2022 NCF-Envirothon Ohio

Current Environmental Issue Study Resources

Key Topic 1: Landfills and Hazardous Materials

1. Describe different types of landfills and explain how they are regulated.
2. Identify examples of hazardous materials and toxic substances and describe their properdisposal and handling.

Study Resources

Municipal Solid Waste Landfills – *US EPA, 2021* (Pages 2-8)

Basic Information About Landfills – *US EPA, 2020* (Pages 9-10)

Learn the Basics of Hazardous Waste – *US EPA, 2021* (Pages 14-18)

Toxic Waste, Explained – *Claire Wolters, National Geographic, 2019* (Pages 19-24)

How to Regulate Our Waste-Full World – *Jen Allan, International Institute of Sustainable Development. 2021* (Pages 25-33)

<u>Study Resources begin on the next page!</u> ➡

Municipal Solid Waste Landfills

Related Resources

- Advancing Sustainable Materials Management: Facts and Figures <https://epa.gov/smm/advancing-sustainable-materials-management-facts-and-figures>
- Landfill Methane Outreach Program <https://epa.gov/lmop>

On this page:

What is a Municipal Solid Waste Landfill?

Definition

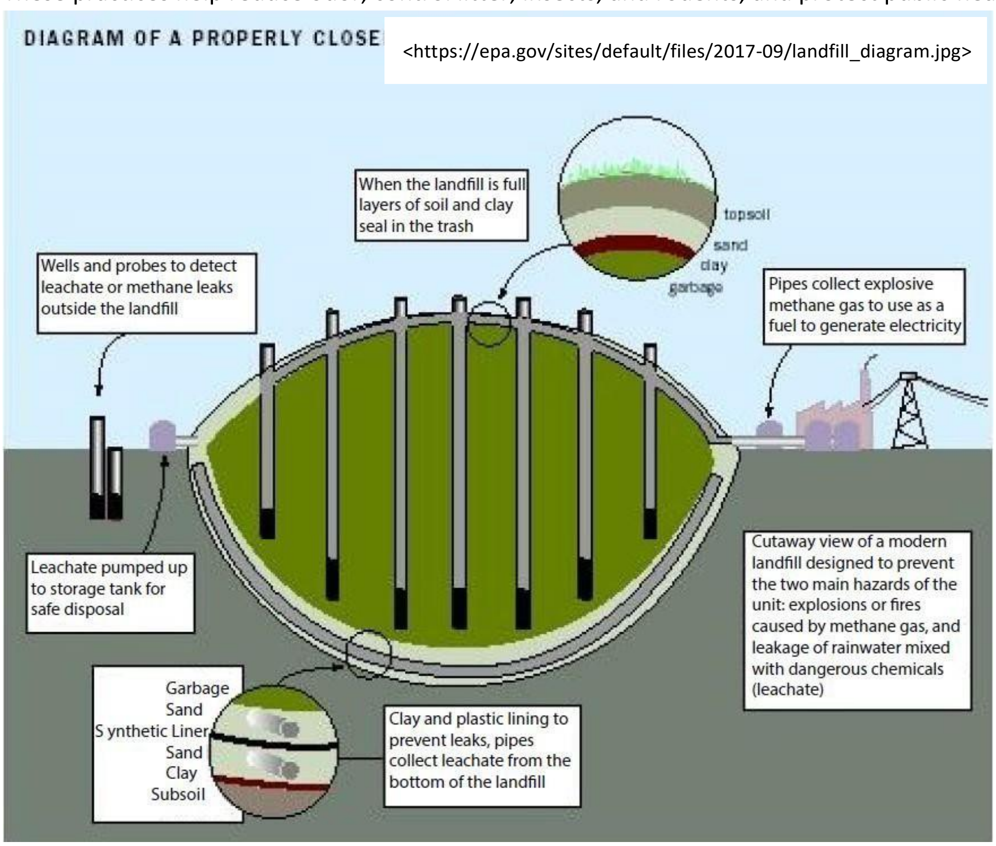
Leachate - formed when rain water filters through wastes placed in a landfill. When this liquid comes in contact with buried wastes, it leaches, or draws out, chemicals or constituents from those wastes.

A municipal solid waste landfill (MSWLF) is a discrete area of land or excavation that receives household waste. A MSWLF may also receive other types of nonhazardous wastes, such as commercial solid waste, nonhazardous sludge, conditionally exempt small quantity generator waste, and industrial nonhazardous solid waste. In 2009, there were approximately 1,908 MSWLFs in the continental United States all managed by the states where they are located.

Non-hazardous solid waste is regulated under Subtitle D of RCRA <https://epa.gov/rcra/resource-conservation-and-recovery-act-rcra-regulations#nonhaz>. States play a lead role in ensuring the federal criteria for operating municipal solid waste and industrial waste landfills regulations are met, and they may set more stringent requirements. In absence of an approved state program, the federal requirements must be met by waste facilities. The revised criteria in Title 40 of the Code of Federal Regulations (CFR) part 258 addresses seven major aspects of MSWLFs, which include the following:

Learn More
Visit the EPA’s RCRA Laws and Regulations site to learn more about the laws that govern MSWLFs. <https://epa.gov/rcra>

- Location restrictions—ensure that landfills are built in suitable geological areas away from faults, wetlands, flood plains or other restricted areas.
- Composite liners requirements—include a flexible membrane (i.e., geo-membrane) overlaying two feet of compacted clay soil lining the bottom and sides of the landfill. They are used to protect groundwater and the underlying soil from leachate releases.
- Leachate collection and removal systems—sit on top of the composite liner and removes leachate from the landfill for treatment and disposal.
- Operating practices—include compacting and covering waste frequently with several inches of soil. These practices help reduce odor, control litter, insects, and rodents, and protect public health.



The image shows a cross-section of a municipal solid waste landfill. Click to enlarge.

<https://epa.gov/sites/default/files/2017-09/landfill_diagram.jpg> <https://epa.gov/sites/default/files/2017-09/landfill_diagram.jpg> <https://epa.gov/sites/default/files/2017-09/landfill_diagram.jpg>

- Groundwater monitoring requirements <https://epa.gov/landfills/requirements-municipal-solid-waste-landfills-mswlfs#groundwater>—requires testing groundwater wells to determine whether waste materials have escaped from the landfill.
- Closure and post-closure care requirements <https://epa.gov/landfills/requirements-municipal-solid-waste-landfills- mswlfs#closure>—include covering landfills and providing long-term care of closed landfills.
- Corrective action provisions—control and clean up landfill releases and achieves groundwater protection standards.
- Financial assurance <https://epa.gov/landfills/requirements-municipal-solid-waste-landfills-mswlfs#financial>—provides funding for environmental protection during and after landfill closure (i.e., closure and post-closure care).

Some materials may be banned from disposal in MSWLFs, including common household items like paints, cleaners/chemicals, motor oil, batteries and pesticides. Leftover portions of these products are called household hazardous waste <https://epa.gov/hw/household-hazardous-waste-hhw>. These products, if mishandled, can be dangerous to your health and the environment. Many MSWLFs have a household hazardous waste drop-off station for these materials.

MSWLFs can also receive household appliances (i.e. white goods) that are no longer needed. Many of these appliances, such as refrigerators or window air conditioners, rely on ozone-depleting refrigerants and their substitutes. MSWLFs follow the federal disposal procedures for household appliances that use refrigerants <https://epa.gov/rad/safe-disposal-procedures-household-appliances-use-refrigerants>. EPA has general information on how refrigerants can damage the ozone layer <https://epa.gov/ozone-layer-protection> and consumer information on the specifics for disposing of these appliances.

Municipal Solid Waste Transfer Stations

Resources

- Waste Transfer Stations: Involved Citizens Make the Difference <https://epa.gov/landfills/waste-transfer-stations-involved-citizens-make-difference>
- Waste Transfer Stations: A Manual for Decision-Making <https://epa.gov/landfills/waste-transfer-stations-manual-decision-making>

Waste transfer stations are facilities where municipal solid waste (MSW) is unloaded from collection vehicles. The MSW is briefly held while it is reloaded onto larger long-distance transport vehicles (e.g. trains, trucks, barges) for shipment to landfills or other treatment or disposal facilities. Communities can save money on the labor and operating costs of transporting the waste to a distant disposal site by combining the loads of several individual waste collection trucks into a single shipment.

They can also reduce the total number of trips traveling to and from the disposal site. Although waste transfer stations help reduce the impacts of trucks traveling to and from the disposal site, they can cause an increase in traffic in the immediate area where they are located. If not properly sited, designed and operated they can cause problems for residents living near them.

Related Information

In 1999, the National Environmental Justice Advisory Council <https://epa.gov/environmentaljustice/national-environmental-justice-advisory-council> undertook a study of the impacts <https://epa.gov/environmentaljustice/epa-regulatory-strategy-siting-and-operating-waste-transfer-stations>that waste transfer stations have on poor and minority communities.

A Regulatory Strategy for Siting and Operating Waste Transfer Stations <https://epa.gov/landfills/regulatory-strategy-siting-and-operating-waste-transfer-stations> provides information about waster transfer stations and the actions EPA has taken to address this issue.

Regulations for Municipal Solid Waste Landfills

Can't find what you're looking for?

Search the EPA archive <https://archive.epa.gov/> using the following keywords:

- municipal solid waste landfill regulations
- solid waste landfill publications

The table below provides links to final and promulgated rules pertaining to the operation and management of MSWLFs. Background information and technical support documents are also available for several rulemakings.

Rulemakings for MSWLFs

Title	Description	Date of final rule

Revisions to Criteria for MSW Landfills: Proposed & Final Rules, July 29, 1997 (PDF) <https://www.govinfo.gov/content/pkg/fr-1997-07-29/pdf/97-19942.pdf>(6 pp, 136 K, About PDF <https://epa.gov/home/pdf-files>)	The Land Disposal Program Flexibility Act of 1996 (LDPFA) directed the EPA Administrator to provide additional flexibility to approved states for any landfill that receives 20 tons or less of municipal solid waste per day. The additional flexibility applied to alternative frequencies of daily cover, frequencies of methane monitoring, infiltration layers for final cover, and means for demonstrating financial assurance. The additional flexibility allows owners and operators of small MSWLFs the opportunity to reduce their costs of MSWLF operations while still protecting human health and the environment. This direct final rule recognizes that these decisions are best made at the State and local level and, therefore, offers this flexibility to approved States.	June 29, 1997
Lead-Based Paint Rule and Supporting Materials <https://www.federalregister.gov/documents/2003/06/18/03-15363/criteria-for-classification-of-solid-waste-disposal-facilities-and-practices-and-criteria-for>	Criteria for Classification of Solid Waste Disposal Facilities and Practices and Criteria for MSWLFs: Disposal of Residential Lead-Based Paint Waste; Final Rule	June 18, 2003
MSW Landfill Location Restrictions for Airport Safety – Technical amendment <https://www.federalregister.gov/documents/2003/10/15/03-25934/municipal-solid-waste-landfill-location-restrictions-for-airport-safety>	EPA amended the location restriction section in the Criteria for MSWLFs under Resource Conservation and Recovery Act (RCRA) to add a note providing information about landfill siting requirements enacted in the Wendell H. Ford Aviation Investment and Reform Act for the 21st Century (Ford Act). The amendment does not change existing criteria under RCRA with respect to siting MSWLF units. Background information for this notice is available through Regulations.gov <http://www.regulations.gov/#!home> using docket number EPA-HQ-RCRA-2002-0034. More information can located using 67 FR 45948 and 67 FR 45915 at FederalRegister.gov <https://www.federalregister.gov/>.	October 8, 2002

Alternative Liner Performance, Leachate Recirculation, and Bioreactor Landfills: Request for Information and Data, April 6, 2000 <https://www.federalregister.gov/documents/2000/04/06/00-8400/alternative-liner-performance-leachate-recirculation-and-bioreactor-landfills-request-for>	EPA considered revisions to the Criteria for MSWLs (40 CFR part 258) regarding the use of alternative liners when landfill leachate is recirculated and allowing the operation of landfills as more advanced bioreactors. EPA requested more information on these types of landfill processes to proceed with any revisions. Background information for this notice is available through Regulations.gov <http://www.regulations.gov/#!home> using docket number F-2000-ALPA-FFFFF. More information can located using 67 FR 45948 and 67 FR 45915 at FederalRegister.gov <https://www.federalregister.gov/documents/2000/04/06/00-8400/alternative-liner-performance-leachate-recirculation-and-bioreactor-landfills-request-for>.	April 6, 2000

Publications and Guidance for Municipal Solid Waste Landfills

The table below includes additional resources and guidance for the operation and management of MSWLFs.

Guidance Documents, Memos, Reports and Fact Sheets

Title	**Description**	**Date**
Disposal of Domestic Birds Infected by Avian Influenza: An Overview of Considerations and Options	Outlines critical factors in the avian influenza disposal process and includes a variety of both on and off site disposal/treatment options, information on cleaning and disinfecting disposal equipment, guidance on transporting infected materials for disposal, and contact information for local and state environmental, agricultural, health, and emergency response organizations.	August 11, 2006

Final Rule: Management of Certain Cattle Origin Material Pursuant to the Substances Prohibited from Use in Animal Food and Feed <https://www.federalregister.gov/documents/2008/04/25/08-1180/substances-prohibited-from-use-in-animal-food-or-feed>	Alternate disposal methods for certain cattle origin materials is necessary, because of the Food and Drug Administration's final rule prohibiting the use of these materials in all animal feed, including pet food.	April 27, 2009
Clarification of April 6, 2004 Memo on Recommended Interim Practices for Disposal of Potentially Contaminated Chronic Wasting Disease Carcasses and Wastes (PDF) <https://rcrapublic.epa.gov/files/14732.pdf>(5 pp, 21.2 K, About PDF <https://epa.gov/home/pdf-files>)	Memo to provide certain clarifications and revisions based on continuing discussions. These practices are particularly appropriate for landfills facing a relatively large number of carcasses from a particular culling or other event.	November 2004
Recommended Interim Practices for Disposal of Potentially Contaminated Chronic Wasting Disease Carcasses and Wastes (PDF) <https://rcrapublic.epa.gov/files/14705.pdf>(4 pp, 39.8 K, About PDF <https://epa.gov/home/pdf-files>)	Memo to provide states and MSWLFs facility managers with options for the disposal of potentially contaminated chronic wasting disease carcasses and wastes in municipal solid waste landfills.	April 2004
Geo-synthetic Clay Liners Used in Municipal Solid Waste Landfills <https://epa.gov/landfills/geo-synthetic-clay-liners-used-municipal-solid-waste-landfills>	Fact sheet to provide information on geo-synthetic clay liners (GCLs) and presents case studies of successful applications.	December 2001
Landfill Reclamation <https://epa.gov/landfills/landfill-reclamation>	Fact sheet to describe how landfill reclamation can be used to expand MSWLF capacity.	July 1997

Contact Us <https://epa.gov/landfills/forms/contact-us-about-landfills> to ask a question, provide feedback, or report a problem.

Basic Information about Landfills

On this page:

- What is a landfill?
- What are the types of landfills?

What is a landfill?

Modern landfills are well-engineered and managed facilities for the disposal of solid waste. Landfills are located, designed, operated and monitored to ensure compliance with federal regulations. They are also designed to protect the environment from contaminants, which may be present in the waste stream. Landfills cannot be built in environmentally-sensitive areas, and they are placed using on-site environmental monitoring systems. These monitoring systems check for any sign of groundwater contamination and for landfill gas, as well as provide additional safeguards. Today's landfills must meet stringent design, operation and closure requirements established under the Resource Conservation and Recovery Act (RCRA).

Disposing waste in landfills is one part of an integrated waste management system. EPA encourages communities to consider the waste management hierarchy - favoring source reduction to reduce both the volume and toxicity of waste and to increase the useful life of manufactured products - when designing waste management systems.

What types of landfills are there?

Landfills are regulated under RCRA Subtitle D (solid waste) and Subtitle C (hazardous waste) or under the Toxic Substances Control Act (TSCA).

Subtitle D focuses on state and local governments as the primary planning, regulating and implementing entities for the management of nonhazardous solid waste, such as household garbage and nonhazardous industrial solid waste. Subtitle D landfills include the following:

- Municipal Solid Waste Landfills (MSWLFs) – Specifically designed to receive household waste, as well as other types of nonhazardous wastes.
  - Bioreactor Landfills – A type of MSWLF that operates to rapidly transform and degrade organic waste.
- Industrial Waste Landfill – Designed to collect commercial and institutional waste (i.e. industrial waste), which is often a significant portion of solid waste, even in small cities and suburbs.
  - Construction and Demolition (C&D) Debris Landfill – A type of industrial waste landfill designed exclusively for construction and demolition materials, which consists of the debris

generated during the construction, renovation and demolition of buildings, roads and bridges. C&D materials often contain bulky, heavy materials, such as concrete, wood, metals, glass and salvaged building components.

  - Coal Combustion Residual (CCR) landfills – An industrial waste landfill used to manage and dispose of coal combustion residuals (CCRs or coal ash). EPA established requirements for the disposal of CCR in landfills and published them in the Federal Register April 17, 2015.

Subtitle C establishes a federal program to manage hazardous wastes from cradle to grave. The objective of the Subtitle C program is to ensure that hazardous waste is handled in a manner that protects human health and the environment. To this end, there are Subtitle C regulations for the generation, transportation and treatment, storage or disposal of hazardous wastes. Subtitle C landfills including the following:

- Hazardous Waste Landfills - Facilities used specifically for the disposal of hazardous waste. These landfills are not used for the disposal of solid waste.

Polychlorinated Biphenyl (PCB) landfills - PCBs are regulated by the Toxic Substances Control Act. While many PCB decontamination processes do not require EPA approval, some do require approval.

LAST UPDATED ON MARCH 2, 2020

Learn the Basics of Hazardous Waste

US EPA, 2021

Hazardous waste that is improperly managed poses a serious threat to human health and the environment. The Resource Conservation and Recovery Act (RCRA), passed in 1976, was established to set up a framework for the proper management of hazardous waste.

Need More Information on Hazardous Waste?

- Check out our RCRA Tools and Resources web page
- View a list of and links to the hazardous waste regulations

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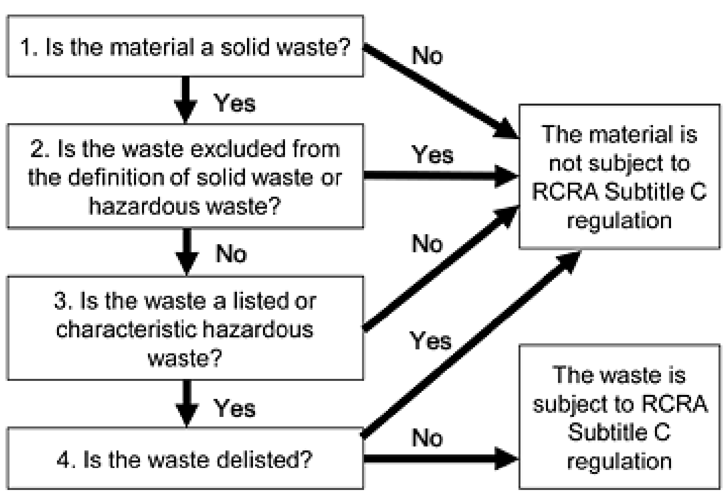
What is a Hazardous Waste?

The hazardous waste management program uses the term **solid waste** to denote something that is a waste. EPA developed hazardous waste regulations that define in more detail what materials are solid waste for the purposes of RCRA Subtitle C (hazardous waste) regulation.
Simply defined, a hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment. Hazardous waste is generated from many sources, ranging from industrial manufacturing process wastes to batteries and may come in many forms, including liquids, solids gases, and sludges.

EPA developed a regulatory definition and process that identifies specific substances known to be hazardous and provides objective criteria for including other materials in the regulated hazardous waste universe. This identification process can be very complex, so EPA encourages generators of wastes to approach the issue using the series of questions described below:

The Hazardous Waste Identification Process



In order for a material to be classified as a hazardous waste, it must first be a solid waste. Therefore, the first step in the hazardous waste identification process is determining if a material is a solid waste.

The second step in this process examines whether or not the waste is specifically excluded from regulation as a solid or hazardous waste.

Once a generator determines that their waste meets the definition of a solid waste, they investigate whether or not the waste is a listed or characteristic hazardous waste. Finally, it is important to note that some facilities petitioned EPA to delist their wastes from RCRA Subtitle C regulation. You can research the facilities that successfully petitioned EPA for a delisting in Appendix IX of Title 40 of the Code of Federal Regulations part 261.

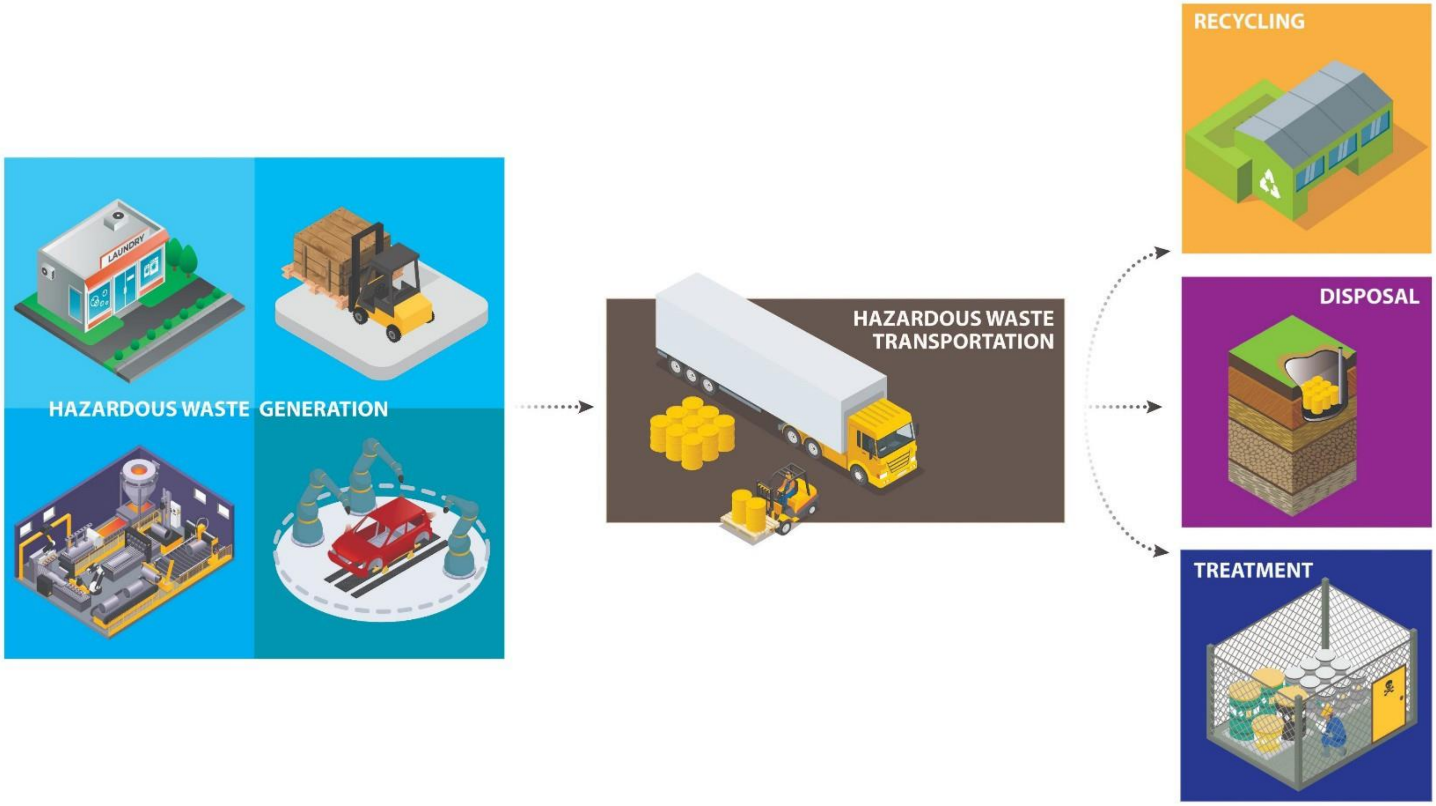
Select a question below to learn more about each step in the hazardous waste identification process.

1. Is the material in question a solid waste?
2. Is the material excluded from the definition of solid waste or hazardous waste?
3. Is the waste a listed or characteristic hazardous waste?
4. Is the waste delisted?

EPA's Cradle-to-Grave Hazardous Waste Management Program

State regulatory requirements for generators may be more stringent than those in the federal program. Be sure to check your state's policies.
In the mid-twentieth century, solid waste management issues rose to new heights of public concern in many areas of the United States because of increasing solid waste generation, shrinking disposal capacity, rising disposal costs, and public opposition to the siting of new disposal facilities. These solid waste management challenges continue today, as many communities are struggling to develop cost-effective, environmentally protective solutions. The growing amount of waste generated has made it increasingly important for solid waste management officials to develop strategies to manage wastes safely and cost effectively.

RCRA set up a framework for the proper management of hazardous waste. From this authority, EPA established a comprehensive regulatory program to ensure that hazardous waste is managed safely from "cradle to grave" meaning from the time it is created, while it is transported, treated, and stored, and until it is disposed:



Hazardous Waste Generation

Under RCRA, hazardous waste generators are the first link in the hazardous waste management system. All generators must determine if their waste is hazardous and must oversee the ultimate fate of the waste. Furthermore, generators must ensure and fully document that the hazardous waste that they produce is properly identified, managed, and treated prior to recycling or disposal. The degree of regulation that applies to each generator depends on the amount of waste that a generator produces.

