Science AMA Series: I'm Jon Powell, a Doctoral Student in Chemical & Environmental Engineering at Yale. I study how waste and discarded materials are managed and recently found that Americans dispose o

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Abstract

EDIT: I'm now live - bring on your burning garbage questions, Reddit! Thanks for so many great questions so far, I'll be hanging out Friday afternoon and checking up on new ones that arrive. Hi reddit, I, along with my co-authors, recently published a manuscript in Nature Climate Change that had a few key findings. First, we found that every American is disposing of about 5 pounds of waste per person per day, but that US landfills generally have several decades of life remaining. Second, we examined engineered systems built at landfills to collect gases produced when waste decomposes and identified the factors that most greatly impact the performance of these systems. Taken together, we identified areas where significant reductions in greenhouse gases can be achieved and uncovered opportunities for additional renewable energy production. I have worked on materials and waste management issues across multiple continents and am passionate about expanding the use of data to better understand how we manage materials in the US, with the goal of identifying hotspots where more sustainable decisions can be made. TL;DR America disposes of a lot of waste and we can reduce current/future gas emissions and produce more energy with improved gas collection practices.

the WINNOWER

REDDIT

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JONTPOWELL R/SCIENCE

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I, along with my co-authors, recently published a manuscript in Nature Climate Change that had a few key findings.
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What do you think of sweden's trash system that claims zero emissions? Is it true? If so, can we replicate it elsewhere?

Tonx86

Based on EU statistics (2013), waste generation in Sweden increased slightly from 2001-2010 (now at ~450 kg/person-yr). Compare this to just disposal in the US, which is about 830 kg/person-yr. The reported recycling rate in Sweden is about 50% as of 2010 – about 15% of this is biological-type waste, while 35% is regular municipal recyclables. The landfilling rate is about 25%, so there is less disposal and waste generation happening, but it's certainly not zero. Sweden has fairly high embedded landfill taxes, which some have advocated as way to reduce amount disposed of in the US. Cost for disposal is also quite high, about triple the cost to dispose of in the US. Sweden's landfill tax alone is greater than the cost to dispose in many areas of the US (>30 EUR/tonne).

In addition to managing methane gas emissions at waste management facilities, what are the biggest

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issues or constraints facing these facilities?

TheManofVirginia

Great question! One struggle for some sites is managing the leachate that is produced. Leachate is the liquid that drains to the bottom of landfills and is collected by the liners and collection piping (think of it like the coffee brewing process – water passes through and picks up the soluble, miscible materials within the waste – that's leachate). Often, this leachate is high in organics which can make finding a suitable wastewater treatment plant difficult.

Have you done any solid waste management research in an arctic or sub-arctic environment? I'm interested about the feasibility of collecting landfill gas in these environments, specifically interior Alaska.

Our unconsolidated recycling opportunities, lack of a market for recyclables, isolation, and extreme temperatures pose many challenges to effective solid waste management.

Thanks for doing this AMA!

iluvbewbies

I've researched waste management practices throughout the world, including those in arctic climates. There are unique challenges in these areas because of dispersed populations and obviously weather patterns and the unique nature of the landscape. For example, there are provisions in Alaska's solid waste rules regarding landfills proposed to be built on areas underlain by permafrost. From a chemical/biological perspective, very cold temperatures can have an inhibitory effect on anaerobic waste decomposition that normally occurs in landfills.

In part of the data set analyzed in my recent paper (http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2804.html) there were a few sites in Alaska, all of which were actively collecting gas. So despite what I mentioned above, we can still have environments where methane production occurs. One thing you have to contend with is above-ground liquid management – gas produced in landfills is normally 100% saturated, so the vapor condenses when the gas is removed, and this is obviously a major challenge in very cold environments.

The few points you mentioned about enhanced materials management are good ones. Dispersed populations make it hard for a critical mass to exist for feasible recyclables recovery and sale.

Why aren't we using Plasmafication more in our waste management systems? Are you seeing a rise in this tech?

