From:	Carol McClelland Fields
To:	Benton Public Comment
Subject:	Three Written Comments resent with Embedded Resources - Oppose/Deny LU-24-027
Date:	Monday, June 16, 2025 2:50:55 PM
Attachments:	Testimony - LU-24-027 - Carol McClelland Fields - Odor-Methane with Resources Included.pdf Written Testimony - Oppose LU-24-27 - Disaster Debris Impacts - Carol McClelland Fields - Resources Included.pdf

Good afternoon.

I have recreated my original three written testimony PDFs to include appended resources.

- CWPP and Fire Risk was originally submitted on 4.29.25. (Includes the entire Benton County Community Wildfire Protection Plan CWPP) - **Attached to next email**
- Odor and Methane was originally submitted on 5.1.25. - Attached to this email
- Disaster Debris Impacts was originally submitted on 6.5.25. -- Attached to this email

In the previous submissions I had links to all of my resources, but since then we've learned that linked resources would not be in the record and therefore can not be read by Planning Commission members. To remedy this, I have included all of my resources within each new PDF document.

Thank you.

Carol

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Carol McClelland Fields, PhD, BCC
541 243 3675
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To: publiccomment@bentoncountyor.gov

Subject: Oppose/Deny LU-24-027 - **Odor Patrol – WITH RESOURCES BELOW**

*(**CORRECTION**: Unfortunately, the previously submitted (May 1, 2025) version of this document duplicated the subject of another testimony document: A Garbage-Truck Sized Hole in the Community Wildlife Protection Plan (CWPP). Please see that document as well! **I also have appended my supporting documents to the end of my written comments.**)*

Dear Benton County Planning Commissioners,

My name is Carol McClelland Fields, and I live at 37326 Soap Creek Rd about four miles from Coffin Butte Landfill.

I strongly oppose Republic Services' Conditional Use Permit application LU-24-027 to expand the Coffin Butte landfill. I urge the Planning Commission to deny this application because the proposed use seriously interferes with uses on adjacent property, with the character of the area, or with the purpose of the zone [Benton County Code 53.215 (1)]

I live 4.1 miles south of Coffin Butte Landfill.

On a good day, I don't smell any landfill stench.

On a bad day, I smell the landfill stench as soon as I walk out my door in the morning. I limit my time outdoors on these days!

On a very bad day, I smell the landfill stench INSIDE MY HOUSE! Specifically on the second floor of my home. This has happened twice in 2025…so far. It's a very disconcerting sensation to meet that acrid stench inside my own home. This is new. Prior to 2025, I had not had this experience. It is hard to escape the stench and toxic cocktail of chemicals when there's no where else to go!

The smell that is not the most disconcerting aspect of this experience…it is knowing that the landfill stench is caused by dangerous chemicals and that methane is highly flammable.

> Methane itself is odorless. However, when methane is released into the atmosphere, methane is accompanied by other toxic pollutants. These chemicals have serious health impacts, primarily on the lungs and immune system.
>
> Why Coffin Butte landfill gas stinks:
>
>> **Hydrogen sulfide [H_2S]:** Rotten-egg smell. Even low concentrations cause eye irritation, sore throat and cough, nausea, shortness of breath, and fluid in the lungs.

Long-term, low-level exposure can cause headaches, dizziness, and memory issues. **Coffin Butte landfill gas has about 8 parts per million by volume.**

Methyl Mercaptan [CH3SH]: Bad fart smell / asparagus-pee smell, also produced by pulp mills. Detectable by humans down to 1 part per billion. **Coffin Butte landfill gas has 2300 times that level.**

Isopropyl mercaptan [C3H8S]: Skunk smell, extremely pungent. **Coffin Butte landfill gas has over 2 parts per million by volume.**

Dimethyl sulfide [(CH3)2S]: Rotten cabbage smell, also what you smell if a batch of home-brew goes bad. **Coffin Butte landfill gas has about 2 parts per million by volume**. #cleanair #corvallis

(Resource 1: Google search)

In addition, methane is highly flammable. Methane mixed with air can be an explosive combination. A disconcerting thought given that the nature of our region is bucolic meadows and forests as well as agricultural lands.

Odor Complaint

When I report the bad and very bad days to the State of Oregon Department of Environmental Quality (DEQ), my complaint is acknowledged by the Permitting and Compliance Specialist -- Air Quality. She informs the Coffin Butte Landfill's Environmental Manager, and he sends a response about what they noted on that day. **Our odor patrol on the Xth at XX am did not detect anything. It includes driving out Soap Creek Road. All landfill systems were operating normally that day. Let me know if you have any questions.** Everyone who submits a complaint receives a message along this theme.

Odor Patrol?

They drive around trying to smell the landfill stench?

Olfactory fatigue occurs when the olfactory receptors in the nose become desensitized to a noxious smell after being exposed to it for a long time. The nose filters out what it considers "background noise." This is a physiological response and cannot be overridden. When this happens, the person can no longer smell the landfill stench. Even if they have a number of people on Odor Patrol, working anywhere near the landfill has likely changed their ability to smell the stench.

Geographic range. How does the Odor Patrol know where to check for landfill stench. Do they only check when they smell it? Is it a daily operation? At what time of day? Are they constantly on the move? Where do they focus? We've heard of landfill stench complaints from people driving by the landfill on 99W as well as from people in North Corvallis, which is 8-12 miles away, and on Hwy 20 south of town.

Altitude. It's not enough to just measure the smell at ground level. Plumes of methane have been reported from drone / flight data. How is the Odor Patrol accounting for altitude? Based on reports by neighbors, I know that someone high on the ridge directly across Soap Creek from my property smells the landfill stench on days I don't smell it on the valley floor. There can be pockets of stench that would be hard to isolate while driving around.

Weather patterns and air currents may mean that they don't smell anything at the landfill, because the wind patterns send the methane mixed with dangerous chemicals up into the atmosphere. When those particles come back down, they can be miles from the landfill and the Odor Patrol.

"All landfill systems were operating normally."

My nose tells me that I have landfill stench inside my home.

The Republic Services claims the landfill systems were operating as they should.

Something doesn't compute.

Without third party methane measurements, this rapidly becomes a "he said/she said" situation.

If the landfill systems are working, then why are the neighbors in the area regularly impacted by the landfill stench?

- Are there leaks that the landfill operators are not aware of? This is likely based on recent EPA reports about large methane plumes above and around Coffin Butte Landfill that were never reported by the landfill operators.

- Are they just measuring methane on part of Coffin Butte Landfill? What's happening on the 47% and 38% of the landfill that has been deemed exempt from monitoring? **Please read about the findings in the following article that will shed more light on this sentence.**

In an article entitled: **Oregon corporate landfills using loophole to avoid methane monitoring, study finds,** Tracy Loew of the Salem Statesman Journal reports: (the following italicized excerpts were taken directly from this article): (Resource 2: https:/www.statesmanjournal.com/story/tech/science/environment/2025/2003/06/oregon-landfills-methane-monitoring-loophole-study/81163394007/)

Oregon's corporate-owned landfills are using a loophole in state law to avoid methane monitoring on an average of about half of their operating surfaces*, a new study concludes.*

County-owned landfills, meanwhile, are exempting an average of 10% of their surfaces, *according to the report released Thursday by the Eugene-based environmental group Beyond Toxics. (That 37-page report: OREGON'S SECRET CLIMATE KILLERS: Pulling Back the Curtain on Hidden Landfill Methane Emissions. March 2025. Authors Mason Leavitt, Lisa Arkin.*

(Resource 3: https://www.beyondtoxics.org/wp-content/uploads/2025/03/Oregons-Secret-Climate-Killers-Feb-2025-Beyond-Toxics.pdf)

The rules require quarterly monitoring of the landfill, by walking the surface with a handheld gas analyzer. Identified leaks measuring over 500 parts per million must be fixed within 10 days.

The rules allow landfills to use "alternative compliance options," including changing walking paths, to exclude monitoring where there are potential safety and other issues, such as steep or slippery slopes and physical obstructions.

Mason Leavitt, data analytics specialist for Beyond Toxics, said companies appear to be abusing that exemption.

For example, ***the 178-acre Coffin Butte Landfill, near Corvallis, exempted 40 acres in the third quarter of 2022 and 30 acres in the fourth quarter of the same year, citing "high vegetation," according to the report. The landfill continued to exempt those areas in 2023 without citing a reason.***

The researchers determined the percentage of each landfill that was unmonitored each quarter. ***Coffin Butte Landfill, near Adair Village, operated by Republic Services: Between 53% and 62%.***

U.S. EPA finds problems with methane monitoring

Beyond Toxics' conclusions mirror those in a recent U.S. Environmental Protection Agency report.

(Resource 4 – EPA Report - https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance)

More than 100 EPA inspections over the past three years found that many municipal solid waste landfills across the country were not properly monitoring emissions.

"While the regulations allow municipal solid waste landfills to exclude certain areas from the surface emissions monitoring (e.g., areas with steep slopes or other dangerous areas), the ***EPA observed during recent inspections that areas that are not dangerous are improperly excluded from monitoring****," the EPA report states.*

"If a municipal solid waste landfill excludes areas from the surface emissions monitoring, the facility should document and explain the basis for excluding each area from monitoring in the surface emission design plan and SEM reports. The regular side slopes of the landfill may not be excluded from monitoring per the regulations," the report reads.

Coffin Butte Landfill was among those the EPA inspected.

Furthermore, we need third-party methane measurements using drone equipment and satellite imaging. Wouldn't it be helpful for Republic Services, DEQ, EPA, surrounding counties, and the residents to:

Know how much danger we are in due to methane with dangerous chemicals mixed in - health impacts, fire danger, greenhouse gases that contribute to climate change, etc.

To know **the extent of the leaks...and more importantly, where to fix those leaks.**

To know the **emissions in the entire plume**, not just at ground level.

To reiterate, these measurements MUST BE monitored by neutral a third party entities. Based on numerous instances in the past, we cannot rely on the Applicant's ability to accurately measure and report what is happening at Coffin Butte.

From the same article referenced above:

In 2022, the EPA found ***Coffin Butte was leaking methane at levels that exceed state and federal limits and what the landfill had publicly reported.***

EPA investigators ***returned in 2024 and found more than 40 locations where methane exceeded limits, including at holes in the cover material.***

EPA, rather than DEQ, is continuing to lead that investigation, Darling said.

Expanding the landfill will dramatically increase the methane / dangerous chemicals production and influence the frequence of the landfill stench. As the landfill moves to different cells, different neighborhoods will be more impacted. **I believe the landfill stench I smelled inside my house had to do with Republic Services rounding a corner to dump trash in a new cell that is more aligned with where my property is.**

I strongly oppose Republic Services' Conditional Use Permit application LU-24-027 to expand the Coffin Butte landfill. I urge the Planning Commission to deny this application.

As noted above: The Applicant's proposed use seriously interferes with my use of my property, just four miles from Coffin Butte, seriously interferes with the character of Soap Creek Valley area and beyond. [Benton County Code 53.215 (1)]

Between the toxic landfill stench, the flammable methane, and the Applicant's loose, reckless, and blatant disregard for State and Federal laws, measuring protocols, and reporting standards, do we know what's actually happening at Coffin Butte Landfill.

We are ALL at risk of health issues, catastrophic fires, dangerous air quality, and deadly water quality – in Benton County and the counties and residents that surround the landfill and drink water tainted by disposal for the toxic leachate. Our lives and the character of our area could easily be irrevocably changed with a spark, breathing the air, or drinking the water!

I appreciated the questions the Planning Commissioners asked during the first night of the hearing. Please continue to ask deep, detailed, and pointed questions to surface the essential details of this situation.

Respectfully Submitted

Carol McClelland Fields, PhD
37326 Soap Creek Road, Corvallis, OR

AI Overview

Coffin Butte landfill gas stinks because it contains several foul-smelling compounds, primarily methyl mercaptan, isopropyl mercaptan, and dimethyl sulfide, along with hydrogen sulfide, which all contribute to a strong "rotten egg" or "rotten cabbage" like odor, even at very low concentrations, due to their extreme pungency and ability to be detected by humans at very low levels.

Key points about the odor components of Coffin Butte landfill gas:

Hydrogen sulfide (H2S):

Known for its rotten egg smell, can cause irritation to eyes, throat, and respiratory system even at low levels, and may lead to headaches, dizziness, and memory issues with long-term exposure.

Methyl mercaptan (CH3SH):

Has a strong "fart" or "asparagus-pee" smell, and is detectable by humans at very low concentrations, making it a significant contributor to the landfill's unpleasant odor.

Isopropyl mercaptan (C3H8S):

Possesses a potent skunk-like smell, further adding to the offensiveness of the landfill gas.

Dimethyl sulfide [(CH3)2S]:

Associated with a rotten cabbage smell, also contributing to the overall odor profile of the landfill gas.

ENVIRONMENT

Oregon corporate landfills using loophole to avoid methane monitoring, study finds

Tracy Loew
Salem Statesman Journal

March 6, 2025 | Updated March 7, 2025, 8:55 p.m. PT

Wildfire burns near Halls Ridge communications tower
Video of the Beachie Creek Fire burning near a radio tower on Halls Ridge above Detroit on Sept. 8, 2020.

Key Points AI-assisted summary

- Beyond Toxics found that corporate-owned landfills in Oregon are avoiding methane. monitoring on about half of their operating areas
- The study analyzed quarterly emission reports from eight out of 11 Oregon landfills subject to new methane regulations.
- Private landfills are more likely to exempt areas from monitoring than county-owned facilities.

This story has been updated with new information from the Oregon Department of Environmental Quality.

Oregon's corporate-owned landfills are using a loophole in state law to avoid methane monitoring on an average of about half of their operating surfaces, a new study concludes.

County-owned landfills, meanwhile, are exempting an average of 10% of their surfaces, according to the report released Thursday by the Eugene-based environmental group Beyond Toxics.

The researchers set out to determine how well Oregon's new landfill methane emission standards, the strictest in the nation, are working.

Landfills are among the nation's largest sources of methane, a greenhouse gas more potent than carbon dioxide and a major contributor to climate change, according to the U.S. Environmental Protection Agency.

Oregon's new rules, part of a larger state effort to curb greenhouse gas emissions, went into effect in October 2021.

The rules require quarterly monitoring of the landfill, by walking the surface with a handheld gas analyzer. Identified leaks measuring over 500 parts per million must be fixed within 10 days.

The rules allow landfills to use "alternative compliance options," including changing walking paths, to exclude monitoring where there are potential safety and other issues, such as steep or slippery slopes and physical obstructions.

A new report from environmental group Beyond Toxics found between 53% and 62% of Coffin Butte Landfill went unmonitored each quarter for methane in 2023. *Abigail Dollins/Statesman Journal*

Mason Leavitt, data analytics specialist for Beyond Toxics, said companies appear to be abusing that exemption.

For example, the 178-acre Coffin Butte Landfill, near Corvallis, exempted 40 acres in the third quarter of 2022 and 30 acres in the fourth quarter of the same year, citing "high vegetation," according to the report. The landfill continued to exempt those areas in 2023 without citing a reason.

Alternative options must be submitted in writing and receive written approval from the Oregon Department of Environmental Quality before they may be implemented, according to state rules. But Leavitt found no evidence that was happening.

"The reports we analyzed did not include information or details on alternative monitoring plans approved by DEQ, so it's difficult to evaluate exactly what agreements are made between private owner-operators and DEQ," the Beyond Toxics report states.

"Half of private landfill surface area is going completely unmonitored for methane leaks," Leavitt told the Statesman Journal. "We're blind to what's happening in those sections of the landfill."

The Oregon Department of Environmental Quality just received the report and is reviewing it, spokesman Dylan Darling said.

The findings come as the Oregon Legislature considers a bill to improve landfill methane monitoring and reporting.

Senate Bill 726 would require municipal solid waste landfills to use advanced technology, such as drones, planes or satellites, to measure methane releases.

It would require landfill owners to report the results to the DEQ, in GIS software, which would make it easier to visualize.

And it would require landfills to fix any areas exceeding limits, and monitor that area again.

No methane monitoring data for 3 Oregon landfills

Oregon's new quarterly surface emissions monitoring rules apply to landfills with more than 200,000 tons of accumulated waste and methane emissions modeled to be greater than 664 tons.

Eleven landfills statewide met that criteria, according to the report.

Beyond Toxics asked DEQ for quarterly emission reports for all 11 landfills for 2023, the first full year of monitoring.

In response, the group received the reports for eight of those landfills.

Roseburg Landfill, managed by Douglas County, had not complied with the new rules. DEQ has issued a pre-enforcement notice to the landfill, warning that it could be cited and fined, Darling said.

The landfill began monitoring in second quarter 2024 and found two exceedances of the methane emission limits, he said.

Because of that, DEQ has given the landfill until June to submit a design plan to DEQ and until December 2026 to install and begin operation of a gas collection and control system. At that time, it will be required to resume methane emissions monitoring.

Hillsboro Landfill, owned by Waste Management, has until April to begin modeling under the terms of its air quality permit, according to DEQ.

And Baker Landfill, managed by a local private company, argued that it actually was two landfills, with each separately falling under the threshold for monitoring. One of the landfills, which are next to each other, closed in 2002, Darling said.

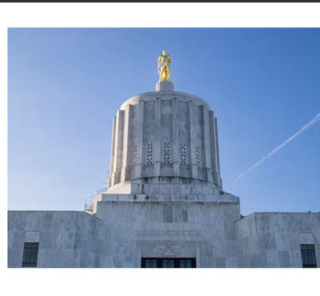
Beyond Toxics found companies exempted as much as 69% of landfill

Landfills provide data in their quarterly monitoring reports in print form, rather than using GIS software.

Leavitt, working with university students, spent about 300 hours translating it into spatial data, to map the areas monitored at each landfill each quarter. Without that work, it's difficult to know which areas of a landfill are unmonitored.

That's another shortcoming of the current rules, Leavitt said.

"That arcane system is currently what DEQ would have to rely on to be able to look at all of this in one place," he said.

DIG DEEPER ON PROPOSED BILLS
Oregon Legislature 2025
→ Budget advances to fund Oregon Public Defense Commission, resolve crisis
→ Oregon lawmakers propose tax hikes and new taxes to fund 2025 transportation bill
→ Data centers to pay new electricity rate under Oregon bill that has passed
→ Oregon House passes bill allowing striking workers to collect unemployment
→ Oregon lawmakers pass bill authorizing governor to fill US Senate vacancies


The researchers determined the percentage of each landfill that was unmonitored each quarter. Here are the results:

- Dry Creek Landfill, in Eagle Point, operated by Waste Connections: 69% each quarter
- Coffin Butte Landfill, near Adair Village, operated by Republic Services: Between 53% and 62%
- Wasco County Landfill, in The Dalles, operated by Waste Connections: Between 46% and 62%
- Finley Buttes Landfill, in Boardman, operated by Waste Connections: Between 27% and 58%
- Columbia Ridge Landfill, in Arlington, operated by Waste Management: Between 12% and 19%
- Knott Landfill, in Bend, operated by Deschutes County: Between 12% and 16%
- Short Mountain Landfill, near Eugene, operated by Lane County: 8% each quarter
- Crook County Landfill, in Prineville, operated by Crook County: Between 7% and 8%

U.S. EPA finds problems with methane monitoring

Beyond Toxics' conclusions mirror those in a recent U.S. Environmental Protection Agency report.

More than 100 EPA inspections over the past three years found that many municipal solid waste landfills across the country were not properly monitoring emissions.

"While the regulations allow municipal solid waste landfills to exclude certain areas from the surface emissions monitoring (e.g., areas with steep slopes or other dangerous areas), the EPA observed during recent inspections that areas that are not dangerous are improperly excluded from monitoring," the EPA report states.

"If a municipal solid waste landfill excludes areas from the surface emissions monitoring, the facility should document and explain the basis for excluding each area from monitoring in the surface emission design plan and SEM reports. The regular side slopes of the landfill may not be excluded from monitoring per the regulations," the report reads.

Coffin Butte Landfill was among those the EPA inspected.

In 2022, the EPA found Coffin Butte was leaking methane at levels that exceed state and federal limits and what the landfill had publicly reported.

EPA investigators returned in 2024 and found more than 40 locations where methane exceeded limits, including at holes in the cover material.

EPA, rather than DEQ, is continuing to lead that investigation, Darling said.

Coffin Butte expansion decision expected by August

The findings come as Coffin Butte Landfill, which takes waste from Marion and Polk counties, has just passed a major hurdle in its yearslong effort to expand.

On Feb. 28, Benton County deemed the company's application for a conditional use permit for the expansion "complete."

Sometime this spring, the county will open a two-week public comment period and a public hearing on the application. The county's planning commission is expected to decide on the application by Aug. 11.

Tracy Loew covers the environment at the Statesman Journal. Send comments, questions and tips: tloew@statesmanjournal.com or 503-399-6779. Follow her on X at @Tracy_Loew

BEYOND TOXICS

OREGON'S SECRET CLIMATE KILLERS

PULLING BACK THE CURTAIN ON HIDDEN LANDFILL METHANE EMISSIONS

March 2025

MASON LEAVITT
LISA ARKIN

BRIEF PURPOSE STATEMENT

In 2022, the Oregon Department of Environmental Quality implemented new rules which regulate landfill gas emissions. The rules require Oregon landfills with greater than 200,000 tons of waste-in-place to obtain an Air Contaminant Discharge Permit to submit data on the landfill characteristics and potentially monitor, collect and/or control landfill gas emissions. The DEQ's purpose was to reduce methane emissions to meet former Governor Kate Brown's directive provided in Executive Order No. 20-04 to give state agencies the authority to establish science-based greenhouse gas emissions reduction goals. Typically, landfill gas is made up of around 50% methane. Methane is a very strong greenhouse gas, more than 80 times as potent as carbon dioxide in the short-term.

In 2024, Beyond Toxics conducted an analysis of landfill operator compliance with Oregon's new landfill methane regulations which went into effect in October 2022. We examined 32 Surface Emissions Monitoring (SEM) reports submitted by eight Municipal Solid Waste (MSW) landfills out of a total of 11 MSW landfills that are required to follow the new rules. Our report is limited to eight landfills because three of the 11 large landfills received exemptions from the Department of Environmental Quality or did not comply with the new rules. Our investigation resulted in the following findings.

KEY FINDINGS

Three out of 11 of Oregon's large, currently operating landfills did not follow the state's surface emissions monitoring rules in 2023, one year after the rules went into effect in 2022. As a result, three of Oregon's largest landfills are completely unmonitored for potent methane emissions. This is important because 90% of the methane emissions produced by industries in Oregon come from its largest landfills.[1]

[1] Industrious Labs (2025). Don't Waste Our Future. Based on U.S. EPA Greenhouse Gas Reporting Program (GHGRP) 2022, U.S. EPA Landfill Methane Outreach Program (LMOP) (July 2023), and U.S. EPA GHG Equivalency calculator.

Our examination of maps submitted by the remaining eight largest MSW landfills reporting to regulators found that privately owned landfills (five out of eight)– all owned by large corporations– on average, excluded 48.6% of the landfill surface area from monitoring for methane emissions. While minor portions of these exemptions are legally justified, for example the open area of the landfill's working face where trash is being dumped, most of these exemptions are ambiguous. The high rate of exemptions calls into question how compliant landfill owner-operators are with Oregon's laws. Notably, it coincides with the U.S. EPA's recent nationwide enforcement alert noting "widespread" noncompliance with surface emissions monitoring rules including exempting substantial portions of landfills from SEM without sufficient justification.[2]

Compared to privately owned landfills, publicly owned landfills managed by local governments excluded, on average, just 10% of the surface area. The difference demonstrates significant disparities in methane emission data between privately owned landfills that are managed for profit, and publicly owned landfill operations that are managed for the benefit of local taxpayers and businesses.

There are key gaps regarding what surface emissions monitoring data is required to be reported to state regulators, which leaves the Oregon Department of Environmental Quality unable to review results. Most Oregon landfills required to conduct monitoring are not reporting their surface emissions monitoring locations using verifiable GPS tracking, making it impossible to verify that owner-operators are monitoring every 25 feet as required by law. As a result, there could be significant gaps in methane detection. There is also no way for state regulators to verify integrated monitoring results because landfills are not required to report basic information such as their 50,000 square foot grids and the average surface emission reading in each of those grids.[3]

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[2] Environmental Protection Agency. (2024, September 25). Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements. EPA Investigations Find Municipal Solid Waste Landfill Operators Are Failing to Properly Conduct Compliant Monitoring and Maintenance of Gas Collection and Control System. https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance

[3] Integrated monitoring results are derived from the averaging of all surface emissions monitoring measurements in a given 50,000 square foot grid.

RECOMMENDATIONS

The state of Oregon Department of Environmental Quality (DEQ) should immediately move to integrate the mandatory use of remote sensing technologies into Surface Emission Monitoring (SEM) rules to detect and pinpoint methane leaks at landfills.[4] One available technology is deploying methane detection equipment mounted on drones. The State can also require third party satellite methane detection systems, which provide comprehensive and more accurate measurements of the concentration of methane plumes, the direction of methane plumes moving off the landfill property, and the exact location of emission exceedances from landfills. DEQ can also require fixed monitors for real-time methane tracking. Gathering this comprehensive data set will lead to rapid mitigation of super-emitter leaks, improved methane capture for use in local energy generation or methane destruction through enclosed flaring.

DEQ should update their regulations to require SEM on all areas of landfills including steep slopes, closed cells, locations with covering vegetation and unspecified exemptions. Combining actionable emissions data from these areas along with mitigation strategies such as horizontal gas collection is critical for reducing greenhouse gas impacts and associated air toxics such as volatile organic compounds (VOCs), hydrogen sulfide, forever chemicals and fine particulate matter thereby improving air quality for local communities and climate mitigation to follow state climate action mandates.

Close reporting loopholes to ensure landfill owner-operators are adequately monitoring for methane. DEQ should immediately update its regulations to require that any owner or operator who conducts surface emissions monitoring must:

1. Report the areas exempted from monitoring and report the reasons for requesting those exemptions. This would address the current issue of exemptions being granted on a de facto basis.

[4] Throughout this report we emphasize Oregon because these are the arenas at which Beyond Toxics focuses its advocacy. Our findings could be replicable in other states or at the federal level.

2. Report measured concentration of methane in ppm for each SEM reading.
3. Report the SEM path walked by owner-operators.
4. All the above data should be in a spatial data format such as a shapefile, which makes for more efficient analysis of data gathered through surface emissions monitoring.