EPA provides detailed online information about the regulations applicable to generators of hazardous wastes.

Hazardous Waste Transportation

After generators produce a hazardous waste, transporters may move the waste to a facility that can recycle, treat, store or dispose of the waste. Since such transporters are moving regulated wastes on public roads, highways, rails and waterways, United States Department of Transportation hazardous materials regulations, as well as EPA's hazardous waste regulations, apply.

For more information on requirements pertaining to this issue, visit EPA’s Web page on hazardous waste transportation.

Hazardous Waste Recycling, Treatment, Storage and Disposal

To the extent possible, EPA tried to develop hazardous waste regulations that balance the conservation of resources, while ensuring the protection of human health and environment. Many hazardous wastes can be recycled safely and effectively, while other wastes will be treated and disposed of in landfills or incinerators.

Recycling hazardous waste has a variety of benefits including reducing the consumption of raw materials and the volume of waste materials that must be treated and disposed. However, improper storage of those materials might cause spills, leaks, fires, and contamination of soil and drinking water. To encourage hazardous waste recycling while protecting health and the environment, EPA developed regulations to ensure recycling would be performed in a safe manner.

Treatment Storage and Disposal Facilities (TSDFs) provide temporary storage and final treatment or disposal for hazardous wastes. Since they manage large volumes of waste and conduct activities that may present a higher degree of risk, TSDFs are stringently regulated. The TSDF requirements establish generic facility management standards, specific provisions governing hazardous waste management units and additional precautions designed to protect soil, ground water and air resources.

Comprehensive information on the final steps in EPA’s hazardous waste management program is available online, including Web pages and resources related to:

- Hazardous waste recycling,
- Regulations that apply to treatment, storage and disposal facilities, and
- Descriptions of land disposal restrictions.

Regulations for Specific Wastes

Related Information

- Cleaning Up, Protecting, and Preserving Tribal Lands
- International Shipments of Waste
- Managing Materials and Wastes from Homeland Security Incidents
- Polychlorinated Biphenyls (PCBs)
- Special Wastes

EPA has tried, to the extent possible, to develop regulations for hazardous waste management that provide adequate protection of human health and the environment while at the same time:

- fostering environmentally sound recycling and conservation of resources,
- making the rules easier to understand,
- facilitating better compliance, or
- providing flexibility in how certain hazardous waste is managed.

Thus, EPA created alternative management standards, exclusions and exemptions for certain types of wastes including:

- Academic Laboratory Wastes
- Cathode Ray Tubes (CRTs)
- Household Hazardous Waste
- Mixed Radiological Wastes
- Pharmaceutical hazardous wastes
- Solvent-Contaminated Wipes
- Universal Waste
- Used Oil

EPA Hazardous Waste Initiatives

After decades of experience with the current system, EPA is looking forward and examining how the hazardous waste program should evolve to meet the new challenges and opportunities of this century. EPA is leading the nation in moving toward that future now by:

- Facilitating the Expedited Removal of Defective Airbags
- Increasing the Recycling of Aerosol Cans
- Tailoring the Rules for Pharmaceutical Wastes
- Updating the Regulations for Generators
- Revising the Import-Export Regulations
- Leading the Electronic Manifest Initiative

Unified Agenda of Regulatory and Deregulatory Actions

The Unified Agenda of Regulatory and Deregulatory Actions (Agenda) reports on the actions administrative agencies plan to issue in the near and long term. To learn more about future U.S. EPA initiatives, use the pull down list and select Environmental Protection Agency.

This Agenda represents rulemakings at the Federal level only. Since most states are authorized to implement the federal hazardous waste regulations, it is important to check out the website for your state environmental agency or contact them for the status of upcoming state rulemakings.

In a chemical accident in Hungary, toxic waste reached a nearby river. Workers clean it up.
PHOTOGRAPHBYDARKOBANDIC,AP

REFERENCE

Toxic waste, explained

Hazardous waste has many sources, and a long history of dangerous pollution. Here's what you need to know.

BYCLAIREWOLTERS

PUBLISHEDJUNE26,2019•7MINREAD

Hazardous, or toxic, waste is the potentially dangerous byproduct of a wide range of activities, including manufacturing, farming, water treatment systems, construction, automotive garages, laboratories, hospitals, and other industries. The waste may be liquid, solid, or sludge and contain chemicals, heavy metals, radiation, pathogens, or other materials. Even households generate hazardous waste, from items such as batteries, used computer equipment, and leftover paints or pesticides.

Toxic waste can harm people, animals, and plants, whether it ends up in the ground, in streams, or even in the air. Some toxins, such as mercury and lead, persist in the environment for many years and accumulate over time. Humans or wildlife often absorb these toxic substances when they eat fish or other prey.

In the past, many hazardous wastes were only loosely regulated, allowing substantial contamination of communities and the environment. In the U.S., toxic waste has been overseen by the federal Environmental Protection Agency (EPA) since 1976, as well as state departments of environmental protection. The EPA now requires that hazardous waste be handled with special precautions and be disposed of in designated facilities. Many towns have special collection days for household hazardous waste.

TOXIC LAKE BURSTS INTO FLAMES

Toxic waste in practice

A common hazardous waste facility is one that stores the material in sealed containers in the ground. Less toxic waste that is unlikely to migrate, like soil containing lead, is sometimes allowed to remain in place and then sealed with a cap of hard clay.

Communities may eventually decide to use these sites for golf courses or parks, or to label them "brownfields" sites, suitable for commercial or industrial uses.

Violations of the law, like dumping untreated hazardous waste on the ground or in town landfills to avoid paying the fees charged by designated waste facilities, may result in hefty fines or even jail time.

Many toxic waste dumps that still pose a threat to communities are holdovers from the era prior to 1976. Other waste sites are the result of more recent illegal dumping.

Toxic waste regulations

The U.S. federal Resource Conservation and Recovery Act regulates how hazardous waste must be handled and stored. Yet some community activists and environmentalists have long complained about what they view as lax enforcement of hazardous waste regulations, both by the federal and state governments.

In particular, many groups have accused governments and corporations of environmental racism when it comes to toxic waste. They point out that a disproportionate number of toxic waste sitestend to be located in or near low-income and communities of color, in part because such communities often have fewer resources to oppose such activities.

At the same time, many corporations argue that regulations on hazardous wastes are too strict, and they often lobby Congress to soften or remove certain restrictions.

One EPA rule that has proved controversial governs handling of sludge—including sewer sludge—generated by some water treatment and industrial processes. The EPA allows certain waste sludges—often called biosolids—to be used in fertilizers that are used by farmers on food crops or sold directly to the public. The agency allows sludges that contain toxic materials to be used, as long as the concentrations of heavy metals, pathogens, or other harmful substances don't exceed legal thresholds.

1 / 6

New York's Grand Central Station overflows with a sea of commuters and travelers at rush hour. Every day, 1.3 million commuters travel into Manhattan to work for the day and then return to their homes at night.
PHOTOGRAPHBYIRABLOCK

Industry groups, and the government, say use of the material is safe. Yet some environmental and health organizations have criticized the practice, saying it could cause harm by introducing dangerous substances over time. One study found neighbors were sickened after sludge applied to a farm field blew over their homes.

Cleaning up hazardous waste

In order to help clean up historic toxic waste sites, Congress passed the Superfund Act in 1980(officially called the Comprehensive Environmental Response, Compensation and Liability Act or CERCLA).

At first, Congress collected a tax on chemical and petroleum industries to create a trust fund (the Superfund) for cleaning up abandoned and uncontrolled hazardous waste sites.

That tax wasn't renewed after 1990, however. And while responsible parties can be forced to pay for cleanup of hazardous waste, in recent years most Superfund work has been funded out of the general treasury. Hundreds of sites have so far seen remediation actions, while hundreds more are waiting on the list and dozens more have been proposed.

Hazardous waste clean-up is a multi-step process, which starts with site visits and reviews to determine if the area threatens human health or the environment. Once confirmed, the site is listed on the National Priorities List as one of the nation's worst hazardous waste locations. It is then further investigated and characterized based on the type of contaminants identified and the estimated cost of clean-up (which can run into tens of millions and take decades).

TOXIC LAND GENERATES SOLAR ENERGY

From there, a clean-up plan is developed, and work begins. Environmental engineers use a variety of techniques to remediate sites, including removing barrels, tanks, or soil for safe disposal; lining and capping pits; installing drainage systems; and seeding beneficial plants or bacteria to absorb or breakdown toxic materials. Once the work is complete, monitoring and scheduled reviews are conducted to ensure that the area remains safe.

Eventually, the site can be considered for reuse. (See how close you live to a Superfund site.)

The Superfund program was launched in response to a series of high-profile toxic waste cases in the 1970s. These included the discovery of tons of hazardous waste dumped below a school and suburban neighborhood at upstate New York's Love Canal and a dumping ground in northern Kentucky dubbed "the Valley of the Drums."

Earth Negotiations Bulletin

BRIEF #23

How to Regulate Our Waste-Full World

Jen Allan, Ph.D.

July 2021

Key Messages and Recommendations

- There is a long history of dumping hazardous wastes in the seas, on land, and in developing countries; management efforts only started in the 1970s.
- The 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal has expanded to include new wastes and to ban shipments from developed to developing countries.
- Proactive management that scans the horizon for new hazardous waste streams has often been missing and is necessary to protect human health and the environment.
- The legitimacy of global governance of hazardous wastes may rest on its ability to enable governments protect the most vulnerable.

Waste is the most tangible form of pollution. At every stage of production and consumption, we create waste and throw it away, rendering it invisible from of our lives. Hazardous waste takes many forms. It includes the by-products of manufacturing or industrial processes, like toxic ash or sludge. It can be discarded commercial products, like pesticides. We produce hazardous wastes from our homes, by throwing away asbestos-laden insultation, medications, paints, and electronic waste (e-waste).

But the products we dispose of do not disappear. Much of our waste has value in its second, discarded life. Minerals and metals can be recovered and reused. Some types of waste can be recycled. In fact, there are entire industries that dispose, recover, and recycle our waste. Some of our trash can be another's treasure.

 Photo: NASA (CC0 1.0)

But hazardous wastes pose serious risks to the environment and human health if not safely managed. They can pollute the air, water, soil, and wildlife. Mercury, lead, and other toxins found in some hazardous wastes can persist in our environment for years. Health impacts can include cancer, miscarriages, and birth defects, among others. These effects can and do harm communities for generations.

Dumping at sea or in developing countries relocates wastes beyond the ability of one country to regulate. Not all countries can safely manage these wastes or effectively regulate companies' behaviour. Yet, they are often the destination for hazardous waste.

Waste was a key issue as "the environment" emerged on the international agenda in 1972. The Stockholm Conference on the Human Environment recast waste and the waste trade as a truly global issue that required cooperation from all countries. However, diplomats and activists in Stockholm could not have foreseen the changes to come. Our patterns of production and consumption have changed enormously. Technological changes, especially computers and other electronics, created entirely new waste streams, each requiring different disposal techniques and technologies.

While traditional hazardous wastes still matter greatly, there are additional challenges posed by consumer products. They are traded and discarded in a truly globalized world (O'Neill, 2019). Most of the global rules for hazardous waste relate to their globalized nature. They are traded worldwide for recycling, recovery, or disposal. Sometimes, wastes are exported and end up illegally dumped somewhere far from the original source. Post-consumer waste, especially e-waste, has reopened old questions on how to manage the global waste trade.

Making Wastes Visible

A direct legacy of the Stockholm Conference was the Convention on the Prevention of Marine Pollution by Dumping of Wastes at Sea. Negotiations for the London Convention, as it is commonly known, began in 1971, through the Stockholm Intergovernmental Working Group on Marine Pollution. However, sticky issues such as enforcement and jurisdiction proved insurmountable in the meetings held before the 1972 Stockholm Conference, leaving countries to meet again in London. The final meeting was a marathon, continuing for an extra three days past its twelve-day schedule, before the Convention was adopted (Duncan, 1973).

The Convention seeks to protect the seas from hazardous waste dumping. It prohibits dumping mercury and radioactive wastes. Companies need permission to dump other wastes at sea, which would be issued by the countries where the waste was loaded onto a ship, or by the country where the ship is registered.

Two other treaties also seek to protect marine environments from dumping hazardous wastes: the Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft (the Oslo Convention), adopted in February

> "States shall take all possible steps to prevent pollution of the seas by substances that are liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea."
>
> **PRINCIPLE 7, STOCKHOLM DECLARATION**

Houses and a school were built on top of 22,000 tons of chemical sludge, that were legally dumped around Love Canal in New York State. (Photo: Digital Collections and Archives, Tufts University).

1972, and the Convention for the Prevention of Marine Pollution from Land-Based Sources (the Paris Convention), adopted in 1974. They added to the growing international interest in the problem but were limited to seas and oceans near developed countries.

Other international bodies also stepped in to address the problem of hazardous waste dumping. It was an unusual mix of organizations, from the Organisation for Economic Co-operation and Development (OECD) to the World Health Organization and even the North Atlantic Treaty Organization (NATO). Their initiatives revealed the "improvised nature" of waste management in most developed countries at the time (Borowy, 2019). The United Kingdom passed perhaps the first legislation on hazardous waste, the Deposit of Poisonous Waste Act, after cyanide waste was discovered on a site used as a children's playground. Other European countries soon followed. US President Carter declared a national emergency in 1978 after a scandal emerged from miscarriages and severe illnesses around Love Canal, New York, the site where 22,000 tons of chemical sludge were legally dumped in the 1940s and 1950s, according to the rules of the time.

Hazardous waste management was on the global agenda, but a treaty would not emerge until further scandals provoked international moral outrage.

Seeing the Dangers of the Hazardous Waste Trade

In the 1980s, waste generators faced higher costs of legal disposal in developed countries due to tightening regulatory regimes. Global transportation was cheaper than ever. Add in the ability for ships to operate under a flag of convenience (a business practice when a ship's owners register a merchant ship in a country other than their own), and conditions were ripe for less scrupulous waste disposal companies to make the waste disappear ... by any means.

There was growing evidence of what Greenpeace labelled "toxic colonialism" or "waste colonialism" (Liboiron, 2018). New York City planned to export asbestos waste to Guatemala. A British company, Thor Chemicals, transported mercury waste from the United States and Europe to South Africa. It was incinerated near what was then a "homeland" for Blacks during the Apartheid era (O'Neill, forthcoming).

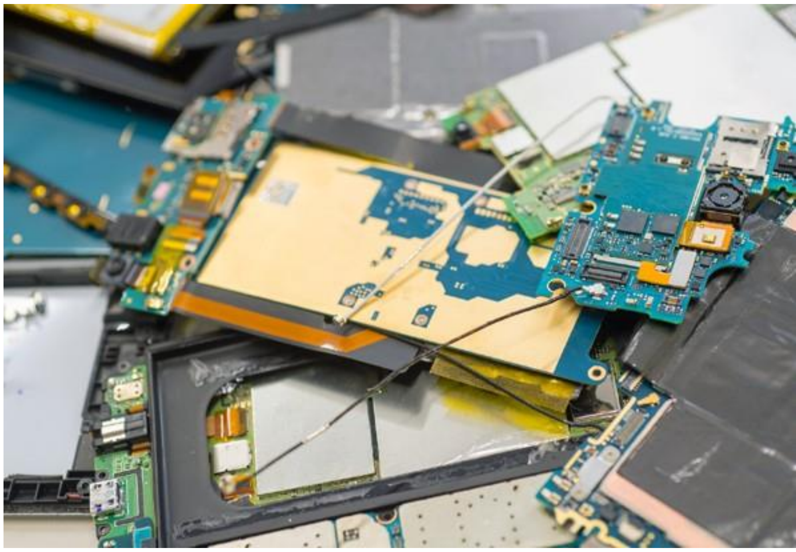
Perhaps the most egregious and most attention-grabbing case happened in the small fishing village of Koko, Nigeria. Nigerian officials uncovered a scheme by two Italian firms to store 18,000 barrels of leaking waste in exchange for USD 100 per month. Nearly one third (28%) contained polychlorinated biphenyl (PCB), a combustible chemical that could produce dioxin, a highly toxic compound. Neighbours suffered nausea, paralysis, and premature births (Buck, 2017).

"Ships of doom" roamed the ocean looking for ports to offload their toxic cargo. Some were at sea for a year or longer. In an infamous example, the Liberian-flagged Khian Sea left Philadelphia, Pennsylvania in September 1986. Several countries in the Caribbean and Africa refused the ship and its cargo—nearly 15,000 tons of toxic ash mislabelled as fertilizer. In 1988, it arrived in Singapore empty. The fate of the waste is unknown, perhaps dumped in the Atlantic or Indian Ocean or offloaded with an illegal broker (Vallette and Spalding, 1990; O'Neill forthcoming).

Given a lack of data, it was difficult to know the extent of these operations. According to the OECD, its members generated 80-90% of hazardous waste in the 1980s. Yet, they shipped only 10% elsewhere, mostly to other OECD members or to Eastern Europe (Krueger, 1998, p.116). These estimates are, however, clouded in uncertainty. Nevertheless, it was clear the hazardous waste trade had "gone global" and it needed to be regulated.

Regulating the Global Waste Trade

The Basel Convention arose out of a specific concern—developed countries were dumping toxic wastes in developing countries without providing information on the hazards or how to manage them. Questions raised during the negotiations are still relevant today: What is waste and what do we do about it?



Electronic waste is the fastest growing waste stream in the world. (Photo: iStock)

What is Waste?

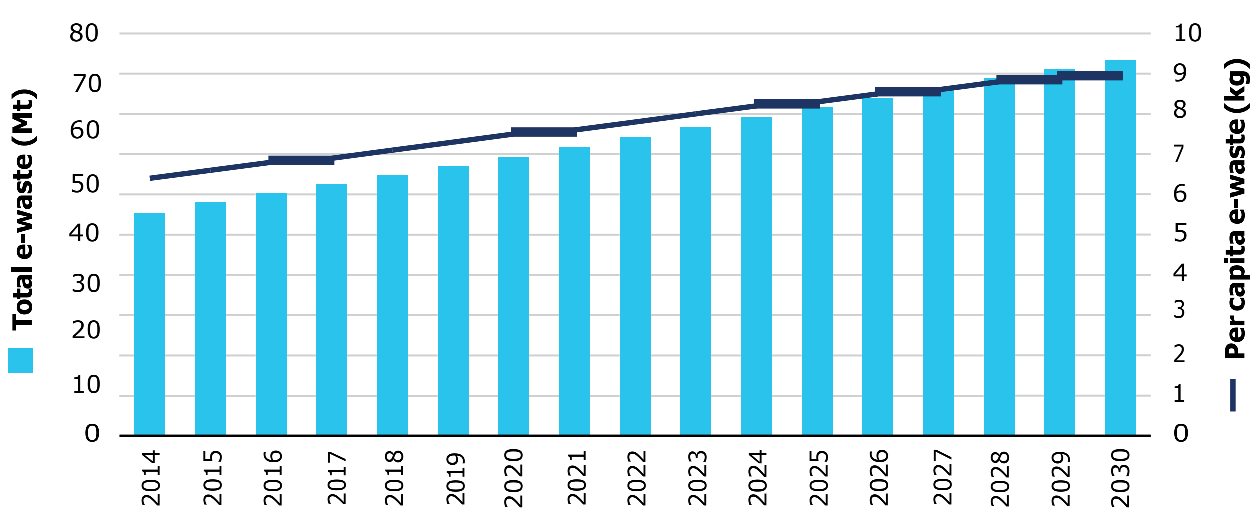
This seems an easy question to answer. Not all waste is hazardous. Second-hand clothing is not toxic, but it is filling landfills at alarming rates. Household wastes are a long-standing concern for developing countries. Some illegal shipments of household wastes enter developing countries labelled as recycling. There was a major diplomatic incident in 2019 after a Canadian "recycling" company exported waste to the Philippines that was falsely labelled as plastic for recycling. Allowed for import after the customs agents were bribed, the shipment actually contained household waste, including diapers, that was left sitting in the port for four years. The company was bankrupt, leaving the Canadian government to repatriate the shipment (Gutierrez, 2019).

During the Basel Convention negotiations, this issue of household wastes divided governments. Several developing countries argued household wastes and incinerator ash should be included in the Convention, while others argued for a strict focus on hazardous wastes, as defined by the OECD. The compromise was to create Annex IX for "other wastes." This allowed for flexibility—the Basel Convention could address household wastes and makes household wastes subject to the prior informed consent (PIC) procedure. But it shopped short of labelling such waste as hazardous. It also created a new annex, which would be useful for later on to address plastics. In 2019, plastic litter became the third entry to this Annex, joining household wastes and incinerator ash—the first global set of rules on plastic litter.

The question of what is waste is complicated by products that are valuable for recycling, such as ships or e-waste. If a ship sails into a port under its own power, is it waste? After years of negotiations, parties said "yes" if the ship was destined for dismantling and disposal. Shipbreaking can be a crucial source of jobs, but it is dangerous work. Ships can contain asbestos and heavy metals, among other dangers. Without proper treatment, these hazardous wastes can lead to health problems, such as cardiovascular diseases and developmental abnormalities, and poison wildlife. Some heavy metals, notably mercury, cycle globally (Selin & Selin, 2020). Poor management in one country can affect someone's health in another.

This debate continues on e-waste. E-waste is anything with a battery or a plug—your computer, smartphone, washer, or oven. E-waste can contain dangerous chemicals, either used in the batteries or components, or as flame retardants to protect the equipment. E-waste is the fastest growing waste stream in the world. On average, the total weight of global e-waste consumption increases annually by 2.5 million metric tons (excluding photovoltaic panels). By 2030, current volumes are expected to double (ITU, 2020). As long as there are few repair options and

Figure 1. E-waste past and future



Source: ITU Global E-Waste Monitor, 2020 shorter life spans for our electronics, the problem will only increase. (See Figure 1.)

There is enormous regional variation in countries' ability to manage e-waste. In Europe, there is 16.2 kg of e-waste per person, compared to just 2.5 kg per person in Africa (ITU, 2020). Mountains of e-waste continue to pile up. Ghana now imports around 150,000 tons of second-hand electrical and electronic equipment a year. In the urban area of Agbogbloshie, many work in the digital dumping ground. It provides jobs, but also poses dangers to those in and around the city of 80,000 (Minter, 2016).

The story of e-waste is sometimes presented as a cautionary tale of how the Global North dumps its problems on the Global South. While this narrative can be true of some hazardous wastes, e-waste is more complex. South-South transfers are increasingly common. Ending overconsumption of electronic products in the North will not stop toxic fumes arising from burning e-waste in Agbogbloshie or in other developing countries (Lepawsky, 2018; Minter, 2016).

Even though the Basel Convention's parties adopted a "provisional" set of guidelines in 2017 to help countries safely manage e-waste and understand the risks, countries still disagree on what is waste and what is a product destined for recycling or reuse.

> "Of the 53.6 million metric tonnes (Mt) of E-waste generated worldwide in 2019 (up by 21% in just five years), according to the UN's Global E-waste Monitor of 2020, only an estimated 17.4% are currently collected and recycled."
>
> **ROLPH PAYET, EXECUTIVE SECRETARY, BASEL, ROTTERDAM, AND STOCKHOLM CONVENTIONS**

What Should be Done?

During the negotiation of the Basel Convention, several developing countries called for a ban of all exports from the Global North to the Global South. Other countries—both developed and some developing—wanted fewer restrictions to allow for wastes to move across borders for recycling, recovery, and re-use.

Governments compromised that the Convention would not ban global movements of hazardous waste. It only stipulated that countries should reduce their exports of hazardous wastes, and that international trade is only justified if a country lacks the domestic capacity to manage or safely dispose of the waste. Countries would use the PIC procedure, which represents the heart of the Basel Convention and is based on four key stages (1) notification; (2) consent and issuance of movement document; (3) transboundary movement; and (4) confirmation of disposal.

The PIC procedure was not the preferred option for several developing countries and non-governmental organizations. There were concerns some waste brokers would misrepresent the wastes to importing countries, labelling the wastes as "safe" to gain consent. This "recycling loophole" might allow hazardous waste to be labelled as recycling and dumped in developing countries (Clapp, 2002). There were even concerns fake recycling companies would export waste under the guise of recycling (Kummer, 1995, p. 49).

Efforts continued to close this loophole, while protecting the legal recycling trade. Shortly after the Convention entered into force in 1992, negotiations began on a more stringent way of managing trade of hazardous wastes. The result was the Ban Amendment that would prohibit developed countries from exporting hazardous wastes to developing countries. Adopted in 1994, it took 25 years until it received sufficient ratifications to enter into force in September 2019.

The Ban Amendment is new and untested, but its effect might be muted. Roughly 87% of the global hazardous waste trade is among developed countries (Yang, 2020). The Amendment was also negotiated in the different world of the 1990s, when global trade of hazardous wastes was dominated by North-North and North-South trade. Today, newly industrialized countries, such as India, China, and the Philippines, are importing increasing amounts of hazardous wastes for recycling and recovery from one another (Yang, 2020). Trade among these countries is not affected by the Ban Amendment because they are considered developing countries under the Convention. The Ban Amendment also anticipates that developing countries lack capacity to manage hazardous waste. This was less true today than it was in the 1990s. Regardless of their capacity, export to developing countries from developed countries (e.g., from New Zealand to Singapore) is now banned.