Sonmi-452

Plasma arc gasification has recently risen in popularity as a potential alternative to disposal or modern waste-to-energy facilities. A major drawback is the energy requirement for these facilities to operate – I have seen figures indicating the process results in a net energy loss, which harms its attractiveness. Another difficulty is that there are not any full-scale operating facilities (to my knowledge), so there is a risk for the first company or municipality to be the first to invest in what would likely be a pretty expensive technology. The good news is that there are many investigators and entrepreneurs who are examining plasma arc and other alternative technologies to help better manage the wastes we produce.

What do you have to say regarding the claim of "we're running out of places to put our trash" ?

UtMed

Fantastic question! We directly addressed this in our paper (http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2804.html, check the Supplementary Information file for details on the calculations), and to my knowledge this is the first time a defensible, quantitative answer to the question of national landfill capacity in the US has been developed.

In the US, the aggregated amount of space remaining was about 75 years in 2013 – meaning, we had enough capacity to accommodate 75 years of waste at 2013's disposal rate. I'll note that disposal capacity is by nature a regional issue (it doesn't really help Alaska if Florida has 50 years of space left). I'm about to submit a new paper that looks at this issue at multiple spatial scales (state-level and county-level).

TL;DR: most areas in the US have plenty of disposal space remaining.

every American is disposing of about 5 pounds of waste per person per day

If Americans need a change of habit to reduce this further to acceptable levels, which one is more eco-friendly, wiping asses with toilet paper or rinsing by using bidet sprays?

FlamingThunderbolt

OK, my favorite question so far, although this is really a municipal wastewater question rather than a solid waste question :).

[Serious Reply] You would need to look at your functional unit – in this case, the function is clean-up following a single BM. One could definitely put together a comparison of using, say, the GHG impact of using 10 squares of TP versus some volume of water with a bidet. For the TP production and Bidet production you'd have to inventory the water used, materials needed, energy required, then normalize those value by your functional unit (one successful clean-up). Sounds like a job for a graduate student!

The realest of all questions: Do you think Mason Lab will ever get renovated? That place is a dump. Also, Dr Zimmerman seemed pretty cool when we met her, great that she got tenure.

Whats a typical daily flow rate from methane capture at a landfill. Do you find significant day-to-day variation?

Wondering if you had any thoughts about GHG emissions from the agricultural sector. I feel like very few people are talking about it, but agriculture accounts for more emmissions than the entire transport industry.

firtree

Whoa, a Mason Lab blast – only on Reddit! I'll say that Mason Lab has a lot of charm, that its greatest quality lies in the people who occupy it. How many departments have a building with a secret tunnel system? And where else can you share the same lab bench space as the inventor of HPLC? Not many I'd wager. Dr. Zimmerman was one of the co-authors on my paper and is one of the many fantastic faculty members we have here in the Chemical & Environmental Engineering at Yale who are truly transforming our field.

As to a typical landfill gas flow rate, I can give you a precise figure based on 880+ operating landfills.

[runs calculation]: 1,370.2 standard cubic feet of total gas per minute. As to your question on variability, flow rates are generally steady (+/- 10%), but you can have some swings (up or down) if there is maintenance to the gas collection system or if you add some new wells.

As for the Ag sector, there's a couple of ways to look at it. First, the US EPA's latest GHG emission sources and sinks report says that agriculture represents about 7.7% of all CO2 emissions (http://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html), with most of these emissions coming from soil management. The second-largest part of agriculture emissions was enteric fermentation (cattle/buffalo toots) and the third largest is manure management. EPA's report indicates the ag sector emits less than transportation, but I'm not sure how those figures look globally.

How comes the US put so much trash in landfills? Here in Italy the per capita waste production is ~3 pound per capita. (And, in many regions the non-recycled fraction has been under 50% for >15 years).

Also, why are landfills so common there? Why isn't incineration used?

lucaxx85

I touched on this in another response, but we have the luxury of lots of space, which contributes to lower costs to manage waste in this manner. In the US, we have quite a few facilities that combust waste and harness energy (more than 80 facilities). I've worked with some engineers in Italy on their waste issues, and I know that landfilling is a challenge there, too. Waste-to-energy plants that combust waste have higher capital costs than building a brand new landfill (1-2 orders of magnitude greater depending on where you are and the size of the facility), which can be a limiting factor.