To prevent future potent methane emissions, governments at all scales can introduce mandatory organics diversion policies requiring consumers and haulers to separate and sort organic waste so that food and yard waste can be sent to facilities other than landfills to make compost and other products thereby preventing future generation of methane in landfills.

EXECUTIVE SUMMARY

Beyond Toxics conducted an analysis of 32 Surface Emissions Monitoring (SEM) reports submitted by eight MSW landfill operators to the Oregon Department of Environmental Quality for the year of 2023.[5] Per state rules, SEM is currently performed at landfills with over 200,000 tons of total lifetime waste and modeled methane emissions greater than 664 tons. We analyzed open landfills currently accepting municipal solid waste (variations of these rules apply to other landfills that are closed and/or accept only industrial waste). According to records from the DEQ, a total of 11 currently operating municipal solid waste landfills in Oregon meet the waste-in-place and methane emissions thresholds for the state's surface emissions monitoring rules. Three of those landfills were not following the new rules; two due to exemptions granted by the DEQ and one did not comply. SEM is performed quarterly by walking portions of the landfill surface with a handheld gas analyzer in a grid pattern to detect methane leaks. Individual leaks detected measuring over 500 parts per million (ppm) require remediation within 10 days. Operators are also required to divide their landfill into 50,000 square foot grids and average their SEM results within each grid, referred to as integrated monitoring. If a grid has an average of 25 ppm or higher, then the operator is required to conduct mitigation efforts to bring it below 25 ppm.

[5] (See OAR 340-239-0100).

These reports were qualitatively and spatially assessed to determine transparency, compliance, completeness and quality of submitted reports and gaps with landfill emissions regulations.

Across eight landfills, five are privately owned and three are publicly owned and managed by a local government. We found that an average of 33.1% of landfill surface area was excluded from surface emissions monitoring. These exemptions include permitted exemptions, such as the working face where garbage is actively being deposited, and exemptions that are more questionable such as final grading (the slopes of landfill sections that are closed and no longer having waste deposited into them).

Although on average 33.1% of landfill surface area was excluded from emissions monitoring, the data revealed that private landfill operators are excluding an average of 48.6% of landfill surface area from SEM. Methane leaks in those areas are going undetected. The result of data omission is accelerated climate damage, dangerous conditions for workers, and air pollution and odors burdening nearby residential neighbors who are exposed to hazardous byproducts escaping along with methane. While some of these areas are too dangerous to be monitored by workers, substantial portions of landfills could have been safely monitored, such as areas with some vegetation or moderately sloped sides. Instead, they were excluded and listed as exempted on the report to the DEQ. Additionally, all of these areas could have been safely monitored with unmanned aerial equipment or fixed sensor systems. For example, owner-operator Waste Connections in Medford argued 69% of Dry Creek Landfill was too steep to monitor despite there being readily available methane detection technology that could fly over these areas.

We observed that, in comparison, public operators excluded only an average of 10% of landfill surface areas from monitoring. The stark difference in the comprehensiveness of surface emissions monitoring calls for further investigation of how landfill operators request exemptions, how transparent they are about their operating procedures, and the frequency and duration of exemption approvals on the part of the DEQ.

Our findings come in tandem with the U.S. Environmental Protection Agency's recent public release of draft white papers that delineate how advanced methane detection technology such as fixed methane sensors and satellites could address serious deficiencies in finding and fixing methane leaks.[6] In fall of 2024, the EPA issued a nationwide enforcement alert, stating, in part, "While the regulations allow MSW landfills to exclude certain areas from the SEM (e.g., areas with steep slopes or other dangerous areas), the EPA observed during recent inspections that areas that are not dangerous are improperly excluded from monitoring. If a MSW landfill excludes areas from the SEM, the facility should document and explain the basis for excluding each area from monitoring in the surface emission design plan and SEM reports. The regular side slopes of the landfill may not be excluded from monitoring per the regulations."[7] Excluding the working face and a few other time-limited activities,[8] state and federal rules require that all areas of landfills should be monitored during SEM. In Oregon, DEQ air pollution permit writers approve or deny exemptions from SEM proposed by operators (referred to as "alternative monitoring plans").[9]

State regulatory agencies need to use their authority to ensure the exceptions they permit are ultimately demonstrated to be necessary. Additionally, requiring operators to use advanced monitoring systems for SEM in difficult to monitor areas could fill this regulatory gap.

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[6] USEPA, Office of Air and Radiation. (2024). White Paper Series: Municipal Solid Waste Landfills – Advancements in Technology and Operating Practices. USEPA, Office of Air and Radiation. https://www.epa.gov/stationary-sources-air-pollution/non-regulatory-public-docket-municipal-solid-waste-landfills

[7] Environmental Protection Agency. (2024, September 25). Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements. EPA Investigations Find Municipal Solid Waste Landfill Operators Are Failing to Properly Conduct Compliant Monitoring and Maintenance of Gas Collection and Control System. https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance

[8] Or. Admin. R. 340-239-0330, "The requirements of OAR 340-239-0200 do not apply to the working face of the landfill or to areas of the landfill surface where the landfill cover material has been removed and solid waste has been exposed for the purpose of installing, expanding, replacing, or repairing components of the landfill gas, leachate, or gas condensate collection and removal system, for conducting a remedial action, or for law enforcement activities requiring excavation; as long as these areas are kept to the minimum size and time duration as possible." [4] Throughout this report we emphasize Oregon because these are the arenas at which Beyond Toxics focuses its advocacy. Our findings could be replicable in other states or at the federal level.

[9] Or. Admin. R. 340-239-500(1)(c) "Alternative walking patterns to address potential safety and other issues, such as: steep or slippery slopes, monitoring instrument obstructions, and physical obstructions;"

We also found that landfill operators are omitting key pieces of data gathered from SEM, which, while legal, is an outcome of weak regulatory requirements and enforcement. For example, Oregon rules require that operators monitor every 25 feet of a landfill's surface area every year. This can be accomplished by monitoring every 25 feet every quarter or by monitoring every 100 feet each quarter but offsetting that path by 25 feet each quarter.[10] However, Oregon rules do not require operators to share their SEM path, so regulators are not able to verify the rule is being followed. Additionally, SEM data that is reported comes in print format, which requires regulatory staff hundreds of hours to translate to a spatial file storage format that provides comprehensive and more accurate data for analysis. This labor to convert the data, despite the existence of accessible Geographic Information Systems (GIS) technology for data analysis, is inefficient and a burden on regulatory agency resources.

Furthermore, landfill operators are only required to report methane leaks over 200 ppm or integrated monitoring exceedances 25 ppm and greater; they do not report all measured SEM values. This is particularly problematic for integrated monitoring results because those results are based on averaging all SEM measurements within a 50,000 square foot section, not just the values over 200 ppm. For example, there could be a series of SEM measurements between 100 ppm and 199 ppm in a concentrated area that would suggest a problem. However, if it were grouped in a 50,000 square foot cell where there were a substantial amount of measurements near 0 ppm, the problem area could be masked through the averaging process. Enhancing the specificity of data reporting and transparency would provide regulatory agencies with a stronger ability to identify problematic areas of methane escaping from landfills and require targeted remediation. Critical to this would be requiring landfill operators to report data in spatial data formats that are usable by widely available GIS software.

Policymakers can act to address data gaps and upgrade methane reporting standards to ensure a healthy climate, protect worker safety and public health and to reduce greenhouse gas emissions and related air pollutants.

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[10] Or. Admin. R. 340-239-0400(2)(a) "The walking grid in OAR 340-239-0800(3)(a)(B) may be reduced to 100-foot spacing so long as the walking grid is offset by 25-feet each quarter so that by the end of one year of monitoring, the entire surface area has been monitored every 25 feet"

BACKGROUND

Mitigating short-term methane emissions, a climate pollutant about 80 times more powerful than CO2,[11] is critical to preventing the world from reaching climate tipping points. Climate tipping points are thresholds at which the climate systems would irrevocably change and upend local weather systems, supply chains, and global food productions. Currently landfills are the third leading cause of methane emissions in Oregon and the United States, and the second leading globally.[12]

Methane emissions are a byproduct of disposing of organic waste into landfills. As organic waste (food scraps, wood, paper, textiles) decomposes in an oxygen deprived environment, methane gas is generated over the course of decades. Most landfills can be thought of as giant plastic bags containing waste (although some landfills have waste in direct contact with the ground). These cells are lined next to and on top of each other in a pyramid-like structure. Pipes line the bottom of cells in horizontal rows to extract liquid byproducts, referred to as leachate. Gas extraction wells are drilled vertically and sometimes horizontally into landfill cells to capture continually generated methane gas before it escapes to the atmosphere.

Currently, federal rules require certain landfills in the United States to implement gas collection and control systems (GCCS), which use gas wells to extract methane from about 600 U.S. landfills, excluding the working face (where waste is deposited on a daily basis).[13] While GCCS are intended to extract and capture methane, several challenges exist regarding their successful and efficient operation.

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[11] United Nations Environmental Programme. (2022, October 18). What's the deal with methane? Climate Action: Chemicals & Pollution Action. https://www.unep.org/news-and-stories/video/whats-deal-methane
[12] Saunois, M., Martinez, A., Poulter, B., Zhang, Z., Raymond, P., Regnier, P., Canadell, J. G., Jackson, R. B., Patra, P. K., Bousquet, P., Ciais, P., Dlugokencky, E. J., Lan, X., Allen, G. H., Bastviken, D., Beerling, D. J., Belikov, D. A., Blake, D. R., Castaldi, S., … Zhuang, Q. (2024). Global Methane Budget 2000–2020. Earth System Science Data Discussions, 2024, 1–147. https://doi.org/10.5194/essd-2024-115
[13] Rocky Mountain Institute, Ebun Ayandele, Tom Frankiewicz, & Ellie Garland. (2024). Deploying Advanced Monitoring Technologies at US Landfills.
https://rmi.org/wp-content/uploads/dlm_uploads/2024/03/wasteMAP_united_states_playbook.pdf

Primary failures include insufficient gas collection coverage, holes in the plastic-lined cells, poorly or non-operating pipe systems, badly calibrated extraction wells, and leachate liquids clogging gas extraction pipelines.[14] Notably, when methane is escaping landfills, other hazardous air pollutants are being released to the air as well. These include hydrogen sulfide, other volatile organic compounds, and airborne PFOAs (aka "forever chemicals").[15] These chemicals harm quality of life and pose public health risks for nearby residents and landfill workers. It is critical to consider landfill air emissions as a public health threat and a significant environmental justice challenge.

SURFACE EMISSIONS MONITORING (SEM)

Certain landfill operators are required to implement and comply with Surface Emissions Monitoring (SEM) requirements. SEM requirements were first introduced by the federal government and administered by the EPA. Federal regulations require that these landfills perform SEM quarterly and follow the EPA's Method 21 guidance,[16] to detect and mitigate emissions greater than 500 parts per million.[17] SEM involves technicians walking the surface of the landfill at regular intervals of 30 meters looking for distressed vegetation, holes in tarps, protruding equipment, and other signs of potential methane leaks. Technicians use hand-held methane gas monitoring equipment to measure methane concentrations in the air just above the surface of the landfill. If a leak above 500 ppm is detected, the operator is required to remediate the cause of the leak.[18]

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[14] Preet Brains, Haley Lewis, Keene Kelderman, & Leah Kelly. (2023). Trashing the Climate: Methane from Municipal Landfills. Environmental Integrity Project. https://environmentalintegrity.org/wp-content/uploads/2023/05/Trashing-the-Climate-report-5.18.23-updated.pdf
[15] Ashley M. Lin, Jake T. Thompson, Jeremy P. Koelmel, Yalan Liu, John A.. Bowden, & Timothy G. Townsend. (2024). Landfill Gas: A Major Pathway for Neutral Per- and Polyfluoroalkyl Substance (PFAS) Release. Environmental Science & Technology, 11(7), 730–737. https://doi.org/10.1021/acs.estlett.4c00364
[16]40 C.F.R. §§ 63.1958(d) and 63.1960(c)-(d)
[17] U.S. Environmental Protection Agency, https://www.govinfo.gov/content/pkg/FR-2021-05-21/html/2021-10109.htm
[18] U.S. Environmental Protection Agency, https://www.govinfo.gov/content/pkg/FR-2021-05-21/html/2021-10109.htm

States including California, Oregon, Maryland, and Washington have promulgated state regulations strengthening various aspects of SEM to detect and reduce methane emissions. However, they are still reliant on a quarterly walking survey grid pattern monitoring, which still allows areas of the landfill to be skipped altogether leading to insufficient detection of leaks (see more in our discussion).

Oregon updated its landfill emissions rules, finalized October 2021, as a result of Executive Order 20-04 initiated by Governor Kate Brown in 2020 to direct state agencies to reduce greenhouse gases to at least 80% below 1990 emissions levels by 2050. The state's 2022 rules differ from federal rules in significant ways. The new regulations require landfill operators to conduct SEM following a walking pattern with no more than 25-foot intervals annually across the landfill's surface area, as opposed to the federally mandated 100 foot intervals. It also requires integrated monitoring for landfills, which averages SEM measurements across 50,000 square foot gridded sections. If a section has an average of 25 ppm or higher, then the landfill operator is required to take action to bring methane levels down.[19] The working face of the landfill is excluded from surface emissions monitoring along with areas under construction for gas collection.[20] Regulations also reduced the size and emissions threshold at which landfills are required to install a GCCS and conduct SEM.[21] The DEQ also added additional requirements to boost methane capture, including stronger GCCS leak component monitoring and data reporting requirements for GCCS equipment indicators and down time, which we did not evaluate in this report.

Our research questions were as follows, for those MSW landfill operators that fall subject to Oregon's regulatory parameters:

1. Which currently operating Oregon landfills accepting municipal solid waste are subject to implementing the updated rules?
2. How much landfill surface area is being included and excluded from SEM?

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[19] Oregon Department of Environmental Quality, Heather Kuoppamaki. (2021, October 1). Landfill Gas Emissions Rulemaking DEQ Presentation. Landfill Gas Emissions Rules Advisory Committee. https://www.oregon.gov/deq/EQCdocs/100121_I_Slides.pdf
[20] https://secure.sos.state.or.us/oard/displayDivisionRules.action?selectedDivision=6533
[21] Ibid.

3. Are the MSW landfill operators monitoring in a walking 25-foot grid pattern over the course of a year, per state regulatory requirements?

4. Are the MSW landfill operators conducting and reporting integrated monitoring results per a 50,000 sq. ft. grid, per state regulatory requirements?

5. Are reports complete, accurate, easy to analyze and useful to ODEQ to help regulators determine compliance and effective methane mitigation?

METHODS

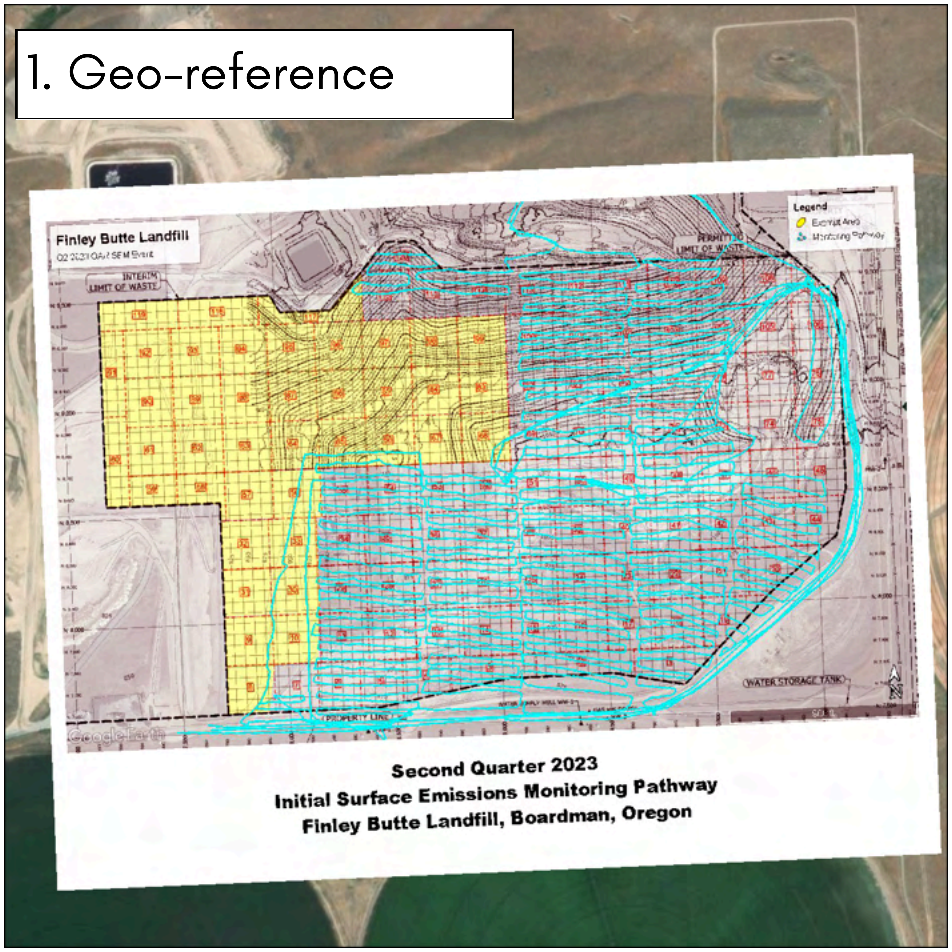
Beyond Toxics procured annual and semiannual reports, which certain landfills are required to file,[22] through a public records request to the Oregon DEQ filed in January 2024. We asked for reports filed by currently operating landfills accepting municipal solid waste that are known to exceed 200,000 tons of waste-in-place and 664 tons of methane a year since those are the thresholds at which Oregon's stricter SEM procedures go into effect.

Records were released in June 2024, and included SEM reports from eight of 11 qualifying Oregon landfills in 2022 and 2023. The other three landfills did not conduct SEM, which we inquired further about and will be discussed later. We analyzed solid waste landfills and we excluded landfills exclusively accepting construction and demolition waste, landfills that take only waste from industrial facilities, and all closed landfills. We performed a records analysis of SEM reports included in semiannual and annual reports to DEQ from 2023 for the eight of 11 currently operating municipal solid landfills required to adhere to stricter SEM requirements. In these reports, we analyzed the reporting of integrated monitoring results, 50,000 square foot grids, SEM exclusions, and SEM walking paths. We did not differentiate between SEM exclusions for the working face, asbestos pits, storage piles, steep slopes, overgrown vegetation, etc. because this information is not consistently available in reports compiled by operators. Operators often listed where they did not monitor without a specific justification.

[22] OAR 340-239-700(3)(c).

For research questions that required a spatial analysis, we georeferenced SEM report maps using ArcGIS Pro software. We then traced mapped features into vector data, which are GPS synchronized shapes that can be spatially analyzed. This allows us to do a few additional modes of analysis. For example, we can calculate the total area of a landfill and the SEM exempted areas. We can also create buffers around SEM paths to see if operators monitored every 25 feet. For the total area of landfill and areas of landfills excluded from SEM, we calculated their surface area in acres. For SEM paths, we created a 12.5 foot buffer around the walking path so we could visualize where gaps larger than 25 feet occurred between walking paths.

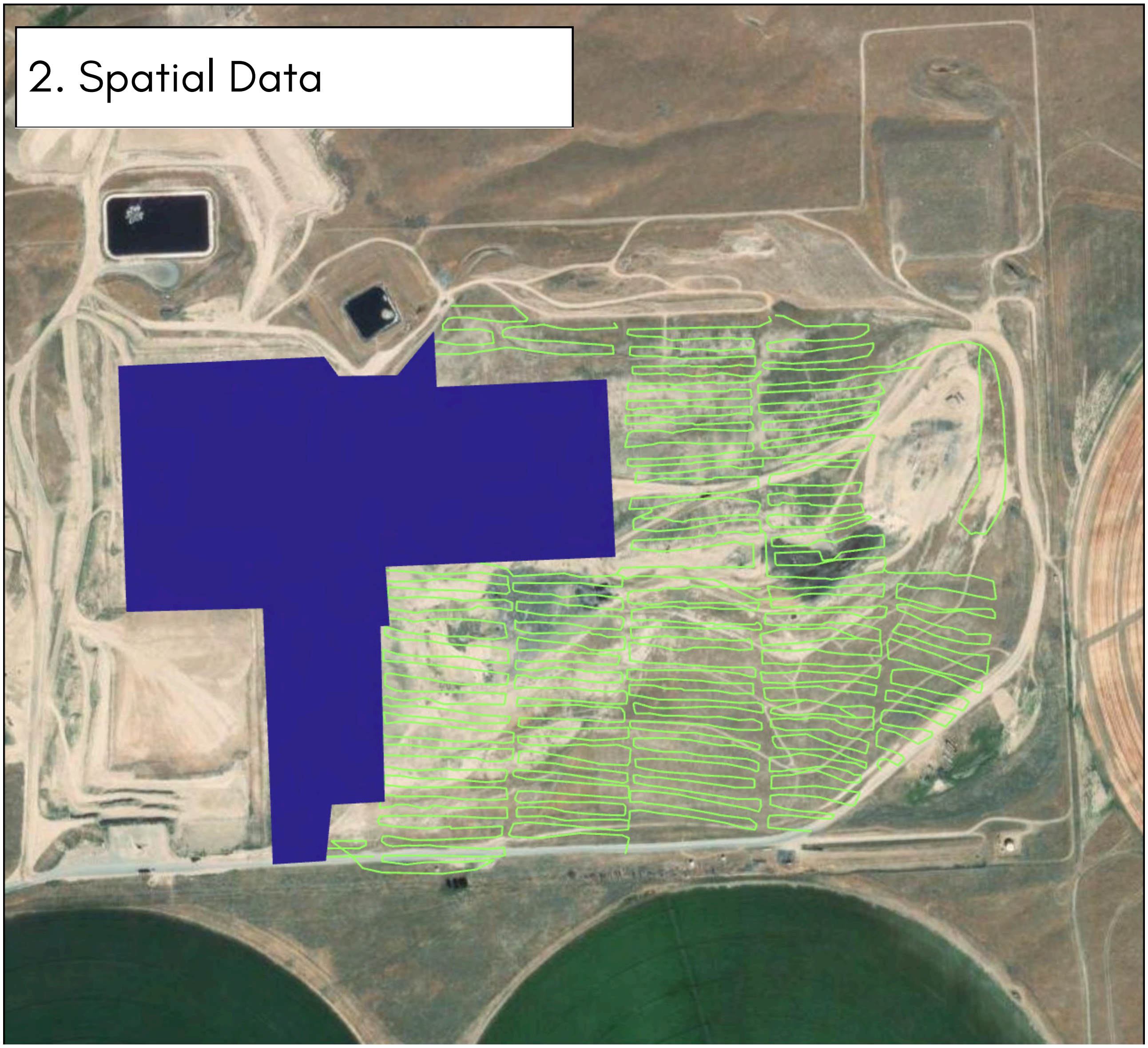
Figure 1: Frame 1, Frame 2, Frame 3, Frame 4



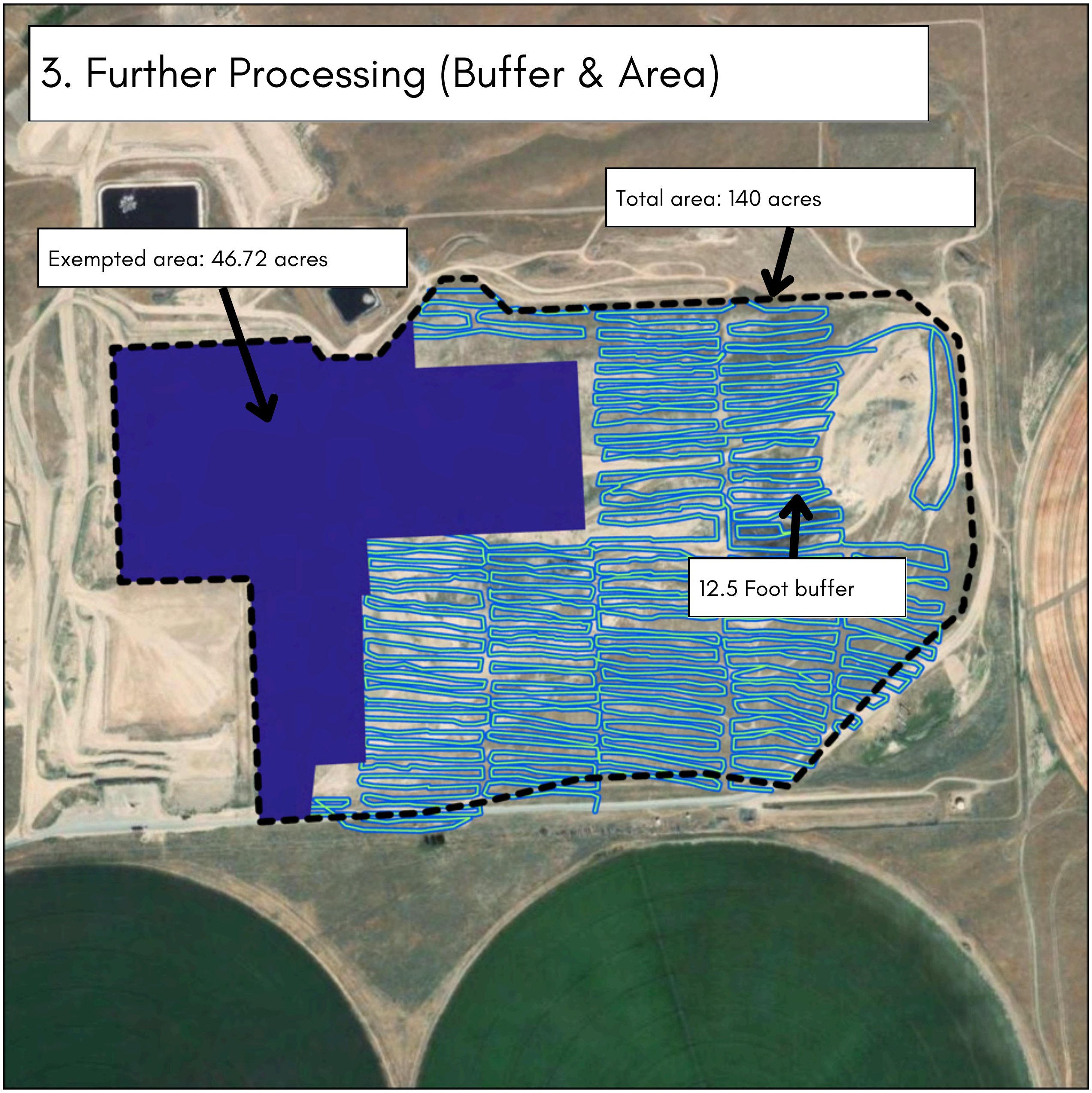
Frame 1: Overall, figure 1 shows our process of spatial data analysis for SEM reports using Finley Butte Landfill managed by Waste Connections in Boardman, Oregon as an example.