Nevertheless, the Ban Amendment could help protect the most vulnerable countries that lack the capacity to safely manage hazardous wastes. Rather than asking customs officials to parse out what is in a shipment and if it is safe to import, countries would not be able to send the shipment in the first place. The simplicity of the Ban Amendment could be its greatest strength.

Shipbreaking can be a crucial source of jobs, but ships can contain asbestos and heavy metals. (Photo: iStock)

Managing Hazardous Waste in the 21st Century

Management of hazardous waste has come a long way. In 1972, unsafe disposal of hazardous waste was common in many developed countries. Dumping in the sea was legal. The mantra was "out of sight, out of mind," ignoring that the toxic effects would become visible in the future. As human health and the environment suffered, rules emerged within and among countries. Still, 1.3 billion people around the world live in unsafe and unhealthy environments (Bullard 2002).

What can we learn from 50 years of hazardous waste management? What challenges lie ahead?

Hazardous waste management has been dynamic. Parties adapted, creating categories of non-hazardous wastes that are a concern to countries, such as household wastes and plastics. E-waste emerged as an important and challenging area of work. While some of these wastes may not be subject to the PIC procedure, there are now technical guidelines and greater monitoring and reporting than there would be otherwise.

But dynamism is not enough. These steps were taken only after a problem was apparent, and developing countries and activists cried foul. Proactive management that scans the horizon has often been missing. Future waste needs will change. We may need to think of how to safely recycle or dispose of older wind turbines. The energy transition will demand more lithium and cobalt. Capacity to safely manage these waste streams will need to increase.

However, all the guidelines in the world cannot help if countries lack the ability to put them in practice. As we saw with the August 2020 explosion in Beirut caused by a huge stockpile of ammonium nitrate, countries need to have facilities to safely dispose of wastes. Or wastes should be repatriated or transported to countries where environmentally-sound management is possible.

Equity must lie at the core of these efforts. Whether within countries, or in a global supply chain, people of colour are disproportionately affected. The perception of the Global North dumping its dangerous waste on the Global South is powerful because of the deep inequities it invokes. While the statistics show most waste is traded and managed among developed countries, and that South-South trade is increasing, the equity challenge is real and must be confronted. The legitimacy of global governance of hazardous wastes may rest on its ability to protect the most vulnerable.

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2022 NCF-Envirothon Ohio

Current Environmental Issue Study Resources

Key Topic 2: Reuse, Recycling and Waste Diversion

1. Explain how the practices of reusing or recycling products conserves natural resources.
2. Describe how recycled materials can be repurposed and further diverted from landfills.
3. Explain how waste can be repurposed.

Study Resources

The U.S. Recycling System – *US EPA, 2019* (Pages 35-39)

What it Means to Go Green: Reduce, Reuse, Repurpose, and Recycle – *Rebecca Mills, Utah State University Cooperative Extension, 2012* (Pages 40-42)

Stockholm Biochar Project – *Nordregio, 2018* (Pages 54-55)

Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy – *US EPA, 2017* (Pages 56-57)

Safe Hazardous Waste Recycling – *US EPA, 2000* (Pages 58-61)

Study Resources begin on the next page! →

The U.S. Recycling System

US EPA, 2020

America Recycles Pledge

Organizations, are you interested in working with EPA and others on recycling?

Check out our America Recycles Pledge page for more information and to sign the Pledge.

In the United States, recycling is the process of collecting and processing materials (that would otherwise be thrown away as trash) and remanufacturing them into new products.

U.S. Recycling System Overview

Learn More

- About America Recycles Day
- About Recycling Basics and Benefits
- About the Framework for Advancing the U.S. Recycling System
- About the Recycling Economic Information (REI) Report

While the recycling process often differs by commodity and locality, there are essentially three main steps: collection, processing and remanufacturing into a new product.

1. **Collection:** Recyclable materials are generated by a consumer or business and then collected by a private hauler or government entity.

2. **Processing:** The materials are transported by the collector to a processing facility, such as a materials recovery facility or paper processor. At the processing facility, the recyclables are sorted, cleaned of contaminants and prepared for transport to a milling facility or directly to a manufacturing facility. Some commodities may require additional processing for additional sorting and decontamination. For example, glass and plastic are often sent to glass beneficiation plants and plastics reclaimers, respectively, where they are processed into mill-ready forms.

3. **Remanufacturing:** After all necessary processing has been completed, recyclables are made into new products at a recycling plant or other facility, such as a paper mill or bottle manufacturing facility.

Benefits of Recycling

Recycling Saves Resources and Creates Jobs

Recycling is an important economic driver, as it helps create jobs and tax revenues. The Recycling Economic Information (REI) Report found that, in a single year, recycling and reuse activities in the United States accounted for 757,000 jobs, $36.6 billion in wages and $6.7 billion in tax revenues. This equates to 1.57 jobs, $76,000 in wages and $14,101 in tax revenues for every 1,000 tons of material recycled. Environmental, economic and community benefits can be attained from recycling.

For the environment, recycling:

- Reduces the amount of waste sent to landfills and incinerators;
- Conserves natural resources such as timber, water and minerals; and
- Prevents pollution by reducing the need to collect new raw materials.

For the economy, recycling:

- Increases economic security by tapping a domestic source of materials; and
- Saves energy.

For communities, recycling:

- Supports American manufacturing and conserves valuable resources; and
- Helps create jobs in the recycling and manufacturing industries in the United States.

Current Challenges Facing the System

While the benefits of recycling are clear, growing and strengthening the U.S. recycling system to create more jobs and enhance environmental and community benefits will require multi-stakeholder collaboration to address the challenges currently facing the system. Current challenges include:

- Most Americans want to recycle, as they believe recycling provides an opportunity for them to be responsible caretakers of the Earth. However, it can be difficult for consumers to understand what materials can be recycled, how materials can be recycled, and where to recycle different materials. This confusion often leads to placing recyclables in the trash or throwing trash in the recycling bin or cart.

- America's recycling infrastructure has not kept pace with today's waste stream. Communication between the manufacturers of new materials and products and the recycling industry needs to be enhanced to prepare for and optimally manage the recycling of new materials.

- Domestic markets for recycled materials need to be strengthened in the United States. Historically, some of the recycled materials generated in the United States have been exported internationally. However, changing international policies have limited the export of materials. There is also a need to better integrate recycled materials and end-of-life management into product and packaging designs. Improving communication among the different sectors of the recycling system is needed to strengthen the development of existing materials markets and to develop new innovative markets.

- Stakeholders across the recycling system agree that more consistent measurement methodologies are needed for measuring recycling system performance. These more standardized metrics can then be used to create effective goals and track progress.

Actions Taken to Address the Challenges

Framework for Advancing the U.S. Recycling System

EPA and its stakeholders have been working together to move the America Recycles Pledge from a commitment to a collection action. EPA developed materials to summarize the workgroups' efforts through June 2019.

EPA and its stakeholders have taken the below actions since November 2018 to address the challenges facing the U.S. recycling system.

Stakeholder Dialogues

In 2018, EPA conducted a series of roundtable conversations with key stakeholders involved in the recycling system. The roundtables were a chance to hear different perspectives on the challenges and opportunities within the system. The conversations led to the identification of four key action areas, and stakeholders formed workgroups to further explore and develop actions around the areas. Within those areas, the stakeholders expressed ideas for future actions that federal, state and local governments; industry associations; recyclers; waste haulers; material users; and non-governmental organizations could take to improve the U.S. recycling system. The action areas are:

- Promote Education and Outreach;
- Enhance Materials Management Infrastructure;
- Strengthen Secondary Material Markets; and
- Enhance Measurement.

America Recycles Day Summit

On November 15, 2018, EPA Administrator Andrew Wheeler hosted the America Recycles Day Summit, which brought together stakeholders from across the U.S. recycling system to join EPA in signing the America Recycles Pledge. All 45 signing organizations, including EPA, pledged to work together to identify specific actions to take in addressing the challenges and opportunities facing the U.S. recycling system. Through the pledge, organizations committed to leveraging their collective expertise, strengths and resources to address these challenges and opportunities. Participants included representatives from federal, local, state and tribal governments; the recycling industry; and manufacturers and brands.

- For more information on actions taken after the Summit, view the Framework for Advancing the U.S. Recycling System.
- View pictures and a highlight video of the event.

America Recycles Pledge

We invite U.S.-based organizations to sign the America Recycles Pledge. Visit our page to sign the pledge and join others that have signed it to work toward a more resilient materials economy.

Families and Communities
UtahStateUniversity COOPERATIVE EXTENSION
extension.usu.edu

June 2012 **Sustainability/Recycle/2012-01pr**

What It Means to Go Green: Reduce, Reuse, Repurpose, and Recycle

Rebecca Mills, M. Ag.
Extension Assistant Professor
Family & Consumer Sciences/4-H Youth Development

People and businesses around the world are concerned about the environment and the availability of natural resources for future generations. This concern is evident in the development and marketing of products like energy efficient appliances, vehicles powered by alternative fuel sources, and even biodegradable potato chip bags. What does it all mean and why is it something to learn about or do? This fact sheet defines some basic terms related to resource use and shares ideas of how simple choices can have a positive impact on the well-being of citizens, businesses, and the environment.

Reduce

Simply put, reduce means “less” as in “use less” or “make less of.” In environmental or “natural” terms it could mean something as simple as turning off the faucet while brushing teeth, thus REDUCING water use. Other ways to REDUCE could be:

- Carpool/walk/bike (reduce fossil fuel use, emissions).
- Turn off/unplug electrical appliances when not in use (reduce electricity use = $$ savings).
- Compost green waste like kitchen scraps or lawn trimmings (reduce garbage in landfill, create a usable product for later).
- Switch to energy efficient light bulbs and appliances (save on energy costs).
- Make double-sided copies (reduce paper use).
- Go electronic—emails, document sharing, online bills/bill pay (reduce paper use).
- Catch and store rainwater for outdoor watering (check first with local ordinances).
- Buy in bulk or purchase products with minimal packaging (reduce waste).
- Have household names/addresses removed from junk mail lists and credit card offers (reduce paper use; for more information visit www.dmachoice.org or www.optoutprescreen.com).

The Environmental Protection Agency (EPA) reports that paper products amount to 28.2% of all municipal solid waste generated in the United States which is the second largest category of all solid waste types reported. The largest category at 29.4%, titled “Other Wastes,” includes food scraps, yard trimmings and miscellaneous inorganic wastes. Small efforts like composting or making double-sided copies could make noticeable differences in the reduction of these two categories.

Efforts to reduce waste are possible in the home, at school, and in the workplace. Even if organized recycling efforts are not available, people everywhere can reduce waste by making simple changes every day.

Reuse

Reuse means using a product again for the originally intended purpose. Reusing items also contributes to the "reduce" principle. Reusing reduces the need to purchase a newer version of an item or product. A simple understanding of supply and demand shows that less demand equals less supply/production. By reducing the need for new products there is less impact on the environment from manufacturing processes as well as less garbage in the land fill. It is a win-win!

Here are some creative ways to reuse items:

- Using a refillable beverage container. (Note: be sure to purchase a "BPA free" product.)
- Store emergency water in green two-liter soda bottles. (Note: Not all types of plastic are recommended for long-term storage or reuse because of deterioration. Be sure your bottles have a number 1 or 2 on them, certifying approval by the Federal Drug Administration (FDA) for use with food/beverage products. Rotate home water storage every 12-18 months.)
- Switch out plastic baggies for plastic containers that can be washed and reused.
- Buy an artificial Christmas tree.
- Use plastic grocery bags as trash bags for small trash cans.
- Purchase/make reusable grocery bags.
- Donate clothing, furniture, and other household goods to charity or others in need.

Repurpose

The word "repurpose" takes on a combination of the terms reuse and recycle and brings a creative flare to the mix. Another term referring to this type of use is "upcycle." Repurpose literally means give an item a new purpose whereas reusing something utilizes the product in its original intended form (container = container, etc.). When repurposing, a container could become a decorative wall hanging or a wall hanging could become a container—the possibilities are endless! Repurposing is a popular way for youth and adults to engage creativity in environmental awareness. A simple internet search will result in hundreds, if not thousands, of ideas to repurpose items and give them a fresh, new, creative use.

Here are a few repurposing ideas:

- Faux metal art from toilet paper tubes (search http://suzyssitcom.com for a free tutorial).
- Pen holder from phone book (search "phone book pen organizer" at http://www.chicaandjo.com) .
- Grocery bags from t-shirts, pet food bags, crocheted/knitted "plarn": "yarn" made from plastic bags (search http://tipnut.com for "reusable grocery bags").

Recycle

The Environmental Protection Agency (EPA) defines recycling as follows: "Residential and commercial recycling turns materials and products that would otherwise become waste into valuable resources. Materials like glass, metal, plastics, paper, and yard trimmings are collected, separated, and sent to facilities that can process them into new materials or products."

The processing of recyclable materials happens in a variety of ways depending on what is being recycled and what the recycled material becomes. For example, plastic bottles are cleaned, sorted according to type (numbers 1-7), and shredded. The shredded plastic is heated to a specific temperature hot enough that the plastic can be formed into small pellets. Manufacturing companies purchase the pellets from plastic recyclers to make a myriad of "new" products from carpet and backpacks to decking and playground equipment.

Another unique recycling process happens with paper. At a recycling mill, paper goes into a large container similar to a household blender. The addition of water in the mixing process turns the paper into a pulp. Depending on the "new" end product, non-recycled paper may be added before manufacturing is complete. Products containing recycled paper range from paper backing on roofing shingles to toilet paper and kitty litter.

Here are other examples of products made using recycled materials:

- Glass: new glass bottles/jars, fiberglass, sand for road work/winter traction.
- Plastic bottles: sleeping bags/ski jackets insulation, polar fleece fabric, Frisbees, new plastic bottles and containers.
- Paper/cardboard: new cardboard, sheetrock, new paper, paper towels, egg cartons, phone books, building insulation, paper plates.
- Metal/aluminum cans: new aluminum cans, bike/car parts, appliances.

Conclusion

Understanding words related to “going GREEN” can be helpful when making consumer decisions. Individuals, families, businesses, and organizations can make important impacts by taking simple steps to reduce, reuse, repurpose, and recycle.”

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Stockholm Biochar Project

June 29, 2018 – Nordregio; Photography by Kari Kohvakka

Managing the increasing amount of waste generated in urban spaces is a common challenge to cities worldwide. Since March 2017, Stockholm has been working to address this problem by opening the first large scale biochar plant. This project reduces carbon emissions while engaging people in the fight against climate change. Residents provide garden waste to the city, which produces biochar – a charcoal-like product that sequester carbon in soil for thousands of years.

Solution

With the help of the city residents and local authorities, garden and park waste are collected and stored in different waste management centers located across Stockholm. Once gathered in the plant, this waste is turned into biochar through a carbonization process. The by-product of the biochar production, pyrolysis gas, generates energy for the city's district heating system.

When delivering garden waste to the management centers, the residents can pick up biochar to use in their gardens. The product is also sold to other local authorities to be used to grow plants and trees in parks and public spaces of the city.

Using biochar in green areas of the city, carbon sinks, plants grow easily, and storm water infiltrates efficiently, helping to manage flooding. Furthermore, a greener city contributes with a whole array of auxiliary benefits such as cleaner air, increased biodiversity while combating heat island effects.

Outcome

Four additional biochar plants are planned to be completed in the following years. These five plants are expected producing 7 000 tons of biochar by 2020, sequestering 25 200 tons of CO_2 (the equivalent of taking 3 500 cars off the road) and producing corresponding 25 200 MW/hour of energy (the equivalent of heat for 400 apartments). Within eight years the project will deliver a revenue on the city's investment estimated approximately over 854 000 EUR.

While there are examples of biochar use across Europe, Stockholm implemented the first large-scale plant with the collaboration of local authorities and residents in the generation of the product. The project is one of the winners in the 2014 Mayors Challenge, which is a competition for cities held by Bloomberg Philanthropies.

Potentials

Stockholm City has received many requests from other cities and organisations that are interested in replicating the program. As a result, the Biochar team has published a replication manual and checklist for reference.

Investigations are already underway into how to develop this system using other kinds of waste (e.g. by-products from forestry and agriculture, straw, sewage sludge and horse manure) and to extend the use of biochar to other applications (e.g. building materials).

Sustainable Materials Management: Non-Hazardous Materials and Waste Management Hierarchy

US EPA, 2021

EPA developed the non-hazardous materials and waste management hierarchy in recognition that no single waste management approach is suitable for managing all materials and waste streams in all circumstances. The hierarchy ranks the various management strategies from most to least environmentally preferred. The hierarchy places emphasis on reducing, reusing, and recycling as key to sustainable materials management.

Source Reduction and Reuse

Source reduction, also known as waste prevention, means reducing waste at the source, and is the most environmentally preferred strategy. It can take many different forms, including reusing or donating items, buying in bulk, reducing packaging, redesigning products, and reducing toxicity. Source reduction also is important in manufacturing. Lightweighting of packaging, reuse, and remanufacturing are all becoming more popular business trends. Purchasing products that incorporate these features supports source reduction.

Source reduction can:

- Save natural resources,
- Conserve energy,
- Reduce pollution,
- Reduce the toxicity of our waste, and
- Save money for consumers and businesses alike.

Recycling and Composting

Recycling is a series of activities that includes collecting used, reused, or unused items that would otherwise be considered waste; sorting and processing the recyclable products into raw materials; and remanufacturing the recycled raw materials into new products. Consumers provide the last link in recycling by purchasing products made from recycled content. Recycling also can include composting of food scraps, yard trimmings, and other organic materials.

Benefits of recycling include:

- Preventing the emission of many greenhouse gases and water pollutants;
- Saving energy;
- Supplying valuable raw materials to industry;
- Creating jobs;
- Stimulating the development of greener technologies;
- Conserving resources for our children's future; and
- Reducing the need for new landfills and combustors.

Energy Recovery

Energy recovery from waste is the conversion of non-recyclable waste materials into useable heat, electricity, or fuel through a variety of processes, including combustion, gasification, pyrolization, anaerobic digestion, and landfill gas (LFG) recovery. This process is often called waste-to-energy (WTE). Converting non-recyclable waste materials into electricity and heat generates a renewable energy source and reduces carbon emissions by offsetting the need for energy from fossil sources and reduces methane generation from landfills. After energy is recovered, approximately ten percent of the volume remains as ash, which is generally sent to a landfill.

Treatment and Disposal

Prior to disposal, treatment can help reduce the volume and toxicity of waste. Treatments can be physical (e.g., shredding), chemical (e.g., incineration), and biological (e.g., anaerobic digestor). Landfills are the most common form of waste disposal and are an important component of an integrated waste management system. Modern landfills are well-engineered facilities located, designed, operated, and monitored to ensure compliance with state and federal regulations. Landfills that accept municipal solid waste are primarily regulated by state, tribal, and local governments. EPA, however, established national standards that these landfills must meet in order to stay open. The federal landfill regulations eliminated the open dumps (disposal facilities that do not meet federal and state criteria) of the past. Today’s landfills must meet stringent design, operation, and closure requirements. Methane gas, a byproduct of decomposing waste, can be collected and used as fuel to generate electricity. After a landfill is capped, the land may be used for recreation sites such as parks, golf courses, and ski slopes.

United States Environmental Protection Agency
Solid Waste and Emergency Response (5306W)
EPA530-E-00-001d
October 2000
www.epa.gov/osw

Safe Hazardous Waste Recycling

The mission of the U.S. Environmental Protection Agency (EPA) is to protect human health and safe- guard the environment. One way EPA helps fulfill its mission is by regulat- ing the management and disposal of hazardous wastes under the Resource Conservation and Recovery Act (RCRA). RCRA has the following three general goals: To protect human health and the environment • To reduce waste while con- serving energy and natur- al resources • To reduce or eliminate the genera- tion of hazardous waste

Hazardous waste recycling activities include combustion for energy recovery, use constituting disposal, reclamation, and direct use and reuse. EPA also regulates the recycling of the following hazardous materials: used oil, pre- cious metals, and scrap metal.

Recycling hazardous waste fulfills two of RCRA's goals by reducing the consump- tion of raw materials and energy and by reducing the volume of waste materials that must be treated and disposed of. There are many benefits of recycling; however, it must be conducted in a way that ensures the protection of human health and the environment.

During the development of RCRA, EPA looked at recycling practices throughout the United States and determined that certain practices would pose a threat to human health and the environment if they were not properly conducted.

Hazardous waste recycling frequently requires the accumulation of large quanti- ties of hazardous waste prior to process- ing. Improper storage of those materials might cause spills, leaks, fires, and cont- amination of soil and drinking water.

To encourage hazardous waste recycling while protecting health and the environ- ment, EPA developed regulations to ensure recycling would be performed in a safe manner.

EPA varies the degree to which a recy- clable material or recycling activity is regu- lated under RCRA based on the threat it poses to human health and the environ- ment. Recycling activities that pose a sig- nificant threat are subject to the same strict regulations as hazardous waste treatment, storage, or disposal. Other haz- ardous waste recycling activities that resemble production processes, with checks and balances that ensure safe management, are subject to less strin- gent regulations. In addition, a hazardous material destined for recycling must be identified by type and recycling process in order to determine its level of regulation.

In other cases, EPA has set special stan- dards for commonly recycled hazardous materials to reduce the regulatory burden on handlers and to encourage recycling.

Printed on paper that contains at least 30 percent postconsumer fiber.

Through other resource conservation initiatives, EPA encourages handlers of hazardous waste to adopt prac- tices and choose materials that will reduce the amount of waste generated, thus preventing pollution at its source. In each case, the public derives significant benefits from EPA's safe hazardous waste recycling regulations.

Combustion for Energy Recovery

Combustion for energy recovery involves burning the haz- ardous waste directly as a fuel or using it as an ingredient to produce a fuel. Used solvents, for example, are fre- quently burned to produce heat or generate electricity.

Because of the potential for release of harmful con- stituents from burning these wastes, EPA regulates this recycling activity as strictly as any other type of hazardous waste combustion. EPA requires combustion units that burn hazardous waste for energy recovery to obtain a per- mit and meet certain performance and operating stan- dards under the boiler and industrial furnace regulations.

Use Constituting Disposal

Use constituting disposal involves applying a hazardous waste directly to the land or incorporating it into a product that will be applied to the land. Examples include using hazardous waste as fertilizer or as an ingredient in asphalt. EPA strictly regulates land disposal of hazardous waste, due to the potential for soil and ground-water conta- mination. Recycling a hazardous waste in a manner that constitutes disposal (land application) presents similar risks. The harmful constituents in hazardous wastes must be treated to reduce their toxicity and ability to leach into soil and ground water before the wastes are applied to the land. When a hazardous waste is used as an ingredient in a product, EPA will evaluate its use to ensure that it serves a legitimate purpose in the function of the product. If it does not, EPA considers this practice "sham" recycling; placing such a product on the land would be illegal.

Reclamation

Reclamation is processing a material to recover a use- able product, such as recovering mercury from broken thermometers, or regenerating a material, such as clean- ing used solvents to make them pure again. Reclamation activities are regulated differently depending on the type of hazardous waste to be recycled. Certain reclaimed materials enjoy "relief" from all hazardous waste regula- tions. Other materials, however, are subject to full regula- tion when reclaimed. EPA made this distinction based on the level of threat posed by common industry practices associated with reclaiming different types of materials.

Other Resource Conservation Initiatives

In addition to the special standards mentioned above, EPA implements two other resource conservation initia- tives: universal waste rules and waste minimization.

These intiatives also accomplish the goals of RCRA by striking a balance between protecting human health and the environment and encouraging recycling.

Universal Waste

Universal wastes include batteries, mercury thermostats, and certain pesticides. EPA regulates these wastes by using less stringent standards than other hazardous wastes to encourage recycling. Because the Agency found that large and diverse communities generate universal wastes that might be present in large quantities in the nonhazardous waste stream, EPA developed ways to encourage recycling.

EPA found that the hazardous waste regulations, as they are normally applied, discouraged collection, recycling, and proper management of universal wastes. To facilitate these activities, EPA streamlined the regulations that apply to universal waste handlers and transporters.

Universal waste handlers, for example, can accumulate universal waste for up to 1 year, while hazardous waste generators can only accumulate waste for a fraction of that time. This extended period allows a universal waste handler to accumulate enough batteries, for example, to make recycling an economically viable option. Many recy- cling operations require large quantities of wastes to operate economically. Universal waste transporters can transport without a manifest or EPA identification number, while hazardous waste transporters must have both. EPA fully regulates universal waste destination facilities (i.e., where the waste is ultimately disposed of or recycled) in the same way hazardous waste treatment, storage, or disposal facilities are regulated, because the risks of recycling or disposing of universal wastes are similar to other hazardous waste management activities.

Direct Use and Reuse

The final type of hazardous waste recycling activity is using a waste directly (without reclamation) as an ingre- dient in an industrial process to make a product or using a waste directly as a substitute for a product.

Under this activity, a facility will use a hazardous waste directly in place of a product, if the waste is similar enough to function in a similar manner. Since direct reuse of the material presents a low risk to human health and the environment, EPA does not regulate these activities, unless the waste will be burned or placed on the land. EPA will evaluate the legitimacy of a recycling practice by ensuring that it is not an attempt to avoid proper treatment or disposal and that the material is recycled in a timely manner.

