

AI vs. Environmental Experts: Are Humans Becoming Obsolete in Remediation Design?

RemTech – Banff, AB
October 13, 2023
Kevin E. French, P.Eng.

Presentation Overview

- Recent Focus on AI in the News
- Portrayal of AI in Popular Culture
- Practical Uses of AI Today
- AI-Assisted Remediation Design
- Take Aways / Lessons Learned
- Questions



Credit: CBC



Overview – Vertex Environmental



Vertex Environmental Inc.

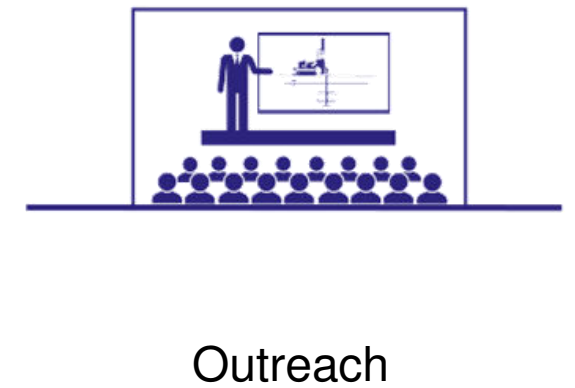
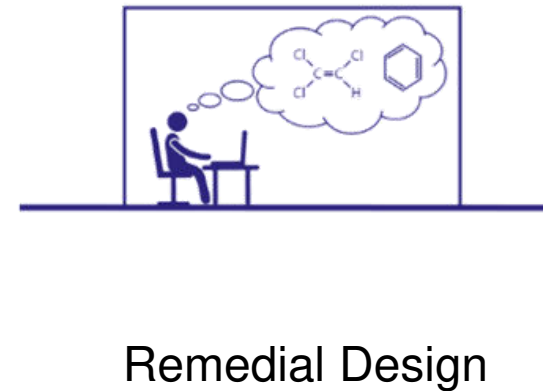
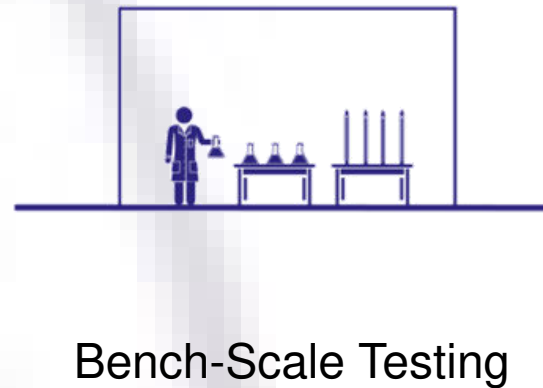
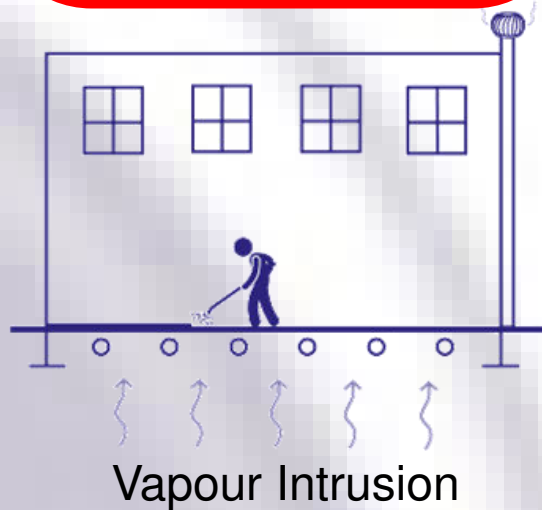
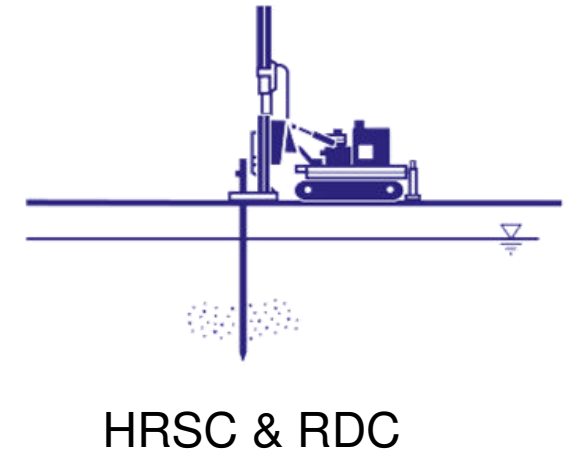
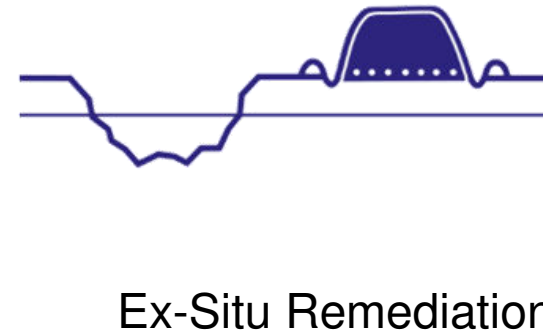
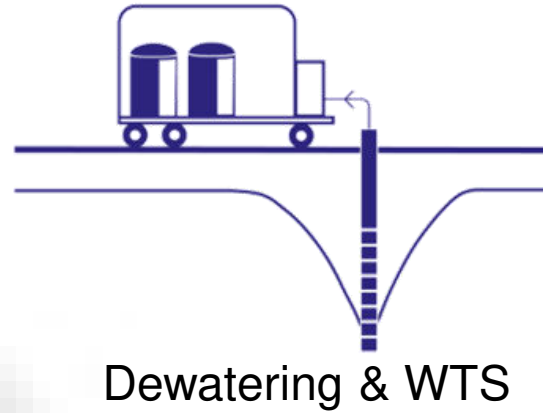
- Founded in 2003
- Specialized Environmental Remediation Contracting (in-situ, ex-situ, systems, HRSC)
- Provides services across Canada