First we take the report graphic provided to the DEQ by the operator, which features a yellow polygon showing the area exempt from monitoring and a blue line showing where operators monitored. The first step is attaching the “paper” graphic to its GPS location. This is referred to as georeferencing. Now the graphic is overlaying its current satellite location.

2. Spatial Data

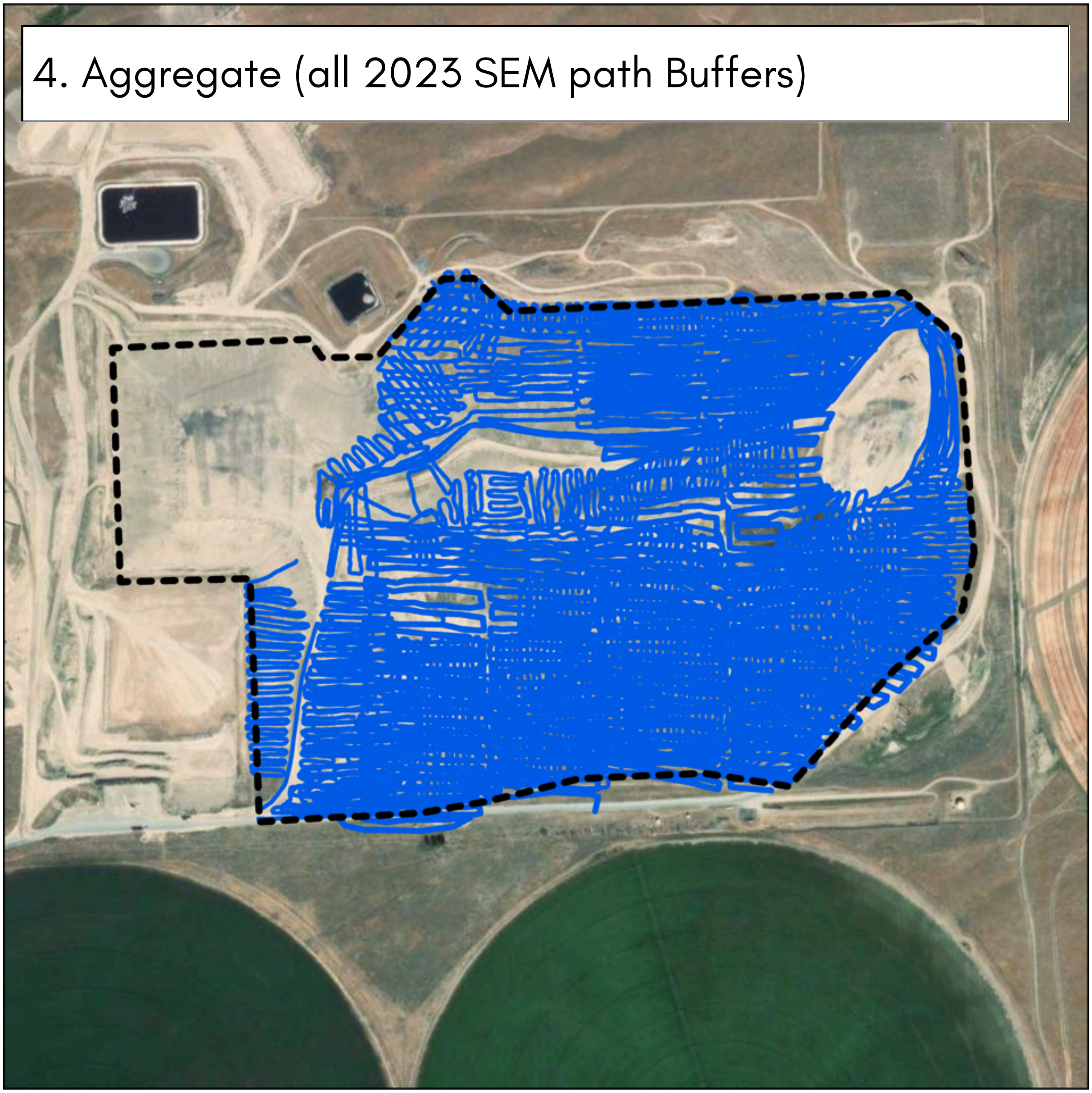


Frame 2: Next we build a shapefile, which is a file storage format used by GIS software. This is accomplished by tracing the exempt area into a polygon and the path into lines. Now, the area the operator exempted from SEM, formerly in yellow, is now in dark blue and the SEM monitoring path, formerly in blue and now depicted in green.



Frame 3: Now that we have a shapefile, we can do further forms of analysis. In this case, we want to know the area of the landfill, which we also traced into a shapefile, and the area of the exempt section. Since the data has been tied to GPS locations, we can calculate those features. The total area of the landfill is 140 acres and 46.72 acres were exempt. We can now calculate that for this quarter, Finley Butte excluded 33.4% of its surface area from monitoring.

We also need to know how well they followed the 25 foot rule. By calculating a 12.5 foot buffer on either side of the path, we can see where the buffers from all paths meet. 12.5 x 2 is 25 feet. We need to put all the paths from the year together to evaluate how well Finley Butte complied with this rule, which we will see in the next graphic.



Frame 4: In this graphic, we have compiled all of the SEM path buffers from each of the four quarters into one graphic. Areas that are in blue are where operators complied with Oregon's 25 foot rule. Areas where we can see the satellite imagery are where paths aren't offset by 25 feet, which means the operator failed to comply with the law. The only way we can evaluate this is through the ability to view all four paths/buffers around paths from each of the quarterly reports. This underscores how GIS analysis makes compliance monitoring more efficient.

WHY THIS METHODOLOGY?

By translating all of this data into a format that is usable in GIS software, we have the ability to look at data from across quarterly reports, or even years, in one environment. This allows us to see if areas have been repeatedly excluded from SEM each quarter, if the landfill operator has indeed monitored every 25 feet of the landfill over the course of a year, or if there are areas that repeatedly have high emissions for integrated monitoring.

Furthermore, we can plug in more spatial data for further exploration. Possibilities we didn't examine in this report, but are possible include: adding data on gas extraction wells, data on landfill cover infrastructure, or pulling in third party methane detection data such as Carbon Mapper, which detects methane plumes from space. The ability to see where landfills are experiencing methane exceedances from different sources of detection alongside their gas collection system infrastructure could generate effective insights on weaknesses in landfill gas systems, areas that need better or more frequent monitoring, or areas that DEQ needs to prioritize inspecting.

RESULTS AND DISCUSSION

Which Oregon landfills accepting municipal solid waste are complying with the DEQ rules adopted in 2021?

Oregon landfills are required to adhere to stricter DEQ requirements for methane management if they exceed 200,000 tons or more of lifetime waste-in-place and if their projected methane generation reaches 664 or more tons a year. Currently 11 Oregon landfills that are open and accepting municipal solid waste meet these metrics based on DEQ provided data (Table 1). Once a landfill reaches these thresholds, they are required to conduct surface emissions monitoring for four consecutive quarterly monitoring periods, with differing requirements thereafter if there is no measured concentration of methane of 200 ppm or greater are discovered during SEM.

Seven of the 11 MSW landfills are privately owned and operated while the other four are owned and operated by a county government. In total, all 11 landfills have a combined modeled methane generation of 169,943 tons in 2023, equivalent to the emissions of 1.6 billion gallons of gasoline burned.[23] The DEQ stated, "In 2017, six of the twenty-five largest stationary sources of GHG emissions in Oregon were landfills."[24] The seven private landfills were typically larger, occupying the top five ranked positions by total waste. On the other hand, the four public landfills held three of the bottom four slots by total waste. All 11 landfills are currently in operation and accepting municipal waste as of 2024.

Based on the numbers in Table 1 from Oregon DEQ, we would expect that all 11 Oregon MSW landfills would be subject to the stricter requirements of the state's current landfill emissions rules pertaining to conducting quarterly surface emissions monitoring. Through analyzing records and conversations with DEQ, we found that three landfills are not held to those higher standards. Each of these three landfills claimed unique circumstances specified below.

Examples of limited or non compliance:

1. Hillsboro Landfill, managed by Waste Management, Inc., was granted an exception to conducting surface emissions monitoring in its Title V operating permit by the DEQ, and does not have to comply with SEM requirements until April 2025. DEQ did not specify why.

2. Roseburg Landfill, managed by Douglas County, has not complied, and, as of May 2024, DEQ has stated they are looking into enforcement. We have not heard any developments since.

3. Baker Sanitary Landfill, managed by a local private company, claimed that its facility is two separate landfills, enabling it to divide its methane emissions between the two facilities and fall below the 664 tons threshold. DEQ has accepted this explanation although its own records present the landfill as one facility.

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[23] [22] OAR 340-239-700(3)(c). We first converted methane to a co2 equivalent of 84.
[24] [22] OAR 340-239-700(3)(c). , page 3

Table 1: Open Oregon MSW Landfills waste-in-place and Annual Methane Generation

Landfill, Owner-Operator	Owner-Operator Type	Total Lifetime Waste In Place (Tons)	Annual Methane Generation (Tons)
Columbia Ridge Landfill, WM	Private	64,358,280	43,497
Coffin Butte Landfill, Republic Services	Private	18,269,157	34,777
Hillsboro Landfill, Waste Management	Private	13,158,408	13,933
Finley Butte Landfill, Waste Connections	Private	13,158,408	13,933
Short Mountain Landfill, Lane County	County Government	11,750,975	13,042
Dry Creek Landfill, Waste Connections	Private	9,075,149	14,090
Wasco County Landfill, Waste Connections	Private	6,006,973	6,138
Knott Landfill, Deschutes County	County Government	4,642,663	3,826
Roseburg Landfill, Douglas County	County Government	3,696,825	35,058
Crook County Landfill, Crook County	County Government	1,116,102	739
Baker Landfill, Baker Sanitary Service	Private	766,113	778

Caption: The table features waste-in-place and methane generation rates for Oregon landfills accepting municipal solid waste while DEQ finalized rulemaking in 2021. Landfills highlighted in green were held to the updated SEM standards in 2023 and included in our analysis.

How much landfill surface area is being excluded from SEM?

We found that Oregon private landfill operators have excluded landfill areas from basic monitoring much more frequently than their publicly operated counterparts. During 2023 private landfills in Oregon exclude an average of 48.6% of landfill surface area from SEM each quarterly monitoring. On the other hand, county government operated landfills exclude an average of 10% surface area from SEM. We documented all exclusions, whether those exclusions have been shown to comply with Oregon rules or are more ambiguous.

Some landfills chose to give a reason for an exemption, and in other cases we were able to speculate a reason based on the design of the landfill. For example, we noticed Short Mountain, operated by Lane County, continuously did not monitor their asbestos pit, but did not specify that reason. In other cases, the landfill simply stated areas were exempt without providing a description and how a claimed exemption complies with the requirements, and we were unable to determine the criteria used to comply with exemption requests. Given this pattern, it was difficult to ascertain which exceptions were for working faces or other reasons consistently across all landfills. For this reason, we combined all exemptions to get a higher level view.

Table 2

Landfill, Operator	Private/Public	Quarter	Total Area (acres)	Exempted areas	% Excluded
Finley Butte, Waste Connections	Private	2023 - 1	140.08	37.52	26.78%
Finley Butte, Waste Connections	Private	2023 - 2	140.08	46.72	33.36%
Finley Butte, Waste Connections	Private	2023 - 3	140.08	80.92	57.77%

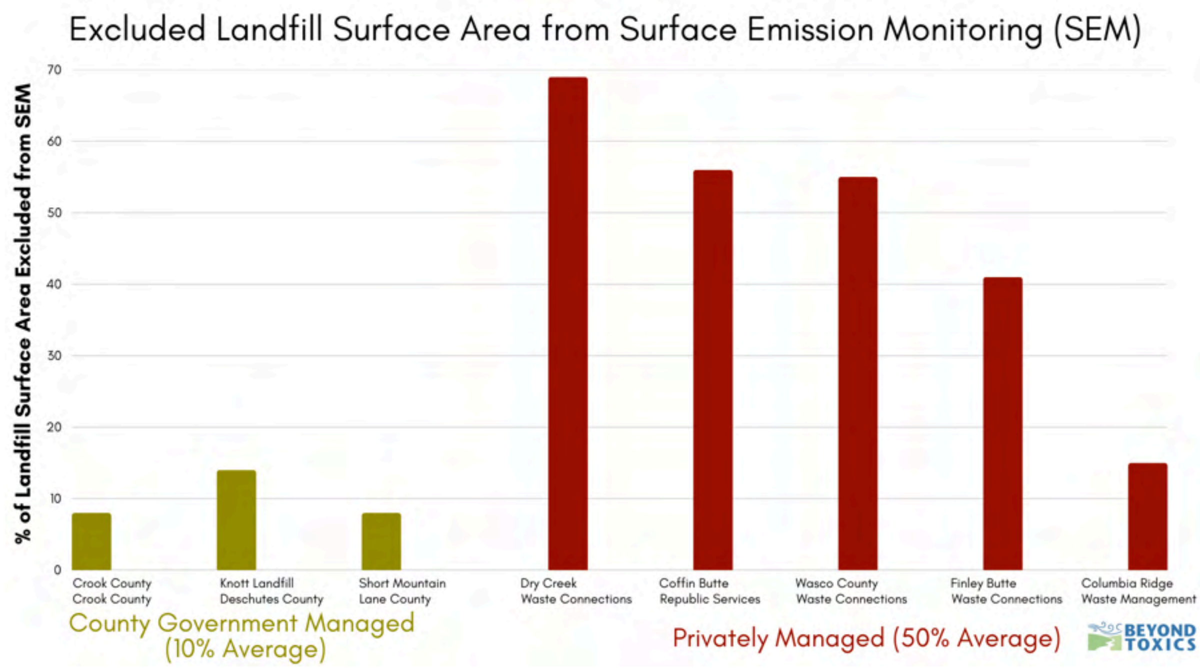
Finley Butte, Waste Connections	Private	2023 - 4	140.08	63.23	45.14%
Dry Creek, Waste Connections	Private	2023 - 1	85.86	59.62	69.45%
Dry Creek, Waste Connections	Private	2023 - 2	85.86	59.62	69.45%
Dry Creek, Waste Connections	Private	2023 - 3	85.86	59.62	69.45%
Dry Creek, Waste Connections	Private	2023 - 4	85.86	59.62	69.45%
Wasco County, Waste Connections	Private	2023 - 1	176.27	109.50	62.12%
Wasco County, Waste Connections	Private	2023 - 2	176.27	81.89	46.45%
Wasco County, Waste Connections	Private	2023 - 3	176.27	89.41	50.72%
Wasco County, Waste Connections	Private	2023 - 4	176.27	100.22	56.86%
Coffin Butte, Republic Services	Private	2023 - 1	136.34	84.21	61.77%
Coffin Butte, Republic Services	Private	2023 - 2	136.34	74.04	54.31%

Coffin Butte, Republic Services	Private	2023 - 3	136.34	74.04	54.31%
Coffin Butte, Republic Services	Private	2023 - 4	136.34	71.87	52.71%
Columbia Ridge, Waste Management	Private	2023 - 1	335.53	41.13	12.26%
Columbia Ridge, Waste Management	Private	2023 - 2	85.86	46.96	14.00%
Columbia Ridge, Waste Management	Private	2023 - 3	85.86	45.83	13.66%
Columbia Ridge, Waste Management	Private	2023 - 4	176.27	64.26	19.15%
Knott Landfill, Deschutes County	Public	2023 - 1	107.48	14.91	13.88%
Knott Landfill, Deschutes County	Public	2023 - 2	107.48	12.92	12.02%
Knott Landfill, Deschutes County	Public	2023 - 3	107.48	16.05	14.93%
Knott Landfill, Deschutes County	Public	2023 - 4	107.48	17.14	15.95%
Short Mountain, Lane County	Public	2023 - 1	111.34	9.30	8.35%
Short Mountain, Lane County	Public	2023 - 2	111.34	9.30	8.35%
Short Mountain, Lane County	Public	2023 - 3	111.34	9.30	8.35%

Short Mountain, Lane County	Public	2023 - 4	111.34	9.30	8.35%
Crook County. Crook County	Public	2023 - 1	84.52	5.82	6.88%
Crook County, Crook County	Public	2023 - 2	84.52	6.29	7.44%
Crook County, Crook County	Public	2023 - 3	84.52	6.96	8.23%
Crook County, Crook County	Public	2023 - 4	84.52	6.50	7.69%

The table above features the eight landfills following stricter SEM protocols and the data we were able to derive from their reports. Note that the working face is included in exemptions for SEM because most landfills did not specify the location and why an area of land was exempt. Total acres for landfills did not change over the course of a year because operators did not add any landfill surface area.

Figure 2.



Caption: The bar graph shows the average percentage of landfill surface area omitted from SEM by landfill site. Privately operated landfills for the most part excluded far more surface area than their government operated counterparts.

Our study found that the five private MSW landfills we analyzed on average omit nearly half (48.6%) of surface area from SEM every quarter (as opposed to the whole year together), leaving operators and regulatory agencies blind to vast portions of the landfill and the emissions emanating from them. While some of these exemptions might be intended to keep workers safe or are legally permissible, the large amount of surface area excluded raises questions as to whether private landfill operators are improperly excluding land from SEM. We found that 75% ofpublic landfills specified their exemptions for the working face, asbestos pits, or gravel and soil stockpiles, which totaled to an average of 10% of landfill surface areas. We were able to cross reference the fourth landfill based on other information they included in their report. On the other hand no private landfills specified the reason for exemptions in 2023 reports. The wide gap between private and public facilities may be an indication of non or limited compliance on the part of private waste corporations.

Examples of reasons given for not conducting surface emissions monitoring on certain areas

1. Waste Connections in Medford exempted 69% of its landfill, Dry Creek, from SEM monitoring without explanation. These areas all had final grade slopes, which could possibly be argued are too steep for monitoring. However, the EPA has stated that regular final grade side slopes of a landfill are not to be exempted.[25]

2. Owner-operator Waste Connections in Boardman, Oregon, chose not to monitor portions of the Finley Butte landfill that the U.S. EPA had monitored in June 2022. Waste Connections repeatedly denied the need to monitor anywhere they had placed waste in the last five years, even if that section of the landfill had waste older than five years. (Five years after waste is placed is the federal regulatory requirement to start SEM monitoring). Owner-operators then argued that the EPA should have never inspected that area due to safety concerns, even though they had never warned EPA of any safety concerns while accompanying them during their inspection. In 2023, Finley Butte Landfill continued to exclude those areas from monitoring.[26]

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[25] Environmental Protection Agency. (2024, September 25). Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements. EPA Investigations Find Municipal Solid Waste Landfill Operators Are Failing to Properly Conduct Compliant Monitoring and Maintenance of Gas Collection and Control System. https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance

[26] Environmental Protection Agency & Daniel Heins. (2022). Clean Air Act Inspection Report Republic Services Waste Connections Finley Buttes Landfill, Boardman Oregon. EPA Region 10.

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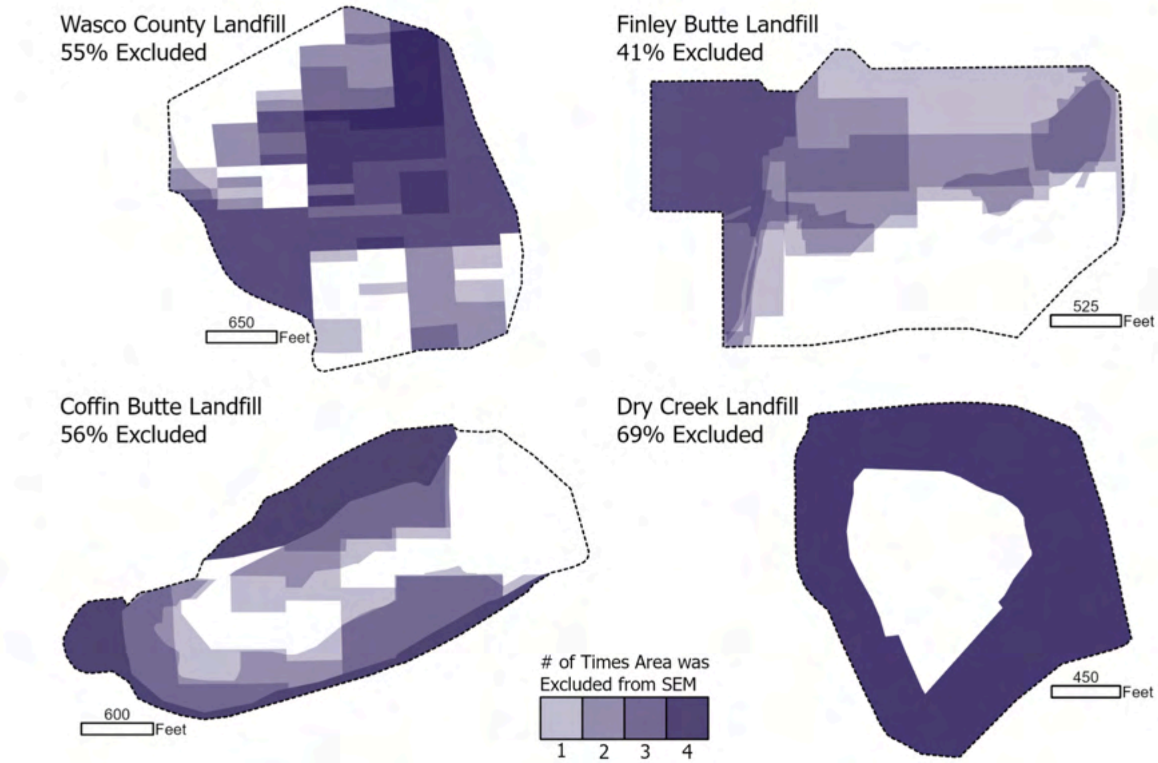
Republic Services, the owner-operator of Coffin Butte landfill near Corvallis, Oregon, argued 30-40 acres[27] of its landfill had too much vegetation to monitor. We would emphasize the owner-operators chose not to maintain the vegetation, which means this is a problem they created. Vegetation breaks through the upper cover material which would be highly prone to methane leakage (figure 3).

Caption: The EPA found multiple instances of vegetation growing through the tarp of the Coffin Butte landfill in both 2022 and 2024. The picture is one such example. The EPA measured methane at 1,000 ppm, twice the regulatory limit, near the base of the plant. Operators are supposed to constantly monitor the tarp integrity to ensure that there are no areas where methane could be leaking.

[27] Coffin Butte specifically exempted 40 acres in quarter 3 2022 and 30 acres in quarter 4 for high vegetation (both outside of our study). However, they continued to exempt the same areas in 2023, which spans the duration of our study, but they decline to specify the reason. We assume they are exempting those areas for the same reason based on satellite imagery from the times of inspection in 2023.

Figure 2



Caption: The maps feature four privately operated Oregon landfills with waste deposits outlined in black dotted lines. Each exempted area for the four quarterly reports in 2024 is layered and features where operators did not conduct SEM. The darker the shade of violet, the more frequently the area of the landfill went unmonitored. Oregon's private landfills excluded an average of 48.6% of landfill surface area from each quarterly monitoring.

Oregon rules exempt "the working face of the landfill to areas of the landfill surface where the landfill cover material has been removed and solid waste has been exposed for the purpose of installing, expanding, replacing, or repairing components of the landfill gas, leachate, or gas condensate collection and removal system, for conducting a remedial action, or for law enforcement activities requiring excavation. Rules specify this exclusion should be kept to the minimum size and time duration as possible."[28]

However, Oregon rules also allow for an alternative monitoring plan for "Alternative walking patterns to address potential safety and other issues, such as: steep or slippery slopes, monitoring instrument obstructions, and physical obstructions" approved by DEQ.

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[28] https://secure.sos.state.or.us/oard/displayDivisionRules.action?selectedDivision=6533

The reports we analyzed did not include information or details on alternative monitoring plans approved by DEQ, so it's difficult to evaluate exactly what agreements are made between private owner-operators and DEQ. Regardless, the large disparity between private and public owner-operators calls for further scrutiny by the DEQ for how and when they allow exceptions to SEM. As of now, the agency and public are completely blind to what is happening on 48.6% of private landfill surface areas. Large swaths of preventable methane leaks may be and likely are going undetected and unrepaired.

Further Limitations of SEM

Excluding large portions of landfills from any SEM is one demonstrated method of reducing the efficacy of methane monitoring. Not only can operators avoid conducting SEM over vast swaths of landfills, the EPA has repeatedly observed poor practices of operating SEM equipment. The EPA recently stated there is a massive gap in the monitoring methodology used by private operators and regulatory agency staff.[29] When conducting limited SEM, as part of inspections of several Oregon MSW landfills in 2022 and 2024, U.S. EPA inspectors found glaring issues with private operators including failing to use SEM equipment at a proper height leading to underrepresented emissions, ignoring protruding waste piercing through landfill cover, not monitoring leachate clean outs and gas wells, and more.[30] These led to landfills filing reports appearing to have fewer methane leaks of lesser severity. For example, at the Coffin Butte landfill owned and operated by Republic Services, a 2022 EPA inspection report stated that "despite Republic having seen no more than six exceedances in the recent SEM reports supplied ahead of the inspection that included penetration monitoring, including reports with zero exceedances, the EPA identified 61 points in exceedance of legal limit of 500 ppm, including 21 points above 10,000 ppm."[31]

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[29] Environmental Protection Agency. (2024, September 25). Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements. EPA Investigations Find Municipal Solid Waste Landfill Operators Are Failing to Properly Conduct Compliant Monitoring and Maintenance of Gas Collection and Control System. https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance
[30] Environmental Protection Agency & Daniel Heins. (2022). Clean Air Act Inspection Report Waste Connections Finley Butte Landfill, Boardman Oregon. EPA Region 10.
[31] Environmental Protection Agency & Daniel Heins. (2022). Clean Air Act Inspection Report Republic Services Coffin Butte Landfill, Corvallis Oregon. EPA Region 10.