Special Standards

To encourage recycling of certain common hazardous wastes, such as used oil, precious metal-bearing waste, and scrap metal, EPA developed different standards for their recycling and management. EPA regulates those materials differently because industry standards already encourage careful management. In addition, some of these materials have considerable value and there is an economic incentive to manage them safely. These special standards reduce the regulatory burden on recyclers while ensuring safe recycling. The public benefits from reducing materials that are disposed of and the amount of raw materials and energy required to produce new materials.

Used Oil

Used oil is crude or synthetic-based oil that has been used and includes impurities or contaminants such as dirt, metal scrapings, water, or chemicals. The most common example is used motor oil from automobile engines, but the term also includes industrial oils such as metal working fluids, hydraulic fluids, and oil from refrigerator compressors. Used oil is easily recycled; about 380 million gallons are recycled annually.

Recyclers can re-refine used oil and return it to its origi- nal purpose, process it to create different products, or burn it for energy recovery.

To encourage used oil recycling, EPA developed less strin- gent standards for used oil handlers than for hazardous waste handlers. Used oil generators can store any quantity of used oil indefinitely and need only ensure that it is stored in tanks or containers that are in good condition.

Waste Minimization

While EPA encourages safe recycling practices, its ulti- mate goal is to promote the minimization of waste before it is generated. EPA encourages generators of hazardous waste to choose materials and practices that will reduce the volume and toxicity of their waste streams. Waste minimization is not just about reducing total waste quantities, but rather about reducing the amount of chemicals in wastes, particularly those chemi- cals that pose the greatest environmental concern.

To ensure that hazardous waste generators practice waste minimization, they must certify, with every ship- ment of hazardous waste they send for treatment or dis- posal, that they have a program in place to ensure waste reduction. Those facilities that treat, store, and dispose of hazardous wastes also are required to regu- larly certify they have a waste minimization program.

Here are some general examples of how a facility that gener- ates hazardous waste can accomplish waste minimization:

Waste Minimization Case Study

A military equipment manufacturer used 8,250 gallons of a hazardous solvent each year. By substi- tuting a nonhazardous solvent for the hazardous solvent, it saved more than $100,000 in disposal, purchasing, and regulatory compliance costs in less than 10 years.

- Set explicit goals for reducing the volume and toxicity of waste.
- Conduct periodic waste minimization assessments.
- Substitute nonhazardous raw materials for hazardous ones.
- Redesign equipment to produce less waste.
- Install systems that reuse waste materials directly in the process.

Used oil transporters do not need to carry a shipping manifest, which EPA requires hazardous waste trans- porters to carry. Used oil processors and re-refiners do not need permits to operate, while hazardous waste treatment, storage, and disposal facilities do. Used oil burners are regulated only if the quantity of harmful con- stituents in the used oil is above specifications.

To address the risks to human health and the environ- ment associated with used oil recycling, EPA set mini- mum good housekeeping standards to ensure safe recycling. EPA requires that used oil be stored in tanks and containers that prevent releases to soil and ground water. EPA requires used oil transporters, marketers, processors, and re-refiners to keep records of the quan- tity, origin, destination, and date of shipment or accep- tance of any shipment of used oil, to ensure that the oil is actually recycled. And, finally, EPA set standards for the cleanup of releases during storage and transit.

Precious Metals

Hazardous wastes can contain significant amounts of precious metals such as gold, silver, platinum, palla- dium, iridium, osmium, rhodium, and ruthenium. The precious metal components of such wastes can be reclaimed. One example is photographic fixer, which contains silver. Since precious metals are valuable commodities, businesses usually handle them very carefully. EPA standards for handling precious metal waste that will be recycled are significantly less strin- gent than for other hazardous wastes.

Scrap Metal

Scrap metal is bits and pieces of metal parts or metal pieces that can be recycled, such as auto bod- ies, used wire, and metal pieces from manufacturing and assembly operations. Scrap metal does not include materials generated from smelting and metal refining operations or materials that contain a signifi- cant liquid component. Reclaimed scrap metal is exempt from all hazardous waste regulations. EPA determined this activity does not pose a threat simi- lar to other types of waste management.

Would You Like More Information?

RCRA, Superfund, and EPCRA Hotline

Call 800 424-9346 or 703 412-9810 in the Washington, DC area. For the hearing impaired, the number is TDD 800 553-7672. You also can access information via the hotline's Internet site at
<www.epa.gov/epaoswer/hotline>.

Additional Documents

These additional documents can help you learn more about the requirements for hazardous waste recycling. These documents are free and can be ordered from the RCRA Hotline. Reference the EPA document number *(EPA530…)* when ordering.

Environmental Fact Sheet: Final Streamlined Regulations for Collecting and Managing Universal Wastes, (EPA530-F-95-011).

Managing Used Oil: Advice for Small Businesses, (EPA530-F-96-004).

Waste Minimization National Plan: Reducing Toxics in Our Nation's Waste, *(EPA530-F-97-028).*

RCRA Orientation Manual: 1998 Edition, *(EPA530-R-98-004).*

Contact Your State

Although EPA regulations set the national standard for compliance, states often have more stringent regulations. Contact your state about specific regulations.
State environmental contacts are available from the hotline.

2022 NCF-Envirothon Ohio

Current Environmental Issue Study Resources

Key Topic 3: Composting and Food Waste

1. Describe composting processes and identify how composting supports waste diversion efforts.
2. Explain how composting improves soil health and provide evidence for how composting supports water conservation efforts.
3. Describe the problem of food waste and explain how it impacts the sustainability of the global food supply.

Study Resources

Composting 101 – *Natural Resources Defense Council, 2020* (Pages 63-82)

Farmers lead composting revolution to heal African soils - *Fernando Naves Sousa, The Ecologist, 2014* (Pages 83-86)

Composting – *USDA NRCS, 1998* (Pages 87-90)

Food Waste in America: Facts and Statistics – *Rubicon, 2020* (Pages 91-97)

Wasting Food Just Feeds Climate Change – *United Nations, 2021* (Pages 98-99)

Study Resources begin on the next page! ➡

Composting 101

Recycling food and other organic waste into compost provides a range of environmental benefits, including improving soil health, reducing greenhouse gas emissions, recycling nutrients, and mitigating the impact of droughts.

July 20, 2020
Shelia Hu

What Is Composting?

Composting is the natural process of recycling organic matter, such as leaves and food scraps, into a valuable fertilizer that can enrich soil and plants. Anything that grows decomposes eventually; composting simply speeds up the process by providing an ideal environment for bacteria, fungi, and other decomposing organisms (such as worms, sowbugs, and nematodes) to do their work. The resulting decomposed matter, which often ends up looking like fertile garden soil, is called compost. Fondly referred to by farmers as “black gold,” compost is rich in nutrients and can be used for gardening, horticulture, and agriculture.

Organic discards can be processed in industrial-scale composting facilities, in smaller-scale community composting systems, and in anaerobic digesters, among other options. This guide focuses primarily on home composting, which is a great way to keep your organic discards out of the waste stream and produce a valuable soil amendment for your own use.

Benefits of Composting

Reduces the Waste Stream

Composting is a great way to recycle the organic waste we generate at home. Food scraps and garden waste combined make up more than 28 percent of what we throw away. Not only is food waste a significant burden on the environment, but processing it is costly. The average cost to landfill municipal solid waste in the United States was around $55 per ton in 2019. With the United States generating more than 267 million tons of municipal waste in 2017 and sending two-thirds of that to landfills and incinerators, we spent billions of dollars on waste management. Composting at home allows us to divert some of that waste from landfills and turn it into something practical for our yards.

Cuts Methane Emissions From Landfills

Typically when organic matter decomposes, it undergoes aerobic decomposition, meaning that it's broken down by microorganisms that require oxygen. When compostable waste goes to a landfill, it gets buried under massive amounts of other trash, cutting off a regular supply of oxygen for the decomposers. The waste then ends up undergoing anaerobic decomposition, being broken down by organisms that can live without free-flowing oxygen. During anaerobic decomposition, biogas is created as a by-product. This biogas is roughly 50 percent methane and 50 percent carbon dioxide, both of which are potent greenhouse gases, with methane being 28 to 36 times more effective than CO_2 at trapping heat in the atmosphere over a century. Although most modern landfills have methane capture systems, these do not capture all of the gas; landfills are the third-largest source of human-generated methane emissions in the United States.

Because our solid waste infrastructure was designed around landfilling, only about 6 percent of food waste gets composted. However, states, cities, and individual businesses and vendors can spearhead zero-waste strategies to increase composting and recycling rates within their jurisdictions and to keep waste from being generated in the first place. There have been many composting success stories around the country, one notable example being San Francisco. In 1996 San Francisco established a large-scale composting program, and by 2000 it was able to divert 50 percent of its wastefrom landfills. By increasing its goals over the years, San Francisco has been diverting more than 80 percent of waste from landfills since 2012. That means more than 90,000 metric tons of carbon emissions are avoided each year—equivalent to the annual greenhouse gas emissions from 20,000 passenger vehicles.

Improves Soil Health and Lessens Erosion

Compost is an essential tool for improving large-scale agricultural systems. Compost contains three primary nutrients needed by garden crops: nitrogen, phosphorus, and potassium. It also includes traces of other essential elements like calcium, magnesium, iron, and zinc. Instead of relying on synthetic fertilizers that contain harmful chemicals, composting offers an organic alternative. Research has shown the capability of compost to increase soil's water retention capacity, productivity, and resiliency.

Conserves Water

Agriculture is a major consumer of water in the United States, accounting for approximately 80 percent of the nation's water use. Irrigation systems are effective but are expensive and time-consuming for farmers to manage. Additionally, water is becoming increasingly difficult to obtain across the country.

How can compost help? Research has shown the water-retaining capacities of soil increase with the addition of organic matter. In fact, each 1 percent increase in soil organic matter helps soil hold 20,000 gallons more water per acre. By using compost to foster healthy soil, farmers do not have to use as much water and can still have higher yields compared with farming with degraded soil.

Reduces Personal Food Waste

Consumers are responsible for a staggering amount of wasted food. An average American family of four throws out about $150 worth of food per month, a 50 percent increase since the 1970s. NRDC research in three U.S. cities indicated that the category of edible food most wasted by households was fruits and vegetables. According to a 2016 report in *The Guardian*, U.S. retailers and consumers throw away about 60 million tons (or $160 billion) worth of produce annually. The best way to reduce impacts from food waste is to prevent waste from occurring in the first place, so NRDC works through its Save the Food campaign and other tools to educate consumers on how to shop for, prepare, and store food to minimize waste. However, even if we do everything possible to decrease food waste, there will still be food scraps that cannot be consumed (e.g., a banana peel). Composting is a great way to recycle those discards instead of tossing them in the trash.

Piotr Malczyk/iStock

Types of Home Composting

Composting can be done both indoors and outdoors and can be as complicated or as simple as you would like. The best way for you to compost at home depends on several factors:

Where you live/availability of space

How much organic waste you produce

What kind of organic waste you produce (kitchen and/or yard waste)

Amount of time you can spend on the composting process

There are two main types of backyard composting: cold (also known as passive composting) and hot (also called active composting). Cold composting breaks down organic matter slowly, but it also takes the least amount of effort and maintenance. Anything organic decomposes eventually; cold composting is just letting Mother Nature do her job with minimal intervention on your part. You do not need to worry about the ratio of compost ingredients, aerate regularly, or monitor moisture levels. Cold composting is the best process if you have little organic waste to compost and not much time to tend to the process, and if you are not in a hurry for finished compost. However, depending on what kind of cold method you use, it can take one to two yearsbefore you get usable compost. Additionally, a cold composting process will most likely not reach a high enough temperature during decomposition to kill off pathogens, so depending on what you've put in the pile, there may be some lingering harmful pathogenic bacteria, fungi, protozoa, worms, and other parasites as well as weed seeds in your finished product. A cold composting process is primarily anaerobic, meaning that your discards are broken down by microorganisms that thrive in an oxygen-deprived environment. In addition to being slower to break down, cold piles may be smellier or wetter than hot piles.

Hot composting is a faster, but more managed, compost process. This method requires attention to keep carbon and nitrogen in the optimum ratio to decompose organic waste. It also requires the right balance of air and water to attract the organisms that thrive in an oxygen-rich environment. Under ideal conditions, you could have the final compost product in four weeks to 12 months. If managed correctly, the high temperature of the pile will destroy most weeds, plant diseases, pesticides, and herbicides, plus any bug larvae or eggs.

How to Compost

Compost Ingredients

Organisms that decompose organic waste need four key elements to thrive: nitrogen, carbon, air, and water. Since all compostable materials contain carbon, with varying amounts of nitrogen, composting successfully is just a matter of using the right combination of materials to achieve the best ratio of carbon to nitrogen and maintaining the right amounts of air and water to yield the best results. The ideal carbon-to-nitrogen ratio for a compost pile is 25 to 30 parts carbon for every 1 part nitrogen. If your pile has too much carbon-rich material, it will be drier and take longer to break down. Too much nitrogen-rich material can end up creating a slimy, wet, and smelly compost pile. Fortunately, these problems are easily remedied by adding carbon-rich or nitrogen-rich material as needed.

"Greens" for Nitrogen

Nitrogen is one of the basic building blocks of life, and it is an essential element for growth and reproduction in both plants and animals. A higher nitrogen-to-carbon ratio is most commonly found in fresh organic material (often referred to as greens). Having plenty of greens in your compost pile makes sure the decomposers can grow and reproduce quickly. Some household greens you can add to your home compost pile are fresh grass clippings, food scraps, and coffee grounds.

"Browns" for Carbon

Another essential compound for all life forms is carbon, higher proportions of which can be found in brown plant material. Carbon acts as a food source for decomposers, helping to keep them alive while they break down waste. Typical browns you can add to a compost pile include dead leaves, branches, twigs, and paper.

To achieve the best carbon-to-nitrogen ratio in your home compost, a rule of thumb is to put in two to four parts brown materials for every one part green materials.

Oxygen and Water

Finally, like any other living organism, decomposers need oxygen and water to survive. To ensure a faster home composting process, you will need to make sure your compost system has the right amount of air and water. As mentioned above, if you are not in a rush for finished compost, you do not have to maintain your waste; the decomposition will still take place, just at a much slower pace. Optimal air flow can be achieved by layering materials, making sure your materials are in small pieces (ideally no thicker than a finger), and turning piles regularly (or adding another type of aeration system). As for water, the ideally moist household compost pile will be about as wet as a wrung-out sponge. If you are including food waste in your pile, it’s likely it will be wet enough, but if not, just add water.

Temperature

Hot composting is achieved when the balance of greens, browns, air, and water creates ideal conditions for aerobic organisms to thrive. The optimal peak temperature for aerobic composting is 130 to 140 degrees Fahrenheit, which occurs when aerobic macro- and microorganisms are breaking down waste and reproducing at a fast rate. This high temperature also kills any lingering bacteria or weed seeds.

Consistent Aeration

Aeration encourages an aerobic environment, which helps to speed up the composting process and reduce odors. It is recommended you turn your pile (or rotate your tumbler) around once a week during summer and at minimum once every three to four weeks during winter. You can also add piping or large sticks to help increase natural airflow.

Maintaining Moisture

Moisture is essential for composting—your pile should always feel like a wrung-out sponge. Too dry a pile may cause the composting process to slow down. Too wet a pile may create an anaerobic environment, which can cause bad odors and also slow down decomposition. Water your pile (or add more wet materials) if it becomes too dry, and add carbon-heavy browns if it becomes too wet.

Size

A 3-foot cube is the ideal size for a compost bin or pile. You need a large volume of waste to be able to produce a high enough temperature for aerobic organisms to thrive. However, piles larger than 5 cubic feet are not likely to allow enough air to reach the decomposers at the center; they may also be harder to turn. Chop up larger pieces of food or yard scraps before adding to your bin or pile. The smaller the pieces, the quicker the decomposition process will be. A good rule is not to include anything thicker than a finger.

Location

The ideal compost location is a dry and shady spot. If you live in a rainy climate, avoid placing your pile or bin under eaves or places with poor drainage, or else the compost may get too soggy. If you live in a sunny environment, find a shady spot so it doesn't dry up too quickly and you don't have to keep adding water.

To start your pile, add alternating thin layers of greens and browns, ending with a layer of browns. (You can keep adding materials over time until you reach the optimal height of 3 feet.) Wet the compost pile if needed as you layer. Then leave the pile alone for four days to allow initial decomposition to begin, after which you can regularly aerate your pile or bin by turning with a pitchfork or garden fork and regularly monitor the moisture level.

Alamy

Compost Bin

Using a bin is the simplest and cheapest method for small-scale, at-home composting.

Closed Bin

A closed compost bin is an enclosed structure that keeps your composting materials together and helps to retain heat and moisture. Typically, closed bins have an open bottom and you place the bin directly on a patch of soil. The open bottom allows the nutrients in the developing compost to travel directly into the soil. You can either buy a compost bin or build one yourself, making sure to include a removable top so you can add more compostable materials as you accumulate them. Depending on the material you build your bin out of, you may have to drill or punch holes along the sides to allow airflow (or turn it manually for a hotter process). You should ensure that any holes or openings in the bin are small enough to prevent entry by rodents or any other animals of concern. You can build your bin to fit the amount of organics you expect to produce over time—size can range from 3 by 3 by 3 feet to a larger, three-bin system

You may already have some materials around the house to use for a DIY bin. Possibilities include:

- Wine crates
- Plastic storage bins
- Old wooden dresser drawers
- Garbage can
- Wire mesh
- Wood pallets

Open Bin

Open-topped bins (or open compost systems) typically require less maintenance and are better suited to composting yard waste (food waste may attract animals, and open bins are not animal proof). An open bin can be as simple as a loop of chicken wire that allows you to dump materials in. You can even just pile materials on the ground without an enclosure. With an open bin, you have easier access to the composting material. The primary disadvantage is that materials are loosely confined and may be easily accessed by animals or insects, or they may spill out over the boundaries of the bin or pile.

Open bins can be purchased, or you can make one yourself by driving metal stakes or wooden posts into the soil, ideally in a 3-by-3-foot square, and then wrapping the posts with wire mesh fencing. If you have the materials handy, you can also make an open bin from wooden pallets. You can use this method for either hot or cold composting, depending how much you'd like to monitor the balance of materials, turn the pile for aeration, and ensure the right moisture level.

Tumbler Bin

A tumbler is a sealed container that is mounted on an axle or base and can be rotated with a handle. By turning the container, you are aerating and mixing the waste inside, which will help foster aerobic conditions to break down the materials and speed up the composting process. A sealed drum tumbler retains moisture and heat (note that you may need to monitor moisture more carefully to ensure it doesn't get too wet). An aerated tumbler with built-in air vents, on the other hand, speeds up the composting process. With ideal conditions, tumblers can convert waste to finished compost in as little as three weeks, though a month or two is much more common. Compost tumblers can be purchased online or in most gardening stores.

Trench Composting

Another form of home composting involves burying your organic waste directly in the soil. Trench composting can help nearby plants develop water-conserving root systems. Moreover, it is odorless and invisible since all the waste is buried underground. Trench composting can be easier than maintaining a compost pile: All you have to do is dig a hole, fill it with organic waste, and cover it up with soil. Earthworms and other organisms in the soil do the rest of the work. You can trench compost any time of year as long as the soil in your yard remains pliable and manageable. However, this method is best suited to a single application of materials and is generally not practical if you want to compost materials on an ongoing basis, unless you have a lot of space and are willing to dig up your yard regularly.

One of the benefits of trenching is that it allows you to compost small amounts of cooked food waste, including meat, grains, and dairy, because animals and insects are less likely to be attracted to the material if it is buried deep underground. If you do decide to compost animal products, be sure to cover them with 12 to 18 inches of soil.

To start a simple compost pit, use a shovel to dig an elongated hole 12 to 24 inches deep. Fill in the pit with your organic waste, making sure the items are quite moist, and then fill the hole back up with soil. One of the downsides to this method, as with all cold composting methods, is that it takes longer for the waste to decompose. Trenching can produce finished compost in about 12 months, sometimes sooner if the conditions are ideal. Note that you will not be able to harvest the finished compost, so it is best to dig your trench wherever you'd like the nutrients to end up.

If you do not have much organic waste or enough space in your yard for a trench, you can also use the "dig and drop" method, which involves digging out small, 12- to 18-inch holes in the ground and burying the waste in them. You can dig and bury as you accumulate your waste and place small markers on top of the holes as you go so you don't dig in the same spot twice.

Tips for Trench Composting

Don't dig near existing root systems so as not to harm or introduce bacteria to those plants.

Don't plant anything directly on top of your trench as the soil will sink during the composting process.

If you live in an arid area, water the soil on top of the trench to maintain moisture.

Matt Nager for NRDC

Vermicomposting

Vermicomposting, or worm composting, is a great indoor option if your outdoor space is limited (it can be done outdoors as well). You can do it year-round in a basement or garage or even under your sink. Vermicomposting produces natural, odorless castings, which are a nutrient-rich fertilizer, in about three to six months. There is very little maintenance required; the most significant time commitment is harvesting the vermicompost every few months.

You can purchase a cheap worm composter in stores or make one yourself. At its simplest, a vermicompost system can be a wooden or plastic bin with holes in the sides and bottom for ventilation and drainage (similar to a regular enclosed compost bin). A worm composter needs to be raised off the ground to allow excess liquids to flow out. A simple setup for worm composting is to place a taller plastic bin inside a shorter one. Then you have to add worm bedding and some soil. Bedding should be made out of carbon-heavy material to help hold the right amount of air and moisture for the worms. Some common materials for bedding are:

- Shredded paper
- Shredded cardboard
- Dry leaves
- Straw

Feed the worms once a week by burying your food waste under their bedding. Ideal food for the worms includes fruit and vegetable scraps, bread and grains, coffee grounds and used tea leaves. Don’t feed them any animal products or fats and oils, or anything too thick (like a watermelon rind or corncob). The moisture level of the bedding should be similar to that of a damp sponge, so make sure you check on that regularly as well.

The best types of worms to use for vermicomposting are red wigglers, a species that is very easy to maintain and actually prefers the compost environment over regular soil. Red wigglers can eat half their body weight in a day. A typical home system needs about a pound of worms. Check out this video to see how much one pound of worms looks like so you can ensure that you buy the right quantity for your bin.

Tips for Vermicomposting

> Avoid using a metal bin as this can cause the inside to be uncomfortably hot or cold for the worms. Worms tend to thrive in temperatures ranging from 55 to 77 degrees Fahrenheit.
>
> Keeping your worm bin indoors is ideal for many locations; you do not want your worms to freeze in the winter or get too warm in the summer.
>
> Give the worms a day or two to adjust to their new environment and ease into the feeding to figure out the best amount of waste to give them. If you add too many food scraps, the worms may not be able to consume it all before the food rots and attracts insects.
>
> Your worms should be fed about once per week. If you are going to be away from home for longer than that, remember to get a worm sitter so your worms don't die.

What Can You Compost?

Anything that comes from the ground can be composted at home. While animal products can often be composted in municipal composting systems, at-home composting should avoid those items as they can attract animals and insects and leave pathogens in the final product.

WHAT YOU CAN AND CAN'T COMPOST IN YOUR BACKYARD

CAN BE COMPOSTED

- **Cardboard** (uncoated, small pieces)
- **Coffee grounds and filters**
- **Eggshells**
- **Fireplace ashes** (from natural wood only)
- **Fruits and vegetables**
- **Grass clippings**
- **Hair and fur**
- **Hay and straw**
- **Houseplants**
- **Leaves**
- **Newspaper** (shredded)
- **Nutshells**
- **Paper** (uncoated, small pieces)
- **Sawdust**
- **Tea bags**
- **Wood chips**
- **Yard trimmings**

SHOULD NOT BE COMPOSTED

- **Black walnut tree leaves or twigs** (release substances that might be harmful to plants)
- **Coal or charcoal ash** (might contain substances harmful to plants)
- **Dairy products and eggs*** (create odor problems and attract pests such as rodents and flies)
- **Diseased or insect-ridden plants** (diseases or insects might survive and be transferred to other plants)
- **Fats, grease, lard, oils*** (create odor problems and attract pests such as rodents and flies)
- **Meat or fish bones and scraps*** (create odor problems, attract pests such as rodents and flies, and might also carry pathogens)
- **Pet feces or litter*** (might contain parasites, bacteria, germs, pathogens, and viruses harmful to humans)
- **Yard trimmings treated with chemical pesticides** (might kill beneficial composting organisms)

*These materials should not be composted at home but may be accepted by your community curbside or drop-off composting program. Check with your local composting or recycling coordinator.

Source: U.S. Environmental Protection Agency, "Composting at Home," www2.epa.gov/recycle/composting-home.

From "Waste-Free Kitchen Handbook" by Dana Gunders

What Not to Compost

Pet Waste

Pet waste contains parasites and bacteria that can be harmful to humans and other animals if ingested. These pathogens can find their way into your body if you use compost that contains pet waste as fertilizer on edible crops. Compost must reach and remain at a minimum of 131 degrees Fahrenheit for three consecutive days to kill pathogens found in pet waste, and it is hard to regulate and monitor that if you are composting at home. It may be possible to compost dog waste in a home system, but you must follow USDA guidance carefully to ensure the proper conditions, and you should not include cat or any other pet waste. The USDA has resources that provide step-by-step instructions on how to compost dog waste, along with some recommendations to decrease health risks, including:

- Confining the compost pile to a specific area in your yard
- Not feeding dogs raw meat or fish and not including waste from unknown dogs
- Not applying dog waste compost to crops you intend to ingest
- Keeping children away from the compost pile

Inorganic Materials, Such as Plastic

Colored or Glossy Paper

Specialized color or glossy paper may contain toxic materials from the printing inks and additives that may be harmful to humans, animals, and plant life.