Kevin French, P.Eng

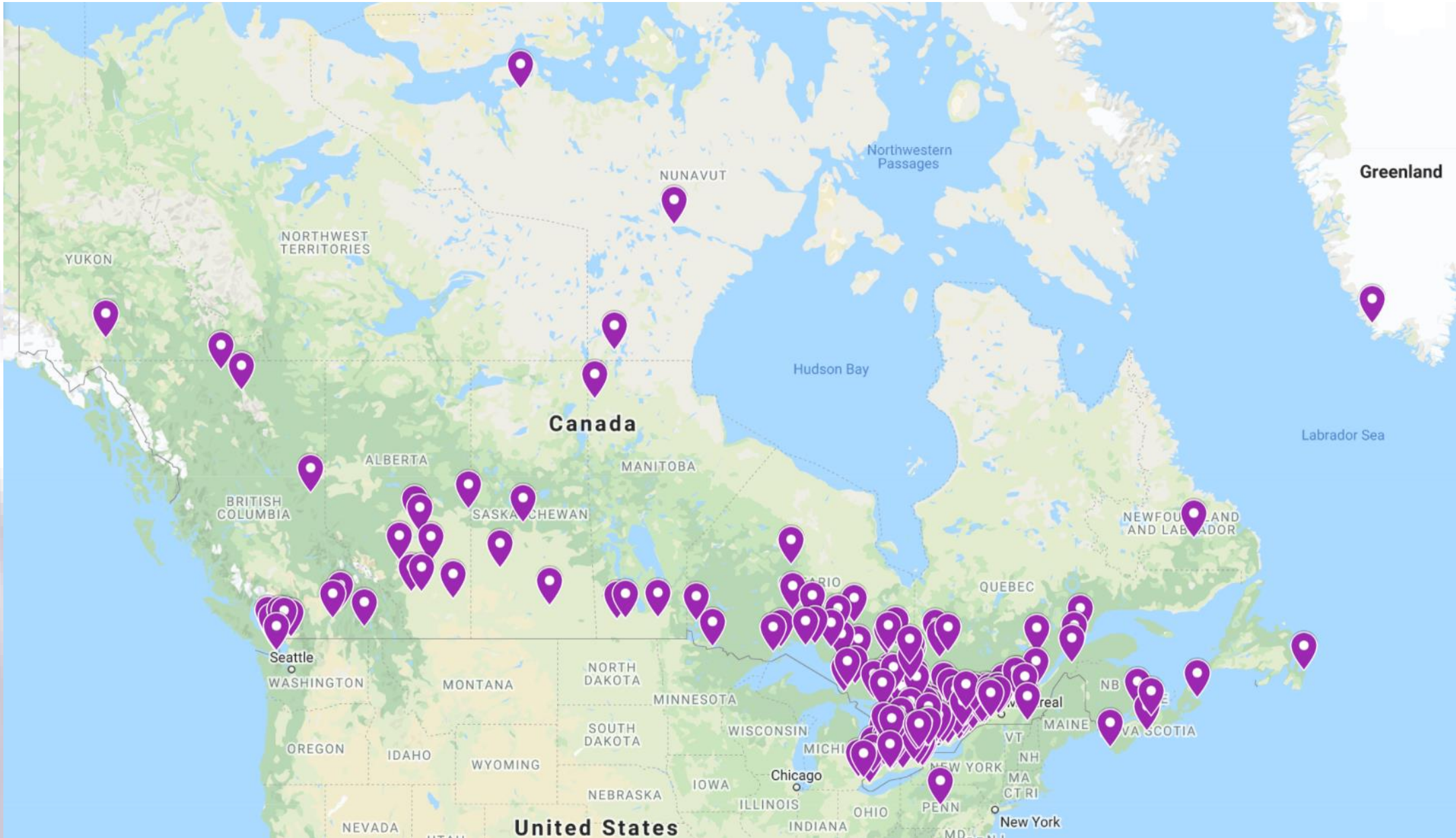
- Vice President, Vertex Environmental
- B.A.Sc., Env. Eng., U. Waterloo
- Environmental engineering (consulting and remediation contracting) since 1988



Vertex Environmental Inc.



Vertex Environmental Inc.



Recent Focus on AI in the News



As It Happens

The 'godfather of AI' says he's worried about 'the end of people'

Geoffrey Hinton fears an AI takeover. But other AI experts say humans are the real threat

Sheena Goodyear · CBC Radio · Posted: May 03, 2023 7:26 PM EDT | Last Updated: May 4



Geoffrey Hinton — a computer scientist known as 'the godfather of AI' — has stepped down from his role at Google and is warning about the potential dangers of a future in which artificial intelligence surpasses human intelligence. (Submitted by Geoffrey Hinton)



Top Headlines Evening

Hello, these are your top stories for [Wednesday, September 27, 2023](#).

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Learn AI now or risk losing your job, experts warn

September 27, 2023 · [12:00 PM EDT](#)

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"Artificial intelligence is going to become the medium by which most humans produce all digital content."