You're right in that many areas in the EU have had quite high diversion/recycling rates relative to the US, and this is at least partly attributable to a host of policies and taxes that are in place to encourage management alternatives to landfilling.

Here in the UK (and probably elsewhere around the world) it is often rumoured that the waste we put out for recycling actually ends up on a barge and goes to China (or other destinations) and is simply dumped in vast landfills. Is there truth to this? And, if there is any suspicion that recycling is not really occurring, wouldn't it be a good idea to 'tag' random elements of domestic waste to find out exactly where it goes - just as they tag whales etc to track them round the world? I would be happy to buy a 'tag kit' if it meant I could hide a transmitter in the stuff I put out for recycling and watch where it went in the world on a webpage and be able to hold my local authority accountable.

BradyArt

As someone who has spent a lot of time in recycling facilities (and landfills) in the US and elsewhere, I can assure you that there are substantial quantities of recycled materials going to our recycling plants, which are ultimately sent to remanufacturers. It is true that China is a large consumer of recycled materials, so after the different paper grades, plastics, etc get separated at a recycling facility, often times this segregated material is sent to China for remanufacture into new paper, etc.

Considering the economics of your scenario, I would wager that it is unlikely that the illicit dumping as you described is happening at any large scale, particularly because there are plenty of landfills in the US (the UK has about a 45% recycling rate based on 2010 data). The tagging idea you mention was something some researchers at MIT did a few years back related to electronic waste (http://senseable.mit.edu/trashtrack/), and one of my research foci includes deploying sensors and utilizing newly-collected data to benchmark and create new opportunities for better materials management, including municipal wastes but also construction wastes and industrial wastes.

Does waste management produce certain problems or benefits that are specific to the US? If so, how do we adapt to tackle these issues?

swiffervsnarwhals

As with anything in life, there are benefits and drawbacks in how we manage our waste. One benefit we have here in the US is a longer regulatory history with waste (relative to other countries), so we've gone through an evolution of approaches to waste management and are able to transmit those lessons learned to other areas of the world who are perhaps just starting to mobilize and address emergent waste management issues.

I think one challenge we have here in the US (which, depending on your perspective, is a benefit and a drawback) is that we have a lot of space relative to other areas (e.g., Japan, many EU nations), so it's a bit easier to continue managing wastes the way that we have been. Economists and others have long-identified how abundant land enables low-cost disposal in many areas of the US.

Is it possible to store the byproduct gases and use it for energy production?

nocargo

Yes. One of the ways to harness energy from landfill gas is to 1) collect the gas and 2) use a cleanup technology to remove everything but the methane (this is done with molecular sieves, membranes, and scrubbing with water or amine). I believe there are about 5-6 projects that do this cleanup and store the gas either as compressed gas (CNG) or liquefied gas (LNG) in the US at the full scale.

Will it be possible to change all packaging to something that is either zero waste or completely recyclable? Here in the US that is. What can we do to reduce the amount of waste going to the landfills?

DogProudSayItLoud

The disposal amounts in the US are a function of many factors – individual factors (consumption patterns), industrial factors (how are items made and packaged, how durable the goods are), and facility availability factors (what methods/technologies for waste management are available in a given region), to name a few. As an individual, certainly consumption choices can have an impact (e.g., using reusable food/drink containers, consuming less, or buying goods from companies who employ practices that use less waste).

There are some areas that have proceeded with some more aggressive policies to reduce waste by shifting the burden of waste management from the consumer to the producer. For example, extended producer responsibility laws for packaging materials. We haven't seen much of that in the US yet, but it's something people are talking about more and more.