Diseased Plants

If your pile doesn’t reach a high enough temperature, plant diseases might survive and be spread to other plants when you use the compost.

Dairy and Other Animal Products

While animal products (meat, fish, eggs, bones, dairy, grease, fat) are organic, they can create odor problems and attract flies, rodents, and other pests to your pile or bin. These products can also carry pathogens that may survive the home composting process. You can trench compost small amounts of animal products.

These materials should be kept away from at-home compost collections. However, if you have a large amount of these materials, see if your municipality accepts food waste for composting, or reach out to a nearby composting program that may accept these items. Large-scale composting facilities can often take in these materials and compost them without the risks faced by a home composter.

More Tips for Composting at Home

Preventing or Getting Rid of Fruit Flies in Your Compost Bin

It is important to note that while fruit flies are annoying, they are harmless to humans and to compost. However, they reproduce quickly and can infest your yard or kitchen if not addressed. Here are some things you can do:

- Increase the carbon-rich browns in your compost pile to help the organic waste dry out. Fruit flies are primarily attracted to greens and will be less likely to linger if you dig a hole in your compost pile and bury greens under a layer of browns.

- Buy or make a fruit fly trap. (Note: Use these traps indoors only, as other critters can easily get trapped if you use them outside.)

- Boil your food waste before adding it to your pile to make it less enticing to fruit flies.

- Don’t add new materials to your pile for a few days to force the fruit flies to go elsewhere for food.

- Purchase a compost keeper to collect food scraps in your kitchen, and add to your pile when it’s full (or once a week or so). There are compost keepers that come with a charcoal filter to help absorb odors.

Safety Precautions

Take standard safety precautions when handling the waste (e.g., washing your hands afterward, avoiding touching your face). If you have a condition that predisposes you to an allergic reaction or infection, wear a dust mask while tending to your pile, especially in dry weather.

How to Use Compost

Compost needs to entirely stabilize and mature before it can be used. Not only can immature compost damage your plants, but it can also attract rodents and other pests to your yard. You will need to stop adding material in order for your pile to mature (although in no-turn systems, the bottom of the pile may provide finished compost even if the top of the pile is still active). You can identify finished compost by looking for these characteristics:

- Texture: Crumbly and smooth, without recognizable scraps.
- Smell: Like a forest on a rainy day, or rich earth. Traces of ammonia or sour odors means the compost needs more time to mature.
- Color: Dark and rich
- Size: One-third the original size of your pile
- Temperature: Within 10 degrees Fahrenheit of the temperature outside (especially in the middle of the pile)

Once you have confirmed that your compost is mature, here are some ways you can put it to use:

- Use it as mulch
- Add it to potting soil
- Work it into crop beds
- Distribute it on lawns

Mix it into garden beds

Feed it to potted plants

Add it to soil around fruit trees

Compost cannot go bad, but it can get too wet, too dry, or too old. You can still use compost that is old; it just might not have as many nutrients in it as fresh compost.

Jim West / Alamy

Don't Want to DIY? Outsource Your Composting

If you don't want to compost yourself or can't compost in your home, you can still collect organic waste and get it to a composter. Some cities have programs that provide curbside collection of organic waste along with regular trash on select days. Check your local municipal website or call 311 to see if your city has such a program. Or find a nearby community or municipal composting site where you can subscribe to a pickup service or drop off your organic waste. If your city doesn't have a composting program, help jump-start interest by lobbying city council members, or start a community composting project yourself. If you outsource your composting, use a compost keeper to store food scraps between pickups or drop-offs. During summertime, you can also freeze your food scraps before taking them to your compost site to reduce the chance of foul odors or maggots.

Composting is not an exact science. It takes time and experience to figure out the best way for you to compost in your environment. Because it is a biological process, results may vary each time you try it, even if you don’t change your method at all. Don’t be afraid to tinker around with your bins, your ratio of browns to greens, or how often you aerate or water your pile. Remember—rot happens! Your compost pile will break down eventually no matter what. The more time you spend with it, the more you will learn.

Farmers lead composting revolution to heal African soils

Fernando Naves Sousa, *The Ecologist*

| 14th October 2014

Moussa Konate cultivating his fields. Photo: Fernando Naves Sousa.

The soils on which African farmers depend are getting poorer, writes Fernando Naves Sousa, depleted of nutrients and organic matter. This creates a huge challenge: to reverse the trend in an environmentally responsible way, while feeding a growing population. But it can be done - using organic composting techniques.

Moussa Konate has a secret. His fields of sorghum, millet and cotton are verdant and productive. Some neighbours are puzzled: they find it hard to believe he does not apply mineral fertilisers and other agro-chemicals.

"We have to feed the earth, so that it gives us what we need", says the farmer of Niamana, a village in southern Mali.

The humid heat of the rainy season makes everyone sweat. Attracted by some of the already mature sorghum grains, a few little red and yellow birds sing nearby. If one of the children throws a stone to scare them away, they escape and hide in the nearest trees.

Moussa uses his hand-made hoe to pluck weeds from his fields, adding them to the compost pile, under the big Baobab and next to the water well. That is where he works on his secret.

"I realized only good compost gives back the land what we take from it in a lasting way, and that is why I started producing it in great amounts."

Compost revolution

Moussa has learned how to produce good quality compost with the Malian organic cotton association, who came to the region five years ago.

Ever since, he has strictly followed the recommendations: to gather organic materials from his fields and kitchen waste, mix the available animal manure, weeds and crop residues and place the materials in layers, watering the pile in the dry season and turning it every two weeks for optimal decomposition. The result is a rich and crumbly black earth ready to nourish his nutrient hungry soils.

He participates in the Syprobio project *(see below)*, which investigates in a participatory way this and other innovations with small-scale farmers, who represent between 70% and 80% of the local population.

Altogether, 100 farmers from Mali, Burkina Faso and Benin participate in this large on-field research, some focusing on how to increase their most precious asset: soil fertility.

Bringing science and farming together

In Moussa's trial, he carefully quantifies and compares the advantages of applying good quality compost, comparing with the traditional habit of spreading undecomposed organic matter in the fields. The results confirm the expectation:

"The cotton parcel where the quality compost was applied has much taller plants and more cotton buds when compared to the parcel where undecomposed organic waste was applied, as we used to do."

Moussa stopped using the mineral fertilisers before learning how to produce the good compost: *"The chemical fertilisers only help the crops in the first year, while the effect of compost can be felt up to three or four years after applying it."*

And compost represents a more durable investment, he emphasises. *"Besides, if it rains after applying mineral fertilisers, they will be washed by the water, whereas compost absorbs water instead of being carried by it, further helping the crops."*

When it rains, the muddy runoff builds up behind the cordons. Over time they grow to form effective and rapidly vegetating catchment barriers, reducing erosion and helping rainwater to infiltrate into the soil.

The other obvious advantage is the economic cost: making compost does mean work - but it costs no money, something of huge importance in a cash-poor society.

'Our food comes from the land we walk on'

Farmers like Moussa know they cannot afford to ignore the quality and fertility of the soil underneath their feet: *"It does not matter if you live in the countryside or in the city, we cannot forget that everything we eat comes from the land we walk on. The way we treat it will determine our future."*

According to the United Nations Food and Agriculture Organisation (FAO), soil degradation and soil fertility loss in Africa have risen in the last few decades. This trend is above all related to decades of inappropriate farming practices, deforestation, desertification, overgrazing and intensive soil erosion.

Over the last 30 years, food production in the continent remained more or less stable, despite a significant rise in cultivated surface. During the same period, however, the continent's population has more than doubled.

To feed a growing population by increasing food production in a sustainable way will probably be Africa's greatest challenge during this century.

'**Holding' the good earth**

Besides returning nutrients to the soil, as Moussa and other farmers are already doing, it is also important to keep the fertile top layers of soil from disappearing.

After decades of deforestation and aggressive agricultural techniques, soils are exposed to erosion. If vegetation is removed and fields are ploughed, torrential rainfall will have a clear road to carry away the top layers of the earth - where soil fertility concentrates.

To prevent water from washing away their livelihood, many farmers in the region started building '*cordons pierreux*', or stone lines. The technique is simple: stones of different sizes are piled in long lines along contours on hillsides subject to rapid water runoff and erosion.

Then when it rains, the muddy runoff builds up behind the cordons. Over time they grow to form effective and rapidly vegetating catchment barriers, reducing erosion and helping rainwater to infiltrate into the soil.

Oh rose thou art sick ...

The links between soil fertility and food security can at times be less obvious. A poorer soil is a headache for farmers, not only due to weaker yields, but also because of an otherwise harmless looking plant: a little pink flower called *striga*.

Despite its beauty, *striga* is a feared parasite which stifles cereals, especially sorghum. The unusual feature of *striga* is that it likes poor soils, therefore having become even more infestive in the nutrient poor soils of Western Africa.

Koro Diarra, from the small village of Kombre, in southern Mali, is one of the farmers who declared war on the little pink flower. Her strategy is to increase her field's fertility by applying compost, which has the double advantage of controlling *striga* and nourishing her crops, increasing yields.

"Sorghum is the base of our diet, it's very important to us, and that's why we cannot ignore striga", says Koro.

In Moussa's fields, *striga* is already rare, as the soil has become too rich for it to thrive. The farmer is seen by local technicians and other farmers as a model producer. *"I invested a lot of effort in compost production. With the good results, I was motivated to increase the amount"*, he says.

Other farmers visit his field to learn from him. *"Some neighbours come to see my fields and understand that the effort of producing compost is worth it. After all, it is the ground that feeds us".*

Fernando Naves Sousa *is a conservation biologist and researcher at FiBL - The Organic Farming Research Institute, in Switzerland. He also contributes to different magazines as a freelance journalist.*

Syprobio - Systèmes de Production Biologiques - is a participatory action-research program developed by FiBL (Organic Farming Research Center) in partnership with farmer associations and research institutions in Mali, Burkina Faso, and Benin, representing a total of 10,000 farmers.

The project is financed by EuropeAid and has a period of 5 years, having started in 2011. Syprobio aims to empower local farmers in the process of investigating and developing organic farming innovations which can promote food security and sovereignty, as well as a better farm income, particularly through the improvement of soil fertility, pest management and adaptation to climate change.

Composting

Composting turns household wastes into valuable fertilizer and soil organic matter.

In your backyard

All organic matter eventually decomposes. Composting speeds the process by providing an ideal environment for bacteria and other decomposing microorganisms. The final product, humus or compost, looks and feels like fertile garden soil.This dark, crumbly, earthy-smelling stuff works wonders on all kinds of soil and provides vital nutrients to help plants grow and look better.

Decomposing organisms consist of bacteria, fungi, and larger organisms such as worms, sow bugs, nematodes, and numerous others. Decomposing organisms need four key elements to thrive: nitrogen, carbon, moisture, and oxygen. For best results, mix materials high in nitrogen (such as clover, fresh grass clippings, and livestock manure) and those high in carbon (such as dried leaves and twigs). If there is not a good supply of nitrogen-rich material, a handful of general lawn fertilizer will help the nitrogen-carbon ratio. Moisture is provided by rain, but you may need to water or cover the pile to keep it damp. Be careful not to saturate the pile. Turning or mixing the pile provides oxygen. Frequent turning yields faster decomposition.

Composting can be as simple or involved as you would like. It depends on how much yard waste you have and how fast you want results.

Backyard Conservation

is a cooperative project of:

USDA Natural Resources Conservation Service

National Association of Conservation Districts

Wildlife Habitat Council

April 1998

One in a series of 10 tip sheets on backyard conservation

Getting started

Many materials can be added to a compost pile, including leaves, grass clippings, straw, woody brush, vegetable and fruit scraps, coffee grounds, livestock manure, sawdust, and shredded paper. Do not use diseased plants, meat scraps that may attract animals, or dog or cat manure which can carry disease. Composting can be as simple or as involved as you would like, and depends on how much yard waste you have, how fast you want results, and the effort you are willing to invest.

Cold or slow composting

With cold or slow composting, you can just pile grass clippings and dry leaves on the ground or in a bin.This method requires no maintenance, but it will take several months to a year or more for the pile to decompose. Cold composting works well if you don't have time to tend the compost pile at least every other day, have little yard waste, or are not in a hurry to use the compost.

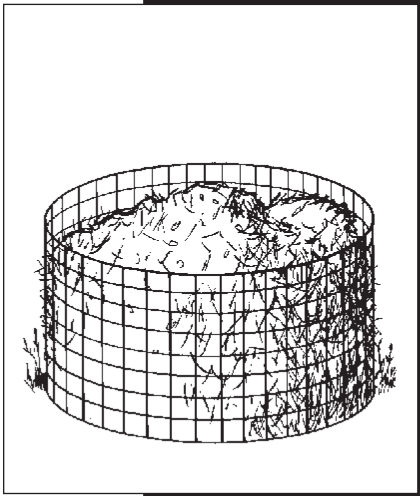
Keep weeds and diseased plants out of the mix since the temperatures reached with cold composting may not be high enough to kill the weed seeds or disease-causing organisms. Add yard waste as it accumulates. Shredding or chopping speeds up the process.To easily shred material, run your lawn mower over small piles of weeds and trimmings.

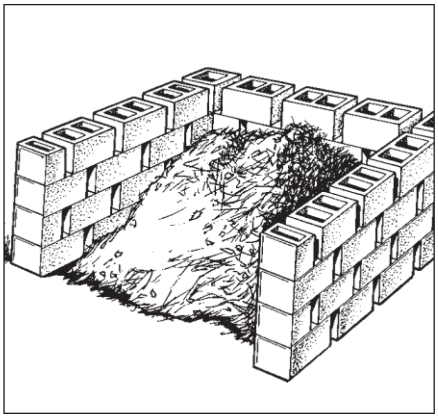
Cold composting has been shown to be better at suppressing soil-borne diseases than hot composting. Cold composting also leaves more undecomposed bits of material, which can be screened out if desired.

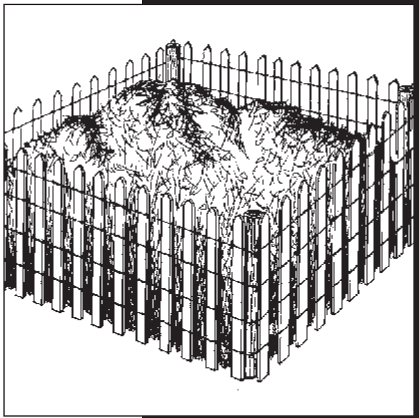
Hot composting

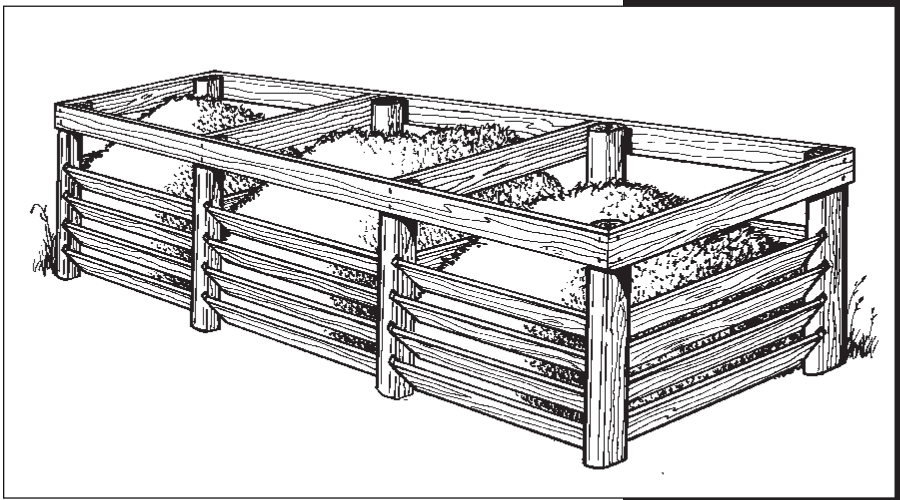
Hot composting requires more work, but with a few minutes a day and the right ingredients you can have finished compost in a few weeks depending on weather conditions. The composting season coincides

Compost bins may be (clockwise from left) as simple as a ventilated garbage can; built with wire mesh; picket fence; pressure treated wood; brick or concrete blocks; and other materials.









with the growing season. When conditions are favorable for plant growth, those same conditions work well for biological activity in the compost pile. However, since compost generates heat, the process may continue later into the fall or winter.

Hot piles do best when high-carbon material and high-nitrogen material are mixed in a 1 to 1 ratio. A pile with the minimum dimensions of 3' x 3' x 3' is needed for efficient heating. For best heating, make a heap that is 4 or 5 feet in each dimension. As decomposition occurs, the pile will shrink. If you don't have this amount at one time, simply stockpile your materials until a sufficient quantity is available for proper mixing.

Hot piles reach 110 to 160 degrees Fahrenheit, killing most weed seeds and plant diseases. Studies have shown that compost produced at these temperatures has less ability to suppress diseases in the soil since these temperatures may kill some of the beneficial bacteria necessary to suppress disease.

Steps for hot composting:

1. Choose a level, well-drained site, preferably near your garden.

2. There are numerous styles of compost bins available depending on your needs. These may be as simple as a moveable bin formed by wire mesh or a more substantial structure consisting of several compartments. (See diagrams.) There are many commercially available bins. While a bin will help contain the pile, it is not absolutely necessary. You can build your pile directly on the ground. To help with aeration, you may want to place some woody material on the ground where you will build your pile.

3. To build your pile, either use alternating layers of high-carbon and high-nitrogen material or mix the two together and then heap into a pile. If you alternate layers, make each layer 2 to 4 inches thick. Some composters find that mixing the two together is more effective than layering. Use approximately equal amounts of each. If you are low on high-nitrogen material, you can add a small amount of commercial fertilizer containing nitrogen. Apply at a rate of ½ cup of fertilizer for each 10-inch layer of material. Adding a few shovels of soil will also help get the pile off to a good start; soil adds commonly found decomposing organisms.

4. Water periodically. The pile should be moist but not saturated. If conditions are too wet, anaerobic microorganisms (those that can live without oxygen) will continue the process. These are not as effective or as desirable as the aerobic organisms. Bad odors are also more likely if the pile is saturated.

5. Punch holes in the sides of the pile for aeration.

6. The pile will heat up and then begin to cool. Start turning when the pile's internal temperature peaks at about 130 to 140 degrees Fahrenheit. You can track this with a compost thermometer, or reach into the pile to determine if it is uncomfortably hot to the touch.

7. During the composting season, check your bin regularly to assure optimum moisture and aeration are present in the material being composted.

8. Move materials from the center to the outside and vice versa. Turn every day or two and you should get compost in less than 4 weeks. Turning every other week will make compost in 1 to 3 months. Finished compost will smell sweet and be cool and crumbly to the touch.

Common problems

Composting is not an exact science. Experience will tell you what works best for you. If you notice that nothing is happening, you may need to add more nitrogen, water, or air. If things are too hot, you probably have too much nitrogen. Add some more carbon materials to reduce the heating. A bad smell may also indicate too much nitrogen.

Cold composting often proceeds faster in warmer climates than in cooler areas. Cold piles may take a year or more to decompose depending on the materials in the pile and the conditions.

Adding kitchen wastes to compost may attract flies and insects. To prevent this problem, make a hole in the center of your pile and bury the waste. Do not compost meat scraps, dead animals, pet manure, diseased plant material, or noxious weeds.

Check on any local or state regulations for composting in urban areas–some communities may require rodent-proof bins.

Vermicomposting

Vermicomposting uses worms to compost. This takes up very little space and can be done year-round in a basement or garage. It is an excellent way to dispose of kitchen wastes.

Steps for vermicomposting:

1. You need a plastic storage bin. One 1' x 2' x 3.5' will be enough to meet needs of a family of 6.

2. Drill 8 to 10 holes, approximately 1/4" in diameter, in the bottom of the bin for drainage.

3. Line the bottom of the bin with fine nylon mesh to keep the worms from escaping.

4. Put a tray underneath to catch the drainage.

5. Shredded newspaper works well as bedding. Rip into pieces and water well so that it is thoroughly moist. Place on one side of your bin. Do not let it dry out.

6. Add worms to your bin. Redworms are recommended for best composting, but other species can be used. Redworms are the common small worms found in most gardens and lawns. You can collect them from under a pile of mulch or order them from a garden catalog.

7. Provide worms with food wastes such as vegetable peelings. Do not add fat or meat products. Limit feed– too much at once may cause the material to rot.

8. Keep the bin in a dark location away from extreme temperatures.

9. In about 3 months the worms should have changed the bedding and food wastes into compost. At this time add fresh bedding and more food to the other side of the bin.The worms should migrate to the new food supply.

10. After a couple of weeks, open your bin in a bright light.The worms will burrow into the bedding. Scoop out the finished compost and apply to your plants or save for use in the spring.

Using compost

Compost can be used for all your planting needs. Compost is an excellent source of organic matter to add to your garden or potted plants. It helps improve soil structure which contributes to good aeration and moisture-holding capacity.

Compost is a source of plant nutrients. Compost can also be used as a mulch material. Studies have shown that compost used as a mulch, or mixed with the top one-inch layer of soil, can help prevent some plant diseases, including some of those that cause damping of seedlings.

On the farm

On the farm, potential waste is turned into a resource that saves money and helps the environment. Producers use livestock manure to fertilize crops.When manure is properly handled, it can be safely applied to the land without the risk of polluting water. Composting is also practiced in some poultry operations.The compost is used as fertilizer on the farms and for lawns and gardens.

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By: Ryan Cooper, Waste Diversion Manager and Organics Recycling Lead   August 25, 2020

Share:

Food Waste in America: Facts and Statistics

Food waste in America has skyrocketed in recent years, with 103 million tons (81.4 billion pounds) of food waste generated in 2018, according to the Environmental Protection Agency (EPA); the equivalent of over 450,000 Statue of Liberties.

This is a shocking statistic which unfortunately becomes less surprising the more you learn about the growing problem of food waste in America.

Globally, we waste a third of all food produced for human consumption, according to the Food and Agriculture Organization (FAO) of the United Nations (UN). In the United States, that equates to approximately one pound of food wasted per person per day. If we keep this up, reports estimate that in ten years, we'll waste the equivalent of 66 tons of food per second across the globe.

What is Food Waste?

Before we go any further, here's a quick primer on the basics of food waste:

Rubicon's mission is to end waste, in all of its forms. In this article, we're going to look at the issues surrounding food waste in the U.S. compared to the rest of the world. We're going to look at what causes food waste at every level of the food supply chain; and how to reduce it. And we're going to uncover the most interesting food waste statistics out there.

Keep reading to learn more about food waste in America.

How Much Food is Wasted in America?

Each day in the United States approximately one pound of food per person is wasted. This equates to 103 million tons (81.4 billion pounds) of food waste generated in America in 2017, or between 30-40 percent of the food supply, according to the United States Department of Agriculture (USDA).

How much food is wasted in the U.S. can be seen directly through its monetary losses. The annual food waste in America has an approximate value of $161 billion, while the average American family of four throws out $1,500 in wasted food per year.

As it stands, the U.S. is the worldwide leader in food waste generation, with the majority of wasted food being sent to landfills. In fact, food waste is the number one material in American landfills, accounting for 24.1 percent of all municipal solid waste (MSW) according to the EPA.

How did we get here? Knowing how much food is wasted in America each year is only the first step toward tackling a problem that is bigger than the simple monetary loss. The reality of food waste in America is that we live in a country in which more than 54 million people are food insecure (18 million of which are children) according to 2020 data collected by Feeding America. These numbers are up from 37 million and 11 million, respectively, in 2019, with the sharp rise in food insecurity due to the effects of the COVID-19 public health emergency and the subsequent economic downturn. (For more food waste statistics, scroll down to the "Food Waste Facts and Statistics" section below.)

What Causes Food Waste in America?

The causes of food waste in America go far beyond just tossing our leftovers in the trash, and they are crucial to understand in order to reduce our nation's collective food waste going forward.

From production and supply, to our tendency to overpurchase, to the unrealistic aesthetic standards we have come to expect from our fruits and vegetables, these are the three main causes of food waste in America:

Production and Supply Chain

Food wastage occurs at every step of the supply chain, with different types of foods being more or less likely to be lost at each step.

According to data from the United States, Canada, Australia, and New Zealand that was collected by the Natural Resources Defense Council (NRDC), 20 percent of fruit and vegetables are lost during production, 12 percent are lost at the distribution and retail level, and a further 28 percent are lost at the consumer level. Seafood faces a similar fate, with 11 percent lost during production, 5 percent lost during processing and packaging, 9.5 percent lost at the distribution and retail level, and a further 33 percent lost at the consumer level. (For more on the specifics of food loss, this paper from Dana Gunders is a must-read.)

Unrealistic Aesthetic Standards

When you're in the produce aisle at your local supermarket, do you ever put back carrots, potatoes, zucchinis, or any other fruit or vegetable because it doesn't look as straight, slender, round, or otherwise how we have been conditioned to believe this item should look?

Food waste in America is exacerbated by unrealistic aesthetic standards for our produce. You're not alone in not picking up that misshapen carrot in the produce aisle. Grocery stores have learned over time that consumers don't tend to purchase misshapen produce. As a result, many stores stop accepting them from their suppliers. Thankfully there are outlets for misshapen produce; restaurants don't care what their carrots look like so long as they can turn them into delicious dishes on the plate, and start-ups such as Imperfect Foods, Misfits Market, and Hungry Harvest make it easy for consumers to receive "ugly produce" right to their door.