The Passionate Eye
23 days ago



Montreal-based AI godfather warns about dangers of artificial intelligence

CBC News: Montreal at 6:00
2 months ago

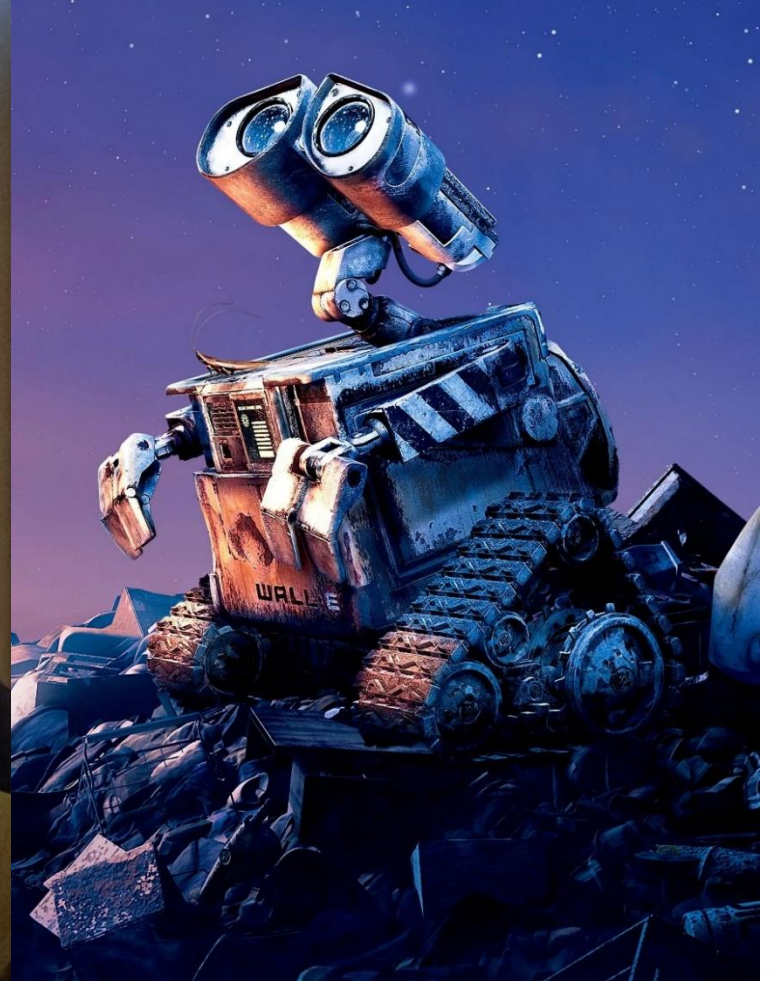
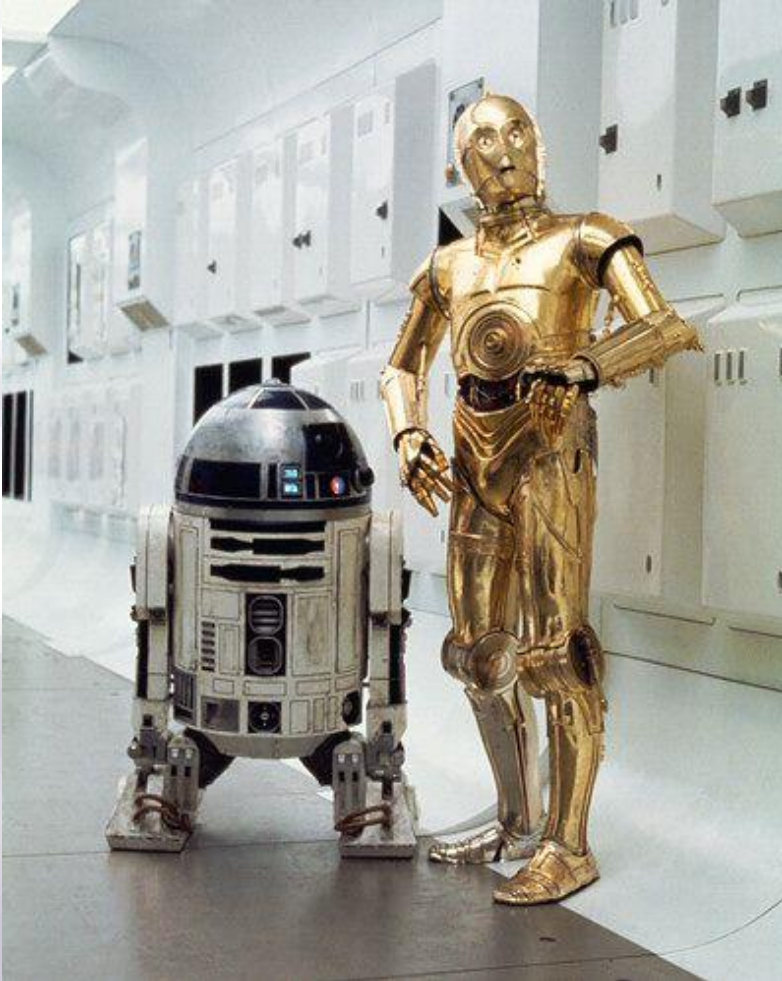


ChatGPT boss urges U.S. to set rules for artificial intelligence

The National
5 months ago



Portrayal of AI in Popular Culture





Practical Uses of AI Today



Good:

- Digital assistants (Google, Siri, Alexa)
- Search engines
- Real time traffic directions
- Banking fraud detection
- Self-driving cars
- “You may also like...” (Amazon, Netflix)
- Chatbots
- Facial / voice recognition
- Facebook news feeds
- ChatGPT?

Evil:

- Phishing emails
- Deepfake videos
- Plagiarism
- Automation-spurred job losses (even ours?)
- Weapons automatization
- Self-aware AI (see S-F examples above)
- Chatbots
- Facial / voice recognition
- Facebook news feeds
- ChatGPT?

Emergence of ChatGPT

Origin:

- Chat Generative Pre-trained Transformer
- Large, language model-based chatbot developed by OpenAI and launched Nov. 30, 2022
- Enables users to refine and steer a conversation towards a desired length, format, style, level of detail, and language
- Successive prompts and replies, known as prompt engineering, are considered at each conversation stage as context

What it is useful for right now:

- Writing report content, essays, resumes,
- Writing / debugging source code
- General learning: explaining concepts, solving math problems
- Writing poetry, songs, jokes, love letters...
- Write environmental conference abstracts?



Emergence of ChatGPT

KE

I would like to write an abstract for an environmental conference. The topic would be on the use of AI like yourself to help design remediation programs. Specifically permeable reactive barriers to treat chlorinated solvents or petroleum hydrocarbons. The abstract will pose the question as to whether human environmental professionals are becoming redundant for this activity. I would like to pose the question as to whether human professionals are now only needed to pose the problem and provide the data inputs or whether they still need to do a reality check on the AI-generated remedial design. I would like the title to be catchy and kind of hyperbolic.



AI vs. Environmental Experts: Are Humans Becoming Obsolete in Remediation Design?

As the environmental remediation landscape evolves, the integration of Artificial Intelligence (AI) has emerged as a transformative force in designing effective solutions. This abstract challenges the traditional role of human environmental professionals by exploring the potential of AI, such as ChatGPT, in shaping and executing remediation programs...