Coffin Butte was not alone. The EPA also found glaring issues at Finley Butte landfill and Wasco County landfill both operated by Waste Connections. EPA inspectors found multiple large pieces of waste protruding through the cover, including wind turbine blade parts and tires, compromising the integrity of Finley Butte's landfill tarp cover.[32] At Wasco County, inspectors noted that the landfill operator had failed to keep adequate records of organic waste, which artificially reduced the projected methane emissions from LandGEM modeling.[33] These are three of the 100 landfills the EPA inspected across the nation before the agency put out an alert of widespread noncompliance with SEM rules.[34]

Recommendation: There are a variety of ready-to-go solutions that Oregon's regulatory agency can leverage to improve SEM and methane emissions prevention. For the immediate future, state regulators should immediately follow-up with MSW landfill operators, require explanations for areas excluded from monitoring and ensure that operators are following state regulations. Further, there are available advanced sensing technologies such as fixed methane sensors and drones that can comprehensively monitor large areas with greater frequency, including steep slopes and areas with vegetation, to provide Oregon operators and regulators with the missing information they need to find and mitigate methane leaks.

Are landfill operators monitoring in a walking 25-foot grid pattern, per state regulatory requirements?

Oregon requires that operators conduct SEM every 25 feet of a landfill over the course of a year. An operator can accomplish this by monitoring every 25 feet every quarter. Or, they can monitor every 100 feet every quarter, then offset that path by 25 feet for each consecutive quarter, so that by the end of the year every 25 feet has been covered. Notably, this rule was not followed in areas that were marked as exempt one or more times in a year.

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[32] Environmental Protection Agency & Daniel Heins. (2022). Clean Air Act Inspection Report Republic Services Waste Connections Finley Buttes Landfill, Boardman Oregon. EPA Region 10.
[32] Environmental Protection Agency & Daniel Heins. (2022). Clean Air Act Inspection Report Republic Services Waste Connections Wasco County Landfill, The Dalles Oregon. EPA Region 10.
[33]Environmental Protection Agency. (2024, September 25). Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements. EPA Investigations Find Municipal Solid Waste Landfill Operators Are Failing to Properly Conduct Compliant Monitoring and Maintenance of Gas Collection and Control System. https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance
[34] Environmental Protection Agency. (2024, September 25). Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements. EPA Investigations Find Municipal Solid Waste Landfill Operators Are Failing to Properly Conduct Compliant Monitoring and Maintenance of Gas Collection and Control System. https://www.epa.gov/enforcement/enforcement-alert-epa-finds-msw-landfills-are-violating-monitoring-and-maintenance

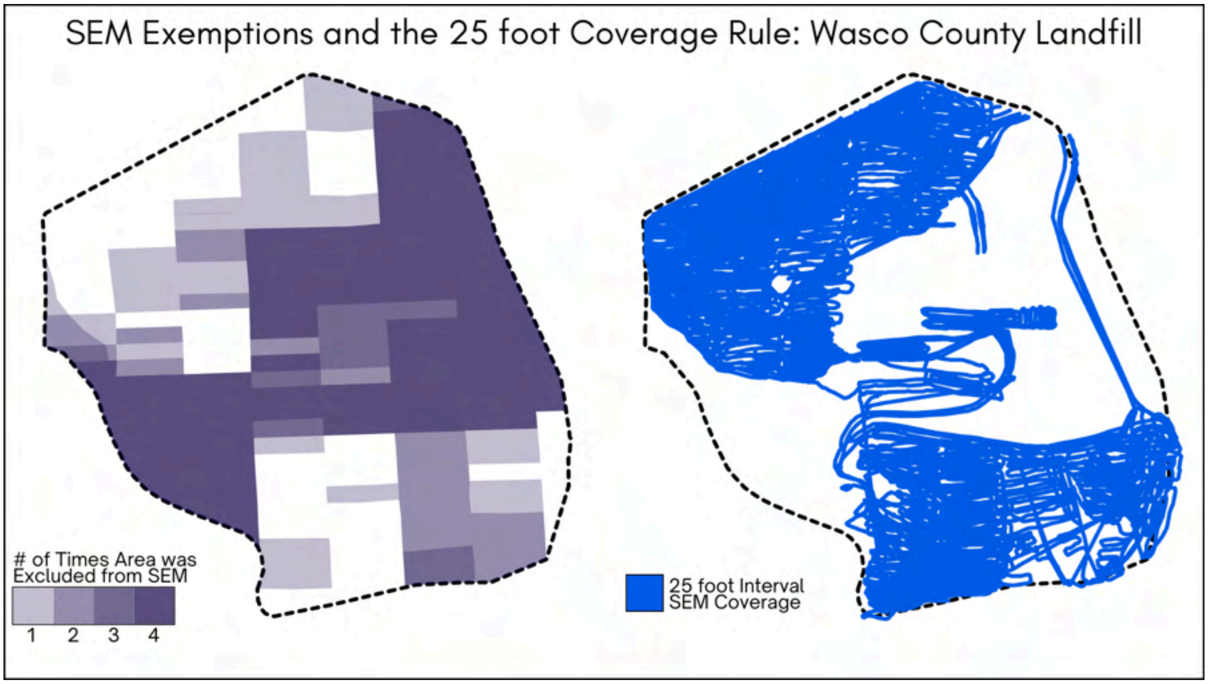
Five of the eight landfill operators did not report the GPS route they took to conduct SEM. Unfortunately, they are not required to report this information by Oregon rule. In our analysis of walking 25-foot grid patterns, we focused on landfill reports that provided actual monitoring paths because actual monitoring each quarter differs substantially from planned monitoring paths (see Figure 4).

Figure 4 - Planned SEM route Differs Greatly from Actual SEM route

Caption: The first frame of the figure features a planned SEM path that the Coffin Butte Landfill operator submitted to the DEQ. The second frame is a map of the actual GPS tracked SEM route. We can see far less of the landfill was actually monitored with the GPS path than the estimated route. These GPS referenced paths are much more accurate than planned routes when evaluating the comprehensiveness of SEM.

Only three out of eight MSW landfills (Coffin Butte, Finley Butte, and Wasco County) that conducted SEM voluntarily reported the GPS tracked SEM monitoring path. Our analysis found that, for the most part, those landfill operators that shared their SEM traversed path in reports appeared to have followed this rule with some room for improvement and one substantial failure. Given many of these operators excluded substantial surface area of their landfill from any SEM (see above section), the 25 foot rule was often not followed in areas that were excluded one or more times (Figure 5).

Figure 5



Caption: On the left is Waste Connections' exempted areas for Wasco County Landfill in 2023. The darker shade of violet, the more often that area was excluded from SEM over the course of the year. On the right, the graphic shows how the 25 foot rule was followed. If an area is completely blue, the 25 foot rule was followed. Gaps of white show where operators failed to monitor every 25 feet. By comparing the two graphics, we can see that operators most consistently met the 25 foot rule in areas that were monitored all four quarters. We can also observe the inverse relationship. The more often operators excluded an area from SEM, the more that area failed to follow the 25 foot rule.

Recommendation: This can easily be remedied by adding GPS tracked SEM paths to the recordkeeping and reporting requirements in OAR 340-239-0700, and a similar mechanism at the federal level. It would be beneficial to require that this data is not only reported in print form, but also in some spatial data format (shapefile, GeoJSON, etc.). The reason for this is Oregon does not require monitoring every 25 feet every quarter. Rather, they require that over the course of a calendar year, every 25 feet of a landfill is monitored. Having access to the spatial data will allow regulatory agencies to view all quarterly monitoring paths and results at once, and quickly verify the results.

Are landfill operators conducting integrated monitoring and reporting results?

Integrated monitoring is a key early identification monitoring strategy to identify where there are problematic methane emissions. It involves dividing the landfill into an integrated monitoring grid of 50,000 square foot cells, an area slightly smaller than a football field. After conducting SEM looking for individual, instantaneous exceedances of 500 ppm, the operators create an aggravate reading for each 50,000 square foot cell by averaging all individual SEM readings within each grid. If a grid has an aggregate SEM average above 25 ppm, then the landfill needs to perform remediation and do follow up SEM to ensure the average falls below 25 ppm.[35] State regulations require the landfill to report integrated monitoring exceedances over 25 ppm. State regulations do not specifically require the reporting of operators' integrated monitoring grids or non-exceedance integrated monitoring results. The requirements only stipulate that operators must tell DEQ if they have a 50,000 square foot cell exceeding 25 ppm.

Given that, we found that seven out of eight landfills reported at least some integrated monitoring result. Two of those landfills only reported their grid cells that exceeded 25 ppm as legally required. Five out of eight voluntarily shared all of their integrated monitoring results – the average SEM reading for each grid cell including their exceedances of 25 ppm.[36] The last landfill either did not have a 25 ppm integrated exceedance, or it simply did not report any data

[35] https://www.oregon.gov/deq/EQCdocs/100121_I_Slides.pdf
[36] https://secure.sos.state.or.us/oard/displayDivisionRules.action?selectedDivision=6533 340-239-0700, 3(c) Semi-Annual Report. A landfill owner or operator subject to this rule, must prepare semi-annual reports for the periods of January 1 through June 30 of each year, unless otherwise approved in writing by DEQ. The Semi-Annual Report will be due on July 30, unless otherwise approved in writing by DEQ. The Semi-Annual Report must contain the following information:

Figure 6

Caption: The above graphic was submitted to DEQ by Waste Management at Columbia Ridge landfill showing how they divided the landfill into 50,000 square foot grids for their integrated monitoring results. In the full report, the operator submitted a table with each grid numbered and the associated average SEM reading result. Ideally, operators should be required to report this information to DEQ. Columbia Ridge is an example of data reporting that should be required by law.

Oregon Administrative Rules do not require operators to report the grid or integrated monitoring results unless a grid exceeds 25 ppm. We strongly recommend regulatory agencies require this basic information and they add a requirement for it to be in a spatial data format. We also recommend agencies require all SEM measurements and the coordinate it was recorded at (also in spatial data). Some landfills already report this information, but it's in a print table, which is too time intensive for a state agency to turn into spatial data.

Recommendation: Given the U.S. EPA’s findings of widespread noncompliance, and as the climate crisis intensifies, Oregon DEQ needs to take a stronger stance in monitoring operators. DEQ should require operators to transfer the data they generate for annual and semiannual reports directly into spatial data formats.

We also recommend that regulators require spatial data on the location of gas extraction wells. Oregon DEQ could then visualize all of this data (integrated monitoring, instantaneous monitoring, SEM paths, Gas Collection and Control infrastructure, leaks detected by satellites, etc.) simultaneously using GIS software. This is important because it allows them to efficiently identify gaps in methane gas collection infrastructure and SEM results including exceedances and integrated monitoring measurements. Regulatory agencies need a complete picture of the puzzle, and allowing operators to spread those puzzle pieces across different reports and in unusable formats wastes public agencies' resources and hinders their ability to conduct oversight.

The Limits of SEM: Additional Solutions to Mitigating and Preventing Landfill Methane

SEM is a critical tool for identifying and mitigating methane leaks from landfills. However, there are more solutions already in use that operators and regulators can leverage to more effectively prevent harmful air emissions. Remote sensing, both passive (solar spectrometer) and active (Lidar), are promising avenues to enhance methane monitoring. Sensors are mounted on planes, satellites, and even drones, which then fly over landfills and detect methane plumes and concentrations at various scales depending on the air/spacecraft and instrument.

The White House National Strategy to Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System notes that remote sensing has found many preventable methane leaks that are currently going undetected by traditional SEM.[37] Recent findings from remote sensing technology have demonstrated that methane emissions are much higher than formula estimates by the EPA.[38] Remote sensing technology has been used to reduce methane emissions and associated environmental justice burdens posed by other air pollutants associated with methane leaks.[39]

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[37] Greenhouse Gas Monitoring and Measurement Interagency Working group. (2023). National Strategy To Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System. The White House. https://www.whitehouse.gov/wp-content/uploads/2023/11/NationalGHGMMISStrategy-2023.pdf
[38] Daniel H. Cusworth et al., Quantifying methane emissions from United States landfills.Science383,1499-1504(2024).DOI:10.1126/science.adi7735
[39] Daniel H Cusworth et al 2020 Environ. Res. Lett. 15 054012

There are readily available advanced methane detection technologies that can detect and pinpoint methane leaks at landfills, as illustrated in EPA's draft White Papers issued in Fall 2024, EPA's Landfill Methane Emissions Workshop in April 2021, EPA's Methane Detection Workshop in August 2021, CARB's Public Workshop on Landfill Methane Emissions in California in December 2022, and EPA's LMOP Webinar on Detecting Landfill Methane Emissions with Drones in September 2023.[40] Technology providers with drone surveying capabilities at landfills include ABB, Aerometrex, Bridger Photonics, Project Canary, Scientific Aviation, SeekOps, and SnifferDrone, among others. Airborne and satellite remote sensing are currently offered by Carbon Mapper and GHG Sat. Drones can survey a full landfill footprint with precision using point sensing or active imaging, measuring methane concentration in parts per million (ppm) or parts per million per meter (ppm-m). One drone provider has its technology deployed at over 150 landfills nationwide.[41] Stationary and land-based methane sensors can be placed strategically to support rapid and ongoing leak detection and repair on the active working face. These methods are the next wave in "smart" landfill design and can identify methane hot spots via always-on sensors on low towers or tripods on the landfill surface – meaning a methane spike can be found and dealt with quickly.

Recommendation: Oregon policymakers should ensure landfills move into the 21st century by requiring advanced methane sensing technology deployment that makes methane emissions visible, accurate and actionable. Both California and Colorado are building out programs that require owner-operators to respond to methane leaks detected by satellites orbiting the earth operated by third party institutions such as Carbon Mapper and GHG Sat.[42]

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[40]Greenhouse Gas Monitoring and Measurement Interagency Working group. (2023). National Strategy To Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System. The White House. https://www.whitehouse.gov/wp-content/uploads/2023/11/NationalGHGMMISStrategy-2023.pdf
[41]Greenhouse Gas Monitoring and Measurement Interagency Working group. (2023). National Strategy To Advance an Integrated U.S. Greenhouse Gas Measurement, Monitoring, and Information System. The White House. https://www.whitehouse.gov/wp-content/uploads/2023/11/NationalGHGMMISStrategy-2023.pdf
[42] https://carbonmapper.org/ and https://www.ghgsat.com/en/

Diverting Organic Waste

Given that methane generation is the byproduct of placing organic waste in landfills, an obvious solution is to stop placing organic waste into landfills. Food rescue, food waste as an animal feedstock, composting food waste, placing synthetic organics (inorganic/organic hybrids for example carpet) in anaerobic digesters, and other forms of waste sorting are desirable alternatives to landfilling or incineration. These strategies preserve space in landfills for other uses, preventing or significantly delaying the need for landfill expansions and, depending on the policy, make progress towards zero-waste circular economies.

It's critical to note that methane is generated over the course of decades. Therefore, while organic diversion is an important solution to implement, we will need to monitor and mitigate methane from active and closed landfills decades into the future regardless.

CONCLUSION

In this report, we analyzed 36 Surface Emissions Monitoring (SEM) reports from eight currently operating municipal solid waste landfills in Oregon. We found that landfills in Oregon have varying levels of compliance with state regulations. Additionally, although legal, owner-operators under-report key pieces of information, which make it hard for regulators to ensure full compliance with the law. The Oregon DEQ needs to act quickly to remedy this situation by requiring owner-operators to monitor larger sections of their landfills and use other forms of monitoring when walking SEM is not possible or to support walking SEM with early identification of leaking emissions. Landfills are responsible for 90% of Oregon's industriously produced methane emissions ahead of both enteric fermentation (cattle) and the oil and gas sector. Curbing the pollutant is key to mitigating climate damage in the immediate future. The technology is available, and taking advantage of it is low hanging fruit for fighting the climate crisis.

Recommendations Review:

1. Use Advanced Methane Sensing Technology. Gathering this comprehensive data set will lead to rapid mitigation of super-emitter leaks, improved methane capture for use in local energy generation or methane destruction through enclosed flaring.

- The Oregon Department of Environmental Quality (DEQ)[43] should immediately move to require the use of advanced methane detection technology such as drones.
- Require landfill operators to respond to third party satellite methane detection systems, which provide comprehensive and more accurate measurements of the concentration of methane plumes, the direction of methane plumes off the landfill property, and the exact location of emission exceedances from landfills.

2. Update regulations to require Surface Emissions Monitoring (SEM) on all areas of landfills
   - Require fixed monitors for real time methane tracking in unsafe or other areas to ensure full coverage and to protect workers from hazards of conducting walking SEM. This requirement should also be instituted for landfills with high volumes of odor complaints from nearby communities.
   - Include steep slopes, closed cells, locations with covering vegetation and unspecified exemptions.
   - Actionable emissions data combined with mitigation strategies such as vertical and horizontal gas collection is critical for reducing greenhouse gas impacts and associated air toxics such as VOCs, hydrogen sulfide, forever chemicals and fine particulate matter thereby improving air quality and climate mitigation.
3. Oregon DEQ should immediately address reporting gaps by updating their regulations to require landfill owners and operators who are required to conduct surface emissions monitoring to:
   - Report all data in a spatial data format such as a shapefile, which makes for more efficient analysis of data gathered through surface emissions monitoring.
   - Report and identify the areas exempted from monitoring and report the reasons for those exemptions.

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[43] Throughout this report we emphasize Oregon because these are the arenas at which Beyond Toxics focuses their advocacy. Our findings could be replicable in other states. Thus regulatory recommendations are likely also applicable to other U.S. states.

- Report measured concentration of methane in ppm for each instantaneous SEM reading and integrated monitoring results.
- The SEM path walked by operators.
- Gas Control and Collection System Infrastructure– Gas extraction wells, piping, landfill cover.

4. To prevent future potent methane emissions, advance mandatory organic diversion policies requiring consumers and haulers to sort organic waste so that food waste can be used as a resource that is sent to facilities other than landfills to make compost and other products thereby preventing future generation of methane in landfills.

Acknowledgements

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Enforcement Alert: EPA Finds MSW Landfills are Violating Monitoring and Maintenance Requirements

EPA Investigations Find Municipal Solid Waste Landfill Operators are Failing to Properly Conduct Compliant Monitoring and Maintenance of Gas Collection and Control System

This Enforcement Alert is intended to remind municipal solid waste (MSW) landfill operators and owners, and their consultants, of their obligation to conduct proper monitoring techniques and system maintenance to ensure compliance with the Clean Air Act's MSW landfill requirements.

The U.S. Environmental Protection Agency (EPA) has found recurring Clean Air Act compliance issues at MSW landfills leading to the significant release of methane, a climate super-pollutant, and other air pollutants. MSW landfills are the third largest source of methane emissions in the United States, and more than 100 inspections over the past three years reveal that that many operators are not complying with the Clean Air Act's applicable regulatory requirements.

Compliance issues include:

- Improper monitoring resulting in excess surface emissions of methane,
- Failure to properly design, install, operate, and maintain the gas collection and control system (also referred to as the "GCCS"), and
- Failure to maintain adequate MSW landfill cover integrity.

Reducing methane emissions from MSW landfills is an integral part of the EPA's Mitigating Climate Change National Enforcement and Compliance Initiative. In this effort, the EPA is concentrating its compliance monitoring efforts on significant sources of air emissions at MSW landfills and employing civil and criminal enforcement resources where needed. In addition to addressing climate concerns, ensuring compliance at MSW landfills will achieve emission reductions that benefit downwind communities.

MSW landfill gas is comprised of roughly 50% carbon dioxide and 50% methane gases by volume. Methane is a greenhouse gas that is 28 times more potent than carbon dioxide in trapping heat in the atmosphere. It is also flammable and explosive if not properly managed. Other trace gaseous constituents include non-methane organic compounds (also referred to as "NMOC"), which include volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), as well as sulfur-based compounds, all of which can contribute to air quality issues and public health concerns.

Methane and VOCs contribute to ground-level ozone formation, and VOC emissions are a precursor to fine particulate matter formation. Ground-level ozone, particulate matter, sulfur gases, and HAP emissions are associated with premature mortality, respiratory distress, irritation, asthma, nausea, and cancer, among other issues. NMOC and sulfur gases contribute to odors and quality of life issues for surrounding communities.

The EPA is issuing two enforcement alerts on MSW landfills at the same time. The other alert addresses violations of the emission reporting requirements that result in landfills improperly avoiding control requirements. Enforcement Alert: EPA Finds MSW Landfills are Violating Landfill Gas Emission Rate Calculation Requirements is available on the Agency's website.

On this page:

I. Regulation of MSW Landfills

MSW landfills are regulated under several environmental laws and regulatory programs. This Enforcement Alert focuses on MSW landfills that may be subject to a combination of the following standards under the Clean Air Act:

- New Source Performance Standards, 40 C.F.R. part 60 subpart XXX;
- State or federal plans implementing the Emission Guidelines, 40 C.F.R. part 60 subpart Cf; and
- National Emission Standards for Hazardous Air Pollutants, 40 C.F.R. part 63 subpart AAAA.

Under these regulations, MSW landfills with a reported NMOC emission rate of above 34 megagrams per year must install and operate a well-designed GCCS to control landfill gas emissions. The purpose of a GCCS is to capture and control the gas generated in the MSW landfill.

Under the Clean Air Act, MSW landfills subject to control requirements are required to conduct quarterly surface emissions monitoring (also referred to as "SEM") to ensure methane emissions are below 500 parts per million (ppm) above background concentrations and to determine if the GCCS is adequately collecting gas from all areas of the MSW landfill. In addition, monthly wellhead monitoring is required for temperature, oxygen (or nitrogen), and wellhead pressure (vacuum) to ensure the GCCS is operating properly and collecting gas at a sufficient rate.

II. Findings from EPA Inspection at Municipal Solid Waste Landfills

More than 100 EPA inspections over the past three years reveal that many MSW landfill operators are not complying with applicable regulatory requirements, including GCCS requirements, SEM procedures, and maintaining cover surface integrity.

A. Surface Emission Monitoring Procedures


Figure 1. Exposed waste creates paths for surface emissions.

In numerous field inspections, the EPA observed that many MSW landfill operators, and their contractors, are failing to comply with the SEM requirements at 40 C.F.R. §§ 63.1958(d) and 63.1960(c)-(d), including properly following Method 21. MSW landfills operators are required to use Method 21 to determine compliance with the surface methane standard. Recent inspections also revealed widespread shortcomings in the SEM program at MSW landfills, including methane emissions at higher rates of exceedance, with many above 50,000 ppm, which is 100 times higher than the regulatory limit.

Clean Air Act regulations require MSW landfill operators to follow the proper monitoring procedures for SEM, as follows:

- **Monitoring speed**: In order to get the most accurate Method 21 readings, the SEM should be conducted while walking at a slow pace. If the pace on the serpentine path is too fast, the equipment will not have adequate time to identify an elevated concentration. The regulations require that the technician must pause and seek the emission source when readings rise, potentially backtracking to account for delayed readings due to instrument response time. Monitoring from ATVs or 4x4 vehicles cannot produce accurate readings. Drone-based SEM may only be conducted if following the requirements of Other Test Method (OTM) 51.
- **Monitoring time**: When elevated readings are observed, Method 21 – 8.3.1 requires technicians to slowly sample until the maximum reading is obtained and then leave the probe at this location for twice the instrument response time.
- **Departure from established path**: The technician should depart from the established path as frequently as necessary to monitor areas of potential emissions. These areas include, but are not limited to dead, distressed, or missing vegetation; seeps, ruts or gullies; cracks and holes; penetrations, including gas extraction wells and any other object ultimately passing through the landfill cover, including exposed waste. See figure 1. Per Method 21 – 8.3.1, sampling should go fully around each penetration. There may be multiple penetrations at wellheads.
- **Expired calibration gas**: The technician should ensure that the equipment is calibrated according to the requirements of Method 21 and that the gases used for calibration are not expired.
- **Excluded areas from monitoring**: While the regulations allow MSW landfills to exclude certain areas from the SEM (e.g., areas with steep slopes or other dangerous areas), the EPA observed during recent inspections that areas that are not dangerous are improperly excluded from monitoring. If a MSW landfill excludes areas from the SEM, the facility should document and explain the basis for excluding each area from monitoring in the surface emission design plan and SEM reports. The regular side slopes of the landfill may not be excluded from monitoring per the regulations.

B. Gas Collection and Control System: Design, Installation, Operations and Maintenance Considerations

A properly designed, installed, operated, and maintained GCCS greatly reduces the amount of landfill gas emissions.

Design: The regulations require the GCCS design to cover all areas where waste has been in place for five years (or two years if at final grade), accommodate the expected maximum landfill gas generation as calculated under the regulations, and ensure the well radiuses of influence fully cover all subject waste. The regulations require a design plan prepared by a professional engineer. The initial GCCS design should be re-evaluated after analyzing operational data to assess the system performance. Design plans should ensure sufficient density of gas collection at all stages of MSW landfill and GCCS build-out.

Installation: Clean Air Act regulations require landfill owner/operators to use proven techniques during GCCS construction to ensure a well-built system that follows the required design specifications. (40 C.F.R. § 63.1962)

Construction oversight is important to identify potential changes in the system design needed to accommodate site conditions. Owner/operators should ensure that "as-built" drawings are maintained to document any changes from the GCCS design plan and provide MSW landfill operators with a reference point to help pinpoint the location of components in the future to address maintenance issues or expansion of the system.

Owner/operators should include changes from the design plan in revised design plans submitted to EPA or its delegate for approval. (40 C.F.R. § 63.1981(e))

Operation & Maintenance: Periodic evaluation of the GCCS will help MSW landfill owners and operators identify areas in need of adjustment or repair. This will optimize the performance of the system and reduce downtime. Clean Air Act regulations require monitoring on a monthly basis of wellhead data. The MSW landfill operator should evaluate these and other data for trends that may indicate a GCCS compliance issue.


Figure 2. Poorly maintained vertical LFG well with cracked hose resulting in emission leaks and introducing oxygen into the GCCS.

Common GCCS issues to watch for include liquid levels at each well (e.g., watered-in wells), subsurface well damage resulting from waste settling, header pipe damage, wellhead damage such as damaged pipes and hoses, and bad seals. See Figure 2. These components should be visually inspected and repaired as needed to ensure the GCCS is operating as originally designed.

As new lifts of waste are deposited and wells are raised, operators should ensure adequate perforation in the wells or install additional collectors to ensure landfill gas collection in the upper levels of waste.