Portion Sizes and Overpurchasing

While not the most dramatic cause of food wastage, increased portion sizes in schools, restaurants, and the home leads to overpurchasing. Subsequently, more food is thrown out because it's gone bad.

Restaurants want to have enough food to serve their customers, so they overbuy and throw out what goes bad. At the consumer level, however, you have the power to ensure you purchase only what you need, you serve portion sizes that work for you and your family, and you don't throw out food too early.

What are the Effects of Food Waste?

While the negative effects of food waste in America are numerous, this article will focus on the three largest.

Environmental Impact

The environmental impact of food waste in America cannot be undersold. As food rots in a landfill, it emits methane, a greenhouse gas 28 to 36 times more potent than the carbon that comes out of passenger vehicles.

Landfills are the third-largest industrial emitter of methane, with food waste alone representing 8 percent of total global greenhouse gas (GHG) emissions. While it is possible to offset the harm of these emissions through organics recycling, composting, and anaerobic digestion, the best way to reduce these emissions is to waste less food in the first place.

Food Insecurity and Global Hunger

While mentioned above, it bears repeating here. We live in a country in which more than 54 million people are food insecure (18 million of which are children) according to 2020 data collected by Feeding America, meaning they lack reliable access to a sufficient quantity of affordable, nutritious food. These numbers are up from 37 million and 11 million, respectively, in 2019, due to COVID-19.

The fact that we as a country are wasting 30-40 percent of the food supply each year when more than 54 million Americans are food insecure is unconscionable.

Wasted Natural Resources

While rotting food in our country's landfills causes harm to our environment after it is wasted, allowing perfectly good food to go to waste is also wasteful of the natural resources that helped this food come to fruition in the first place.

When we waste food, we waste the water, energy, and physical labor it took to produce, package, and ship this food. We waste the fuel that was used to transport this food from one part of the country to another. When we waste food, it's not just the food itself that is being wasted.

How to Reduce Food Waste in America

Reducing food waste in America is going to take some time. Highlighting food waste statistics and facts, such as those below, is a good way to help get the word out about this ever-growing problem, but our work can't stop there.

As we just learned, there's more to food waste than what we do and don't eat. We're wasting $161 billion annually (with the average American family of four throwing out $1,500 in wasted food per year) while depleting our natural resources, harming our environment, and wasting food that the more than 54 million food insecure people in the United States could benefit from.

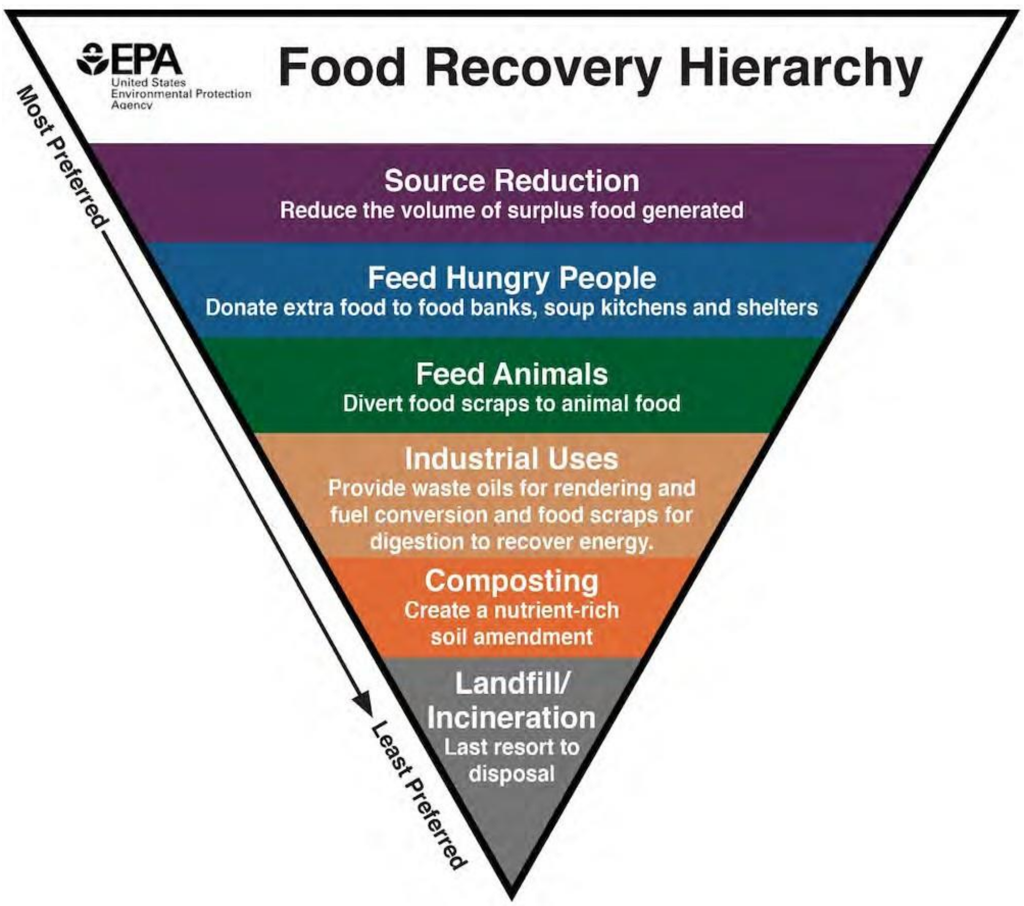
Here are some ideas for what you can do to reduce food waste in America:

- Put together a detailed shopping list before you go to the grocery store by planning your meals in advance—and avoid impulse purchases.
- Take leftover containers to restaurants. While some don't provide takeout containers, they would be hard-pressed to stop you from using your own.

- Recognize that while your eyes may be bigger than your stomach, your plate doesn't have to be. Using smaller plates can help you to properly portion your food.
- Don't be afraid of an emptier fridge. When you can't see the food you have purchased, you're more likely to forget about it and let it rot.
- Keep track of the food you're throwing away the most to cut down on trends. Add a dollar sign value so you can see the impact it has on your budget.
- Expiration dates are misleading and nonstandardized, leading many to toss out perfectly good food. Trust your sense of smell, and your gut, before throwing items away.
- Read the EPA's "Too Good to Waste" implementation guide and toolkit to reduce wasteful food management practices.

The Food Recovery Hierarchy

When we talk about reducing food waste in America we would be remiss to not mention the Food Recovery Hierarchy.



Developed by the EPA, the Food Recovery Hierarchy prioritizes actions businesses and individuals alike can take to prevent and divert wasted food. As you can see, source reduction, or simply purchasing less food in the first place, is number one. This is followed by food donations to those in need, sending food scraps to animal feed, then industrial uses including anaerobic digestion and ethanol facilities, before moving on to composting.

Hopefully, food waste is never landfilled because it has so many beneficial uses.

Food Waste Facts and Statistics

The following food waste facts and statistics tell the story of food waste in America.

As I noted earlier on in this article, reading food waste statistics that tell us just how much food is wasted in America on an annual basis is a good way to help get the word out about the problem of food wastage in this country—but we must go further to reduce food waste at every level of the food supply chain.

If you are a restaurant owner looking to implement food waste reduction programs, or you're a business owner looking to run a more sustainable business, reach out to Rubicon's Sustainability team at sustainability@rubicon.com and we will be happy to help.

Without further ado, here are 20 of the most interesting food waste facts and statistics:

1. 103 million tons (81.4 billion pounds) of food waste was generated in the United States in 2018, the equivalent of over 450,000 Statue of Liberties.
2. An estimated 1.3 billion tonnes of food is wasted globally each year, one third of all food produced for human consumption.
3. In ten years, the United States will waste the equivalent of 66 tons of food per second across the globe.
4. If food waste was a country, it would be the third largest emitter of greenhouse gas emissions in the world after the United States and China.
5. The United States wastes 30-40 percent of its food supply each year.
6. The annual food waste in America has an approximate value of $161 billion.
7. The average American family of four throws out $1,500 in food per year.
8. Food waste is the number one material in America's landfills, accounting for 24.1 percent of all municipal solid waste (MSW).
9. More than 54 million people are food insecure (18 million of which are children) according to 2020 data, accounting for one in six people. These numbers are up from 37 million and 11 million, respectively, in 2019, due to COVID-19.
10. Approximately 38 percent of grain products are lost, 50 percent of seafood, 52 percent of fruits and vegetables, 22 percent of meat, and 20 percent of milk.
11. As food rots in a landfill, it emits methane, a greenhouse gas 28 to 36 times more potent than the carbon that comes out of passenger vehicles.
12. Food waste represents 8 percent of total global greenhouse gas emissions.
13. Only 6.3 percent of food waste in America was composted in 2017.
14. The healthier you eat, the more important it is that you stay on top of your consumption. If you buy perishable food in bulk, such as fruits, vegetables, and meat, organize your refrigerator so what you need to eat first is up front and visible.
15. Americans discard approximately 35 percent (204 million pounds) of edible turkey meat each year, the majority after the Thanksgiving holiday.
16. Food is often safe to eat even after it "expires." Expiration dates are misleading and nonstandardized, leading many to toss out perfectly good food.

. Global preferences for a western diet consisting of a high intake of carbohydrates, sugar, and sodium are major contributors to environmental burdens such as greenhouse gas emissions and land use.
. Shrink wrapping produce helps to reduce food waste by increasing its shelf life. But remember to recycle the shrink wrap and other plastic bags, wraps, and filmthat are clean and dry.
. Lack of awareness of basic nutrition adds to food waste among consumers. While many people believe it's better to buy fresh food, in reality, frozen food products often retain more nutrients while lasting longer.
. The size of your refrigerator can impact the amount of food you waste. You're more likely to forget about food you have, improperly store your food, and buy more than you can eat before it goes bad.

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To learn more about Rubicon's work transforming the entire category of waste and recycling, be sure to download our inaugural Environmental, Social, and Governance (ESG) Report.

If you have any questions about food waste in America, or any of the food waste facts and statistics on this page, you can reach out to Rubicon's Sustainability team directly at sustainability@rubicon.com, or contact our sales team at (844) 479-1507.

Ryan Cooper is a Waste Diversion Manager and the Organics Recycling Lead at Rubicon. To stay ahead of Rubicon's announcements of new partnerships and collaborations around the world, be sure to follow us on LinkedIn, Facebook, and Twitter, or contact us today.

Sources: 1, 7, 8, 11, 13, 20) Environmental Protection Agency (EPA); 2, 12) Food and Agriculture Organization (FAO); 3, 19) Boston Consulting Group (BCG) Henderson Institute; 4) World Resources Institute; 5, 10) Natural Resources Defense Council (NRDC); 6) U.S. Food and Drugs Administration; 9) Feeding America; 14) Municipal Waste Association; 15) Waste Dive; 16) Reuters; 17) United States Department of Agriculture (USDA); 18) Australian Broadcasting Corporation (ABC) News.

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Wasting food just feeds climate change, new UN environment report warns

Unsplash/Sanjog Timsina More than 900 million tonnes of food is thrown away every year.

4 March 2021 **Climate and Environment**

More than 930 million tonnes of food sold in 2019 landed in waste bins, according to new UN research, released on Thursday, in support of global efforts to halve food waste by 2030.

Produced by the UN Environment Programme (UNEP) and partner organization WRAP, the Food Waste Index Report 2021 reveals that between food wasted in homes, restaurants and shops, 17 per cent of all food is just dumped.

Some food is also lost on farms and in supply chains, indicating that overall a third of food is never eaten.

The study represents the most comprehensive food waste data collection, analysis and modelling ever done, and offers a methodology for countries to accurately measure loss.

“If we want to get serious about tackling climate change, nature and biodiversity loss, and pollution and waste, businesses, governments and citizens around the world have to do their part to reduce food waste”, said Inger Andersen, Executive Director of the UN Environment Programme (UNEP).

Revealing picture

Although food waste had been thought of as a problem mostly affecting rich countries, the report found levels of waste were surprisingly similar in all nations, though data is scarce in the poorest countries.

The study reveals that households discard 11 per cent of food at the consumption stage of the supply chain, while food services and retail outlets waste five and two per cent, respectively.

This has substantial environmental, social and economic impacts, according to the report, which points out that eight to ten per cent of global greenhouse gas emissions are associated with unconsumed food.

“Reducing food waste would cut greenhouse gas emissions, slow the destruction of nature through land conversion and pollution, enhance the availability of food and thus reduce hunger and save money at a time of global recession”, said Ms. Andersen.

Conserving across platforms

In 2019, some 690 million people were impacted by hunger and three billion were unable to afford a healthy diet.

Against that backdrop and with COVID-19 threatening to exacerbate these numbers, the study urges consumers not to waste food at home. It also pushes for food waste to be included in Nationally Determined Contributions (NDC), plans through which countries commit to increasingly ambitious climate actions in the Paris Agreement .

Meanwhile, target 12.3 of the Sustainable Development Goals (SDGs) aims to halve per-capita global food waste at retail and consumer levels and minimize food losses along production and supply chains.

> **Reducing food waste would cut greenhouse gas emissions, slow the destruction of nature…and save money at a time of global recession – *UNEP chief***

“The UN Food Systems Summit this year will provide an opportunity to launch bold new actions to tackle food waste globally”, Ms. Andersen said.

Comparable data lacking

Of the growing number of countries measuring food waste, 14 have collected household data in a way that is compatible with the Food Waste Index, while a further 38 countries use methods similar to the SDG 12.3 compatible estimate.

While the household breakdown between edible and uneatable food, like shells and bones, is available only in select high-income countries, there is a lack of information in lower-income countries where proportions may be higher.

It is crucial to fill this knowledge gap, according to the report.

UNEP will launch regional working groups to aid countries’ capacities to measure and record food waste in time for the next round of SDG 12.3 reporting in late 2022. It will also support these countries as they develop national baselines to track progress towards the 2030 goal, and design strategies to prevent food waste.

2022 NCF-Envirothon Ohio

Current Environmental Issue Study Resources

Key Topic 4: Combustion with Energy Recovery (Waste-to-Energy)

1. Identify examples of closed loop energy systems and facilities.
2. Compare methods of carbon sequestration and describe their potential as an energy source.

Study Resources

Closing the loop: integrative systems management of waste in food, energy, and water systems – *Davis et al., 2016* (Pages 101-111)

Carbon Sequestration – *UC Davis, 2021* (Pages 112-116)

Waste-to-Energy Where it is Needed the Most – *United Nations, 2018* (Pages 121-122)

<u>Study Resources begin on the next page!</u> ➡

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Closing the loop: integrative systems management of waste in food, energy, and water systems

Sarah C. Davis[1] & Derek Kauneckis[1] & Natalie A. Kruse [1] & Kimberley E. Miller[1] & Michael Zimmer[1] & Geoffrey D. Dabelko[1]

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Abstract Modern food, energy, and water (FEW) systems are the product of technologies, techniques, and policies developed to address the needs of a given sector (e.g., energy or agriculture). Wastes from each sector are typically managed separately, and the production systems underlying FEW have traditionally treated pollution and waste as externalities simply diffused into the ambient environment. Integrative management that optimizes resource use presents opportunities for improving the efficiency of FEW systems. This paper explains how FEW systems can be optimized to (1) repurpose or cycle waste products, (2) internalize traditional externalities, and (3) integrate wastes with resource inputs across systems by diverting waste by-products from one system to meet demands of another. It identifies the means for "closing the loop" in production systems. Examples include management of legacy wastes from fossil fuel industries (coal and natural gas) and integrative designs for advanced renewable systems (biogas from waste, bioenergy from CAM plants, and solar). It concludes with a discussion of how studying the governance of such systems can assist in tackling interconnected problems present in FEW systems. New governance arrangements are needed to develop solutions that can align with regulatory frameworks, economics incentive, and policies. Four aspects of governances (property rights, policy design, financing, and scale) emerge as tools to facilitate improved institutional design that stimulates integrative management, technology innovation and deployment, and community development. The conclusion offers a framework through which integrative management of FEW systems can be linked to value chains in closed-loop systems.

Keywords Closed-loop production systems · Integrated systems analysis · Bioenergy · Biogas · Hydraulic fracturing · Acid mine drainage · Irrigation · Water consumption · Public policy · Governance

Introduction

Many modern societal challenges stem from systems inefficiencies that waste resources. These inefficiencies are myriad and fundamental. Of the 103 exajoules (1 exajoule = 2.78×10^{11} kWh) of energy consumed in the USA annually, only 73 % are delivered to an end use, reflecting 27 % waste (EIA 2011). In the case of food systems, an average of 33 % of grain, vegetables, red meat, and poultry are wasted annually (Buzby et al. 2011; Giovannucci et al. 2012). Irrigation of crops that support food production consumes 135 million m^3 of water, amounting to 77 % of all water consumption in the USA, even though only 6–14 % of agriculture is irrigated in this country (USDA 2007, 2012). Improving efficiencies of the systems that supply food, energy, and water (FEW) requires major infrastructure overhaul and substantial financial investment. Near-term solutions for co-managing FEW systems more efficiently provide critical steps during a more fundamental transition to policy, economics, and infrastructure that closes the loop on waste. This article describes strategies that view wastes from FEW production as opportunities for enhancing overall efficiency if systems are managed with an integrative perspective and provides a framework for evaluating how systems might be more tightly integrated.

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Energy systems in the USA are still predominantly fueled by fossil resources, with waste products that impact air, land, and water quality. Major air pollutants from the coal industry include mercury, sulfur oxides, and nitrogen oxides, among others. Water pollutants include metals such as iron and aluminum, and sulfur that leads to acid mine drainage. Prior to the establishment of the Clean Air Act of 1970, Clean Water Act in 1972, and the Surface Mine Control and Reclamation Act of 1977, these pollutants were generally unregulated and assumed to be diluted and discarded upon discharge. Despite increased regulation and quality standards since the 1970s, the pollution from historic activity persists in the environment along with newly generated waste from modern fossil fuel extraction technologies. Horizontal drilling and hydraulic fracturing for natural gas production is a recent technological advance for the fossil fuel industry, but is the source of new methane emissions, has a high water demand, and generates a new form of waste water to be regulated.

Alternative energy systems are growing as a means to offset the impacts of fossil fuel systems. Yet systems that use renewable resources generate waste as well. The manufacturing processes associated with solar, wind, hydrogen, biomass, and hydroelectricity all consume resources and generate waste even if at a lower level than fossil fuel technologies (Pehnt 2006; Varun et al. 2009). For example, large-scale solar energy deployed in arid regions requires substantial water for cleaning to maintain efficient energy generation (Ravi et al. 2014). Some renewable energy systems, however, use waste as the feedstock for energy generation, demonstrating the potential for improving systems efficiencies by integrative management. Municipal solid waste management is an industry unto itself, but integrating energy and waste management creates opportunities for reducing life-cycle impacts of otherwise separate production processes (Cherubini et al. 2009; Münster and Lund 2009). It is estimated that animal manure alone, the largest waste resource that is uniform in format, could generate between 9 and 25 exajoule (EJ) (Hoogwijk 2003), or 7 % of global energy consumption (IEA 2013).

The US food system depends heavily on international trade despite the large agricultural land resource available domestically. Agricultural production in the USA is dominated by corn (*Zea mays*) crops, with the majority of corn grain used for livestock feed and bioethanol. There are 35 million ha (86 million acres) allocated to this one crop in the USA with only ~8 % used for human food (FAOSTAT 2015). In the USA, there has been a decline in farmland since the middle of the twentieth century as crop diversity decreased and farming in some regions was abandoned (USDA 2012). Yet, the American diet has become more diversified over the same time period through the increase of imported food commodities. With ca. 33 % of food resources wasted (Giovannucci et al. 2012), there are clear opportunities for improving the efficiency of the food economy. An alternative to reducing waste is to utilize it for other purposes. Both abandoned agricultural land and wastes can be used for bioenergy feedstocks (Campbell et al. 2013; Davis et al. 2014). Agricultural lands can also be diversified to enhance nutrition, ecosystem services, and efficiency within food supply chains (Giovannucci et al. 2012).

Food and energy systems impact water in many ways. Agriculture is the leading consumer of water. Even in the USA, where only 6 % of farmland is irrigated in an average year (USDA 2007), and 14 % in a recent drought year (USDA 2012), irrigation accounts for an average of 77 % of water consumption (Kenny et al. 2009; Scown et al. 2011). Consumption of water for irrigation is of growing concern due to risk of increased drought expected in some regions as climate change progresses, and opportunities for reducing or reusing water would greatly benefit this production system. Water resources are also affected by withdrawals that result in a change to water quality. In this case, water is not technically consumed, but is altered before being returned to the source drainage basin. Depending on the change in quality, there can be substantial chemical and biological consequences for this change. The vector of change (e.g., heat, chemical load) is a waste from the industrial system that uses withdrawn water.

The structure of economic incentives in FEW systems has led to wastes being treated as externalities. However in some cases of both current and legacy system wastes, these by-products may offer value-added opportunities for both improving efficiency of production and reducing environmental impacts. Systems that are designed to incorporate waste back into one or more stages of production are known as BclosedLoop systems.^Closed-loop systems improve the sustainability of manufacturing a product by focusing on the entire life-cycle from the extraction of raw material to disposal. It focuses on recapturing and reusing material within a process, across processes, or across different products, and the use of biodegradable/bio-compostable materials to reduce the environmental impact of production and consumption (Dekker et al. 2013; Ellen MacArthur Foundation and McKinsey & Company 2014; Winkler 2011). In the text that follows, we provide four examples of how integrated FEW systems can be designed as closed-loop production systems where waste is repurposed and utilized for multiple values along and across different production cycles. We then describe the potential for successful integrated systems management with governance that carefully addresses property right institutions, policy design, long-term financing, and scaling issues.

Example 1: coal mining waste repurposed as useful chemicals

Coal mining creates a large waste stream including tailings and, in some cases, acid mine drainage (AMD). AMD is formed through oxidative weathering of sulfide minerals exposed during the mining process and is a metalliferous, acidic waste stream. Once exposed, many underground mines continue to discharge decades after mining ceased. Reclamation efforts can treat AMD, but do not eliminate it, and create large public costs expended toward maintaining water quality. There is potential for material reuse and resource recovery to reduce the ongoing waste stream created by mining.

Reuse or processing of AMD has been investigated for three key uses: metal recovery, phosphorous removal from municipal wastewater, and hydraulic fracturing source water (Fig. 1). Each has the potential to increase the sustainability of mining and reduce the impact of AMD if the processes are made more efficient. Hedin (2006) showed that a saleable product can be extracted from AMD; the author extracts iron oxy-hydroxide sediments from treatment systems for abandoned coal mines to sell as pigment for paints and even crayons (Hedin 2006). Various extraction methods have been suggested including biochemical methods (Sahinkaya et al 2009), sequential precipitation (Matlock et al 2002; Wei et al 2005), and titration (Jenke and Diebold 1983), although few of these processes have been widely adopted. AMD is a diffuse pollutant, so a decentralized, low cost, potentially portable approach could lead to increased revenue potential and increased adoption by the industry.

The iron compounds present in AMD are known to be effective sorbents for phosphate (e.g., Dobbie et al. 2009), so much so that phosphorous availability has been identified as a potential limitation to recovery of AMD impacted waterways (e.g., DeNicola and Lellock 2015). Wei et al. (2008) and Dobbie et al. (2009) show effective phosphorous removal using iron precipitates from AMD when applied as tertiary treatment of municipal wastewater, and these results are consistent with studies describing co-treatment of AMD and municipal wastewater (e.g., Strosnider and Nairn 2010). While there is widespread potential application for phosphorous control using AMD, the proximity of either major agricultural pollution or municipal wastewater to iron-rich AMD limits widespread application of the technology.

AMD has also been explored as source water for hydraulic fracturing (Macy et al. 2015). Since hydraulic fracturing requires a large amount of water, the Pennsylvania Department of Environmental Protection has suggested use of AMD rather than freshwater as source water (PDEP 2013), and other states are following this example. Drawbacks such as trucking distances, potential for well bore scaling due to high iron concentrations, and reactions with sulfate in the AMD to form insoluble barite or toxic hydrogen sulfide gas could limit reuse of AMD for hydraulic fracturing. Efficient, low cost treatment to remove key constituents and effective planning to reduce trucking distance could allow for this reduction in waste. Integrative management of AMD and source water for hydraulic fracturing has the potential to reduce both water withdrawals and new waste in regions that still struggle to contain legacy waste from mining.

Other pathways for reusing AMD are reviewed by Kruse and Strosnider (2015), and include iron seeding in the ocean (Hedin and Hedin 2015) and sequential flooding of mine pits to maximize CO_2 sequestration (Younger and Mayes 2015). Each of these pathways is associated with other consequences that are controversial and would need to be weighed carefully against the benefits for waste remediation.

Fig. 1 Conceptual diagram of waste from coal mining (acid mine drainage) repurposed to meet resource demands within the energy industry (injection water for hydraulic fracturing) and resource demands for other markets (pigment and phosphorous remediation). Image for phosphorus remediation used with permission from Kate Heal, University of Edinburgh (www.geos.ed.ac.uk/research/cecs/water.html)

Example 2: hydraulic fracturing flowback and produced water reuse and treatment

Horizontal drilling and hydraulic fracturing are used together to extract gas, gas condensates, and oil from hydrocarbon-rich shale formations deep underground. The process requires a large volume of water (about 5 million gallons per well) that is mixed with various chemicals and produces significant quantities of wastewater (25–50 % of the injected fluid). The fluid that is injected is a mixture of water (~85 %), crystalline silica used as a proppant (~14.5 %), and chemicals (~0.5 %) including hydrochloric acid, glycols, methanol, ammonium chloride, petroleum distillates, and a number of organic chemicals that act as inhibitors and bactericides (e.g., fracfocusdata.org). The initial composition varies by producer; some states require disclosure of the fluid chemistry on the web repository, fracfocus.org, although details about some constituents are withheld due to their proprietary nature. The water that returns to the surface is termed produced water; it is Bproduced^ when the pressure is released from the well bore, allowing the fluid to return to the surface. Management solutions for this wastewater are still needed.