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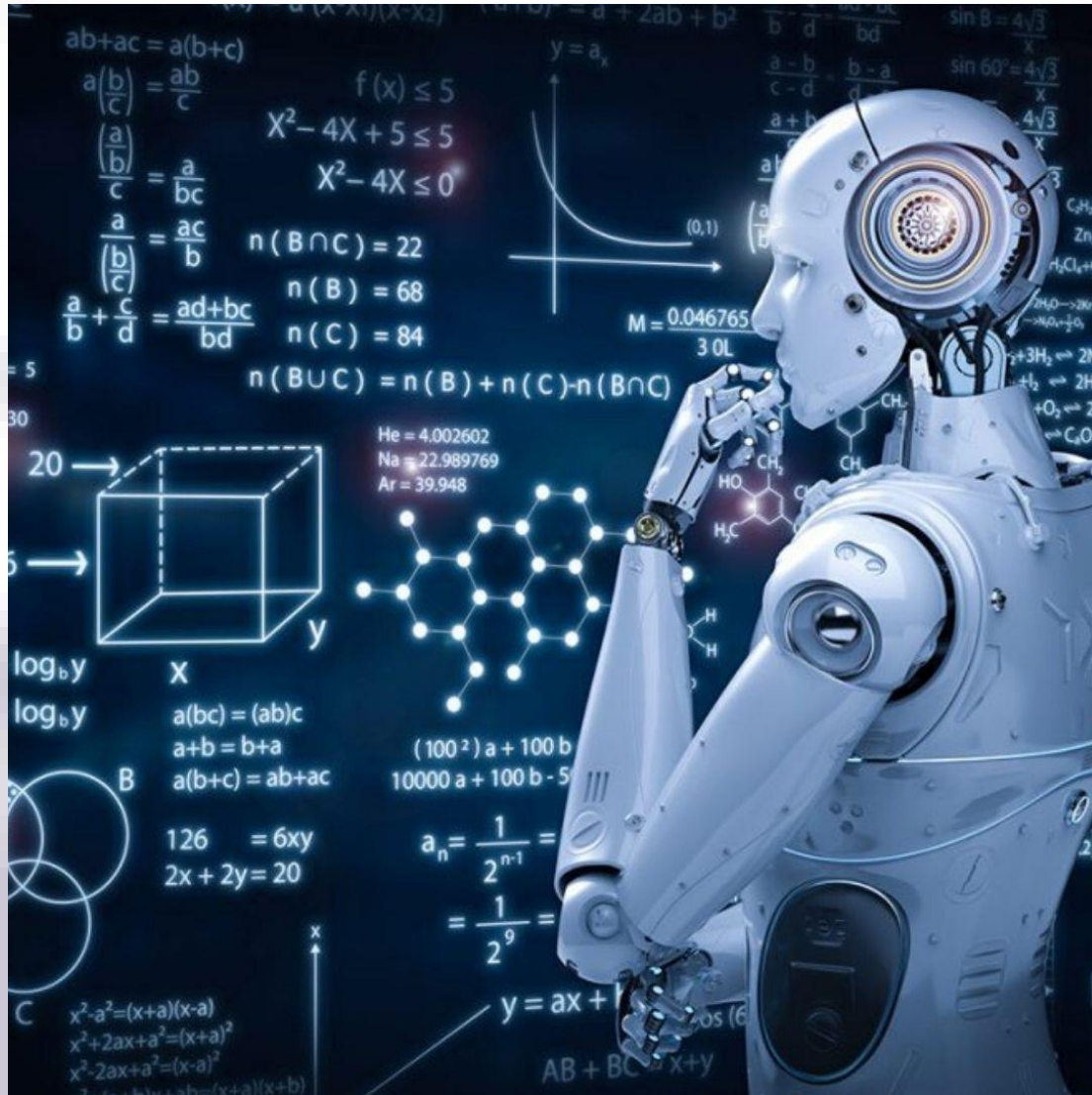
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Emergence of ChatGPT



- Currently no publicly-available environmental science and engineering design AI
- Some private applications mainly designed for monitoring and detection, data analysis and predictive modeling
- ChatGPT is available and broadly used for a wide variety of applications
- **If ChatGPT can do a wide range of things that people traditionally do, can it tackle other tasks like environmental remediation design?**

AI-Assisted Remediation Design

KE

Can you help me to design an in-situ environmental remediation workplan if I input relevant site details, such as contaminant type, concentration, soil type, etc.?



Yes, I can provide you with **some guidance** on designing an in-situ environmental remediation workplan based on the information you provide about the site. Here are some steps that you can follow:

- **Step 1: Identify the contaminant type and concentration.**
- **Step 2: Determine the soil type and characteristics.**
- **Step 3: Choose a remediation technology.**
- **Step 4: Develop a remediation workplan.**
- **Step 5: Implement the workplan and monitor the site.**

I hope this provides you with some guidance on designing an in-situ environmental remediation workplan. Please keep in mind that the specific details of the workplan will depend on the site-specific factors and the remediation technology selected. **It is always recommended to consult with a qualified environmental professional before implementing any remediation work.**

AI-Assisted Remediation Design

KE

Can you design a permeable reactive barrier for a site?



Yes, I can help you design a permeable reactive barrier (PRB) for your site. Please provide me with the following information:

- Contaminant type and concentration: What is the contaminant that you are trying to remediate and what is the concentration of the contaminant in the groundwater?
- Soil type and characteristics: What is the soil type at the site, and what are its characteristics such as porosity, hydraulic conductivity, and organic matter content?
- Hydrogeology: What is the groundwater flow direction, depth to groundwater, and the hydraulic conductivity of the aquifer?
- Site dimensions: What are the dimensions of the site where the PRB will be installed?

Once I have this information, I can provide you with a more detailed design for the PRB.



AI-Assisted Remediation Design

KE

- Contaminant type and concentration:
 - PCE = 5 µg/L, TCE = 22 µg/L, C12DCE = 187 µg/L and VC = 17 µg/L
- Soil type and characteristics:
 - Mixed sand and gravel fill to 2.5 m, then silty sand to sandy silt to 5.5 m, then silty clay till below 5.5 m
 - Porosity of the silty sand unit is 0.3
- Hydrogeology:
 - Depth to groundwater is 3.0 m
 - Hydraulic conductivity of the silty sand unit is 1×10^{-6} m/s
 - Hydraulic gradient is 0.01
 - Flow direction is to the south
- Site dimensions:
 - Southern property boundary is 50 m wide

AI-Assisted Remediation Design



Based on this information, a PRB consisting of a reactive material such as **zero-valent iron** can be installed perpendicular to the groundwater flow direction to intercept and treat the contaminants. The design for the PRB is as follows:

- Dimensions:
 - Length: 50 m (equal to the width of the property)
 - Depth: **from the ground surface to the bottom of the silty sand layer** (about 5.5 m)
 - Width: 1 m (assumed)
- Reactive material:
 - Zero-valent iron (ZVI) granules or powders
- Installation:
 - Excavate a trench 1 m wide and to the bottom of the silty sand layer
 - **Fill the trench with ZVI granules or powders**
- Maintenance:
 - Regular monitoring of the groundwater and PRB performance
 - Replacement of the ZVI if necessary

AI-Assisted Remediation Design

KE

What concentration of ZVI should go in the trench?