C. MSW Landfill Cover Integrity

MSW landfill regulations require owners and operators to inspect the landfill cover monthly to identify and repair any cover integrity issues. A well-maintained MSW landfill cover plays a critical part by retaining gas within the MSW landfill, preventing air intrusion into the landfill (and thus avoiding sub-surface oxidation events), and preventing excessive liquid infiltration into the landfill which can cause flooded wells and create difficulty in managing leachate. The EPA observed during inspections that cover integrity issues such as exposed waste, leachate breakouts, and erosion gullies continue to be a widespread problem. Additionally, the EPA has found that many landfills do not have rigorous programs to identify and correct cover integrity problems.

III. Overview of Recent Enforcement Cases

Case examples include:

- **Riverbend Landfill – McMinnville, OR (2021)**: For failing to conduct compliant SEM, ensure proper MSW landfill cover integrity, and monitor all gas wells monthly, Riverbend Landfill agreed in a settlement with the EPA to correct these Clean Air Act violations, pay a penalty, and follow improved monitoring standard operating procedures.
- **City of Midland Landfill – Midland, MI (2020)**: The City of Midland Landfill failed to (1) submit semi-annual reports of GCCS operations and SEM; (2) meet the surface methane standard; (3) perform monthly cover integrity inspections; and (4) contain and control gas migration from the MSW landfill. As part of a settlement agreement to resolve these Clean Air Act violations, the city committed to a revised SEM plan and the installation of new gas extraction wells with accompanying reports documenting their operation.
- **Gary Sanitary Landfill – Gary, IN (2020)**: The City of Gary failed to adequately design and properly operate, monitor, and maintain the gas collection and control system as required by the Clean Air Act. The city agreed in a settlement with EPA to pay a penalty and undertake the following corrective actions: (1) follow specific procedures to monitor active and passive gas wells for pressure, gas temperature, and oxygen levels; (2) follow SEM procedures and keep methane emissions below 500 ppm; (3) report and mitigate any methane exceedances; (4) maintain adequate cover integrity; and (5) monitor gas probes to prevent gas migration.

IV. Resources

Helpful resources to assist owners and operators with information to achieve compliance are available on the following EPA web pages and sites:

- MSW Landfill New Source Performance Standards (NSPS), Emission Guidelines (EG) and Compliance Times web page
- MSW Landfills: National Emission Standards for Hazardous Air Pollutants (NESHAP) web page.
- EPA Compliance website.

Disclaimer: *This Enforcement Alert addresses select provision of EPA regulatory requirements using plain language. Nothing in this Enforcement Alert is meant to replace or revise any Clean Air Act permit, any EPA regulatory provision, or any other part of the Code of Federal Regulations, the Federal Register, or the Clean Air Act.*

Last updated on September 25, 2024

To: publiccomment@bentoncountyor.gov

Subject: Oppose/Deny LU-24-027 – Disaster Debris Impacts

Dear Benton County Planning Commissioners,

My name is Carol McClelland Fields, and I live at 37326 Soap Creek Rd, Corvallis.

This testimony was originally submitted on 5.6.2025 with links to the supporting documents. I am re-submitting this testimony with the supporting documents included in this PDF. **Scroll down past my comments to see the corresponding supporting documents. Thank you.**

I am writing because I **strongly oppose** Republic Services' Conditional Use Permit application LU-24-027 to expand the Coffin Butte landfill. I urge the Planning Commission to deny this application.

- The proposed use ***does* seriously interfere with** uses on adjacent property, with the character of the area, or with the purpose of the zone [Benton County Code 53.215 (1)]
- The proposed use ***does* impose an undue burden on** any public improvements, facilities, utilities or services available to the area [Benton County Code 53.215 (2)]

I want to draw your attention to a recent segment that was broadcast on **60 Minutes** (CBS) on March 31, 2025: **California wildfires left behind *9 billion pounds* of toxic ash and debris. (Resource 1: https://www.youtube.com/watch?v=iYFksPCL-I8** *- For copyright reasons, I have no other way to share this 60 Minutes episode. I did include a screenshot of the page.)*

You are likely aware of the devastating wildfires that ravaged neighborhoods and cities in Los Angeles, California in January 2025. Watching this short 15-minute segment raised my awareness of what happens after wildfires:

> **Debris Removal Phase 1 – Removing hazardous waste, electric car batteries, power wall chargers, or any other battery.** Even after a fire, lithium batteries can explode or reignite because they are unstable. It takes six people up to two hours to remove six drums of cells from each battery, then the cells go into a saltwater bath for three days, and finally they are steamrolled to make sure they can no longer function. This material can't be recycled, it **must go to *hazardous material* landfills.**

Debris Removal Phase 2 – Removing the rest of the debris – in this case, **9 Billion (yes, that's a B) pounds of toxic ash and debris from the 2025 LA Fires** – and depositing the debris in 17 landfills and recycling center in various ***dry-climate landfills*** throughout the southwest. In addition, they **scraped 6 inches of contaminated soil throughout the region.** (The current "rule" is that anything deeper than 6 inches is said to be due to prior contamination.)

Devastating Limbo for Homes that Didn't Burn – 10,000 homes didn't burn to the ground during the LA Wildfires, which might sound like cause for celebration until you learn that these **homes are filled with soot, ash, and toxins, asbestos, exploded batteries, insulation, lead levels, arsenic, and debris. The indoor air quality within these homes is incredibly toxic.** There is a film of toxic dust throughout every home and smell the toxicity. Can these homes be cleaned to the point of being livable? Or are they total losses. Unfortunately, this is new territory and because they haven't suffered a "physical loss," the clean-up and their losses may not be covered by insurance.

This information concerns me for two reasons.

1. **If a large fire originates on Coffin Butte Landfill + Expansion or is sparked by flying embers from a nearby fire, the toxic nature of a burning landfill** (smoke, ash, soot, particulate matter, gases, and chemicals), **would negatively impact the entire region – where the fire burned and downwind of the fire.**

   In the aftermath of a large wildfire, *even if your home survives the fire,* the ash, chemicals, and soot penetrate the buildings through cracks around windows and doors, **making your home unlivable**. *Furthermore,* ***it is toxic and dangerous to continue to live in the region***. Ensuing health challenges range from: headaches, dizziness, and cognitive trouble to reproductive, kidney, respiratory problems, cardiovascular problems, and cancer.

   A 2023 study by researchers at the **Environmental Protection Agency (EPA)** found that emission factors for some toxic compounds were more than 1,000 times **higher in urban wildfires than in fires that burned in woodland areas.** (Resource 2: https://academic.oup.com/pnasnexus/article/2/6/pgad186/7202258)

   Excerpt from Abstract
   Fires that occur in the wildland urban interface (WUI) often burn structures, vehicles, and their contents in addition to biomass in the natural landscape. Because these fires

burn near population centers, ***their emissions may have a sizeable impact on public health****, necessitating a better understanding of criteria and hazardous air pollutants emitted from these fires and how they differ from wildland fires.*

Excerpt from Significance Statement
Wildfires in the wildland urban interface (WUI) burn homes and vehicles leading to potentially greater emissions of hazardous air pollutants than from wildfires burning only natural vegetation. *The greater proximity of these wildfires to population centers and the potentially more toxic emissions* ***make fires in the WUI a unique threat to public health****…Our results demonstrate that WUI fires are a potential major source of hazardous air pollutants and a better understanding of what and how much is emitted from them is needed.*

Now imagine how toxins generated from a Coffin Butte Landfill-based fire would contribute to the impact of a local WUI fire.

> *Burning trash can cause long-term health problems. The* ***toxic chemicals*** *released during burning include nitrogen oxides, sulfur dioxide, volatile organic chemicals (VOCs) and polycyclic organic matter (POMs). Burning plastic and treated wood also releases* ***heavy metals*** *and toxic chemicals, such as dioxin.*
>
> *Other chemicals released while* ***burning plastic*** *include benzo(a)pyrene (BAP) and polyaromatic hydrocarbons (PAHs), which have both been shown to cause cancer. If agricultural bags or containers are contaminated with pesticides or other harmful substances, those will also be released into the air.* *(Resource 3: https://dnr.wisconsin.gov/topic/OpenBurning/Impacts.html)*

Increasing the size of the landfill with an expansion would contribute additional toxins to any local WUI fire.

- The proposed use **does seriously interfere with** uses on adjacent property, with the character of the area, or with the purpose of the zone [Benton County Code 53.215 (1)] – *A Toxic fire definitely interferes with use of adjacent property and beyond – nearby homes, Benton County, surrounding counties; the entire character of the area would be irrevocably changed; and Rural Residential properties and Urban would no longer be livable.*

- The proposed use **does impose an undue burden on** any public improvements, facilities, utilities or services available to the area [Benton County Code 53.215 (2)] – *Undue burden would especially impact fire & emergency services, health services, mental health services, Republic Service employees, utility employees, and residents who pay county taxes.*

The Bottom Line: Expanding the landfill in such close proximity with residential neighborhoods, agricultural lands, and forested areas, creates greater fire risk and more likelihood that WUI fires would be catastrophic in nature.

2. **Given wildfire debris from structures is so hazardous** – asbestos, insulation, plastics, exploded batteries, appliances, coolant fluid, polyester curtains, cleaning products, lead, arsenic, mercury, cadmium, chromium and a variety of other dangerous PFAS chemicals – ***Why on Earth is hazardous/disaster debris coming to Coffin Butte Landfill?***

Corporate Republic Services Site lists several services under **Disaster Response**: (Resource 4: https://www.republicservices.com/environmental-solutions/emergency-response-services/disaster-response)

Disaster Debris Removal and Waste Disposal

- *Flood water management and mobile treatment*
- *Construction and demolition (C&D) waste*
- *Asbestos containing material and PCBs*
- *Compressed gas cylinders and other volatile hazards*
- *Biological material and biohazardous waste*
- *Hazardous waste disaster cleanup*
- *Hazardous and non-hazardous waste transportation and disposal*
- *Hazmat disaster cleanup*

Wildfire Hazardous Waste Response

Significant quantities of hazardous material and debris create unique challenges for cleanup and recovery from the widespread destruction caused by a wildfire. Our dedicated crews have supported hazardous waste disaster cleanup efforts for dozens of wildfires, including countless major disasters over recent years. During each event, our crews worked closely with regulators to provide management, assessment and removal of Household Hazardous Waste (HHW), asbestos containing material, and other hazardous debris from ***thousands of sites across the Pacific Northwest and other areas of the country.***

Republic Services' Environmental Services Map **does NOT list Coffin Butte Landfill as an**

Environmental Services Facility.
(Resource 5: https://www.republicservices.com/facilities/environmental-solutions)

In addition, **I don't see any mention of these disaster services on the Coffin Butte Landfill's site.**

DEQ Fact Sheet: Protect Surface Waters While Cleaning Up Your Property
(Resource 6: https://www.oregon.gov/deq/wildfires/Documents/wfSWHomeownersFS.pdf)

> *After a Wildfire:* ***Ash and debris generated from wildfires can be harmful to our rivers and streams.*** *When rainwater carries sediment and debris from burned areas it also transports pollutants to our surface waters.* ***Many of these pollutants can be toxic to humans and aquatic life.*** **Water seeping through hazardous disaster debris would amplify these effects.**

Under their Corporate PFAS Solutions Services, Republic Services describes their Long-Term Secure Disposal Options are RS' landfills in Grand View, Idaho, and Beatty, Nevada, that have special design and construction ***"with the added natural protection of being in arid locations with very little rain and low humidity."*** *(Resource 7:* https://www.republicservices.com/environmental-solutions/treatment-disposal/pfas-solutions)

The pollutants from disaster debris are toxic to humans and water species.
The best place to put disaster debris is in an arid location. We all know this area is not an arid location with very little rain and low humidity. **Coffin Butte Landfill + Expansion has the exact opposite description – high levels of rain and humidity.**

Why on Earth is the Coffin Butte location / expansion taking in hazardous waste?

> **Given our wet climate, adding more dangerous disaster debris into the Coffin Butte Landfill + Expansion will generate even MORE toxic leachate** than the current landfill already does. This toxic commodity needs to be disposed of even though no local water treatment plant has the ability to remove PFAS from the leachate to create non-harmful water.
>
> Instead, the diluted leachate gets released into the Willamette River upstream from cities that receive their drinking water from the Willamette River.
>
> **Given that the detrimental impacts of PFAS chemicals are cumulative,** this means human bodies, wildlife, and the environment will have **increasing levels of PFAS in their systems.**

Republic Services may be "getting rid" of a noxious problem, but **at what cost to the people, wildlife, and ecosystems downstream?**

- The proposed use **does seriously interfere with** uses on adjacent property, with the character of the area, or with the purpose of the zone [Benton County Code 53.215 (1)] – *Additional leachate that is even more toxic than the "regular landfill leachate" impact adjacent properties and beyond – local wells, water intakes along the Willamette River; if our waterways become polluted due to the extra toxic leachate and the regular toxic leachate, the character of our area and the state of Oregon would be compromised. Imagine the public relations nightmare if people along the Willamette River have health impacts from leachate chemicals in their drinking water.* ***What kind of reputation will Corvallis and Benton County have then?***

- The proposed use **does impose an undue burden on** any public improvements, facilities, utilities or services available to the area [Benton County Code 53.215 (2)] – *Extra toxic leachate from disaster debris + additional leachate from the expansion would impose an undue burden on health services, agriculture, and residents throughout the Willamette Valley.*

The Bottom Line: Disaster Debris does not belong in a landfill in a wet climate. Republic Services built state of the art landfills in dry climates for this very reason!

Please reject LU-24-027. Thank you for your consideration and for protecting the health and future of Benton County.

Sincerely,
Carol McClelland Fields
Corvallis, OR 97330

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Research Report

Hazardous air pollutant emissions estimates from wildfires in the wildland urban interface

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Edited By: Cristina H. Amon

Abstract

Fires that occur in the wildland urban interface (WUI) often burn structures, vehicles, and their contents in addition to biomass in the natural landscape. Because these fires burn near population centers, their emissions may have a sizeable impact on public health, necessitating a better understanding of criteria and hazardous air pollutants emitted from these fires and how they differ from wildland fires. Previous studies on the toxicity of emissions from the combustion of building materials and vehicles have shown that urban fires may emit numerous toxic species such as hydrogen cyanide, hydrogen fluoride, hydrogen chloride, isocyanates, polycyclic aromatic hydrocarbons (PAHs), dioxins and furans, and a range of toxic organic compounds (e.g. benzene toluene, xylenes, styrene, and formaldehyde) and metals (e.g. lead, chromium, cadmium, and arsenic). We surveyed the literature to create a compendium of emission factors for species emitted from the combustion of building and vehicle materials and compared them with those from wildland fires. Emission factors for some toxic species like PAH and some organic compounds were several orders of magnitude greater than those from wildfires. We used this emission factor compendium to calculate a bounding estimate of the emissions from several notable WUI fires in the western United States to show that urban fuels may contribute a sizeable portion of the toxic emissions into the atmosphere. However, large gaps remain in our understanding of the fuel composition, fuel consumption, and combustion conditions in WUI fires that constrain our ability to estimate the impact of WUI fires.

Keywords: smoke, structure fires, toxic emissions, particulate matter

Significance Statement

Wildfires in the wildland urban interface (WUI) burn homes and vehicles leading to potentially greater emissions of hazardous air pollutants than from wildfires burning only natural vegetation. The greater proximity of these wildfires to population centers and the potentially more toxic emissions make fires in the WUI a unique threat to public health. We estimate the emissions from several recent WUI fires in California and find greater emissions of some hazardous air pollutants attributable to urban fuels when compared with natural biomass and other anthropogenic sources in the airshed. Our results demonstrate that WUI fires are a potential major source of hazardous air pollutants and a better understanding of what and how much is emitted from them is needed.

Introduction

The wildland urban interface (WUI) is the area where residential and commercial buildings are intermixed in wildlands or high population densities are adjacent to wildlands. In recent decades, the WUI has been growing in area, people, and homes (1). This mingling of the urban environment with the natural has led to increasingly destructive wildfires (2). Wildfires have also been increasing in intensity with a warming climate and overgrowth of fuels, with some fires experiencing explosive growth, rapidly consuming thousands of acres and destroying entire neighborhoods within a day or several days (3). WUI fires occur across the world, with some areas like the Mediterranean, Australia, and California repeatedly experiencing highly destructive fires. Although infrequent, catastrophic fires like Northern California's Camp Fire in 2018 and Australia's 2019/2020 fires destroyed over 10,000 structures to become two of the most destructive fires in modern times. Smaller WUI fires, where several hundred to over a thousand structures destroyed, are much more frequent and are widespread (4). These small WUI fires occur across North America but are concentrated in areas that are prone to wildfire. Recent examples include the 2021 Marshall Fire in Colorado (1,091 structures), the 2016 Ft McMurray Fire in Alberta (3,244 structures destroyed), the 2016 Gatlinburg Fires in Tennessee (2,460 structures), the 2015 Bastrop County Complex in Texas (1,500

Competing Interest: The authors declare no competing interest.
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structures), and so on (5). The upward trend of destructive wildfires has accelerated in recent years in California (6) and in other parts of the United States as fire danger and at-risk population continues to grow (7).

Wildland fires are one of the largest sources of pollutants to the atmosphere and, in some parts of the United States, can contribute as much as 50% of the fine particulate matter ($PM_{2.5}$) during active fire years (8) and cause poor air quality in large parts of the United States for weeks at a time (9). The smoke from wildfires is composed of a diverse mixture of chemical species, including many hazardous air pollutants, like formaldehyde and polycyclic aromatic hydrocarbons (PAHs), which are known to cause cancer (10). This smoke has been linked to adverse health outcomes such as increased all-cause mortality and increased respiratory illnesses (11). Children, the elderly, and those with underlying conditions are particularly susceptible to the adverse effects associated with smoke exposure (11).

When fires occur in the WUI, a common question is if the smoke is any different from a "normal" wildfire burning only natural vegetation (i.e. biomass), and if more or different actions are needed to reduce exposure and protect vulnerable populations. The burning of structures and vehicles has differing and potentially more toxic emissions from those fires burning biomass, typical of wildfires on wildlands. Studies of occupational exposure of municipal firefighters have identified a range of acutely toxic and carcinogenic species such as isocyanates, volatile organic compounds (VOCs), and heavy metals from structure and vehicle fires (12–15). As such, firefighters use personal protective equipment and carry out decontamination procedures on their equipment to reduce exposure to these species (16). Because WUI fires will also emit these hazardous air pollutants, they may pose a unique threat to human health apart from normal wildfire smoke. Toxic metals have been observed at sites downwind of WUI fires, and increasing concentrations coincide with increasing numbers of structures destroyed in the fire (17). However, there remains minimal information about WUI fire emissions and their potential impact on first responders and public health (18).

The combination of more intense wildfires, longer fire seasons, and larger population in the WUI lead to an increased risk of catastrophic WUI fires. Because these fires occur near where people live, the emissions from burning of structures and vehicles may have an outsized impact on public health compared with wildfires that occur in more remote and less populated areas. The objective of this study was to develop an estimate of WUI fire emissions to identify the potential types and amounts of chemical species that may be emitted from these fires. We draw upon emissions data developed for structural fire environmental impact assessments and fire toxicity testing to provide an initial estimate of what may be emitted from WUI fires. We compare WUI fire emissions with other air pollution sources to provide some context for the importance of WUI fire emissions on public health. This information is a critical first step to guide future measurement efforts, to develop emissions inventories, and inform on the potential public health risks to WUI fires.

Results

Demographics of the WUI emission factor compilation

Of the 92 references identified that discussed emissions from structural, vehicular, furnishings, plastics, chemical, wiring, or other standard household materials, 28 references reported emission factors (also referred to as yields) for a total of 346 test conditions covering a range of chemical species that were included in the urban fuel emission factor compilation (Table S1). Many of these observations were derived from studies done by the SP Swedish National Testing and Research Institute, now the Research Institutes of Sweden (RISE), to develop inputs for their Fire Life Cycle Analysis (LCA) tool (19). These studies ranged in scale and comprehensiveness of the materials investigated and the chemical species measured. The studies included in the compilation were carried out from 1993 (20) through 2020 (21) with the median study year of 2005. The average home age in 2022 is ~44 years (22). Additionally, the major structural components of a house may not change over its lifetime (23); therefore, older studies' burning structural components may still provide representative data for current homes. However, older furnishings burned in studies done in previous decades may not be representative of newer furnishings that may contain differing amounts of compounds like flame retardants. Additionally, consumer electronic products and vehicles have changed substantially over the past three decades and older studies with these materials may not be representative of what exists in a modern home (18). Finally, homes in the WUI may differ from the US-wide averages. For example, WUI homes may be newer, reflecting the growth of WUI areas in the past few decades, and may consist of more fire-resistant materials, reflecting building codes intended to reduce wildfire risk.

Given the limited amount of data to draw from, simplified fuel categories (Table S1) were developed to provide some insight into the different types of emissions from different materials in the urban environment. Most observations were from tests with structural or other household materials (house category: 242 observations, 70%), followed by vehicles or their components (vehicle category: 48 observations, 14%), bulk chemicals or plastics (chemical category: 29 observations, 8%), and electronic waste or cables (electronic category: 27 observations, 8%). Most of the house category consisted of furnishings or textiles found in the home (253 observations) with few studies investigating wood products (36 observations), which are estimated to contribute the bulk of the combustibles in the home (18). The vehicle category consisted mostly of car components—such as dashboards and seats (32 observations)—and tires (10 observations). These categories do not have distinct boundaries as many materials may be easily assigned to multiple categories, such as polyurethane foam, which can be found in seat cushions in vehicles or in mattresses in the home. Nonetheless, these categories are illustrative of the combustible materials that may exist in certain compartments of the urban environment.

We also categorized emissions by their scale: full scale being multicomponent mixtures combusted at their full size (e.g. full room or vehicle), large scale being multicomponent mixtures burned at less than their full size (e.g. portions of carpet and padding) or single component mixtures (e.g. tire pile), and small scale being small pieces of materials burned in controlled benchtop experiments (e.g. tube furnace or small cone calorimeter).

We identified only six observations of full-scale fires with furnishings in the home (24, 25) and nine full-scale vehicle fires (21, 26–28). The coverage of different species reported from these full-scale tests was variable. For example, Willestrand et al. (21) only reported inorganic gas phase emissions such as carbon dioxide (CO_2), carbon monoxide (CO), hydrogen cyanide (HCN), hydrogen fluoride (HF), hydrogen chloride (HCl), total hydrocarbons (THC), and various size fractions of PM from burning electric vehicles, while Fiani (27) and Lonnermark and Blomqvist (26) reported a wide range of inorganic gases, PM, metals, VOCs, PAHs, and dioxins from burning vehicles.

There were several large-scale experiments (20, 25, 27–36) resulting in 94 observations for a range of materials (electronics, appliances, furniture, and chemicals). Many of the observations (nearly 70%) were from small-scale experiments carried out in a tube furnace or cone calorimeter (26, 31, 37–48). Some of these small-scale experiments were done with a controlled atmosphere (i.e. controlled air composition) to represent different combustion phases that occur in enclosure fires where oxygen can become deficient as it is consumed in the fire.

Most of the emission factors reported were for the primary combustion emissions (CO_2, PM, and NOx) and particularly for the potent asphyxiants, CO and HCN, which are critical for estimating fire toxicity (49). Several studies (24–27, 31, 32, 34, 35) measured a wide range of hazardous pollutants including VOCs, PAHs, and polychlorinated dibenzodioxins and furans (PCDD/F). No study measured the full complement of hazardous air pollutants that may be important drivers of health risk, and lumping the studies into categories was needed to create a more complete set of emission factors as a first approximation of the emissions from WUI fires.

Variation of emission factor by category

We compare emission factors across WUI categories with those used to estimate wildfire emissions (50, 51) for select species in Fig. 1. Violin plots are shown for species representing primary combustion emissions, criteria air pollutants, and hazardous metals that were selected with the greatest coverage across categories. Emission factors for all species for WUI categories are provided in Table S1.

There are some clear trends across the fuel categories by species type (Table S2). Species like CO_2, CO, and PM (including $PM_{2.5}$ and inhalable particulate matter—PM_{10}) that are produced from all combustion systems are emitted at similar levels from all fuel categories. Some hydrocarbons and oxygenated hydrocarbons typical of biomass combustion (e.g. methane, formaldehyde, and acrolein) are emitted in greater amounts from biomass combustion compared with urban fuels. However, most species had larger emission factors for urban materials compared with biomass. Generally, the inorganic gases and VOC emission factors are one to three orders of magnitude greater from urban fuels compared with biomass. Emission factors for HCl and PAHs are three orders of magnitude and dioxins/furans are five and six orders of magnitude greater for urban fuels compared with biomass. Some of these large differences (i.e. dioxins/furans) are not only because of very large emission factors for urban fuels, but also because the emission factors are comparatively very low from biomass.

There are many gaps in the emissions data that make it difficult to compare for all species from all categories. Even for biomass burning that has been well studied in the past few decades (52), there is still minimal data on metal emissions from wildfires. Metal emissions may serve as a unique fingerprint for WUI fires (17) but are not included in the Smoke Emissions Reference Application (SERA) database from which our biomass burning emission factors were derived (51). Therefore, we estimated biomass metal emission factors by applying SPECIATE (US EPA's repository of speciation profiles) PM compositional profiles to PM emission factors to compare with median emission factors from structure and vehicle fuels (Fig. 2). These comparisons show Cu over 61,000% and Zn over 412,000% greater for vehicle emissions compared with biomass (Table S2), which correspond to the elevated Cu and Zn emissions observed from fires with greater numbers of structures involved in the analysis by Boaggio et al. (17). This provides further evidence that WUI fires may have a distinct metal signature from wildfires burning only biomass.