How does recycling fit into your conclusions? Some have recently brought up the argument over whether our recycling practice are beneficial or actually just a wasted effort, so given the knowledge you gained in this study, what are your thoughts on how recycling fits into the picture of national/global waste management and climate impacts?

asumz

I'm familiar with the editorial you linked to, and many of these arguments have been made in the past. There is a degree of truth to some of the observations that were made. Certainly, looking holistically at recycling programs is important, as it can be true that recycling certain components of the waste stream are quite energy intensive and may ultimately result in a separated material stream with no market, which are both problematic situations. I do not necessarily agree with painting a large country in the US with a broad brush and suggesting that only recycling a couple of items makes sense. Many areas of the US are well-positioned (either coincidentally or by design) to have an efficient system where many materials with value can be recovered rather than disposed or incinerated, and viable markets exist who can truly benefit from the recovered product(s).

Where our study ties into the larger scheme is that, when we look at landfills, we see that our disposal amounts are higher than we previously thought and indications are this will continue in the future. We identified specific near-term approaches to take at landfills to achieve substantial GHG emission reduction gains (and perhaps increased renewable energy production through biogas conversion) when compared to, say, implementing a brand new recycling program from the ground up. One thing I always point out is that we have modern landfills today for a reason – because "zero waste" is objectively a difficult goal, and as we continue implementing ways to better manage waste, we need to have a well-managed repository so today's discards to not have an impact on humans or the environment today or in the future.

How effective (and green) are recapture devices in landfills? Does it help with whatever decomposition is going on?

AviateAndNavigate

Nice question! The 'green' question boils down to whether the life-cycle impacts of manufacturing and installing a gas collection well outweigh the benefits it provides while it is in use. Given the GHG impact of methane emissions (which are climate forcers 20-25x that of carbon dioxide) and the duration that methane production occurs in landfills (decades) and the service life of a well-designed and constructed collection well, the net GHG benefits are very strongly in the favor of using a well rather than not using a well, especially when you factor in co-benefits like reducing odor emissions and the potential to harness the collected gas for energy production.

Do you feel that using landfill scales that measure weight can be applied universally to measure space in landfills? As in if every person generates 5 lbs of garbage per day, can that be equated to a volume of garbage? Before and after compaction? This may be helpful in determining curbside container sizes and frequency of pick-ups.

KazSzy

Good question. Normally, landfills are permitted based on a volume (e.g., you have a certain footprint where you are putting waste, which is fixed, then you have a maximum height to which you'd put waste, then there are thumb rules for how steeply you'd slope the sides). Routine surveys are typically used along with the permitted volume number and the waste scale records to calculate the remaining capacity. So it's a pretty straightforward manner to examine landfill space on a site-to-site basis, which is what we did in our paper.

If we consider a standard mix of municipal waste in a landfill, 5 lb per person per day occupies about 0.11 cubic feet after considering compaction with heavy equipment. This may not sound like a lot. But if we extrapolate that to all people, we find that about 13.5 billion cubic feet of landfill space gets occupied every year - enough to fill the AT&T dome in Dallas (i.e., JerryWorld) 130 times.

Regarding container sizes, you bring up a good question - there are a couple of start-ups who are using RFID and other sensors to determine optimal waste pickup frequency and container size on a small scale right now. These are a couple examples of leveraging new technologies, including IoT-type sensors, to better understand exactly what's going on out there rather than relying on old rules of thumb.

Jon, Great informative paper! The paper says that the fires are equally likely in landfills irrespective of the LFGCS installation. What are options that can be used to prevent or minimize these fires? Can anaerobic bioreactor be a solution that simultaneously may accelerate the waste degradation? In your landfill data analysis, have you seen any fire instances in an anaerobic bioreactor landfill?
Also, if there are fires, that mean elevated temperatures. Is there a way to extract that heat and covert in to energy.

ssr13

Thank you for the kind words.

One thing on the operations side that can be done is ensuring a rigorous and timely examination of all monitoring data. Often, very large landfills have dozens or even hundreds of individual collection points, and it is quite an effort just to collect operating data from these points. Many pieces of information that are required to be collected at gas wells (e.g., nitrogen or oxygen content, which can be an indicator of air intrusion (a common contributor to elevated temperatures in landfills), operating vacuum, etc) can help us track performance of the gas collection system and indicate what's going on within the waste mass.