Typically, the ZVI concentration used in a PRB **ranges from 5% to 20% by weight** , although higher concentrations can be used in some cases.

In your case, the contaminant concentrations are relatively low, and the hydraulic conductivity of the silty sand layer is relatively low, so a lower concentration of ZVI may be appropriate. **A concentration of 10% by weight is a common starting point for ZVI concentration in PRBs.**

It is always recommended to consult with a qualified environmental professional to design a PRB tailored to the specific site conditions and contaminant characteristics.



AI-Assisted Remediation Design

KE

Is there a method that this PRB could be installed by injection rather than trenching since there is restricted access at this site?



Yes, it is possible to install a permeable reactive barrier (PRB) by injection instead of trenching, particularly if there is restricted access to the site:

- **Direct push injection:** This method involves using a direct push drill rig to create injection points along the length of the PRB. Once the injection points are established, a slurry of the reactive material (e.g., ZVI) and a carrier fluid (e.g., water or a polymer solution) is injected under pressure into the subsurface. The carrier fluid is used to facilitate the injection of the reactive material and to distribute it uniformly in the subsurface.

KE

What type of ZVI should I use for the injection approach?



For the injection approach, **a fine-grained ZVI material** with a high surface area is typically preferred since it can be more easily injected into the subsurface and provides a larger reactive surface area for contaminant degradation.



AI-Assisted Remediation Design

KE

What mass of ZVI will I need for this PRB?



Assuming a PRB thickness of 2 m, a hydraulic conductivity of 1×10^{-6} m/s, and a porosity of 0.3 for the silty sand unit, we can estimate the volume of the PRB as follows:

- Volume of PRB = width of property x PRB thickness x **depth to groundwater**
- **Volume of PRB = 50 m x 2 m x 3 m Volume of PRB = 300 m³**

Using a conservative estimate of ZVI reactivity, we can assume that one gram of ZVI can remove approximately 1 micromole of contaminant per minute. Therefore, the mass of ZVI needed can be estimated as follows:

- Mass of ZVI = (target contaminant mass to be removed) / (ZVI reactivity x PRB lifespan)

Assuming a PRB lifespan of 10 years, we can estimate the mass of ZVI needed as follows:

- Mass of ZVI = (target contaminant mass to be removed) / (1 gram/micromole/min x 525,600 min/year x 10 years)
- **Mass of ZVI = (5 ug/L x 300 m³ x 1000 L/m³ x 1 mg/1000 ug) / (1 ug/micromole) / (1 gram/micromole/min x 525,600 min/year x 10 years) Mass of ZVI = 0.071 kg or 71 grams**

This amounts to 25 sand sized particles of ZVI per L of PRB volume!

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KE

Should I inject more ZVI mass to create a minimum distribution of ZVI in the subsurface to ensure the contaminants in the groundwater plume come into contact with the ZVI and are destroyed?



Yes, it may be beneficial to inject more ZVI than the estimated minimum mass to ensure that the ZVI is distributed evenly throughout the subsurface and can effectively come into contact with the contaminants in the groundwater plume.

KE

What is the mass of ZVI that I should inject at this site to ensure the recommended minimum in-situ distribution of ZVI is achieved?



As a rough estimate, a typical range of ZVI mass for injection-based PRB applications is **between 1-5% of the soil mass**. For example, if the volume of the PRB is estimated to be 300 m³ and the soil density is assumed to be 1.6 g/cm³, the soil mass would be approximately 480 MT. **In this case, the range of ZVI mass needed would be between 4.8 and 24 MT.**

This answer is now 67,000 to 334,000 times the previous answer!



AI-Assisted Remediation Design

KE

OK, I am going to inject 12 MT of ZVI at this site. What is the recipe I should use for mixing up the ZVI into a slurry so I can inject it?



To create a ZVI slurry for injection, you will need to mix the ZVI powder with water and a stabilizing agent to keep the ZVI particles suspended in the solution. Here is a general recipe for creating a ZVI slurry:

Ingredients:

- ZVI powder: 12 MT
- Water: approximately 60,000 L (calculated based on a 5:1 ratio of water to ZVI mass)
- Stabilizing agent: such as carboxymethyl cellulose (CMC) or guar gum, as needed



AI-Assisted Remediation Design

KE

How much guar gum will I need to suspend the 12 MT of ZVI powder in the 60,000 L of water to create the slurry?



The amount of guar gum needed to suspend the 12 MT of ZVI powder in the 60,000 L of water to create the slurry can vary depending on the particle size distribution of the ZVI powder and the desired slurry properties. As a general guideline, a concentration of 0.1-0.2% by weight of guar gum is often used as a starting point for ZVI slurries.

Assuming a guar gum concentration of 0.1% by weight, you would need 12 MT x 0.1% = 12,000 kg (or 12 MT) of guar gum to create the slurry.

Now it's getting basic math wrong! The answer should be 12 kg!