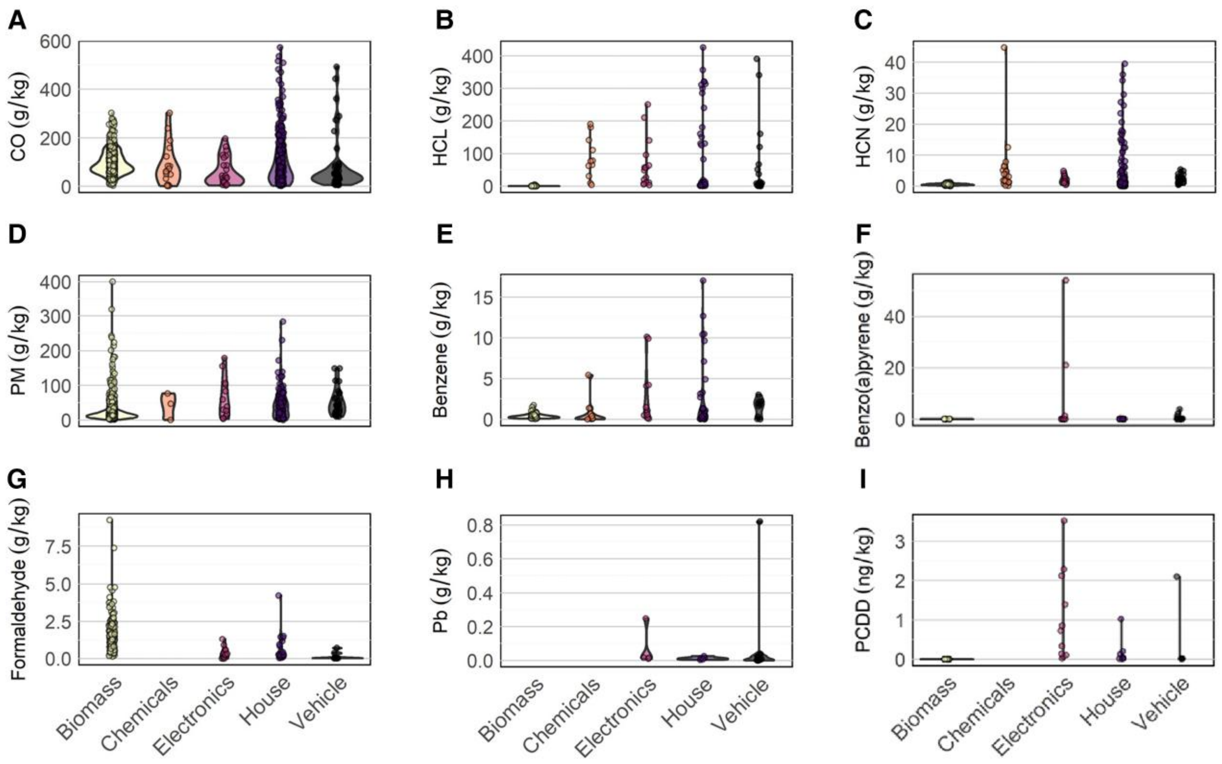

Fig. 1. Violin and strip plots of emission factors for select chemical species [A) CO; B) HCl; C) HCN; D) PM; E) benzene; F) benzo(a)pyrene; G) formaldehyde; H) Pb; and I) PCDD] for each of the major categories: biomass, chemicals, electronics, house, and vehicle.

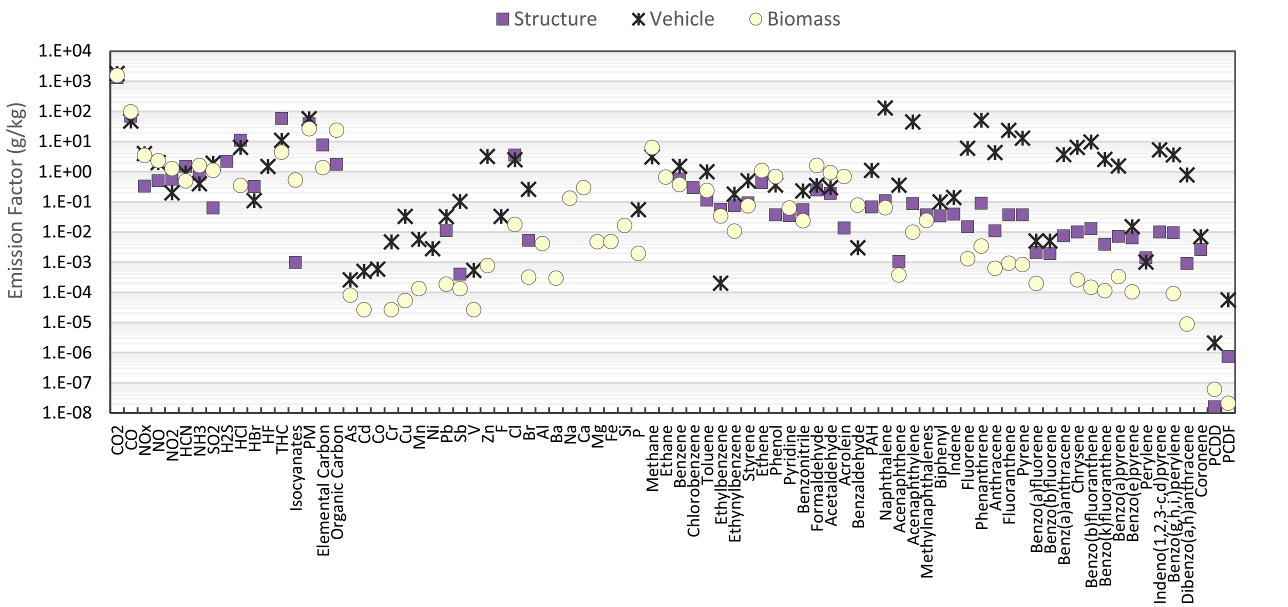

Fig. 2. Median structure and vehicle emission factors compared with mean biomass emission factors from the SERA database (data in Table S2).

Table 1. Case study destructive WUI fires in California occurring during 2020 and 2017.

Fire name	Air basin	Cause	Duration	Burned area (acres)	Structures destroyed	Vehicles destroyed[a]	Structures destroyed/ area burned (building/ mile^2)
Tubbs[b]	SF Bay Area	Power line	2017 October 8–2017 October 31	142,813	7,774	7,070[c]	98.0
Thomas	South Central Coast	Power line	2017 December 4–2018 January 12	281,893	1,063	1,526	2.4
North Complex	Mountain	Lightning	2020 August 17–2020 December 5	318,935	2,352	3,377	4.7
Glass/LNU Lightning Complex	SF Bay Area	Lightning/ arson	2020 September 27–2020 October 20 2020 August 17–2020 October 2	363,220	3,011	4,323	2.6
CZU Lightning Complex	North Central Coast	Lightning	2020 August 16–2020 September 22	86,509	1,490	2,139	11.0
August Complex	North Coast	Lightning	2020 August 16–2020 November 12	1,032,648	935	1,343	0.6

[a]Estimated from the vehicle to structure ratio destroyed in the 2018 Camp Fire, which was 1.44 as described in the Methods section.
[b]Includes Nuns, Patrick, and Atlas Fires which occurred in the same air basin during the same time.
[c]The Camp Fire vehicle to structure ratio was used for the Nuns, Patrick, and Atlas Fires and summed with that reported for the Tubbs. The California DMV estimated 4,000 vehicles destroyed in the Tubbs Fire in a 2018 blog post: https://www.dmv.ca.gov/portal/news-and-media/dmv-identifies-thousands-of-vehicles-destroyed-in-northern-california-wildfires/.

Estimated air pollutants emitted from WUI fires

We used several wildfires that burned in California in 2017 and 2020 to demonstrate a variety of WUI fires (Table 1). These wildfires span from those with very large burn area consuming primarily biomass fuels (August 2020 Fire) to relatively small wildfires with a small burn area, but large numbers of structures and vehicles destroyed (Tubbs 2017 Fire). The locations and the extent of the wildfires are shown on the map in Fig. 3. We compared the emissions from each wildfire with other air pollution sources in the same air basin to provide a frame of reference for the quantity of emissions that population is routinely exposed to. These emissions were derived from the most recent release of the National Emissions Inventory (NEI), 2017 (53), and include the annual emissions for all nonfire sources for counties in the air basin.

Emissions were categorized as "Fire" for emissions from burning wildland biomass in each wildfire (derived from NEI estimates), "WUI" for emissions from burning vehicles and structures (calculations described in the Methods section), and "Other" for emissions from all other sources in the air basin (derived from NEI estimates). Other sources included point sources like industrial facilities, area sources like oil and gas operation, and mobile sources from on-road and off-road operations and represent their emissions over the entire year. For some air basins, the Other category is sizeable due to densely populated areas and many anthropogenic activities. The wildfires analyzed here impacted a range of air basins, with the

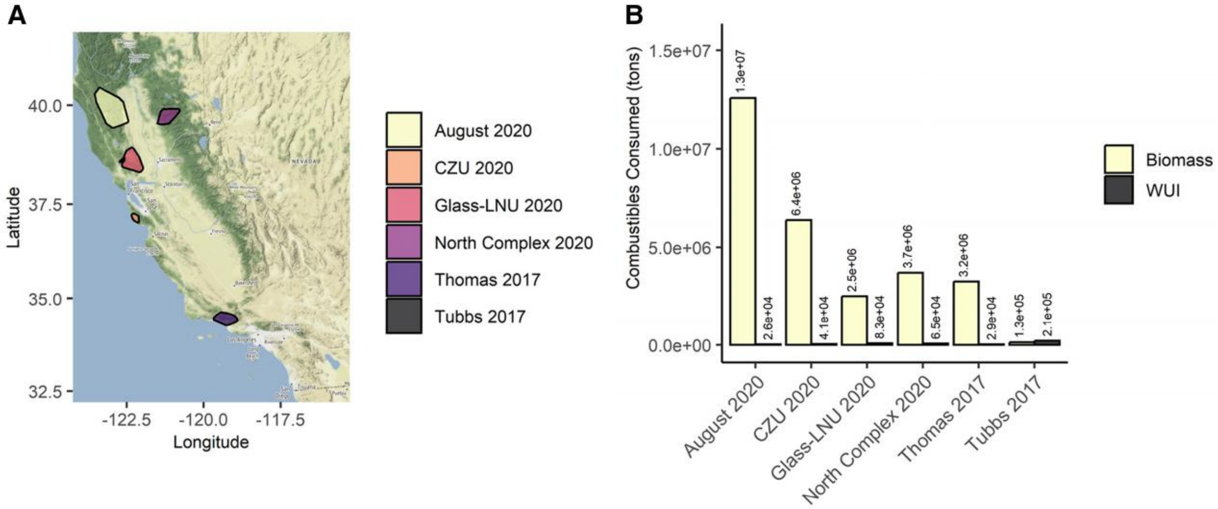

Fig. 3. Location and combustibles consumed for destructive WUI fires in California during 2017 and 2020 used in this analysis. A) Final spatial extent for each wildfire. B) Consumed combustibles for each fuel type, for each fire, as described in Table S3.

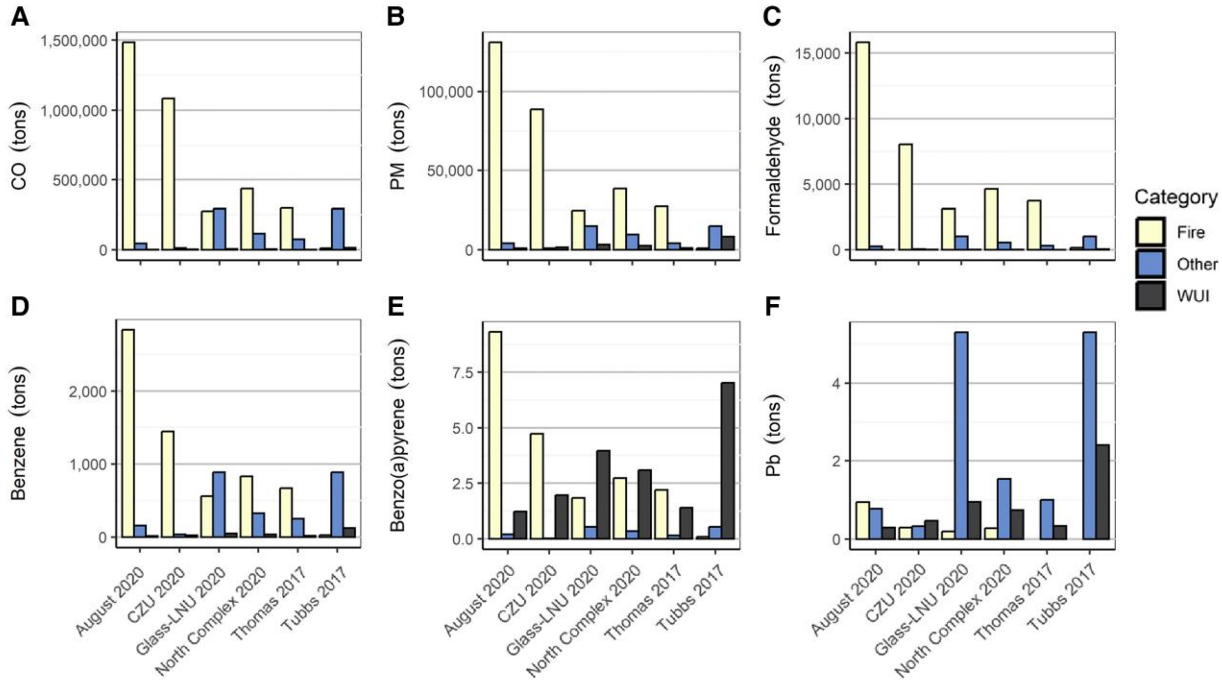

Fig. 4. Emissions estimates in tons for criteria pollutants and select hazardous air pollutants [A) CO; B) PM; C) formaldehyde; D) benzene; E) benzo(a) pyrene; and F) Pb] for Fire, Other, and WUI categories for each case study fire.

most densely populated being the San Francisco air basin, which was impacted by the Tubbs 2017 and Glass-LNU 2020 Fires. Conversely, the CZU Complex Fire impacted the mostly rural/agricultural areas in North Coastal air basin that has much lower Other emissions compared with the other air basins in California. Another key point is the difference in temporal distribution of these emissions, where Other emissions are for the entire year, the Fire emissions are spread out over the several weeks of the wildfire, and the WUI emissions are occurring over just a few days. By not distinguishing across these time frames, our comparison may obscure the importance of differing acute exposures for emissions distributed over days, weeks, or a year.

Primary combustion emissions

Figure 4 compares the total emissions by category for select species for each wildfire (all species are listed in Table S3). The WUI emissions are minimal compared with the Fire and Other sources for most criteria air pollutants (i.e. PM, CO, NOx, and SOx) and primary combustion species (i.e. CO_2, CH_4, and other hydrocarbons). These results suggest that the regulatory air pollution monitoring network would not be able to detect any difference in emissions from a WUI fire when compared with other sources or wildfires. Not surprisingly, the Fire emissions are generally larger than Other emissions for these primary combustion pollutants for all wildfires, except for the two that impacted the San Francisco Bay Area air basin, where there are substantial emissions over the year from anthropogenic activity.

For most of the wildfires evaluated here, the WUI emissions for oxygenated hydrocarbon species are much lower than the Fire emissions of those species. This is not surprising, since oxygenated hydrocarbons such as formaldehyde, acetaldehyde, and acrolein are emitted from biomass burning in large amounts. The one exception to this trend is for the Tubbs wildfire, which has comparatively low acreage burned (<150,000 acres), but many structures destroyed (>7,700). For the Tubbs wildfire, the WUI emissions are either greater or similar to the Fire emissions, but typically less than Other emissions in the densely populated San Francisco Bay Area air basin.

Hazardous air pollutant emissions

The hazardous air pollutants like PAH, toxic metals, and chlorinated hydrocarbons exhibit different trends from the criteria pollutants and hydrocarbon pollutants. Fire and WUI categories both have high PAH emissions of similar magnitude. Only the August Fire and CZU Fires, with their low destroyed structure to area burned ratios (Table 1), routinely had larger Fire PAH emissions compared with WUI PAH emissions. Again, the Tubbs Fire is notable in this comparison with 78 times higher benzo(a)pyrene emissions compared with Fire emissions and 13 times Other emissions in the San Francisco Bay Area air basin (estimated for 2017). Lead (Pb) (Fig. 4F) was the only metal for which data were available from all three categories, but not from all wildfires. Pb emissions were two to three times Other and Fire emissions for all wildfires. There were limited data for all other hazardous air pollutants, prohibiting comparison across the three main categories (Fire, Other, and WUI).

A more comprehensive view across many species can be made with a heat map of the ratio of WUI to Fire categories (Fig. 5A) and WUI to Other categories (Fig. 5B). Different species are shown in each figure since not all categories have all species. The heat map presentation also makes it readily apparent that the Tubbs Fire is the only wildfire in our case study where the WUI emissions dominate the Fire emissions for all species but the oxygenated hydrocarbons and primary combustion emissions. One interesting feature is the high ratios for phenanthrene differing from the other PAH. This is likely due to the vehicle emission factors, which were much higher than the other fuel categories. These emission factors were for full-scale burns where combustion involved the entire vehicle and may be more representative of emissions in a WUI fire. However, there are too few emission factor observations for the other categories for this difference to be conclusive.

The ratio of the WUI to the Other heat map also shows some distinctive patterns, with all the PAH ratios well above 1. Chlorobenzene, Cl, Sb, and HCl also have ratios much larger than 1. This is the first evidence that WUI fires may be the largest emission source for some of these species into an air basin. Some of these air pollutants may be important drivers of health risk and in current emissions inventories they are not estimated.

Discussion

Emissions inventories play an important role in identifying the major sources of air pollution and the drivers of health risk. This information can be used to guide policy decisions made to reduce

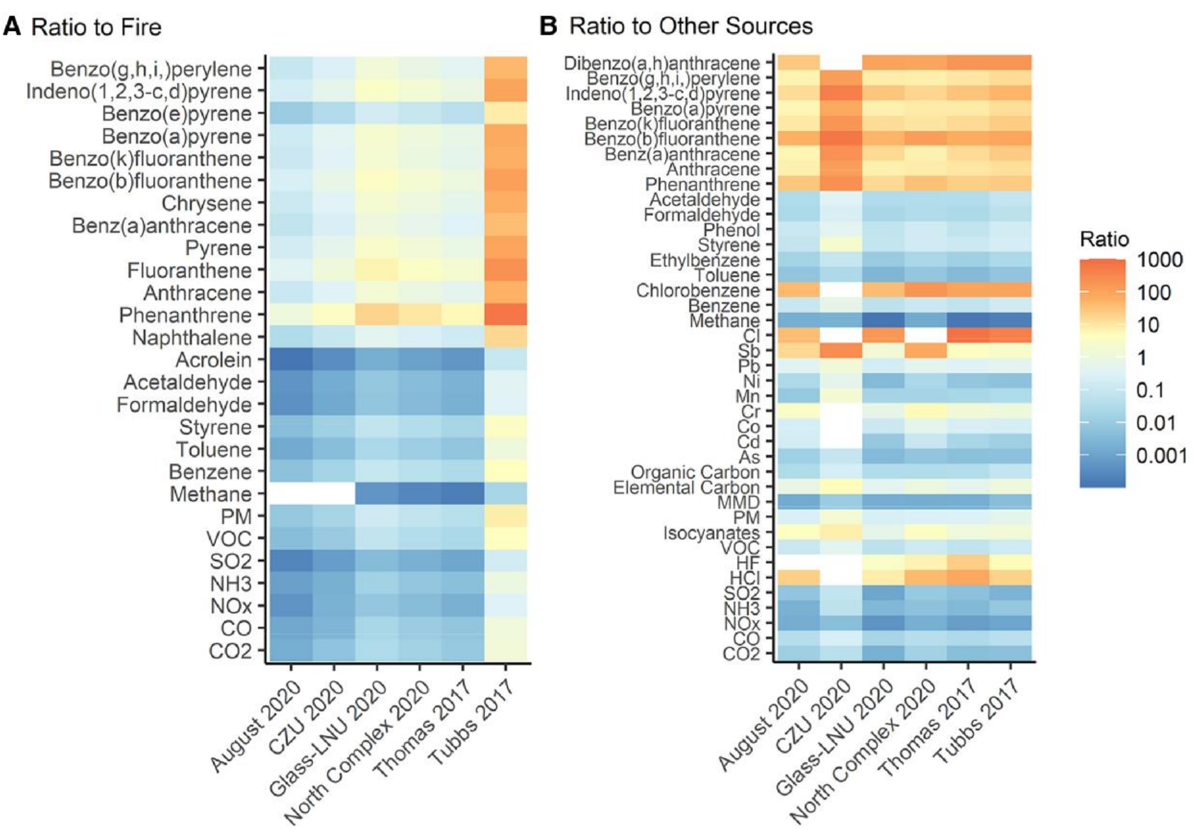

Fig. 5. Heat map of the ratio of emissions between categories. A) WUI emissions to Fire emissions. B) WUI emissions to Other emissions for each wildfire.

the public health risk to hazardous air pollution, including decisions on future research efforts, air quality monitoring infrastructure, public health outreach, and mitigation measures. Until now, structural fire emissions have not been inventoried in the United States and thus were not included in assessments of the impacts of air pollution on human health. We demonstrate that WUI fires may be a sizeable source of certain hazardous air pollutants, but not necessarily contribute to increased criteria air pollutants or greenhouse gases that are routinely monitored. Moreover, in some locations and some years, WUI fires may constitute the single largest source of these pollutants and may be an important driver of risk.

Although there is likely very large uncertainty in the inventory developed here, there is no unambiguous method to validate a WUI fire emissions inventory. Such an evaluation would require measurements of before and after fire fuel loadings, assessment of combustion conditions during the fire, in addition to near-fire emissions measurements. This type of data set does not currently exist. Furthermore, ambient monitoring data are not suitable for comparison because dispersion, atmospheric chemistry, and the impact of other sources need to be factored in, all of which introduce large uncertainties. We ensure our inventory has the highest data quality by following recognized good practices for developing a bottom-up inventory that is transparent, complete, and accurate given the available information (54, 55). Although we have attempted to generate an inventory with the best available information to achieve the greatest accuracy, there are many data gaps that result in large uncertainty of the estimates presented here. Our study improved upon existing methodologies by applying assumptions appropriate for WUI fires, but the data sources for calculating the inventory need further improvement to better estimate average emissions and uncertainty estimates.

We examined each input into the inventory to identify where improvements are needed. A large source of uncertainty in the WUI fire emissions inventory is the amount, composition, and condition of the fuel. Similar to wildfire emissions inventories, the data inputs on the fuel can be the largest source of uncertainty in the emissions estimate (56). Statistics on new home construction (57) and home energy usage (58, 59) can provide some information and the major materials that are used in structures (e.g. roofing and siding), but not information on insulation or indoor surface finishes, plumbing fixtures, or wiring. Moreover, these sources do not provide detailed information on the chemical composition of the materials in the structure. There is no standardized source of information on commercial buildings, which may also be consumed in a WUI fire. Information on the contents in the home are derived from fuel loading surveys, the majority of which focus on fire risk and only quantify the combustibles inside the structure, while it is clear from the metal emission factor data that noncombustible materials are being transformed in the combustion process and emitted into the air. Much more detailed information on the composition of all the materials in the structure and contents are needed to estimate emissions for environmental health risk.

Even with detailed knowledge of the amount and chemical composition of the structure, vehicle, and their contents, there are many unknowns related to the combustion conditions, potential chemical interactions, and resulting emissions. One critical unknown is the amount of WUI fuel that is consumed in the fire. Current fire statistics only report if a structure is destroyed or damaged, but there is no linkage to how much of the original structure remains in each of these categories. We assumed 80% of the combustibles are consumed when a structure is destroyed and did not include damaged structures. This may be a conservative estimate since many postfire images show complete destruction, but these images may show a biased subset of homes. More information is needed on how much of the destroyed or damaged structure or vehicle remains after the fire to provide a better estimate of fuel consumption and how that may vary between fire scenarios.

The sizeable literature on fire safety engineering and fire toxicity has highlighted the importance of the chemical composition of the fuel, the oxygen available for combustion, and the temperature in controlling the amount and composition of emissions (49). Standardized methods have been developed to study the emissions of materials combusted in a range of conditions that are typical for enclosure fires occurring within a structure (49). However, there is currently no information on the combustion conditions in WUI fires and what fraction of the fuel may burn at high temperature under- or overventilated or in low-temperature smoldering processes. This uncertainty also exists in the wildfire emissions inventory where common practice is to assume that a fraction of the fuel burns in flaming conditions versus smoldering conditions (60, 61). The flaming–smoldering fraction is modeled depending upon the fuel characteristics and environment conditions (62).

Drawing upon our understanding of pollutant formation in waste incineration and open waste burning, we know that fuel chemistry, temperature, and residence time all interact and greatly impact emission rates of some species (63–65). Much of the emissions data relied on for this inventory are derived from the combustion of individual materials and often in the absence of the inorganic support structures or surfaces that may exist in homes. Additionally, the few studies carried out at full scale likely have combustion conditions that differ than those in WUI fires that often occur during extreme winds (66).

The emissions estimates compiled here are a reasonable first approximation despite the large number of unknowns. These results suggest that some hazardous air pollutants, but not criteria air pollutants, may be emitted from WUI fires in much larger amounts than wildfires in wildlands or other anthropogenic sources. However, this estimate may greatly differ than what is truly emitted, and additional research is needed to develop and refine data inputs to the emissions model and this needs to be verified with measurements of concentrations near WUI fires to constrain and improve this emissions estimation method. Current monitoring networks focus on criteria pollutants and have measurements of detailed chemical composition with minimal spatial and temporal resolution (18). Supplemental measures of detailed chemical composition of ambient concentrations near WUI fires, in addition to information on urban fuels and combustion conditions, are greatly needed to improve the emissions estimates developed in this study.

Methods

Emission factor compilation

We compiled emission factors from a comprehensive literature search of simulations of fires of structures, vehicles, and their components (Table S1). Web of Science and Google Scholar were used to identify peer-reviewed and other data sources reporting emissions from the burning of urban materials. Key words included combinations of “fire,” “smoke,” “toxicity,” “municipal,” “structure,” “vehicle,” “car,” “furnishings,” and a variety of individual materials (e.g. “wood,” “plastic,” “fabric,” and “textile”). Each

Table 2. Comparison of assumptions for emissions estimates from structure fires across estimation methods.