The wastewater that returns within the first 10 days is called Bflowback^ water. The flowback portion of the produced water tends to have a composition more similar to the injected fluid than the later produced water, and makes up approximately 15 % of the produced water (Mantell 2011), depending on the shale play geology. The remaining produced water returns to the surface throughout the life of the well. Barbot et al. (2013) analyzed several hundred produced water samples; they found that BFlowback water is dominated by Cl-Na-Ca with elevated bromide, magnesium, barium, and strontium content,^ while over time, the produced water will be more representative of the shale formation brine, potentially including elevated chloride, bromide, sodium, calcium, barium, strontium, and radium. This large waste stream, comprised of flowback and produced water, must be managed and is typically treated for reuse through filtration and minimal removal of dissolved salts, treated for discharge using industrial wastewater treatment methods that ought to remove contaminants to meet discharge permit requirements, or disposed of in a Class II Injection Well.

Class II Injection Wells are wells used for injection of liquid waste from oil and gas operations as defined in the Safe Drinking Water Act. In the Marcellus and Utica Shale region of PA, WV, and OH, the Injection Well infrastructure is available mostly in Ohio, so produced water is trucked long distances for disposal (Mantell 2011; Lutz et al 2013; Rodriguez and Soeder 2015). Injection wells have potential problems including induced earthquakes and wastewater migration following the path of undocumented abandoned wells (Justinic et al 2013; Keranen et al 2013; Kim 2013; Rodriguez and Soeder 2015). An alternative pathway for the chemicals in produced water is needed to reduce cost and environmental impacts of hydraulic fracturing.

The clearest application of produced water reuse is for source water for further hydraulic fracturing. This is often the fate of the Bflowback^ portion of produced water. There are several chemical limitations to this, but Mantell (2011) reports high potential for produced water reuse. High total dissolved solids will dictate the mixing ratios between freshwater and wastewater, while high total suspended solids must be filtered out in order to reduce friction. Sulfate can drive precipitation of barite, scaling a future well, or be metabolized by sulfate-reducing bacteria to create toxic hydrogen sulfide gas (e.g., Mantell 2011; Murali Mohan 2013; Macy et al 2015). Trucking and storage are other limitations that companies must overcome for direct reuse of produced water for hydraulic fracturing.

Beyond direct reuse, there have been failed attempts at land application of produced water that led to soil degradation and vegetation damage including a test application to 0.2 hectares of Fernow Experimental Forest in West Virginia in 2008 (Adams 2011). Land application in Fernow Experimental Forest led to death of over half of the trees in the test plot within 2 years, soil had elevated sodium and chloride concentrations that decreased over time and the author suggests that the application may have impacted organic matter cycling (Adams 2011). Some jurisdictions, including parts of Ohio, Pennsylvania, and New York, also allow use of oil and gas brine for road deicing, although this practice varies widely from place to place (e.g., Schlanger 2015). Typically, no pretreatment is required; however, regulations require a certain distance between an application site and waterways in recognition of the potential for migration of contaminants into water bodies through runoff (Schlanger 2015).

Treatment of produced water is a challenging field due to the high concentrations of total dissolved solids and the complex chemistry of the fluid; fluid composition varies spatially (Barbot et al 2013) due both to the initial composition of the hydraulic fracturing fluid and local geologic conditions. Desalination (Shaffer et al 2013), membrane technologies, and thermal technologies (Rodriguez and Soeder 2015) are all suggested treatment methods for produced water. Unpublished research conducted at Ohio University aims to sequentially treat produced water to extract saleable products from the waste stream (personal communication, Dr. Jason Trembly). This is a new and growing area of research to find reliable, low cost treatment technologies that are competitive with the cost of underground injection. Integrative management of hydraulic fracturing waste with water management and other system resource demands could be a step towards more environmentally sustainable energy.

Example 3: anaerobic digestion as an opportunity for integrating waste management across food, energy, and agricultural systems

Energy generation from diversified waste streams has many benefits relative to corn, the primary biofuel in the USA today. If bioenergy feedstock were instead sourced from wastes, there would be (1) savings in both land and energy requirements (for manufacturing fertilizer, cultivation, and harvesting), (2) reduced greenhouse gas emissions from soil disturbance, and (3) reduced costs of waste disposal. It is estimated that 254 million tons of municipal solid waste are generated in the USA annually, with only 34 % recycled into other products (EPA 2015). The cost of disposal is $50 per ton, amounting to a national cost of 8.4 billion dollars spent annually on disposal of 168 million tons of food, agricultural, and landscaping wastes (EPA 2015). These wastes could instead serve as feedstocks for anaerobic digestion (AD) to generate methane fuel (gas or liquid) identical to the natural gas that is extracted from underground deposits and consumed at a rate of 29 terajoules annually in the USA (EIA 2015).

The production of methane biogas using AD is not new technology, but has only recently been developed commercially in the USA following successful examples that have emerged throughout the world in the last few decades (Aslanzadeh et al. 2014; Mata-Alvarez et al. 2000). Traditional AD efforts are focused on processing human and animal biosolids and municipal wastewaters, but there is a growing body of literature on AD of food and plant-based waste products (Kiran et al. 2014; Mata-Alvarez et al. 2011; Zhang et al. 2007; Zhang et al. 2014). The establishment of dry AD as an alternative to slurry-based wet AD has also helped advance the potential of food and other solid waste materials as desirable substrates for biogas generation (Brown and Li 2013; Michele et al. 2015).

Codigestion, AD with mixed materials instead one uniform feedstock, is also gaining increased scientific attention because sorting and processing of raw waste materials is a major limitation for system sustainability and there is mounting evidence for increased biomethane potential during codigestion (Mata-Alvarez et al. 2011; Siddiqui et al. 2014). Optimizing complex codigestion remains a challenge because the highly variable feedstock encountered in practice at the commercial scale forgoes the possibility of using one set of precise conditions. Nevertheless, there are examples of commercial AD that use multiple waste streams simultaneously. With continued research in this area, there is tremendous potential for energy generation from waste.

By-products of AD can be used for fertilizer. Unlike other pathways for converting waste to fertilizer, like livestock waste (manure) applied to crops as organic fertilizer or composted food wastes used as soil amendments, the AD system produces energy as primary product. Another example of wastes from a bioenergy production system that is used for fertilizer is the nutrient-rich by-products of fermentation in sugarcane biorefineries that are recycled backed to fields where the crops are grown. Similarly to this example, effluent from AD is used to fertilize plants cultivated as feedstocks or for other purposes. The effluent can also be applied to field crops to replace the need for conventional fertilizers that are manufactured at a high energy cost.

Prototype systems are being tested for the efficacy of managing anaerobic digestion and hydroponic vegetable production in the same greenhouse, for example at Ohio University (Fig. 2). This system is developed as an off-grid greenhouse that is passively heated by solar energy and the heat from the digester. Rainwater collected on the roof of the greenhouse is used in the hydroponic system and to make the slurry in the anaerobic digestion system. Effluent from the digester is diluted and then added to the hydroponic solution as a fertilizer. This is perhaps the best example reviewed here of a closed-loop system that includes food, energy, and water: Energy in the form of biogas and heat is produced from waste, the by-product of this energy production is used as fertilizer to grow food, the structure that houses the energy and food production collects water that cycles through both the energy and food production systems, and the waste from the food production can be returned to the digester as a feedstock. The project at Ohio University aims to determine the scale that would be required for these systems to be completed closed-loop.

Developing the infrastructure for AD systems requires investment, but when considered in the context of savings that can be made in other sectors (agricultural and waste management), this investment can be offset by both environmental and economic returns. Management that considers waste,

Fig. 2 Inside view of pilot-scale AD research at Ohio University where digestion units and a hydroponics system are managed together in a glasshouse enclosure to purposefully capture the wastes from one system to be used for the other. Water for both systems is obtained through a rainwater collection system (not pictured) installed on the glasshouse

energy, and agriculture under one umbrella can improve efficiency and increase environmental benefits, moving systems that are currently costly and wasteful to a more closed-loop condition.

Example 4: reduced water consumption through integrated management of renewable energy in arid regions

The focus of advanced bioenergy development goals has moved away from lands that are used for food crops or native ecosystems, and more toward degraded, abandoned, and marginal lands (e.g., Somerville et al. 2010; Campbell et al. 2013). In these conditions, that are usually less ideal for agriculture, greater inputs are required unless crop species with traits specifically suited to the environment can be identified. In arid conditions, plants that use crassulacean acid metabolism (CAM) are adapted to thrive with very low water inputs. In the USA, where 77 % of water consumption is used to irrigate 6–14 % of cropland, mostly in drier climates, there are substantial benefits to exploiting CAM species in agricultural production instead of conventional crop species (Borland et al. 2009; Davis et al. 2011, 2014, 2015; Cushman et al. 2015).

Plants with CAM photosynthesis are increasingly recognized as potential crop species that can thrive in abandoned dry land agriculture because they take up carbon dioxide through stomata at night instead of during the day (e.g., Davis et al. 2014). The cooler nighttime temperatures allow reduced water loss from the plants relative to the water lost through evapotranspiration if stomata opened during the day, as most crop species do because of their reliance on C_3 or C_4 photosynthetic pathways. Reduced water loss leads to a lower water demand. With small amounts of irrigation, CAM species like those in the *Agave* genus can yield as much as other commercial crops that receive anywhere from two to ten times the water inputs (Davis et al. 2014, 2016). Given the amount of water used in agriculture in the arid USA, and the clear difference between common commodity crops and potential CAM crops, irrigation is wasting water that might otherwise be used for other purposes.

Arid regions are often also targeted for solar development because the low level of cloud cover maximizes the radiation available for conversion to electrochemical or heat energy, either through photovoltaics or thermal solar power plants. While these systems are efficient renewable energy generators with much lower greenhouse gas emissions than fossil fuel energy systems, there is substantial water required to clean dust from the solar panels and maintain optimum power production (Ravi et al. 2014). It has recently been calculated however that the co-management of solar panels and CAM crops for bioenergy could improve the efficiency of energy generated (Ravi et al. 2014). By using the waste water from washing the solar panels to irrigate (in small quantities) CAM plants grown side-by-side with the panels, both solar energy and biomass energy production are optimized (Ravi et al. 2014; Cushman et al. 2015).

Advanced bioenergy systems require careful consideration of land resources, competing land uses, ecological suitability, and crop tolerance to climate change. The need for renewable energy sources that reduce greenhouse gas must be weighed against the resource demands required for renewable energy production. An integrative management perspective would allow resources wasted by one system to be used to meet the demands of another, in effect closing the loop on waste. Resource inputs for agricultural systems that support bioenergy vary depending on the crop species and location where the crop is grown. The example of integrative management reviewed here works in arid ecosystems, but there are parallel opportunities for integrative management of agriculture and energy in any region.

Governance of integrated FEW systems: challenges and opportunities

The diverse examples provided above demonstrate how pollution and waste can be reduced by treating them as productive inputs, and eliminating needless inefficiencies with more inclusive technical and integrated approaches. The ability to realize these gains will however challenge current governance arrangements for FEW systems to achieve tighter feedback between waste and inputs, even though significant opportunities exist for improved system design. A recent study by the MacArthur Foundation and McKinsey (2014) suggests there is an estimated $4.5 trillion to gain in economic growth from altering the current structure where by-products are treated as waste to a closed-loop system in which materials are reincorporated into production processes. Understanding how current FEW systems have evolved to miss these opportunities and how redesign can close waste systems will require examining the governance arrangements which have incentivized current production, distribution, and waste management systems.

Governance as a field of study looks at how the institutional structures of public and private economies influence outcomes. It includes a broad array of social and natural sciences that examine how social coordination is achieved to produce and implement collectively binding rules and provide public goods (Risse 2011). Governance systems are composed of institutions, defined as the collection of both formal and informal rules used for determining inclusion in decision making, what actions can be taken, the consequences of these actions, and how individual actions are aggregated into collective decisions (Kiser and Ostrom 1982; Ostrom 1990). Institutions are what structure incentives and risk, the distribution of the benefits and costs of actions, and largely influence the sustainability of natural resource systems (Hanna et al. 1996; Ostrom 2008).[1] We highlight four critical aspects of the governance arrangements around FEW systems that are challenges to integration: property right institutions, policy design, long-term financing, and scale.

1. Property right institutions and resources

Central to any resource allocation system are property right institutions (Bromley 1991). Property rights determine the flow of both rights and benefits, as well as responsibilities and costs from the use of a resource. They are particularly important in the study of integrated FEW systems as they govern what is considered an economically useful component of a resource and what is considered waste. For example, property rights to mineral resources are associated with land rights which historically have led to the benefits from mineral extraction out-valuing the damage to land and water resources. Regulatory policies have now placed an additional cost and responsibility on mineral extraction in an attempt to internalize the costs of associated environmental damages; however, these regulatory costs occurred too late to deal with historic impacts, and while the rights to the economic benefits went to private owners, the responsibilities for the negative impacts were allocated to the public in terms of environmental clean-up.

Creating systems that better align rights with responsibilities and create incentives to recycle and reuse waste streams will require new property rights structures. Emerging initiatives toward closed-loop systems such as cradle-to-cradle production have created value in the waste stream as manufacturers (1) design materials that can be reused as raw material and (2) purchase end-of-life products from consumers via upfront contracts and rebate programs (Braungart and McDonough 2002; McDonough and Braungart 2013). Contractual arrangements with consumers for material that will be incorporated back into production has effectively allocated a new property right to the waste stream as raw material, and incentivized the allocation of material for reuse and recycling directly to the manufacturer through rebate agreements.

2. Policy design for closed-loop systems

Designing effective policy instruments to incentivize and facilitate closed-loop FEW systems will entail subtle changes to property rights and the associated responsibilities. Traditionally, the policy instrument used for internalizing externalities into production decisions has been regulations, which allocate a responsibility to minimize or prevent negative externalities in using natural resources by imposing a cost (Bromley and Paavola 2002). However, these first generation policy instruments have been critiqued as not providing a reason to go beyond mere compliance, not providing significant flexibility toward improved economic efficiency, and not generating incentive to develop new technologies, or in terms related to this discussion, create new integrative closed-loop production systems (Susskind et al. 2001; Kraft and Vig 2006). Research suggests that flexibility of market-based policy instruments are favorable over that of regulatory policies for (1) stimulating the innovation of new technologies, (2) incentivizing environmental behavior beyond mere compliance, and (3) reducing the economic inefficiencies associated with regulations (Gunningham et al. 1998; Stavins 2003).

If closed-loop production is to be successful, the next generation of environmental policy instruments will need to be designed to not only mimic markets as do cap-and-trade policies, but rather to directly stimulate new resource allocation systems that create value in what are today regarded as wastes. Policy design will need to generate new systems for reducing environmental and economic inefficiencies in production systems and reframe waste as a valued resource rather than a cost in production. An example of such a program is the recent Bfeebate^ program introduced in California in 2008 where high emissions vehicles are charged an additional fee that is used as a direct rebate for purchases of low emissions vehicles (Bunch et al. 2011). The emission waste is utilized as a disincentive for the purchase of high emissions vehicles and simultaneously provides a subsidy for the purchase of low/zero emissions vehicles. Similar programs have been proposed for landfill and waste management (Puig-Ventosa 2004).

3. Financing long-term investments

Many of the policy interventions needed to produce more efficient and effective closed-loop waste systems and tightly integrated FEW management will have to be directed at better aligning private and public interests in capital markets. Financial instruments are needed to invest and redesign infrastructure that allows integration across systems. The haphazard development of water, waste management, food system, energy production, and distribution infrastructures, including associated infrastructure for transportation and utilities, has not taken into consideration potential complementarity. Whereas waste disposal has traditionally been designed to move waste out of urban areas, integration into food and energy production will require new infrastructure investment options. For example, biogas production facilities that can utilize waste require site integration into regional plans, connection to energy supply grids, and locations on transportation

[1] Alternative approaches within the broad field of governance studies do exist, across the theoretical spectrum. This paper uses that within the positivist political economy tradition in order to focus on incentives that structure the reduction of negative economic externalities.

networks that can allow access to waste products (e.g., sewage facilities, food water, agricultural and landscape waste) rather than being isolated from the locations where wastes are produced and situated far from energy production and demand.

Existing capital markets are poorly suited for funding infrastructure and projects that can improve long-term resource efficiencies but that cannot be translated into short-term economic efficiency, increased revenue, or reduced risk (Labatt and White 2003). For example, bonds are associated with the jurisdictional entities that offer the backing to secure investment risk (municipalities, states, nations) and provide a poor fit to resource systems that cross jurisdictional divisions at a regional and even international level. The Water Infrastructure Finance and Innovation Act (WIFIA), a major source of funding for water infrastructure in the USA, has heavy federal oversight and is considered too inflexible for meeting the needs of green infrastructure and closed-loop financing. Green bonds, a relatively new financial tool, have been critiqued as being poorly linked to environmental outcomes and more about branding than actual impact (The Economist 2014). A new generation of financial instruments will be needed to improve infrastructure and promote projects that gain value from integration, instead of funding separate independent initiatives.

The risk burden for investments in FEW has a number of characteristics particular to the integrative nature of the desired systems. Financial instruments and incentives will need to take into account (1) how risk is managed by agricultural producers, (2) investors in the infrastructures needed to process and move waste materials, and (3) the incentives facing investors in both small-scale projects and large regional infrastructure. The importance of understanding risk is ubiquitous. For example, corn has emerged as the dominant biofuel crop due to the existence of multiple markets for the product and the ability of a farmer to use this as a hedge against risk in commodity price changes for any single market. Depending on demand, it can be sold for animal feed or as biofuel feedstock, as well as qualifying for federal farm subsidy programs (Demirbas 2008; Hochman et al. 2008).

Similarly, many production activities occur within a larger supply chain of multiple producers and suppliers interacting to manufacture a final product. Innovation is curtailed by limits on how an individual action will interact with other components of the system. For example, the ability of a producer to switch to alternative crops for biofuels will require more than a single buyer in the marketplace, otherwise producers subject themselves to the prices the buyer is willing to offer in a noncompetitive market, as well as price volatility from the supply chain of the buyer in using the stock for a biofuel, which may be subject to political uncertainty due to government subsidies and competing biofuel sources. In order to create incentives to cultivate alternative crops for a new market, the relative risk from entering these new markets will need to be offset. Private/public partnerships and policies that can explicitly support new technologies and bear the risk of innovation are beginning to enter policy discussions (see Leyden and Link 2015; Mazzucato 2013).

4. Scaling interventions

The level of risk associated with innovations in integrating waste in FEW systems will change with the scale of development. Trade-offs exist in the scale of the interventions intended to foster greater integration and feedback across the FEW sectors (Hill and Engle 2013). FEW systems exist at multiple spatial scales, from community and local government to state, regional, national, and international. What determines the appropriate scale of any policy intervention will depend on the size of three existing systems: natural (watershed, river basin, land), social (markets, communities, regional economies), and built systems (water infrastructure, energy grids, transportation network) relevant to the specific policy challenge (Wilson et al. 1999; Ostrom 2012).

Smaller scale interventions will tend to better fit local conditions while larger scaled innovations have the potential to achieve economies of scale and scope (Oates and Portney 2003; Kauneckis and Andersson 2009). In terms of environmental benefits, the regional scale (defined by climate and land use parameters) may grant the greatest overall gains due to regional differences in energy systems and hydrological regimes and food production; however, small scale (community level) systems allow for greater experimentation. Some combination of nested governance systems that recognizes the importance of local heterogeneity in natural systems, built infrastructure, and local preferences within large-scale systems of regulatory policy and national markets will certainly be necessary (Ferraro 2003; Adger et al. 2005).

One explicit trade-off in scaling systems is how to control Bleakage,^ the phenomenon of forcing environmental externalities outside the system of study. Local systems that close the loop on waste may simply lead to larger waste streams outside the system. A second major challenge with utilizing current research on scaling policy interventions is how to incorporate the networked nature of modern economies and global supply chains.

Closing the loop on waste in value chains at the FEW nexus

Closed loop systems provide an opportunity to decrease the environmental impact of waste by-products while improving efficiencies in the production cycle. Figure 3 represents the four examples (described above) of potential waste streams being incorporated as inputs back into energy, food, and water systems. Each figure uses a modified version of a closed-loop

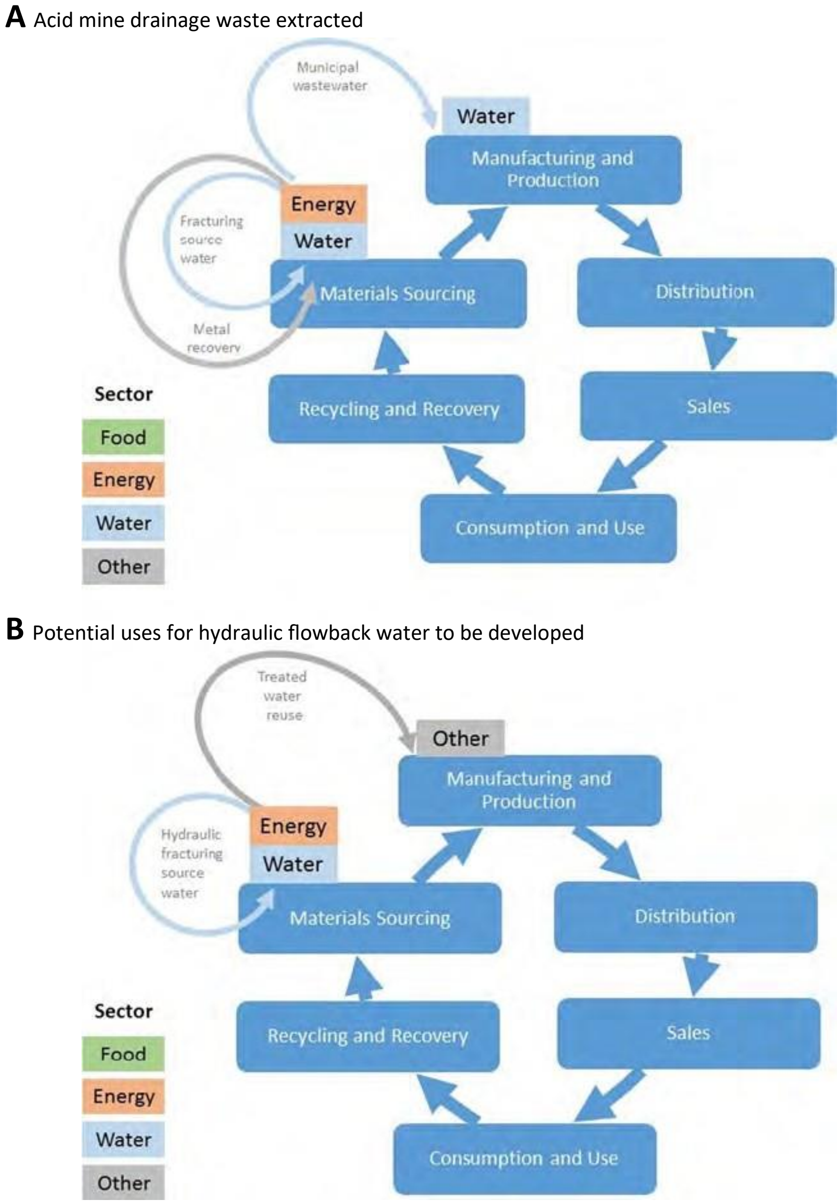
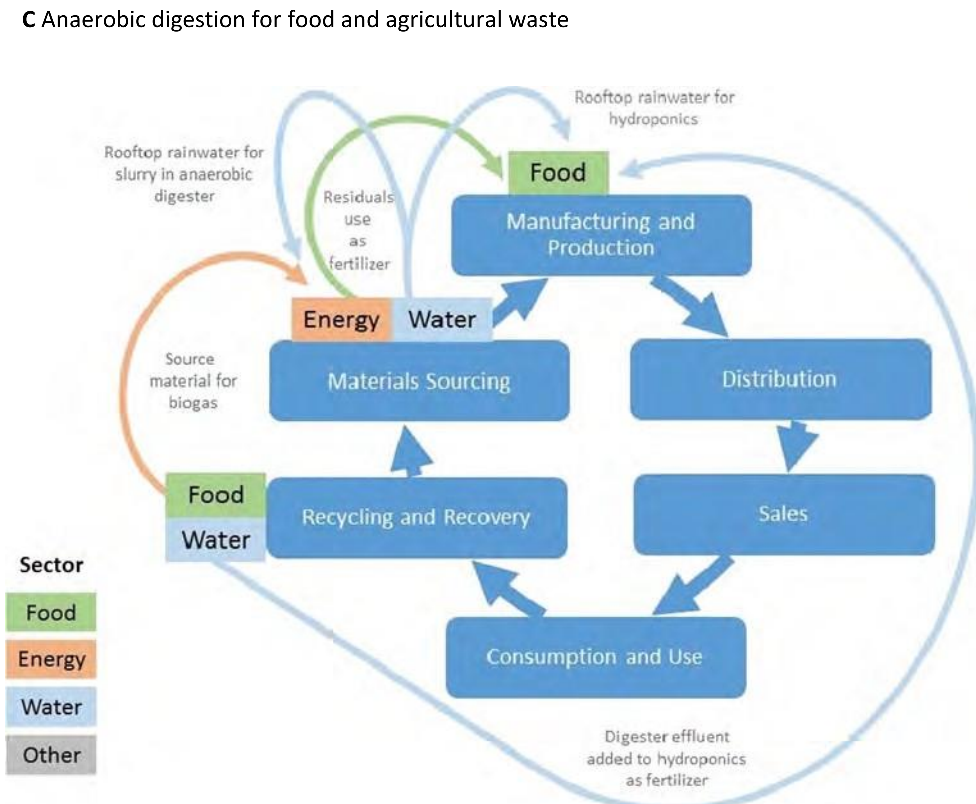


Fig. 3 Schematic of closed loop value chain for acid mine drainage (AMD) wastes (a), hydraulic fracturing flowback (b), anaerobic digestion (c), and crassulacean acid metabolism (CAM) plants for bioenergy on arid lands (d); each depicted in a life-cycle framework for closed-loop systems

value chain originally presented by the World Economic Forum (2009). There are six stages of the life cycle of a product: materials sourcing, manufacturing and production, distribution, sales, consumption and use, and recycling and recovery. While the examples discussed here primarily improve the material extraction and recycling/recovery stages, other waste products could be looped in to different stages of the life cycle. In order to illustrate interactions across FEW sectors, the sector in which the waste is produced is color coded and labeled in each figure, and the sector into which the waste product is being looped is color coded as food, energy, water, or other.