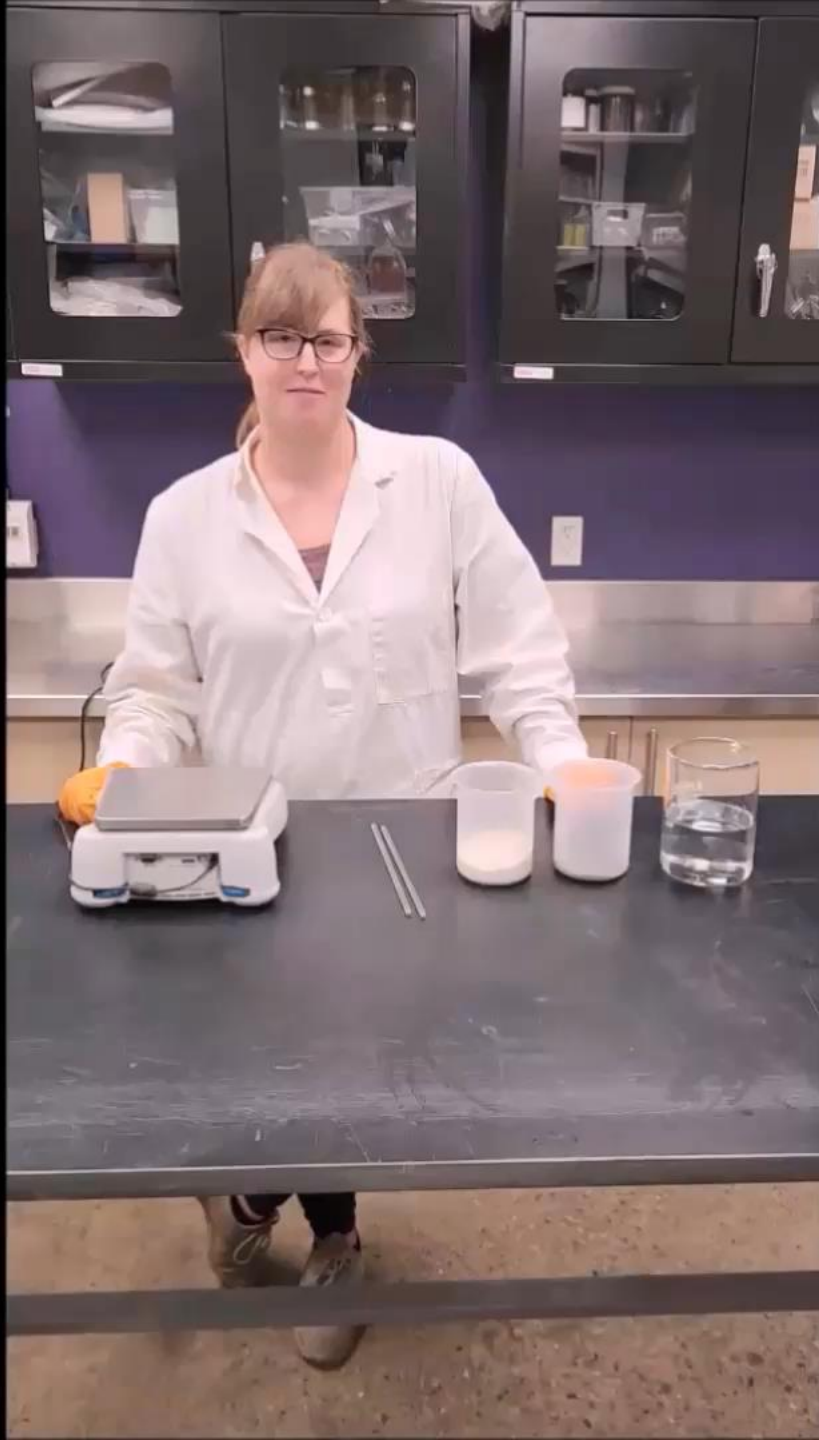
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Instructions:

- Add the ZVI powder to a large mixing tank or container.
- Slowly add the water to the mixing tank while stirring continuously to avoid clumping of the ZVI powder.
- **Continue stirring until the ZVI powder is fully mixed with the water and there are no visible clumps or settled particles.**
- **If needed**, add a stabilizing agent such as CMC or guar gum to help keep the ZVI particles suspended in the slurry.
- Mix the stabilizing agent into the slurry until fully dissolved.
- If possible, test the ZVI slurry for particle size distribution and other properties to ensure that it is suitable for injection. Adjust the slurry properties as needed before injection.





AI-Assisted Remediation Design

KE

Would a different type of PRB be needed if the groundwater contamination was 1,500 $\mu\text{g}/\text{L}$ of **gasoline range PHCs** instead of the chlorinated solvents noted initially?



For gasoline range PHCs, a common approach is to use an organic substrate-based PRB, which **typically consists of a mixture of carbon-based materials (such as AC, biochar, or other organic matter)** that can sorb and biodegrade the contaminants.

KE

How much AC would I need for this gasoline range PHC PRB so that it will last 10 years?



Therefore, approximately **62 kg of AC** would be needed for this gasoline range PHC PRB to last 10 years. It is important to note that this is only an estimate and the actual amount required may vary depending on site-specific conditions.



AI-Assisted Remediation Design

KE

Is there a minimum mass of AC that I should put in the PRB to ensure contact with the PHC contamination in the groundwater?



Yes, there is a minimum mass of AC that should be used to ensure proper contact with the groundwater contamination. Typically, **a minimum of 5% to 10% by weight of the AC** is used to ensure sufficient contact with the contaminants.

KE

Considering the minimum mass requirement you mention, how much AC would I need for this PRB?



So, approximately **1,825 kg of AC** would be needed for this PRB to ensure sufficient contact with the PHC contamination in the groundwater.

At least we're a bit closer this time; only off by ~30 times the previous answer!



AI-Assisted Remediation Design

KE

Would I need to add any other amendments to the PRB to assist in the degradation of the PHCs?



Yes, it is often beneficial to add other amendments to the PRB to assist in the degradation of PHCs. One common approach is to **add a mix of electron donors, such as molasses or lactate**, to stimulate the growth of indigenous microorganisms that can degrade the PHCs. In addition, **adding nutrients like nitrogen and phosphorus** can also enhance the biodegradation process.

AI-Assisted Remediation Design

KE

How much electron donors and nutrients should I add to the AC for this PRB?



The amount of electron donors and nutrients needed for the PRB would depend on several factors, including the site-specific conditions, the characteristics of the PHC contamination, and the desired degree of treatment. In general, the addition of electron donors and nutrients to the PRB is typically **based on a ratio of carbon to nitrogen to phosphorus (C:N:P) of 100:10:1.**


Assuming a mass of 5,000 kg of AC in the PRB , the recommended amount of electron donors and nutrients would be approximately:

- **Carbon source: 500 kg (based on C:N:P ratio of 100:10:1)**
- **Nitrogen source: 50 kg**
- **Phosphorus source: 5 kg**



AI-Assisted Remediation Design

KE What type of long-lasting carbon source should I use?