	CARB 1999	SP 2009	BC 2000	WUI Fire 2022
Reference	California Air Resources Board, Lozo 1999 (67)	SP Technical Research institute of Sweden, Blomqvist and McNamee 2009 (68)	British Columbia Ministry of Water, Land, and Air Protection, Wakelin 2000 (69)	This study
Combustible structure	1,649 ft^2 11 tons			2,150 ft^2 33.4 tons
Combustible content	7.9 lb/ft^2	3.69 lb/ft^2		5.87 lb/ft^2
Fraction consumed	7%	5% room of origin 35% several rooms 80% multiple structures		80%
Loading factor—mass burned per structure	1.23 tons/fire		1.04 tons/fire[a]	39.72 tons/fire

[a]Total combustible fuel consumed per fire incident, assumed one incident equivalent to one structure.

source was reviewed for relevance to a WUI fire; specifically, we determined if the fuel was representative of a human-made (e.g. vehicle) or human-processed natural material (e.g. wood decking) and if the combustion conditions were a suitable simulation of open burning. Lab-scale studies focusing on waste incineration or those using devices such as a fluidized bed reactor, which may have high temperatures and/or pressures, well-mixed fuel and oxidizer, or mechanically processed fuel (e.g. pulverized), were deemed to be not representative of open burning conditions that may occur in a WUI fire and were excluded from the data set. The list of relevant sources was further expanded by reviewing sources citing the initial list of sources. Sources providing only concentration data were excluded from the data set since they could not be used to generate emission factors. Sources reporting duplicate information were identified and the source with the most comprehensive data reported was included in the data set. Only full-scale data were retained for experiments using the identical fuels at multiple scales (e.g. the TOXFIRE experiment (33)).

Emission factor or yield data from each study were consolidated in an Excel spreadsheet and categorized by the scale of the experiment: full scale (involving multiple items at full size) or other (e.g. lab scale, bench scale, and microscale); type of material: house or vehicle; material subtype: furnishing, component, or tire; and combustion conditions: flaming, overventilated or smoldering, underventilated. Emissions were reported as factors (e.g. g emitted species/kg load) or yields (e.g. g emitted species/kg combustible load) from combustion of structural or vehicular components. In the absence of information on combustibles per fuel charge, it was assumed that the entire fuel charge was made of combustible material. Units were converted for all species to grams per kilogram. An initial review of the compilation was made for each species by category. Outliers were investigated and sources with consistently higher emission factors were removed. Removal of these sources reduced the number of species reported, but they were limited to small-scale experiments.

A summary emission factor data set was developed for use in emissions inventory development by taking the median of all observations for any house materials, regardless of scale or combustion conditions. For the vehicle category, the median of the full-scale experiments was used since there were more comprehensive emissions available for those experiments. In the case that emissions data from full-scale vehicle experiments were not available, the median emission factor from the entire data set for any vehicle material was used. Species where this gap-filling approach was used are highlighted in red text in Table S2.

Biomass burning emission factors for comparison with the WUI emission factors were derived from the online SERA database (51). The complete SERA database for all vegetation types and experimental approaches was filtered to remove emission factors associated with slash fires and outliers and downloaded on 2022 December 1.

Emissions inventory methodology

Several methods for estimating emissions from structures and vehicles have been published in the context of municipal fires (67–70). All methods use the same basic emissions inventory development approach of:

$$E_x = A \times B \times F \times EF_x \quad (1)$$

where E_x is the mass of emissions of species x, A is the activity (e.g. number of houses or vehicles consumed by fire), B is the combustible mass of fuel, F is the fraction of the fuel consumed, and EF_x is the emission factor for species x. Major differences among methods exist in the assumptions used to estimate the combustible fuel loading for the structure (or vehicle), the fraction of fuel consumed in the fire, the emission factor, and the chemical species. We have translated these methods for the WUI fire context by modifying key assumptions of fuel load and consumption (Table 2) and updating and expanding emission factors.

Emissions estimates from municipal fires assume a small percentage (e.g. ~7% in CARB 1999 (67)) of the structure is consumed and that most of the fuels are from the room of origin. Images of neighborhoods after a wildfire has passed through show many houses are reduced to only the noncombustible components, such as masonry. Therefore, we assumed a greater percentage of the combustible loading would be consumed in a WUI fire. We used 80% as an initial estimate following a survey of fire investigators in Sweden estimating ~80% loss when the fire spreads to multiple structures (68). This may be an underestimate for a WUI fire in the United States where most of the homes are wood construction (18), which is relatively uncommon in Sweden (68). Since most of the combustibles are consumed in WUI fires, we also inventoried the entire home as opposed to just the rooms where most municipal fires begin (kitchen and bedroom) to include in the combustible load.

The structural combustible load is estimated from data for a typical North American house built in 1998 compiled by the National Academies (18) and detailed in Table S4. The house contents are estimated from the median of fire load density measurements in North American residences of 600 MJ/m^2 reported in Xie et al. (71). Fire load density is converted to combustible mass using the material distribution from SP 2009 method (68) and the material energy content from Elhami-Khorasani et al. (72) (detailed in Table S5A and B). The vehicle composition was similarly calculated for a typical sedan model year of 2017 (detailed in Table S6) of 93 lb of tires and 810 lb of combustible material (18, 73).

The CARB 1999 and BC 2000 emissions estimates are based on a set of default emission factors that are applied per ton of combustible mass burned. The SP 2009 emissions estimate breaks down the combustibles by type (e.g. wood, paper, textiles, rubber, and plastics) and uses material-specific emission factors (68). There is a paucity of emissions data available for each combustible type and only a few have complete data for a wide range of hazardous pollutants. There was insufficient data to adequately capture the impact of the variation within a type (e.g. textiles may be cotton, wool, or acrylic), so emission factors were lumped into the two general categories for house and vehicles as described above. These emissions measurements spanned all combustion conditions: pyrolysis, smoldering, and flaming; in the absence of information on typical structural/vehicle combustion conditions in a wildfire, the median was taken for all observations.

WUI fire case studies

We identified WUI fires within California with corresponding EPA NEI data to obtain estimates of burned area and emissions from each wildfire and comparison data from other source sectors (e.g. industrial emissions). The NEI calculates fire emissions using the BlueSky Framework, which models the fuel loading, fraction consumed, and applies vegetation-specific emission factors for each fire (74). The NEI is produced every 3 years with 2020 the most recent release (74). While other wildfire emissions inventories exist with greater temporal coverage, they do not include emissions from other emissions sources and may not include emissions for a wide range of hazardous air pollutants. Eight of the current Top 20 Most Destructive California Wildfires (compiled by Cal Fire as of 2022) occurred during 2020 and 2017 (75). These fires provide a range burned acreage and structures destroyed and were used in this analysis to illustrate the scale of WUI fire emissions in comparison with other emissions sources. The ratio of structure destroyed to burned area ranges from 0.6 to 98 (building/mile^2) and encompasses that observed in the Camp Fire (78.5 building/mile^2), which is the most destructive fire in California, but could not be included in the analysis because of the lack of an NEI emissions estimate for the wildland biomass fuels.

California provides records of the number of structures destroyed but does not report the number of vehicles destroyed in each fire. The California Department of Resources Recycling and Recovery estimated 27,000 destroyed vehicles were recovered from the cleanup operation after the Camp Fire, which results in an estimated 1.44 vehicles per structure destroyed in the fire. This ratio is applied to all other fires to provide an estimate of the vehicles consumed in each of the wildfires. However, the actual number of vehicles destroyed may vary widely between fires depending upon the time allowed for evacuation, since vehicles may be moved from the area threatened by the fire.

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Supplementary material

Supplementary material is available at *PNAS Nexus* online.

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Author contributions

A.L.H. conceived the study. A.L.H., A.A., J.M.V., and V.R. collected the data. A.L.H. and A.A. analyzed the data. A.L.H. wrote the draft manuscript. All authors contributed to the final manuscript.

Data availability

All data used to generate the figures and tables in this manuscript may be found in the supplementary material.

References

1 Urban wildland interface communities within the vicinity of federal lands that are at high risk from wildfire. 2001. Federal Register, p. 751–777.
2 Bowman DMJS, *et al.* 2020. Vegetation fires in the Anthropocene. *Nat Rev Earth Environ*. 1:500–515.
3 Higuera PE, Abatzoglou JT. 2021. Record-setting climate enabled the extraordinary 2020 fire season in the western United States. *Glob Change Biol*. 27:1–2.
4 St. Denis LA, Mietkiewicz NP, Short KC, Buckland M, Balch JK. 2020. All-hazards dataset mined from the US National Incident Management System 1999–2014. *Sci Data*. 7:64.
5 Barrett K. 2022. Wildfires destroy thousands of structures each year. (Headwaters Economics); [accessed 2022 Dec 1]. https://headwaterseconomics.org/natural-hazards/structures-destroyed-by-wildfire/.
6 Buechi H, Weber P, Heard S, Cameron D, Plantinga AJ. 2021. Long-term trends in wildfire damages in California. *Int J Wildland Fire*. 30:757–762.
7 Peterson GCL, Prince SE, Rappold AG. 2021. Trends in fire danger and population exposure along the wildland–urban interface. *Environ Sci Technol*. 55:16257–16265.
8 O'Dell K, Ford B, Fischer EV, Pierce JR. 2019. Contribution of wildland-fire smoke to US $PM_{2.5}$ and its influence on recent trends. *Environ Sci Technol*. 53:1797–1804.
9 Li Y, *et al.* 2021. Dominance of wildfires impact on air quality exceedances during the 2020 record-breaking wildfire season in the United States. *Geophys Res Lett*. 48:e2021GL094908.

10 O'Dell K, *et al.* 2020. Hazardous air pollutants in fresh and aged western US wildfire smoke and implications for long-term exposure. *Environ Sci Technol*. 54:11838–11847.
11 Cascio WE. 2018. Wildland fire smoke and human health. *Sci Total Environ*. 624:586–595.
12 Fent KW, *et al.* 2018. Airborne contaminants during controlled residential fires. *J Occup Environ Hyg*. 15:399–412.
13 Fabian TZ, *et al.* 2014. Characterization of firefighter smoke exposure. *Fire Technol*. 50:993–1019.
14 Fent KW, *et al.* 2020. Flame retardants, dioxins, and furans in air and on firefighters' protective ensembles during controlled residential firefighting. *Environ Int*. 140:105756.
15 Keir JLA, *et al.* 2020. Polycyclic aromatic hydrocarbon (PAH) and metal contamination of air and surfaces exposed to combustion emissions during emergency fire suppression: implications for firefighters' exposures. *Sci Total Environ*. 698:134211.
16 Stolpman D, Williams DN, Solouki T, Harris DD. 2022. Decontamination of metals from firefighter turnout gear. *J Occup Environ Hyg*. 19:79–86.
17 Boaggio K, *et al.* 2022. Beyond particulate matter mass: heightened levels of lead and other pollutants associated with destructive fire events in California. *Environ Sci Technol*. 56:14272–14283..
18 National Academies of Sciences, and Medicine. 2022. *The chemistry of fires at the wildland-urban interface*. Washington (DC): The National Academies Press.
19 McNamee M, Butry D, Kneifel J. Tools and techniques for impact analysis. 2023. In: Meacham BJ, McNamee M, editors. *Handbook of fire and the environment: impacts and mitigation*. Cham: Springer International Publishing. p. 289–322.
20 Lemieux PM, Ryan JV. 1993. Characterization of air pollutants emitted from a simulated scrap tire fire. *Air Waste* 43:1106–1115.
21 Willstrand O, Bisschop R, Blomqvist P, Temple A, Anderson J. 2020. Toxic gases from fire in electric vehicles. RISE Report. 2020:90.
22 Anonymous, American Community Survey; [accessed 2022 Dec 9]. https://data.census.gov/mdat/#/search?ds=ACSPUMS1Y2021&cv=YRBLT&wt=WGTP.
23 US Environemental Protection Agency. 2016. Analysis of the life-cycle impacts and potential for avoided impacts associated with single family homes. 530-R-13-004.
24 Blomqvist P, Rosell L, Simonson M. 2004. Emissions from fires part II: simulated room fires. *Fire Technol*. 40:59–73.
25 Andersson P, Simonson M, Rosell L, Blomqvist P, Stripple H. 2003. Fire-LCA model: furniture study. SP Report. 2003. 22.
26 Lönnermark A, Blomqvist P. 2006. Emissions from an automobile fire. *Chemosphere* 62:1043–1056.
27 Fiani E. 2013. Improvement of the knowledge of the atmospheric emission from vehicles fires contribution of this source to the national emission inventory. INERIS-DRC-13-119925-05193A-Synthesis.
28 Guerin S, Collet S. 2019. Atmospheric emissions of dioxins and brominated furans in accidental fires of waste containing brominated substances. INERIS-170785-00117B.
29 Gann RG, Averill JD, Johnsson EL, Nyden MR, Peacock RD. 2010. Fire effluent component yields from room-scale fire tests. *Fire Mater*. 34:285–314.
30 Lönnermark A, Blomqvist P, Mansson M, Persson H. 1996. TOXFIRE—fire characteristics and smoke gas analyses in under-ventilated large-scale combustion experiments. SP Report. 1996. 46.
31 Andersson P, Rosell L, Simonson M, Emanuelsson V. 2004. Small and large scale fire experiments with electric cables under well-ventilated and vitiated conditions. *Fire Technol*. 40:247–262.
32 Andersson P, Simonson M, Rosell L, Blomqvist P, Stripple H. 2005. Fire-LCA model: cable case study II-NHXMH and NHMH cable. SP Report. 2005. 45.
33 Lönnermark A, Blomqvist P, Mansson M, Persson H. 1996. TOXFIRE—fire characteristics and smoke gas analysis in under-ventilated large-scale combustion experiments: Tests in the ISO 9705 Room. SP Report. 1996. 45.
34 Lönnermark A, Blomqvist P. 2005. Emissions from fires in electrical and electronics waste. SP Report. 2005. 42.
35 Lönnermark A, Blomqvist P. 2005. Emissions from tyre fires. SP Report. 2005. 43.
36 Andersson P, Blomqvist P, Loren A, Larsson F. 2013. Investigation of fire emissions from Li-ion batteries. SP Report. 2013. 15.
37 Blomqvist P, Hertzberg T, Tuovinen H, Arrhenius K, Rosell L. 2007. Detailed determination of smoke gas contents using a small-scale controlled equivalence ratio tube furnace method. *Fire Mater*. 31:495–521.
38 Blomqvist P, McNamee M, Stec A, Gylestam D, Karlsson D. 2010. Characterisation of fire generated particles. SP Report. 2010. 1.
39 Durlak SK, Biswas P, Shi J, Bernhard MJ. 1998. Characterization of polycyclic aromatic hydrocarbon particulate and gaseous emissions from polystyrene combustion. *Environ Sci Technol*. 32:2301–2307.
40 Fabian TZ, *et al.* 2010. Firefighter exposure to smoke particulates. IN 15941.
41 Hertzberg T, Blomqvist P, Dalene M, Skarping G. 2003. Particles and isocyanates from fires. SP Report. 2003. 5.
42 Kozlowski R, Wesolek D, Wladyka-Przybylak M. 1999. Combustibility and toxicity of board materials used for interior fittings and decorations. *Polym Degrad Stab*. 64:595–600.
43 Persson B, Simonson M. 1998. Fire emissions into the atmosphere. *Fire Technol*. 34:266–279.
44 Reisen F, Bhujel M, Leonard J. 2014. Particle and volatile organic emissions from the combustion of a range of building and furnishing materials using a cone calorimeter. *Fire Saf J*. 69:76–88.
45 Stec AA, Rhodes J. 2011. Smoke and hydrocarbon yields from fire retarded polymer nanocomposites. *Polym Degrad Stab*. 96:295–300.
46 Stec AA, Hull TR. 2011. Assessment of the fire toxicity of building insulation materials. *Energy Build*. 43:498–506.
47 Wesolek D, Kozlowski R. 2002. Toxic gaseous products of thermal decomposition and combustion of natural and synthetic fabrics with and without flame retardant. *Fire Mater*. 26:215–224.
48 Blomqvist P, Sandinge A. 2018. Experimental evaluation of fire toxicity test methods. RISE Report. 2018. 40.
49 Stec AA, Hull TR. 2010. *Fire toxicity*. Cambridge: Elsevier Science.
50 Prichard SJ, *et al.* 2020. Wildland fire emission factors in North America: synthesis of existing data, measurement needs and management applications. *Int J Wildland Fire*. 29:132.
51 University of Washington. 2022. Smoke Emissions Reference Application (SERA); [accessed 2022 Dec 1]. https://depts.washington.edu/nwfire/sera/.
52 Urbanski SP, O'Neill SM, Holder AL, Green SA, Graw RL. Emissions. 2022. In: Peterson DL, McCaffrey SM, Patel-Weynand T, editors. *Wildland fire smoke in the United States: a scientific assessment*. Cham: Springer International Publishing. p. 121–165.
53 U.S. Environmental Protection Agency. 2020. 2017 NEI interactive report.
54 European Environmental Agency. 2019. EMEP/EEA air pollutant emission inventory guidebook 2019. EEA report no 13/2019.
55 IPCC. 2019. *Refinement to the 2006 IPCC guidelines for National Greenhouse Gas Inventories*. Switzerland: IPCC. p. 2019.

56 Larkin NK, Raffuse SM, Strand TM. 2014. Wildland fire emissions, carbon, and climate: U. S. emissions inventories. *For Ecol Manag*. 317:61–69.
57 National Association of Home Builders. 2022. National statistics; [accessed 2022 Dec 1]. https://www.nahb.org/news-and-economics/housing-economics/national-statistics.
58 U.S. Census Bureau. 2022. American Community Survey (ACS).
59 U.S. Energy Information Administration. 2022. Residential Energy Consumption Survey (RECS).
60 Anderson GK, Sandberg DV, Norheim RA. 2004. Fire Emission Production Simulator (FEPS) user's guide; [accessed 2022 Dec 1]. https://www.frames.gov/catalog/6921.
61 Urbanski S. 2014. Wildland fire emissions, carbon, and climate: emission factors. *For Ecol Manag*. 317:51–60.
62 Finney MA. 1998. FARSITE: fire area simulator-model development and evaluation. RMRS-RP-4.
63 Linak WP, Wendt JOL. 1993. Toxic metal emissions from incineration: mechanisms and control. *Prog Energy Combust Sci*. 19:145–185.
64 Lemieux PM, Lutes CC, Santoianni DA. 2004. Emissions of organic air toxics from open burning: a comprehensive review. *Prog Energy Combust Sci*. 30:1–32.
65 McKay G. 2002. Dioxin characterisation, formation and minimisation during municipal solid waste (MSW) incineration: review. *Chem Eng J*. 86:343–368.
66 Keeley JE, Syphard AD. 2019. Twenty-first century California, USA, wildfires: fuel-dominated vs. wind-dominated fires. *Fire Ecology* 15:24.
67 Lozo C. 1999. Structure and automobile fires; [accessed 2022 Dec 1]. https://www.arb.ca.gov/ei/areasrc/fullpdf/full7-14.pdf.
68 Blomqvist P, McNamee MS. 2009. Estimation of CO2-emissions from fires in dwellings, schools and cars in the Nordic countries. SP Technical Note. 2009. 13.
69 Wakelin T. 2005. 2000 British Columbia emission inventory of criteria air contaminants: Methods and calculations.
70 Eastern Research Group. Chapter 18: structure fires. 2001. In: *EIIP*. Volume 3. Research Triangle Park (NC): U. S. Environmental Protection Agency.
71 Xie Q, Xiao J, Gardoni P, Hu K. 2019. Probabilistic analysis of building fire severity based on fire load density models. *Fire Technol*. 55:1349–1375.
72 Elhami-Khorasani N, Salado Castillo JG, Gernay T. 2021. A digitized fuel load surveying methodology using machine vision. *Fire Technol*. 57:207–232.
73 Davis SC, Boundy RG. 2021. *Transportation energy data book: edition 39*. Oak Ridge (TN): Oak Ridge National Laboratory. ORNL/TM-2020/1770.
74 Office of Air Quality Planning and Standards. 2021. *2017 national emissions inventory: January 2021 updated release, technical support document*. U.S. Environmental Protection Agency. EPA-454/R-21-001.
75 CAL FIRE. 2022. Top 20 Most Destructive California Wildfires; [accessed 2022 Dec 1]. www.fire.ca.gov/media/t1rdhizr/top20_destruction.pdf.

Resource 3: *https://dnr.wisconsin.gov/topic/OpenBurning/Impacts.html*

https://dnr.wisconsin.gov/topic/OpenBurning/Impacts.html

n Substack WaveApps WCCU Site ConvertKit Stripe Asana Squarespace Zoom Google Analytics iDrive Edit Synology Pocket 5 Calls Paleovalley | Winter W

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

HUNTING FISHING PARKS CLIMATE ENVIRONMENT FORESTRY LICENSES NEWS ABOUT CONTACT

HEALTH IMPACTS OF SMOKE

IMPACTS OF SMOKE FROM BURNING CLEAN WOOD AND LEAVES

When household waste, like wood and leaves, are burned, they produce smoke, which contains vapors and particulate matter (solid and liquid droplets suspended in the air). Air pollution from smoke can impact human health.

People exposed to these air pollutants can experience eye and nose irritation, difficulty breathing, coughing and headaches. People with heart disease, asthma, emphysema or other respiratory diseases are especially sensitive to air pollutants. Other health problems aggravated by burning include lung infections, pneumonia, bronchiolitis and allergies.

IMPACTS OF SMOKE FROM BURNING TRASH AND PLASTIC

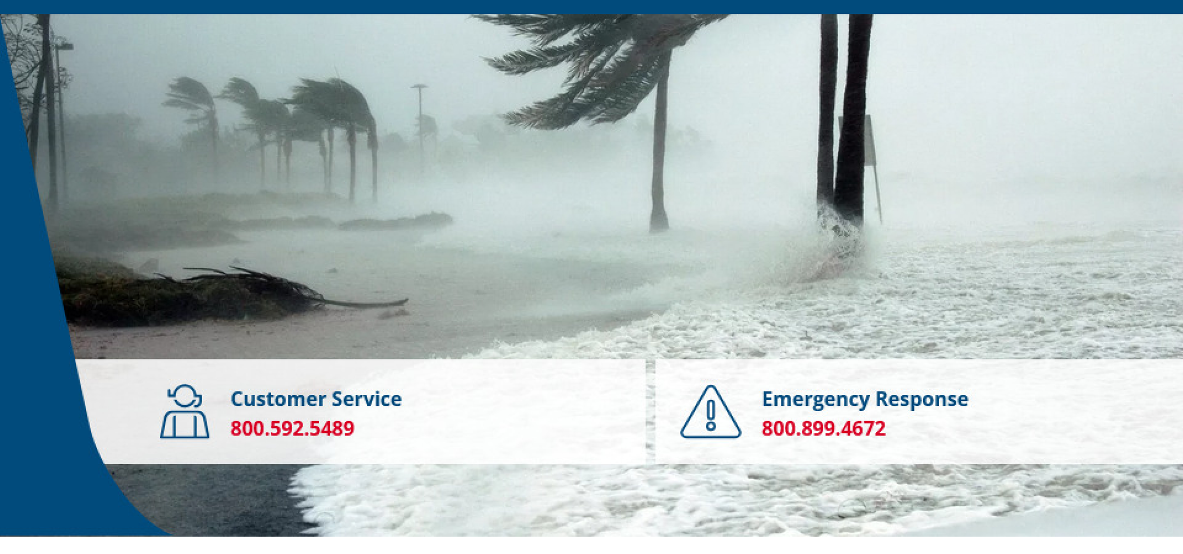
Burning trash can cause long-term health problems. The toxic chemicals released during burning include nitrogen oxides, sulfur dioxide, volatile organic chemicals (VOCs) and polycyclic organic matter (POMs). Burning plastic and treated wood also releases heavy metals and toxic chemicals, such as dioxin.

Other chemicals released while burning plastic include benzo(a)pyrene (BAP) and polyaromatic hydrocarbons (PAHs), which have both been shown to cause cancer. If agricultural bags or containers are contaminated with pesticides or other harmful substances, those will also be released into the air.

Disaster Response

Plan for the unexpected and protect your assets with industry leading services provided by one of the most trusted and experienced disaster response companies.

Contact Us



Customer Service
800.592.5489

Emergency Response
800.899.4672

Locate an Environmental Services Facility

Specialized Solutions

In the aftermath of a natural disaster or catastrophic event, our experienced crews provide disaster waste emergency response and management, cleanout and decontamination, debris removal and hazardous waste disaster cleanup and disposal service.

Dependable Incident Preparedness.

Being prepared for natural disasters and other catastrophic events can minimize the impact to your operations and make all the difference in how quickly you're back up and running. Republic Services is here to help you plan for the unexpected and protect your assets with industry-leading services provided by the most trusted and experienced disaster response companies.

Fastest Mobilization. Exceptional Service.

We understand the importance of getting operations back up and running as fast as possible. Republic Services leads the industry in reliability and efficiency, with the fastest mobilization times and best available resources. Our experienced crews provide exceptional service throughout each step of a response, ensuring all work is done thoroughly, safely and in compliance with all regulations.

Our Capabilities

Incident Response and Management

- Full ICS/NIMS support teams
- Onsite HSEQ and Regulatory Compliance Specialists
- Oil spill response and recovery
- Chemical and hazardous materials response
- Disaster waste emergency response
- High hazard response and standby
- Biological and infectious disease response and decontamination

Disaster Debris Removal and Waste Disposal

- Flood water management and mobile treatment
- Construction and demolition (C&D) waste
- Asbestos containing material and PCBs
- Compressed gas cylinders and other volatile hazards
- Biological material and biohazardous waste
- Hazardous waste disaster cleanup
- Hazardous and non-hazardous waste transportation and disposal
- Hazmat disaster cleanup

Clean out and Decontamination Services

- Retail/facility decontamination services
- Chemical identification and packaging
- Emergency lab packing
- Pressure washing services
- Vacuum services including emergency pump outs and hydro excavation

Hurricane Hazardous Waste Response

Our comprehensive programs offer innovative solutions and 24/7 support when you need it most. In the aftermath of a hurricane, our experienced crews provide dependable disaster waste emergency response and incident management, hazardous waste disaster cleanup and decontamination, debris removal and waste disposal services. We have helped thousands of customers in the wakes of some of the most devastating hurricanes to make landfall including:

- Ian
- Ivan
- Katrina
- Rita
- Sandy
- Harvey
- Wilma
- Irma
- Michael

Wildfire Hazardous Waste Response

Significant quantities of hazardous material and debris create unique challenges for cleanup and recovery from the widespread destruction caused by a wildfire. Our dedicated crews have supported hazardous waste disaster cleanup efforts for dozens of wildfires, including countless major disasters over recent years. During each event, our crews worked closely with regulators to provide management, assessment and removal of Household Hazardous Waste (HHW), asbestos containing material, and other hazardous debris from thousands of sites across the Pacific Northwest and other areas of the country.