I've spent a lot of my career examining ways to make waste decompose more quickly because of the host of potential benefits this way of operating (often called bioreactor, as you mentioned) can provide. But this is not a trivial direction to go in because of the enhanced operational engagement and data collection required. I've worked with multiple sites who have benefited from operating as a bioreactor to enhance waste decomposition, but this way of operating must be done with the right design and operational plan to be successful. We examined performance of gas collection systems at sites who recirculate leachate a lot (a proxy for bioreactor operation) and found the gas collection efficiencies were generally lower, which is not a desirable outcome.

The term 'landfill fire' is tough because there can be different types of reactions at a landfill with some common characteristics, but they aren't all fires. This is an active area of research - identifying conditions that occur which can lead to fires, how to mitigate situations when elevated temperatures occur, etc. I'm not familiar with anyone who has developed a technique to capture heat produced in landfills to harness that for energy, but there are plenty of sites who do this for collected landfill gas to up the efficiency of their energy conversion systems.

How likely is it that we can have a fully recyclable disposal implemented nationwide within the next few decades? Is it practical?

I feel that waste is a major issue and we seemingly aren't doing anything about it :(

exclusivemuffin

I would argue that there are many fine folks throughout the country who are thinking hard and working hard to identify the best way to manage discarded materials in their area. A key issue I've alluded to in previous remarks is the multi-faceted nature of how we handle waste - individuals have some control, economic forces have some impact, manufacturers and companies have some effect, and governments have some effect. The "right" waste management solution in one area is not necessarily

the right one in another area, so many of these challenges have to be looked at fresh each time in a lot of ways.

I'd say it's unlikely that we have 100% recycling/recovery of wastes anytime soon. The good news is that we are starting to gather a lot of useful data and we have excellent analytical tools at hand to help us apply lessons learned and create better environmental, economic, and social outcomes from one place to another.

Hi Jon, question:

What are your thoughts on the tend toward larger regional landfills compared to smaller local landfills?

ascandalia

There are pros and cons. As our scientific understanding of how landfills operate increases, generally we see an evolution of regulatory requirements for these sites (typically more and more stringent over time). As the cost to comply with these regulations increases, it makes sense that we'd start seeing smaller facilities go away because the economies of scale don't work. Coupled with this is the fact that environmental control systems and energy conversions result in far more complex systems that landfills 40+ years ago, which were essentially trenches people dug, waste was put in, then the waste was covered. As the complexity of these systems increases, the operations of the facility must likewise become more sophisticated, which may favor a smaller number of larger sites.

One thing I've been thinking about is just how dramatic is this transition from smaller to larger sites and what does that all mean. I'm working on an analysis right now that attempts to quantify just how big this shift is in the US.

I hope I'm not too late for this!

Thank you for the AMA. So one of the arm chair theories I have for dealing with landfills is the idea of constructing and prepping them so that in 50-100 years, they can be mined with a traditional mining operation to re extract the raw materials like metals and maybe even petrochemicals. What would the real world viability of something like that be?

cole20200

Excellent question! I and some of my colleagues have worked on full-scale landfill mining projects, which are pretty fascinating. For one, we've found that yes, you have substantial material stabilization 30-40 years after waste is initially placed. To put a number to it, you may initially fill the landfill with about 80% waste and 20% soil (the soil reflects daily cover and final cover that you put on the waste to seal it), but you'll have 60% soil or degraded waste after you dig it up, with the rest being the metals and plastics that don't readily degrade.

I'm doing some very interesting analysis right now quantifying the resource availability across different time scales in the US, which I hope to publish in the next couple of months.

Do you agree that papers are more readily published in the digital age? Of course that also reduces greenhouse gas emissions.

bigwaz77

If I understand your question correctly, you're asking whether or not we're using less paper in the digital

age. Great question. Broadly speaking, I know that in many localities the quantity of paper being sent to recycling facilities has declined in recent years. Now it's an interesting question to consider whether or not the decline in paper usage has led to a decline in GHG emissions, because you have to consider the GHG emissions associated with the mining of materials, manufacture of the products we use to digitally read/develop documents (for example), and the final management of those products to determine whether or not you're increasing or decreasing GHG emissions for some functional unit of, say, information contained in one sheet of paper.