 **A commonly used carbon source for PRBs is emulsified vegetable oil (EVO).** EVO can provide a long-lasting and slow-release carbon source, promoting microbial activity and biodegradation of contaminants.

KE **Won't EVO take up adsorption sites on the AC and make it less effective?**

 **Yes,** it is possible that EVO can compete with the contaminants for adsorption sites on the AC, reducing the overall effectiveness of the PRB.

KE **Is there anything else I should add to this PRB to ensure adsorption and degradation of the PHCs in the groundwater?**

 In addition to the activated carbon and electron donors/nutrients, **it may be beneficial to also incorporate a source of microbes to the PRB.**

AI-Assisted Remediation Design

KE

Would you typically need more or less colloidal activated carbon (CAC) than PAC to adsorb the same mass of gasoline range PHCs?



Generally, CAC may require a higher mass compared to PAC to adsorb the same mass of gasoline range PHCs. This is primarily because CAC has a smaller particle size, which can result in a larger surface area and potentially higher adsorption capacity per unit mass.

KE

If CAC has a higher adsorption capacity per unit mass as compared to PAC, wouldn't you require less CAC than PAC to adsorb the same mass of PHCs?



Apologies for the confusion in my previous response. You are correct, CAC typically has a higher adsorption capacity per unit mass compared to PAC. Therefore, you would generally require less CAC than PAC to adsorb the same mass of PHCs.

Now I'm starting to doubt everything it's telling me!



AI-Assisted Remediation Design

KE

I must admit that I am getting a little bit frustrated by the inconsistencies and errors in some of your responses. How can I be sure that the PRB designs you have been assisting me with will actually perform as expected?



I apologize for any frustration caused by the inconsistencies and errors in my previous responses. As an AI language model, I strive to provide accurate and helpful information, but I am not infallible, and there can be limitations and occasional mistakes in the responses generated.

One of the main problems with ChatGPT is that it answers questions it doesn't know the answer to instead of saying it doesn't know the answer!

AI-Assisted Remediation Design

KE

I think I will consult with a qualified environmental professional on these matters in the future.



That is a wise decision. Consulting with a qualified environmental professional is highly recommended when dealing with complex projects and environmental remediation. They have the expertise and experience to assess your specific site conditions, understand regulatory requirements, and design effective remediation strategies tailored to your needs.

By working with environmental professionals, you can benefit from their knowledge and guidance throughout the project, including the design, implementation, monitoring, and evaluation stages. Their expertise will help increase the likelihood of a successful and compliant remediation process.

If you have any further questions or need assistance in the future, feel free to reach out.
Best of luck with your environmental remediation project!



AI-Assisted Remediation Design

Lastly, Alyson was doing some research on natural vs chemical remediation of LNAPL and ChatGPT offered up the following reference:



Mancini, S. A., Ulrich, G. A., Lacrampe Couloume, G., Sleep, B. E., Edwards, E. A., & Major, D. W. (2003). Field demonstration of phenol biodegradation in the presence of LNAPLs. *Environmental Science & Technology*, 37(6), 1133-1140. DOI: 10.1021/es020942d.

This study provides information on the biodegradation of light non-aqueous phase liquids (LNAPLs) at a former gas station site in New Jersey, USA, and the role of naturally occurring microorganisms in the subsurface in breaking down the hydrocarbons. The study found that biological degradation was the dominant process for LNAPL removal at the site, rather than physical extraction using multi-phase extraction (MPE).



AI-Assisted Remediation Design

KE

Where did you obtain the above reference from Mancini?



I apologize for any confusion, but I don't have access to specific databases, publications, or sources. **The reference provided earlier was based on a fictional scenario created for illustrative purposes and does not correspond to an actual study by Mancini or any other researcher.**

KE

Where do you get your information from then?



I have been trained on a diverse range of data sources, including books, articles, websites, and other text-based material, to develop a broad understanding of human language. My training encompasses various topics, allowing me to provide information and answer questions on a wide range of subjects. It's important to note that while I strive to provide accurate and up-to-date information, **my responses may not always reflect the most current news or developments since my training data goes up until September 2021.**



AI-Assisted Remediation Design

What do you think the current qualifier / disclaimer is on the bottom of the page on the ChatGPT website?

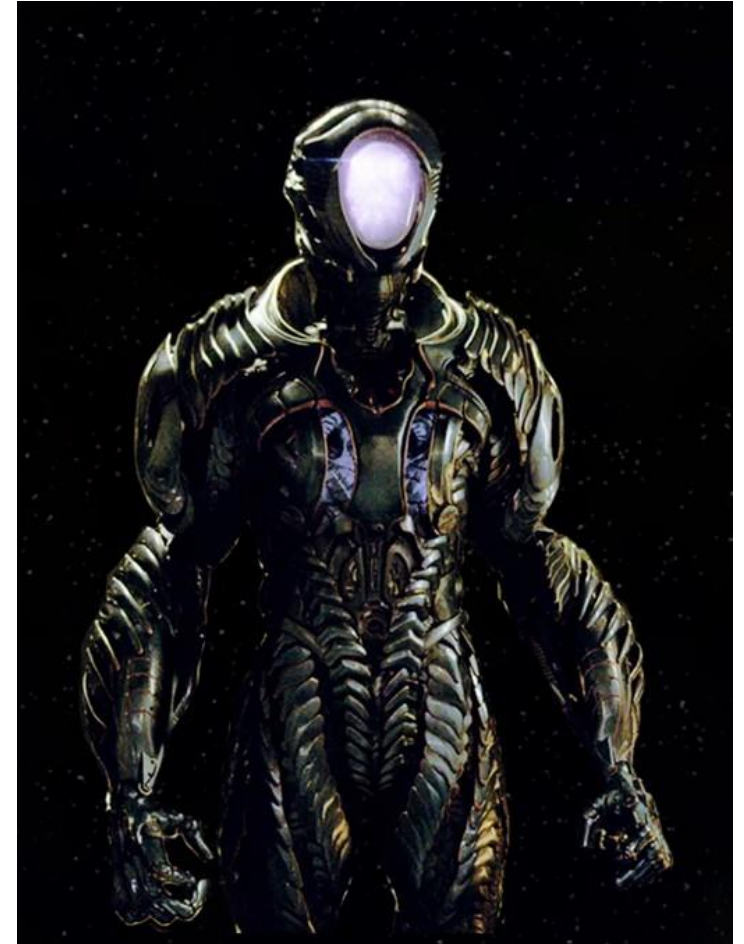


ChatGPT may produce inaccurate information about people, places, or facts.



