-harmful substances such as chloroform, which is the by-product of disinfecting drinking water, carbon tetrachloride, a solvent, and vinyl chloride, a substance used to make plastics.

In 2007, scientists at the University of Washington grew genetically engineered poplar trees in the laboratory. These poplars were able to break down the pollutants into harmless by-products at 100 times higher rates than the "normal", unaltered plants. In these laboratory conditions, the genetically engineered plants removed 91% of Trichloroethylene (TCE) from a liquid solution, whereas the untransformed plants were only able to remove 3% of TCE from the solution.



Picture 1: the process of phytoremediation

In 2008, the plants were then to be tested outside in the "real world". Researchers from Purdue University, Indiana, collaborated with Chrysler LLC in a project to remove trichloroethylene from a site contaminated by oil stored there in the 1960s. The chemical, which had been used as an industrial solvent, lay within 10 feet of the surface, thus making it accessible for the roots of the poplars. However, the poplars from the lab weren't suited for Indiana's climate, thus, cold-hardy poplars, which are generally more difficult to alter, had to be transformed first.

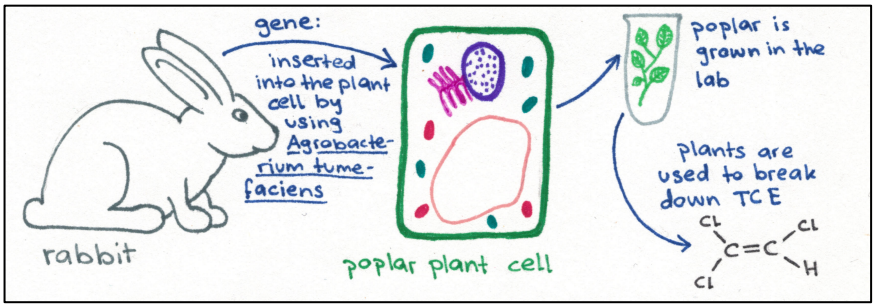
Their late flowering comes in handy with supervision, as there are strict regulations concerning the use of the modified plants: Federal regulations do not allow commercial growing of transgenic trees, they are only allowed in greenhouses for controlled research. There were concerns that transgenes, might escape and incorporate into natural tree populations. Thus, the poplars in the project had to be cut down before they reached sexual maturity. "In fact, coppicing (cutting stems at ground level) of poplars causes them to revert to a juvenile condition (thus preventing flower formation) and induces the formation of root suckers, so that the site becomes more fully occupied." (Richard Meilan, Interview 2016 – see further below)

This technology is also less costly, less invasive and more aesthetic than other techniques used e.g. pumping the groundwater out of the ground and allowing the contaminants to evaporate into the air, or pumping sugars into the ground: the sugars can clean up the contaminants, however, they make the water anaerobic (oxygen starved) and they can produce other toxic by-products.

Poplars can also be used for ethanol, and they might one day help mitigate air, as well as water pollution, as in air pollution experiments the transgenic plants had increased absorption of gaseous TCE as well as benzene, which is a pollutant associated with petroleum.

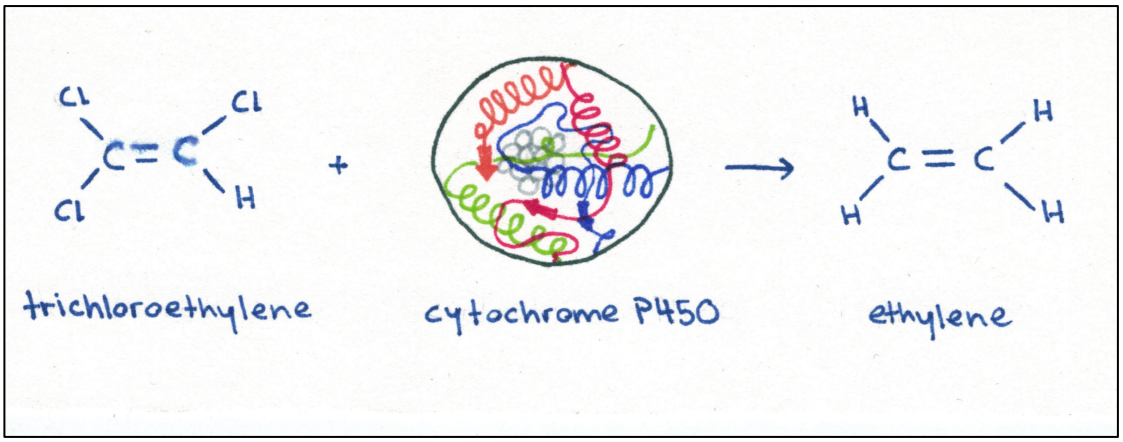
DESCRIPTION OF ENGINEERING TECHNIQUE

Poplar trees have been found to produce enzymes, which are able to break down the molecule trichloroethylene (TCE). The molecular formula of trichloroethylene is C_2HCl_3. Trichloroethylene can influence the human central nervous system and might even be carcinogen. It can be used to solve organic compounds such as greases, oils and fats. It is the most widespread groundwater pollutant in the United States. Therefore, it is important to find a cheap and effective way to remove pollution of trichloroethylene. Even though unchanged poplar trees already produce the enzymes that can break down trichloroethylene, the altered poplar trees produce much more of those enzymes and can break down the trichloroethylene much quicker.