Considering ChemE or pharmacy if medicine doesn't work out ,could you help me weigh up my options and perhaps offer some insight

Fogharballs

I may be biased, but I am always in favor of more talented people getting into engineering if it is a good fit! Consider your time horizon for schooling – it's no secret how many years of additional schooling, residency, and fellowships are required before you get your first position as a physician. Cost obviously factors into that equation, too, as does your passion for medicine.

Engineers can get positions of real impact right out of their undergraduate schooling, which is a plus for many people. The pharmacists I know also enjoy what they do, the compensation is good, and there isn't a huge amount of additional schooling required beyond undergraduate studies.

How does recycling play into this?

sep1986

Recycling is just one way that we can manage a discarded material. If people do not recycle certain materials, then these materials can be ultimately landfilled or combusted. If people do not adhere to their specific recycling program, then those materials will eventually be discarded (e.g., if you put glass in your recycling bin but your locality doesn't include glass in its recycling program). The numbers vary depending on the facility, but anywhere from 5 to 10+% of materials delivered to material recovery facilities ends up going to landfill because of contamination or the material simply isn't something that's recovered at that facility.

There are many who rightfully point out that a more impactful move is to reduce the amount of waste produced in the first place (which ties into things like consumption patterns, manufacturing practices, and the like), but individuals sometimes have little direct control over waste reduction, and sometimes waste reduction can be hard to measure. I argue that recycling is important because it's a very real and immediate thing that individuals can participate in.

What can the everyday citizen do to reduce plastics ending up in our oceans?

MightBBlueovrU

Great question, and certainly an exciting area of research right now. A colleague of mine recently published a great paper that provided an accurate estimate of the amount of plastic waste being discharged into the world's oceans: http://www.sciencemag.org/content/347/6223/768.

As for what everyday citizens can do, I'd say first start with yourself by making sure you're managing plastics in a responsible way (if you have them) or consuming in a manner that limits the amount of plastics you deal with. You can certainly get involved with cleanup efforts, too, which can do some good. Unfortunately, as with other waste issues, the ubiquity of plastics results from several factors,

many of which are difficult for the individual consumer to impact in an immediate, tangible way.

Is it true that the majority of NYC's human waste was deposited straight into the Hudson River for decades?

-CitizenOfTheCosmos-

I haven't looked at NYC's specific wastewater management practices, but here is a link describing some of the history: http://www.nyc.gov/html/dep/html/wastewater/wwsystem-history.shtml

Do you think the US EPA should change their yearly MSW facts and figure methodology to one similar to your study? The disparity between your waste disposal figure and the EPA looks like a problem. Apologies if this was already stated in the paper; I lost journal access.

887YMMV2

I would love to see our method incorporated by as many groups as possible, in addition to being used by researchers and others to explore many of the research questions that arise when considering how and where we are managing waste.

I am a big believer in using measured, bottom-up type data whenever possible, and I greatly appreciate that the US EPA's Greenhouse Gas Reporting Program data set was available since it (in part) enabled the development and application of the methodology in our paper.

Your 5 lbs per day is preposterous! How large was your sample? What demo did you sample? Where did you get the quantity data? Additionally, title title is in itself a trolling effort.

baldgoon

Hi!

My data set and analysis largely comes from measured quantities from more than 900 operating landfills in the US, reflective of >90% of all municipal waste disposal in the country. Nearly all of these landfills used certified scales to weigh incoming loads of waste and outbound, emptied vehicles. The aggregated disposal quantity is tracked (usually via a software program) at every site, and this quantity must be reported to the US EPA annually. Persons preparing and submitting these data to the US EPA must certify that the data are true and accurate, and the US EPA has an algorithm that checks every report for data anomalies.

Thus, based on the data, we have excellent confidence (far greater than any previous estimate) in the waste amount. Now, if we divide the disposal amount in a given year by the population in a given year, we arrive at the per-capita waste disposal rate, which was about 5 lb/person-day. The figure may be unsettling to you since this exceeds previously-reported waste generation rates (waste generation is the sum of all disposal, recycling, and waste-to-energy amounts) in the US alone.