Take Aways / Lessons Learned

- AIs are very good at what they were designed for and learn incredibly fast; but that **doesn't mean they're good at everything**
- They are just tools and like any tool **you need to know what they can be used for and how to use them**
- They can regurgitate information and data, do calculations, provide realistic responses and perhaps even provide some insights
- They “learn” by digesting vast amounts of information, recognizing patterns and **imitating human responses**
 - **By their very nature AIs are derivative: they lack innovation and intuition**

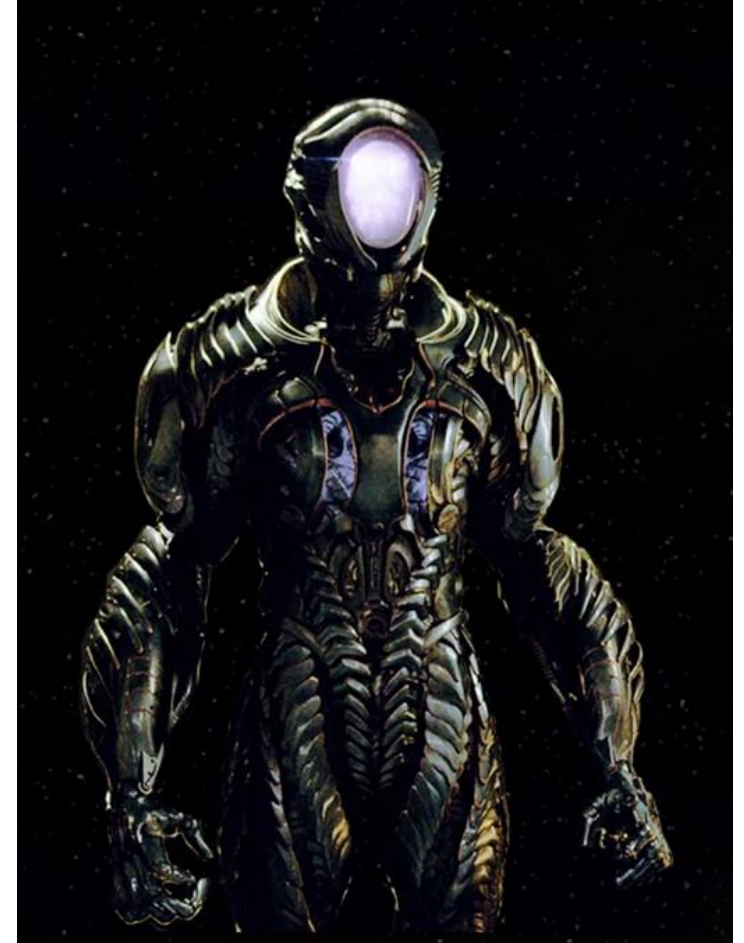


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Take Aways / Lessons Learned

- Also, what information do they currently have access to and, more importantly, **what don't they have access to?**
 - Any published information available after their cut-off date
 - Latest conference proceedings
 - Proprietary information
 - Industry experience or “tribal knowledge”
- No specific AI yet that is designed for environmental remediation design, but undoubtedly there will be one day soon

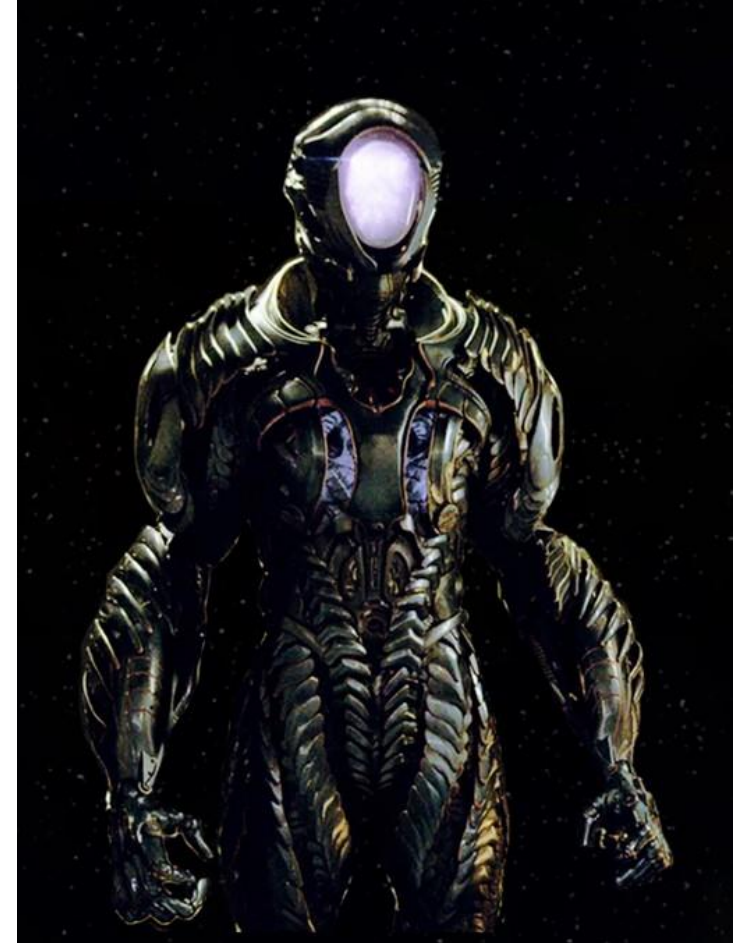


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Take Aways / Lessons Learned

- Even then, AI will likely not ever take the place of (human) environmental professionals, but will likely make some parts of our jobs easier
- **The user still needs to know enough to ask the right questions and validate the answers provided since there is no built-in audit check:**
 - Incorrect basic math
 - Wrong chemistry
 - Contradictory answers
 - Made up references, etc.
- **The main thing ChatGPT did get correct was advising the user to contact an environmental professional!**



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Don't worry:
Your job is safe!
(for now?)

Questions?

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