Resources

Learn more about our Environmental Services and solutions.

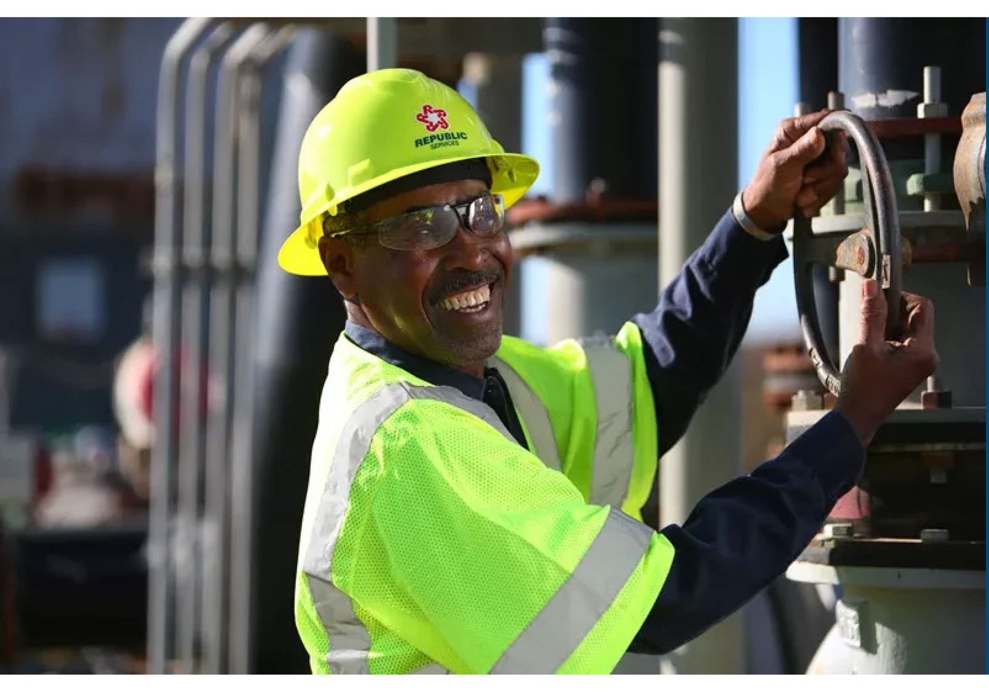
View More →

Disaster Response and Recovery Brochure

The Imperative of Natural Disaster Preparedness for Businesses

Hurricane Ida Recovery

Recovery Efforts in Louisiana after Hurricane Ida Makes Landfall



Why Republic Services?

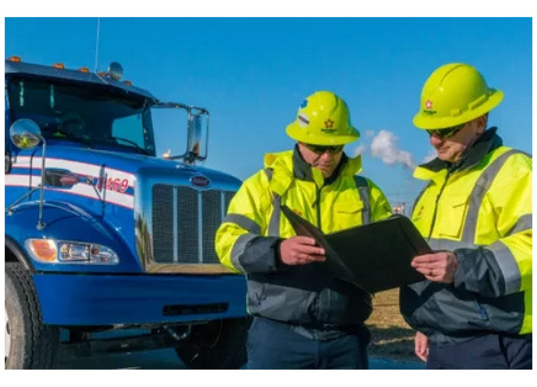
- 24/7 emergency response hotline
- More than 30 years of emergency response experience
- Preparedness, response and recovery all from the same provider
- Convenience and reduced risk
- Nationwide network of owned and operated disposal assets

Other Services

Treatment & Disposal

A leader in hazardous waste treatment and disposal, we provide safe, compliant solutions for all your waste streams with a comprehensive set of disposal options and advanced treatment capabilities.

Learn More →



Field & Industrial

Expert support for field and onsite environmental needs with solutions including remediation, retail, lab pack, industrial cleaning, vacuum services, tank and equipment rental, and industry-leading disposal and transportation capabilities.

Learn More →

E&P Services

Oil- and gas-specific waste treatment, recovery and E& waste disposal landfill operations (including oil drilling waste and fracking wastewater) are permitted and ide located and operate 24/7.

Learn More →

Give Us a Call

Customer Service

800.592.5489

- Current and prospective business customers can talk to a support specialist, 9-5pm ET
- Find out more about our solutions for all your regulated waste needs

Emergency Response

800.899.4672

- Receive ER incident support from our 24/7 command center
- Hazardous waste incident containment and response
- Natural disaster response
- High-hazard (SRS) and Oil spill (NRC) response

Send Us an Email

First Name | Last Name

Email | Phone Number

Company Name | Check if current customer

Zip Code 97330 | Industry

Please provide any additional information on your service needs and if you're a direct generator or 3rd party.

Submit

COR Customer Web Portal

Transform your business with our Environmental Services account management platform. Register for faster approvals, and access an extensive list of documents, forms and reports. COR provides customers superior service from any device for complete account management of all your waste to increase productivity and efficiency while meeting your sustainability goals.

Go

Leading the Way in Environmental Services

At Republic Services, we're dedicated to creating a cleaner, safer, healthier world for all. Working with our customers, we provide solutions that make businesses more efficient while taking care of the planet – and protecting the bottom line.

See our Sustainability in Action

Find an Environmental Solutions Facility

Browse Facilities By State | Browse International Facilities

Need a Residential or Business Facility Instead?

12 results

Filter Services

1. Boise

101 S. Capitol Blvd, Ste#1000
Boise, ID

800.590.5220

Service Center

View Details

2. Grand View Facility

20400 Lemley Rd
Grand View, ID

800.274.1516

Landfill

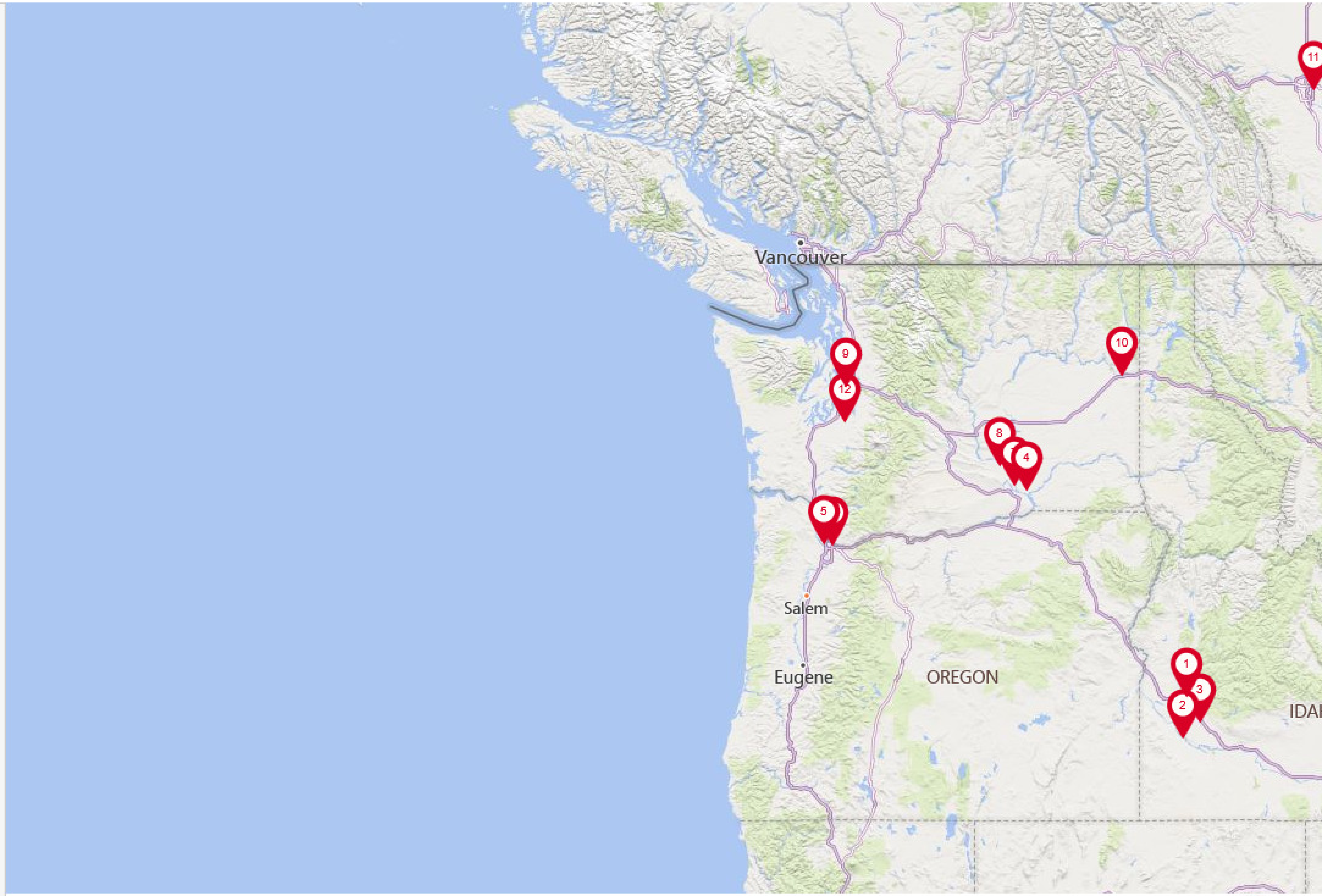
TSDF

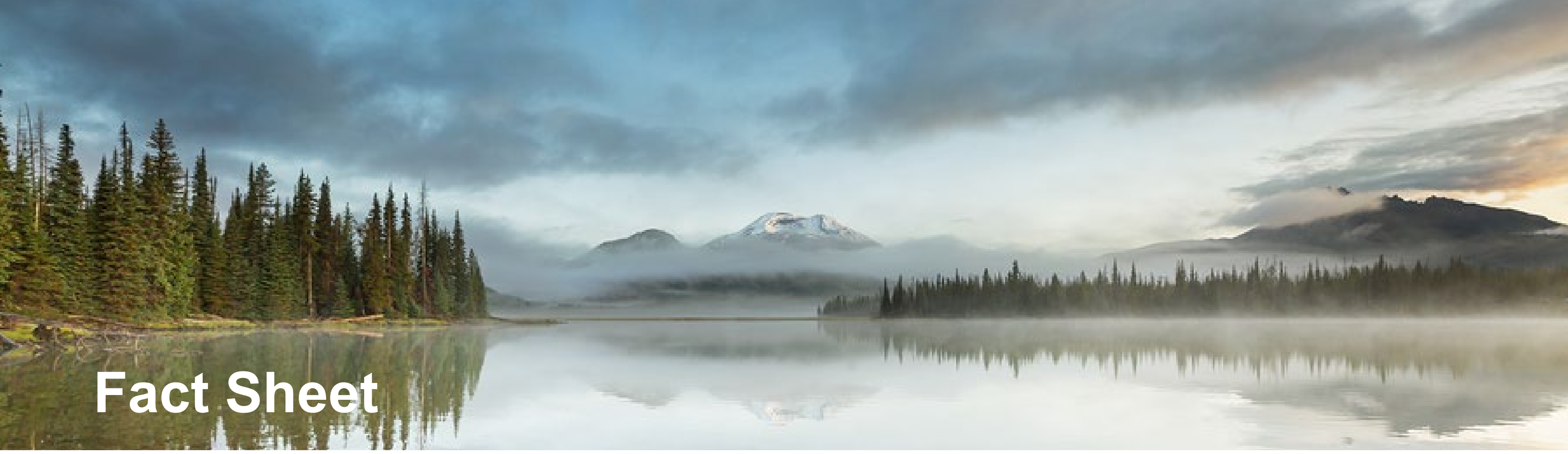
View Details

3. Mayfield

17355 NW US Ecology Ln,
Mayfield, ID

Service Center





Protect Surface Waters While Cleaning Up Your Property After a Wildfire

This fact sheet provides homeowners with guidance for protecting water quality during wildfire cleanup by using stormwater management techniques. Ash and debris generated from wildfires can be harmful to our rivers and streams. When rainwater carries sediment and debris from burned areas it also transports pollutants to our surface waters. Many of these pollutants can be toxic to humans and aquatic life.

Cleaning up the ash

When cleaning up ash, be sure to use the appropriate safety measures. Visit the Oregon Department of Environmental Quality's How to Safely Clean Up Ash and Debris From Burned Buildings page for more information about safely cleaning up ash and debris. Never hose ash into streets or storm drains. Instead, direct wash water to vegetated areas or other areas of your yard where the lawn or plants help filter the ash out of the water as it soaks into the ground. Clean out accumulated debris in storm drains and stormwater conveyance ditches on your property to prevent flooding.

Stabilizing your site

Control the perimeter: Place straw wattles, long tubes of straw often available at local hardware stores, around burned structures or vehicles to contain debris and filter runoff. Wattles can also be placed at the top of streambanks or around storm drains on your property. If you don't have access to wattles, you can use fallen branches, small berms like the photo to the right, or check dams to contain debris.

Preserve existing vegetation: Preserving the existing vegetation on a burned site is typically the best preventative measure for erosion and the least expensive. Vegetation prevents soil from eroding and carrying ash and debris with it. When possible, leave vegetation in place and prevent equipment from driving over it.

Stabilize entry and exit points: Protect areas where vehicles and heavy equipment travel into and off of the property. Use paved access points if they are available, or place gravel on entry and exit points.

Compost berm to stabilize site.

Translation or other formats

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800-452-4011 | TTY: 711 | deqinfo@deq.oregon.gov

State of Oregon
DEQ Department of Environmental Quality

Install soil stabilization measures: For larger areas of exposed soil, apply a layer of weed-free straw. The straw will reduce the impact of raindrops on soil particles and will prevent erosion. For hillsides and slopes, erosion fabric and wattles are effective for preventing transport of sediment.

Graveled site entrance.

Vegetate for long-term stabilization: Reseed areas where it is appropriate, and plant larger shrubs and trees for additional soil stabilization from plant roots.

Manage household hazardous waste: Burned structures can leave behind contaminants. Visit DEQ's How to Safely Clean Up Ash and Debris From Burned Buildings page for more information about how to manage household hazardous waste in ash and fire debris.

For more information

There are partners and resources available assist homeowners after wildfire. The following partners, programs and resources may be especially relevant:

- DEQ's basin coordinators for questions on water quality impacts.
- Oregon Department of Forestry - Help after a wildfire.
- County soil and water conservation districts, Oregon State University Extension Service and local watershed councils can often provide technical assistance and link landowners with funding resources.
- Oregon Department of Emergency Management – Wildfire Response and Recovery website.

Non-discrimination statement

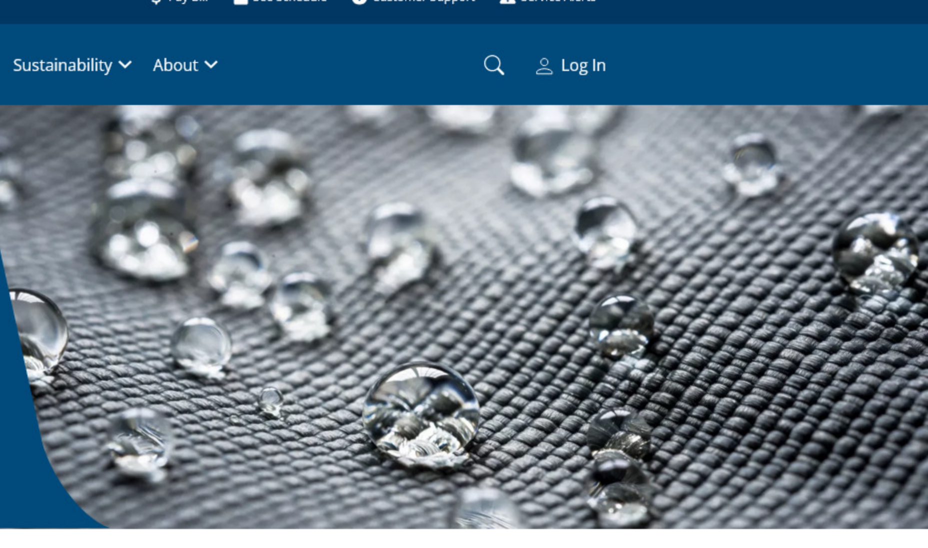
DEQ does not discriminate on the basis of race, color, national origin, disability, age, sex, religion, sexual orientation, gender identity, or marital status in the administration of its programs and activities. Visit DEQ's Civil Rights and Environmental Justice page.

700 NE Multnomah Street, Suite 600, Portland, Oregon 97232
Phone: 503-229-5696, Toll-Free in Oregon: 800-452-4011

PFAS Disposal Solutions

Republic Services offers the technology and expertise to responsibly manage the per- and polyfluoroalkyl substances (PFAS) waste needs of customers while working closely with local, state and federal regulators to ensure compliance with the evolving regulatory framework.

Contact Us



Locate an Environmental Services Facility

Single-Source Solution

We are a single-source solution for the responsible management of waste containing PFAS, with a network of specialized facilities designed to dispose of or treat these types of complex waste streams. We manage remediation projects from start to finish – from collection to transport to the final disposal or treatment location. We ensure that all regulatory requirements are followed during each phase.

Accepted Waste Streams

- Aqueous Film Forming Foam (AFFF) and fire-related debris
- Contaminated or impacted soil, sludge and biosolids
- Liquid and liquid-phase waste
- Wastewater, leachate, filter cake

Technology and Expertise

With more than 70 years of experience providing comprehensive environmental services throughout North America, Republic Services is an industry leader with the technology and expertise to address your PFAS hazardous waste needs and achieve compliance.

- We provide safe, viable and permanent PFAS waste disposal options customized to fit your needs while protecting the environment from future contamination.
- Our experts also work closely with federal and state regulators to assess the evolving regulatory framework surrounding PFAS management to ensure compliance.

Industries We Serve

- Federal and state government
- Environmental engineering and consulting firms and fire protection consultants
- Fire departments and wastewater treatment plants
- Chemical, oil and gas, refining, automotive and aerospace manufacturing industries
- Aviation

Our Capabilities

- RCRA Subtitle C landfills in arid climate with zero leachate discharge at our western U.S. landfills
- Subtitle D disposal
- Underground injection well disposal for liquid and liquid phase waste
- Thermal, carbon filtration, ion exchange or resin filtration systems capable of meeting water quality standards set by local POTWs
- Turnkey PFAS remediation, transportation and additional waste disposal solutions

Long-Term Secure Disposal Options

Republic Services' landfills in Grand View, Idaho, and Beatty, Nevada, offer the securities of RCRA Subtitle C landfill design and construction with the added natural protection of being in arid locations with very little rain and low humidity.

The design, construction and quality assurance requirements of Subtitle C landfills offer the most stringent performance capabilities to prevent waste from impacting the environment. As a result, disposing of PFAS-contaminated waste in Republic Services' Subtitle C arid climate landfills ends the mobility cycle and stops future contamination.

Our Subtitle C Landfills

Grand View - Idaho
Beatty - North Carolina

- Double or triple synthetic liners
- Multiple leachate collection and removal systems
- Leak detection systems
- Run on, runoff, and wind dispersal controls
- Construction quality assurance program

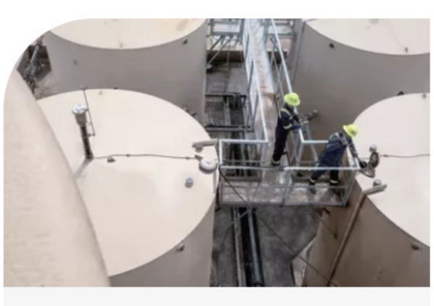
Injection Well Disposal Solutions

Injection wells allow hazardous and non-hazardous waste to be disposed of in deep, confined rock formations. Injection wells offer safe, compliant and cost-effective wastewater disposal solutions.

Our Injection Wells

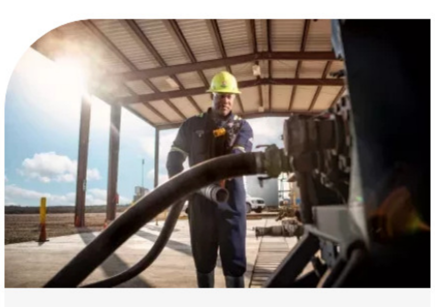
Winnie Facility - Texas
Detroit Industrial Well - Michigan

- Permitted for all Class I and Class II non-hazardous industrial waste
- Multiple steel and cement barriers and constant monitoring prevents leakage
- Safe, cost-effective alternative to traditional wastewater treatment options
- Accept hazardous wastewater as bulk waste, tankers, small containers and totes by road or rail



Benefits of Injection Wells

- A simple and safe solution
- Material fully encapsulated eliminating further environmental impact
- Leak detection systems
- Cost-effective
- Adheres to EPA guidance for PFAS-contaminated liquid waste



Accepted PFAS Liquid Waste

- Landfill leachate
- AFFF
- End-of-life products, like cleaning solvents
- Process water residual from manufacturing facilities

Safety and Compliance

- Waste streams are responsibly stored until injected
- Waste sampled and analyzed to ensure injection compatibility
- More than 4,500 feet deep with approved Class I no-migration petitions
- Liquids with high solids content are handled with a filter press system
- Frequent Mechanical Integrity Testing (MIT)

Thermal Treatment Solutions

Our compliant thermal treatment of PFAS-contaminated soils and sediments creates a clean and recycled product.

The Thermal Treatment Process

1. Ensure materials are non-RCRA or RCRA-exempt
2. Inject contaminated soil into a kiln
3. Heat the soil to 1200-1500°F
4. Draw gas vapors and particulates into a secondary combustion chamber to destroy PFAS compounds with 1800-2000°F temperatures
5. In the cooling tower, spray gases and particulates with water to cool to 350°F
6. Cool exhaust gases in the quench duct before they enter the scrubber
7. Expose gases to caustic solution
8. Exhaust gases through a stack on top of the scrubber

Our Thermal Facilities

Moose Creek Facility - Alaska

- High temperature thermal oxidizer
- Remediates any level of hydrocarbon contamination
- Superior cleanup with wet scrubber
- Assures air quality is 5x cleaner than stringent state regulations

Industrial Services for AFFF

Our Industrial Services professionals have the latest equipment and training to safely and efficiently decommission large-scale AFFF deluge hangar fire suppression systems and manage handheld fire extinguishers.

Our Capabilities

- Evacuate AFFF concentrate from fire suppression system tanks
- Dismantle tanks, hose reels, piping and valve removal
- Remove AFFF bladders
- Transport and dispose of AFFF and rinse waters in drums, totes or bulk tankers
- Transport LTL for small quantities
- Containerize and transport debris and piping in roll-offs
- 24/7 Emergency Response

Comprehensive Remediation Solutions

Republic Services takes a partnership approach to provide premier turnkey remediation services for your waste segregation, profiling, excavation, loading, transportation and disposal of PFAS-contaminated soils, water, sediment and debris.

With $10 billion in funding available through the Infrastructure Investment and Jobs Act for PFAS remediation projects, Republic Services is working with industrial, government and environmental engineering and consulting firms nationwide to provide soil remediation and environmental cleanup services that remove and dispose of PFAS-contaminated soil, low-level radiation and other hazardous or non-hazardous materials safely and compliantly.

Resources

Learn more about our Environmental Services and solutions.

PFAS Solutions Brochure

PFAS Injection Well Disposal Solutions

Safe and Compliant PFAS Industrial Services

PFAS White Paper

View More →

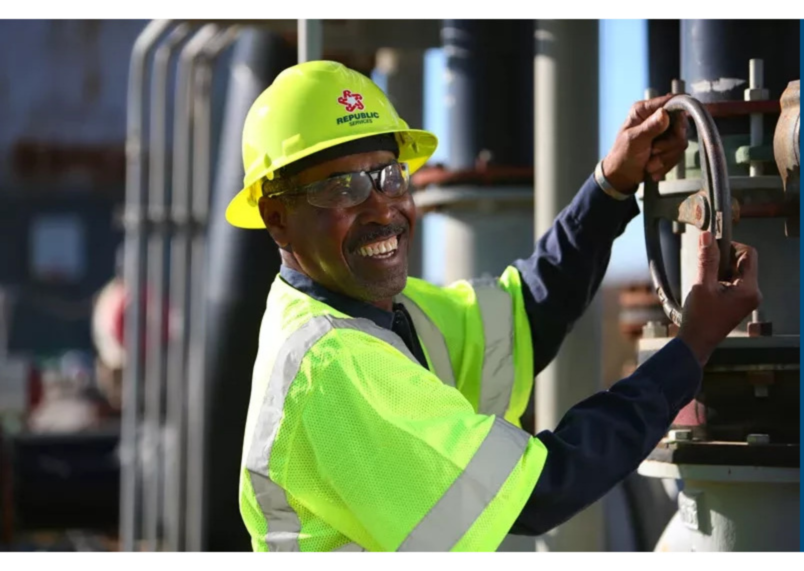
Case Studies

See how we implement our environmental solutions in the field.

Air Force Civil Engineers PFAS Remediation

City of Ionia, MI Dispose PFAS-Contaminated Waste Solids

O'Hare Airport and Republic Services Join Forces to Remediate New Runway Site



Why Republic Services?

- Safe and secure PFAS disposal
- Compliance with evolving regulatory framework
- End the mobility cycle
- Unmatched capacity and capabilities
- Ability to handle any waste volumes/needs
- Experienced professionals

Other Services

Landfill Services

A comprehensive suite of disposal solutions for hazardous and non-hazardous waste streams through a nationwide network of owned and operated RCRA-, Subtitle C-, Subtitle D- and TSCA-permitted landfills.

Learn More →

Wastewater Treatment

Environmentally safe solutions for industrial wastewater including metal, acid, base, organic, cyanide, suspended solids, petroleum-contaminated water, latex, water-based paints, industrial process wastes, tank rinse and used oil.

Learn More →

Remediation Solutions

From project start to completion, our experienced tear offer you turnkey environmental remediation service a waste disposal packages.

Learn More →

COR Customer Web Portal

Transform your business with our Environmental Services account management platform. Register for faster approvals, and access an extensive list of documents, forms and reports. COR provides customers superior service from any device for complete account management of all your waste to increase productivity and efficiency while meeting your sustainability goals.

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- Natural disaster response
- High-hazard (SRS) and Oil spill (NRC) response

Send Us an Email

First Name | Last Name

Email | Phone Number

Company Name | Check if current customer

Zip Code 97330 | Industry

Please provide any additional information on your service needs and if you're a direct generator or 3rd party.

Submit