Picture 2: altering of the genetic information of poplars

The enzyme needed to break down the trichloroethylene is called cytochrome P450. So in the transgenic plants cytochrome P450 is produced a lot faster than in the unaltered plants. To genetically manipulate the poplar plants and make them produce more cytochrome P450, scientists clone a gene from rabbits and then insert it into the poplar cells. The gene is inserted by using bacteria called *Agrobacterium tumefaciens*, which is able to insert DNA into plant cells. Then, those changed cells are used to grow whole poplar plants in the laboratory.
Cytochrome P450 breaks down the trichloroethylene by replacing the three chlorine atoms with hydrogen atoms. The now free chloride ions (Cl^-) remain dissolved in the water inside the plants and the newly formed, harmless molecule is called ethylene. Ethylene is a plant hormone, which controls the ripening of fruit and other processes, so it does not harm the plant or the environment.



Picture 3: the process of breaking down the trichloroethylene

INTERVIEW

To learn more about pollution-combatting poplars, we contacted Dr. Richard Meilan, a Professor of Molecular Tree Physiology at Purdue University in Indiana, United States. He led the project involving the use of poplar trees to clean up a contaminated site in Indiana (mentioned earlier in this paper).

How did you get involved with the project of using poplar trees to clean up polluted areas?

R. Meilan: A colleague of mine from the University of Washington, Milt Gordon, who is now deceased, approached me about the idea.

Is the project still going on? If not, why was it cancelled? Did it succeed?

R.M.: We tested the plants in the laboratory but have not been able to fully evaluate them in the field. I applied for and received funding from Chrysler back in 2007 to test these trees on one of their contaminated sites. I did receive a grant from them, but the support was withdrawn when they declared bankruptcy, so the project was terminated. I subsequently and repeatedly applied from funding from the U.S. Department of Defense but never received a grant from them.

How and where did you extract the transgenes from? How were they inserted?

R.M.: The gene was originally cloned from rabbit. It was inserted into poplar cells using *Agrobacterium tumefaciens*. Individual, transformed poplar cells were then used to regenerate whole plants *in vitro*.

Do you see a future in this way of handling pollution?

R.M.: I think so, but money is needed to conduct further research and I can't seem to get anyone interested in pursuing this further.

Are there any major problems with this technique, and if so, what are they?

R.M.: None that I can think of.

Where and why is the technique used? Are there areas especially suited for this technique?

R.M.: These trees would be ideal for use at several military installations where the groundwater is heavily contaminated with TCE.

Are there any alternative treatments?

R.M.: There are existing, physical remediation techniques, such as pumping and air-stripping, but they are labor-intensive, expensive, and wasteful.

How is trichloroethylene processed into a harmless by-product?

R.M.: The three chloride atoms in the TCE molecular are enzymatically removed and replaced with hydrogen atoms, resulting in the formation of ethylene, a naturally occurring, gaseous plant hormone.

-How long can you let the trees grow without them influencing our environment negatively (passing on the transgene) or becoming invasive?

R.M.: Federal regulators are likely to require the development of an effective transgene confinement system before they allow transformed trees to be deployed commercially. However, the prevention of transgene spread during such phytoremediation projects can be achieved most simply by cutting down the trees before they reach sexual maturity. In fact, coppicing (cutting stems at ground level) of poplars causes them to revert to a juvenile condition (thus preventing flower formation) and induces the formation of root suckers, so that the site becomes more fully occupied.

-Are there any restrictions in experimenting in this scientific field?

R.M.: In the U.S., transgenic trees can only be grown for experimental purposes, and only for three years, unless the trees are coppiced (see above) regularly.

Thank you very much for your time.

Picture 4: Richard Meilan inspecting a row of hybrid poplars

DISCUSSION

The only existing research group about pollution-combatting poplar plants we found is the one in Indiana with Richard Meilan. Until now the modified plants were only tested inside the laboratory. Unfortunately, the project had to be terminated because they didn't get enough funds from Chrysler, the firm they were working with, or the U.S. Department of Defence. The project can't be continued until they get the funds needed and the permission to grow the trees outside a greenhouse.

There are many benefits in using poplar trees for this kind of purposes:
They are fast growing plants and they can grow for several years without flowering, meaning that they could be harvested before blooming, thus to prevent seeds from generating. And unlike some other kinds of trees, their branches do not take root in soils when falling to the ground. Furthermore, they produce deep and extensive root systems, and have a high demand for water, and they grow across a wide geographic range in many different climates, all in all creating desirable conditions and characteristics for phytoremediation. Other advantages are that the method isn't very expensive and that the poplar plant are not invasive, so they don't harm other plants growing on the same site.

Disadvantages for using altered poplar trees to clean up pollution are that the process stops in winter. Another general disadvantage of using plants to clean pollution is that even fast growing plants like poplars aren't as fast as other ways of cleaning pollutions (e.g. pumping out the ground water). Some people see it as a danger to let genetically altered plants grow in nature because the transgenes could spread into natural habitats such as forests and disrupt the fragile eco system there. It is also a problem for animals, such as bugs, which feed on those plants. Feeding on genetically modified plants could have a negative impact on them.

SUMMARY

Genetically modified poplar trees can be used to remove pollutants such as trichloroethylene (TCE). Trichloroethylene is used as solvent to solve organic compounds like grease and fat, but it pollutes the groundwater.
In 2007 a research group from the University of Washington created genetically altered poplar plants which were able to remove 100 times more TCE from water than the unaltered plants. One year later another group of researchers from Purdue University, Indiana, wanted to test those modified plants outside in the real world, so they began a project with Chrysler LLC. But when Chrysler LLC went bankrupt the project had to be terminated because the U.S. Department of Defence didn't want to fund it and Chrysler LLC didn't have any money to fund it.
To genetically alter those plants so that they break down the TCE a transgene is inserted into the plant cells. This gene is taken from rabbits. It is a gene, which causes the plant to produce more cytochrome P450, which is an enzyme that can break down TCE. The transgene is inserted into the plant cell by using bacteria, which can insert DNA into plant cells. Then the cells are grown into plants in the laboratory.

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