Figure 3a illustrates the potential loops of acid mine drainage wastes. The waste occurs at the nexus of energy and water in the materials sourcing phase of energy production from coal. The waste of AMD offers three potential loops back into production activities. These include the use of AMD in treating municipal wastewater, which uses a waste product from the energy sector directly as an input into the water sector. AMD is actively being explored for use in hydraulic fracturing as a water source. Finally, metal recovery from AMD has been used as a pigmentation material from a production cycle other than FEW.

Figure 3b represents the potential uses for waste water from hydraulic fracturing, both as re-usable source water for hydraulic fracturing activities and as treated water for reuse in other sectors. Both of which have significant technical



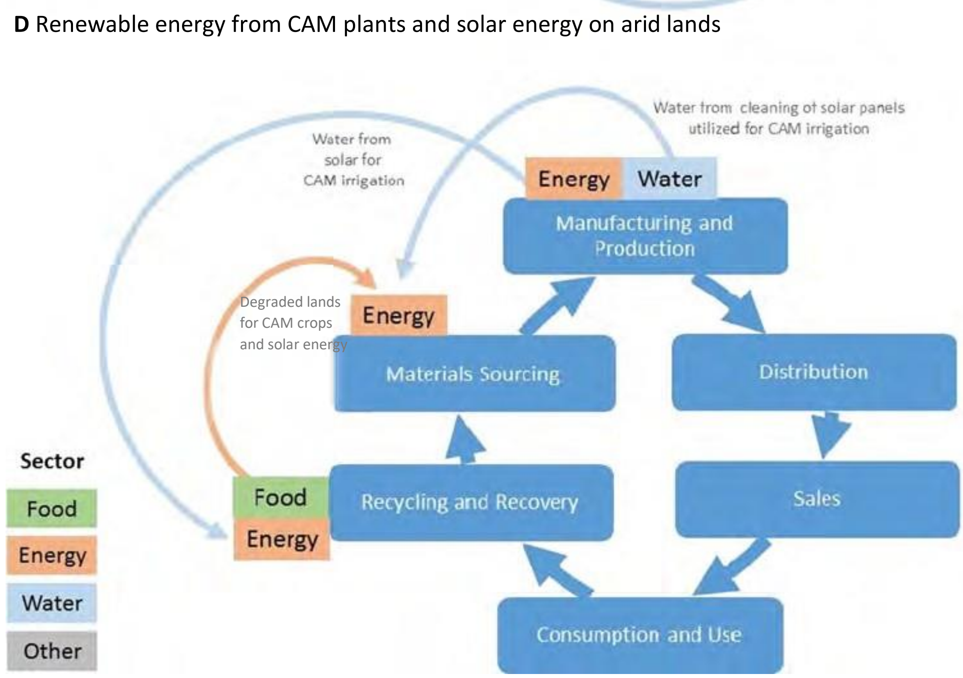


Fig. 3 (continued)

challenges in restoring water quality for either use. Solutions for waste reduction in this example have been the least developed. To contrast, anaerobic digestion systems by definition consume waste. Figure 3c shows how anaerobic digestion for the production of biogas links the food and energy sectors and reduces water consumption. Recycled food waste becomes source material for biogas production, and residuals from biogas can then be returned to the food system (or other agricultural production systems) as fertilizer. With integrative management of food and energy production in a greenhouse-like infrastructure (as depicting in Fig. 2), it is also possible to internalize water management and cycle water through both production systems (Fig. 3c).

Figure 3d includes the waste loops that can be accomplished through integrated renewable energy systems for arid regions. Degraded agricultural lands can be used for the growth of CAM crops that are then used for bioenergy production. This agricultural activity has the potential to replace agricultural systems with greater water input demands, reducing water consumption. Solar energy systems can be co-located CAM crops so that the water used in the maintenance of solar panels can provide the minimal irrigation needed for the crop. Additional value chains (not depicted) could be created through waste system loops in other phases of the life cycle.

Analyzing opportunities for closed-loop systems through a governance framework

Analyzing FEW systems through a governance framework is critical for understanding the potential of implementing emerging technologies and techniques. Challenges and opportunities for incorporating waste streams into and across FEW systems are globally common if locally specific, making this research widely applicable across a variety of scales and locations. Opportunities for integrated systems are often context-specific and depend on local conditions. The examples of AMD, biogas production, and the production of renewable energy on arid lands all involved local governance challenges.

When reviewing the example of AMD in light of the governance framework outlined here, a specific challenge for governance that would not necessarily apply in other examples emerges: how to assign responsibility for a legacy waste. AMD, a continuously generated waste that could have other uses, e.g., for pigment, phosphorus remediation, or fracturing water (Fig. 1), is the product of mining that occurred historically and the entities responsible are no longer liable in many cases. Neither is there any expectation of being able to end this waste stream. Coal mines are so extensive and continuous underground in the Appalachian Region for example that the source of the waste cannot be contained. Iron extracted from this waste may be a resource produced into the foreseeable future, but property right institutions and policy design will both require greater direct governmental and citizen involvement than cases where a manufacturer of waste can be directly involved. Long-term financing is essential and might be incentivized through economic stimulation associated with products. The scale of the resource in this case might be assumed as fixed if the current mining practices immediately remediate effects of new AMD under modern law.

In the case of biogas production that makes use of wastes from food systems and agriculture while yielding energy and fertilizer, governance issues are very different. The challenge for this system lies with unifying producers from economic sectors that have traditionally been isolated from one another. Contractually obligated property rights would incentivize the use of waste for value-added products. The Bfeebate^ approach would allow partnering manufacturers to save costs for waste disposal by offsetting the cost with a subsidy directly linked to the usage of waste. The scale of development in this case should be expected to change because biogas production is not yet widely practiced in the USA.

Renewable energy production on arid lands might face fewer challenges for governance due to public perception of problems related to drought in this region. In the western United States at least, there are already practical incentives for reducing water consumption. Water resources are expensive, creating clear opportunity for technologies with lower production costs. Here, awareness of the best alternatives and most beneficial partnerships would require policy design that promotes research.

Vision for integrated systems that close the loop on waste in FEW requires a governance framework that encourages dialogue among traditionally independent sectors of the economy. Creative solutions for converting waste to resources in a closed-loop infrastructure demand institutional frameworks that reward internalized waste management and partnering of manufacturers. Figure 3 summarizes how integrated systems can be used to minimize externalities and promote waste as a resource. Every opportunity for integrative management would benefit from research that targets optimized solutions for closed-loop infrastructure because solutions, and partners capable of achieving them, have not yet been clearly identified in many cases (e.g., hydraulic fracturing). Research can benefit from the interdisciplinary perspective offered here that links technological innovation to a governance framework that encourages progress toward harmonized environmental and economic sustainability.

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(For additional references, see original article by clicking here.)

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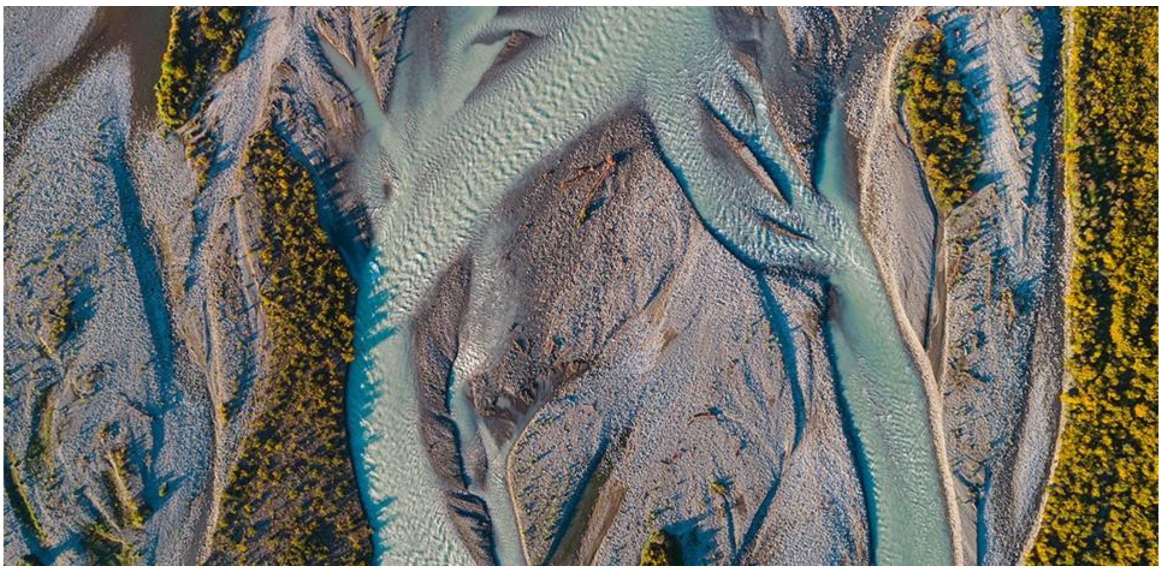
Carbon Sequestration

University of California – Davis, 2021

What is Carbon Sequestration?

Carbon sequestration secures carbon dioxide to prevent it from entering the Earth's atmosphere. The idea is to stabilize carbon in solid and dissolved forms so that it doesn't cause the atmosphere to warm. The process shows tremendous promise for reducing the human "carbon footprint." There are two main types of carbon sequestration: biological and geological.

What is Carbon?



In many ways, carbon is life. A chemical element, like hydrogen or nitrogen, carbon is a basic building block of biomolecules. It exists on Earth in solid, dissolved and gaseous forms. For example, carbon is in graphite and diamond, but can also combine with oxygen molecules to form gaseous carbon dioxide (CO2).

Carbon dioxide is a heat trapping gas produced both in nature and by human activities. Man-made carbon dioxide can come from burning coal, natural gas and oil to produce energy. Biologic carbon dioxide can come from decomposing organic matter, forest fires and other land use changes.

The build-up of carbon dioxide and other **'greenhouse gases' in the atmosphere can trap heat and contribute to climate change**.

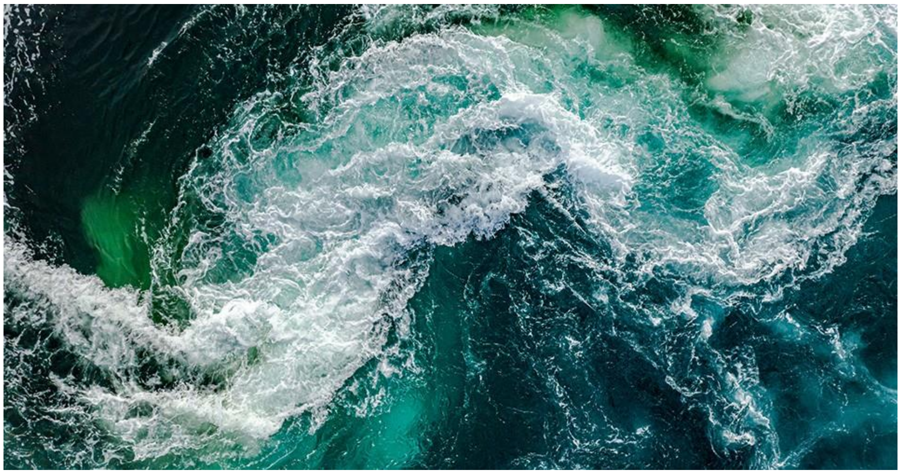
Learning how to capture and store carbon dioxide is one way scientists want to defer the effects of warming in the atmosphere. This practice is now viewed by the scientific community as an essential part of **solving climate change**.

Types of Carbon Sequestration

Biological

Biological carbon sequestration is the **storage of carbon dioxide in vegetation such as grasslands or forests**, as well as in soils and oceans.

Biological Carbon Found in the Oceans

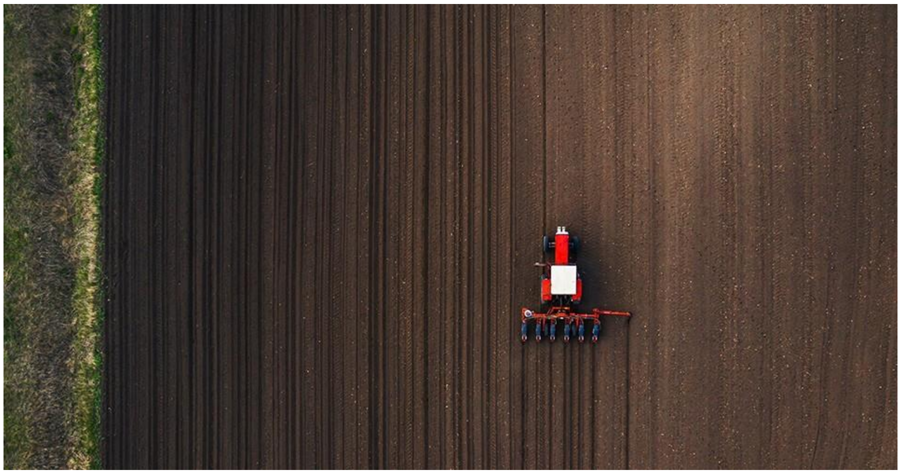


Oceans absorb roughly 25 percent of carbon dioxide emitted from human activities annually.

Carbon goes in both directions in the ocean. When carbon dioxide releases into the atmosphere from the ocean, it creates what is called a positive atmospheric flux. A negative flux refers to the ocean absorbing carbon dioxide. Think of these fluxes as an inhale and an exhale, where the net effect of these opposing directions determines the overall effect.

Colder and nutrient rich **parts of the ocean are able to absorb more carbon dioxide** than warmer parts. Therefore, the polar regions typically serve as carbon sinks. By 2100, most of the global ocean is expected to be made up of carbon dioxide, potentially altering the ocean chemistry and lowering the pH of the water, making it more acidic.

Biological Carbon Found in Soil



Carbon is sequestered in soil by plants through photosynthesis and can be stored as soil organic carbon (SOC). Agroecosystems can degrade and deplete the SOC levels but this carbon deficit opens up the opportunity to store carbon through new land management practices. Soil can also store carbon as carbonates. Such carbonates are created over thousands of years when carbon dioxide dissolves in water and percolates the soil, combining with calcium and magnesium minerals, forming “caliche” in desert and arid soil.

Carbonates are inorganic and have the ability to store carbon for more than 70,000 years, while soil organic matter typically stores carbon for several decades. Scientists are working on ways to accelerate the carbonate forming process by adding finely crushed silicates to the soil in order to store carbon for longer periods of time.

Biological Carbon Found in Forests

About 25 percent of global carbon emissions are captured by plant-rich landscapes such as forests, grasslands and rangelands. When leaves and branches fall off plants or when plants die, the carbon stored either releases into the atmosphere or is transferred into the soil. Wildfires and human activities like deforestation can contribute to the diminishment of forests as a carbon sink.

Biological Carbon Found in Grasslands

While forests are commonly credited as important carbon sinks, California's majestic green giants are serving more as carbon sources due to rising temperatures and impact of drought and wildfires in recent years. Grasslands and rangelands are more reliable than forests in modern-day California mainly because they don't get hit as hard as forests by droughts and wildfires, according to research from the University of California, Davis. Unlike trees, grasslands sequester most of their carbon underground. When they burn, the carbon stays fixed in the roots and soil instead of in leaves and woody biomass. Forests have the ability to store more carbon, but in unstable conditions due to climate change, grasslands stand more resilient.

Geological

Geological carbon sequestration is the process of storing carbon dioxide in underground geologic formations, or rocks. Typically, carbon dioxide is captured from an industrial source, such as steel or cement production, or an energy-related source, such as a power plant or natural gas processing facility and injected into porous rocks for long-term storage.

Carbon capture and storage can allow the use of fossil fuels until another energy source is introduced on a large scale.

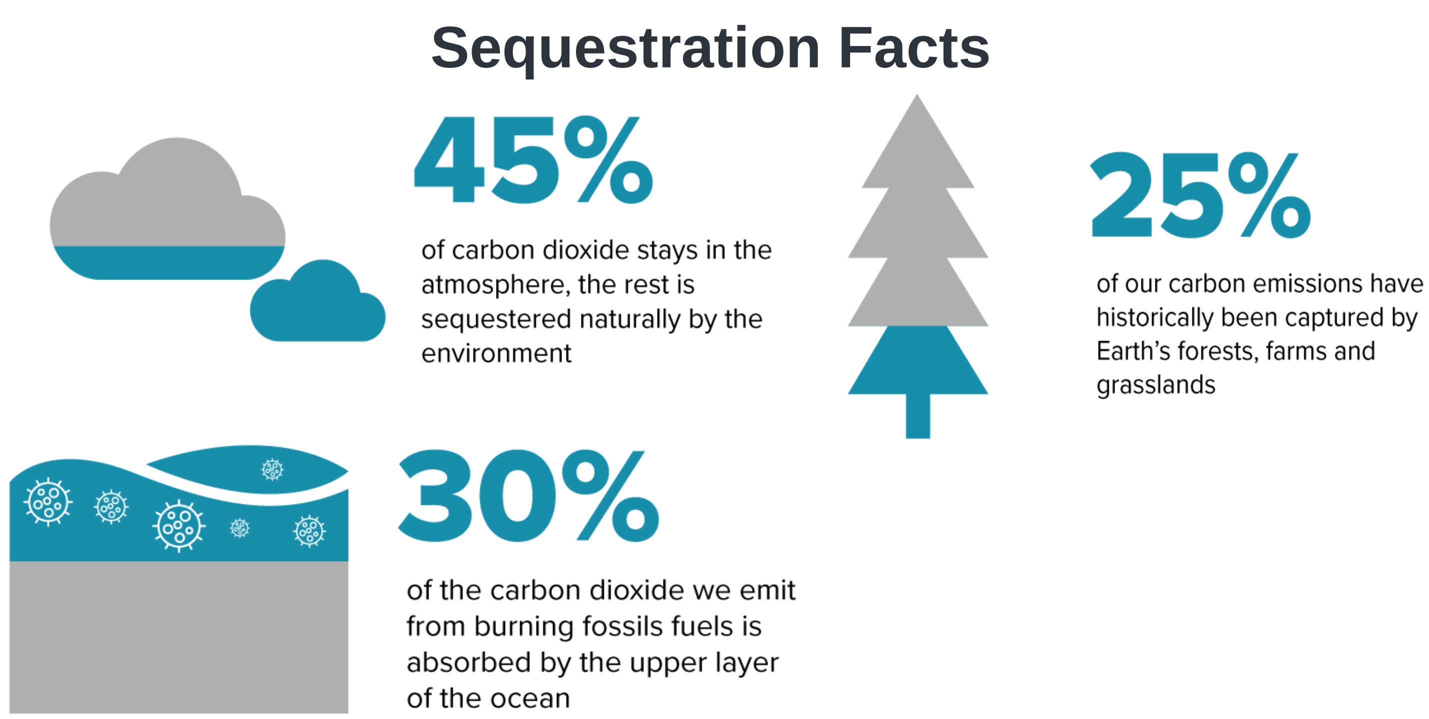
Technological

Scientists are exploring new ways to remove and store carbon from the atmosphere using innovative technologies. Researchers are also starting to look beyond removal of carbon dioxide and are now looking at more ways it can be used as a resource.

Graphene production: The use of carbon dioxide as a raw material to produce graphene, a technological material. Graphene is used to create screens for smart phones and other tech devices. Graphene production is limited to specific industries but is an example of how carbon dioxide can be used as a resource and a solution in reducing emissions from the atmosphere.

Direct air capture (DAC): A means by which to capture carbon directly from the air using advanced technology plants. However, this process is energy intensive and expensive, ranging from \$500-\$800 per ton of carbon removed. While the techniques such as direct air capture can be effective, they are still too costly to implement on a mass scale.

Engineered molecules: Scientists are engineering molecules that can change shape by creating new kinds of compounds capable of singling out and capturing carbon dioxide from the air. The engineered molecules act as a filter, only attracting the element it was engineered to seek.



The Future of Carbon Sequestration

Scientists are exploring **new ways to remove and store carbon** from the atmosphere using innovative technologies. Researchers are also starting to look beyond removal of carbon dioxide and are now looking at more ways it can be used as a resource.

Graphene production: The use of carbon dioxide as a raw material to produce graphene, a technological material. Graphene is used to create screens for smart phones and other tech devices. Graphene production is limited to specific industries but is an example of how carbon dioxide can be used as a resource and a solution in reducing emissions from the atmosphere.

Impacts of Carbon Sequestration

- **About 25% of our carbon emissions have historically been captured by Earth's forests, farms and grasslands. Scientists and land managers are working to keep landscapes vegetated and soil hydrated for plants to grow and sequester carbon.**
- **As much as 30% of the carbon dioxide we emit from burning fossils fuels is absorbed by the upper layer of the ocean. But this raises the water's acidity, and ocean acidification makes it harder for marine animals to build their shells. Scientists and the fishing industry are taking proactive steps to monitor the changes from carbon sequestration and adapt fishing practices.**

Closing The Loop: Waste-To-Energy Trends

Overflowing landfills and islands of garbage floating in the Pacific. Over reliance on non-renewable energy sources.

These two seemingly unrelated global problems have a shared solution: Convert the waste into energy.

Waste to energy (sometimes termed “energy from waste”) generally refers to the process of generating energy--electricity and/or steam from the combustion of non-reusable waste. Industrial waste, agricultural waste, municipal solid waste, and your garbage are all fodder.

These technologies can produce biogas, as well as synthetic and liquid biofuels, which can be converted into electricity. It won’t completely solve either the waste or energy problem, but it provides an important first step.

These evolving waste-to-energy trends are a larger movement toward **the circular economy**, in which materials are continuously repurposed until they are finally recycled. It’s a closed loop, hence the *circle*. Waste-to-energy focuses on that final step, recycling waste into energy.

Europe has been leading the way. Already, less than 1 percent of Sweden’s household waste ends up in landfills. The nation even *imports* garbage to turn into energy.

The most common waste-to-energy processes involve heat. Although these thermal-based processes are the dominant approach, one of the most interesting--and rapidly evolving--waste-to-energy trends *doesn't* involve heat; we'll start with that one.

Anaerobic Digestion

Anaerobic digestion produces a biogas (methane and carbon dioxide). The process can happen naturally or in a plant.

This approach has been particularly useful in the developing world, creating enough energy for cooking and lighting in homes. It's even used to run gas engines. China and India are among the leaders in this area.

It's starting to gain traction in the States, *Waste 360* reports. The focus is on food waste. In West Hartford, Conn., for example, about 130 homeowners participated in a 15-week food waste recycling pilot. Michigan State University processes up to 24,000 tons of food waste annually, generating 380 kilowatts of electricity per hour.

It's more than a novelty. Expect adoption to accelerate--perhaps dramatically. New**research** out of Cornell University has identified a way to make anaerobic digestion more feasible: Using hydrothermal liquefaction *before* anaerobic digestion could make the process more efficient and faster; what took days could soon take hours.

On another front, anaerobic digestion technology may soon be used to turn plastics into energy and fertilizer, reports ***Plastics News Europe***.

Anaerobic digestion is becoming increasingly common worldwide and some analysts, including those at Statistics MRC, predict significant growth rates--higher than those for thermal. But for now, thermal dominates.

Thermal Approaches, From Incineration to Depolymerization

The most common thermal approach is incineration, which uses waste as a fuel to ultimately make steam, which is then used to generate electricity. And although the term "incineration" conjures up images of smokestacks pumping toxic black smoke into the sky, current air emission standards require stack output to meet a 99.999% purity standard. Essentially, waste-to-energy recycling emits clean water vapor to the atmosphere.

Each year provides new technology breakthroughs. Among the latest are

Gasification, which involves the superheating of waste in an oxygen-controlled environment. Gasification converts waste into synthetic gas. (**Plasma gasification** does, too, but at much higher temperatures, using a plasma torch.)

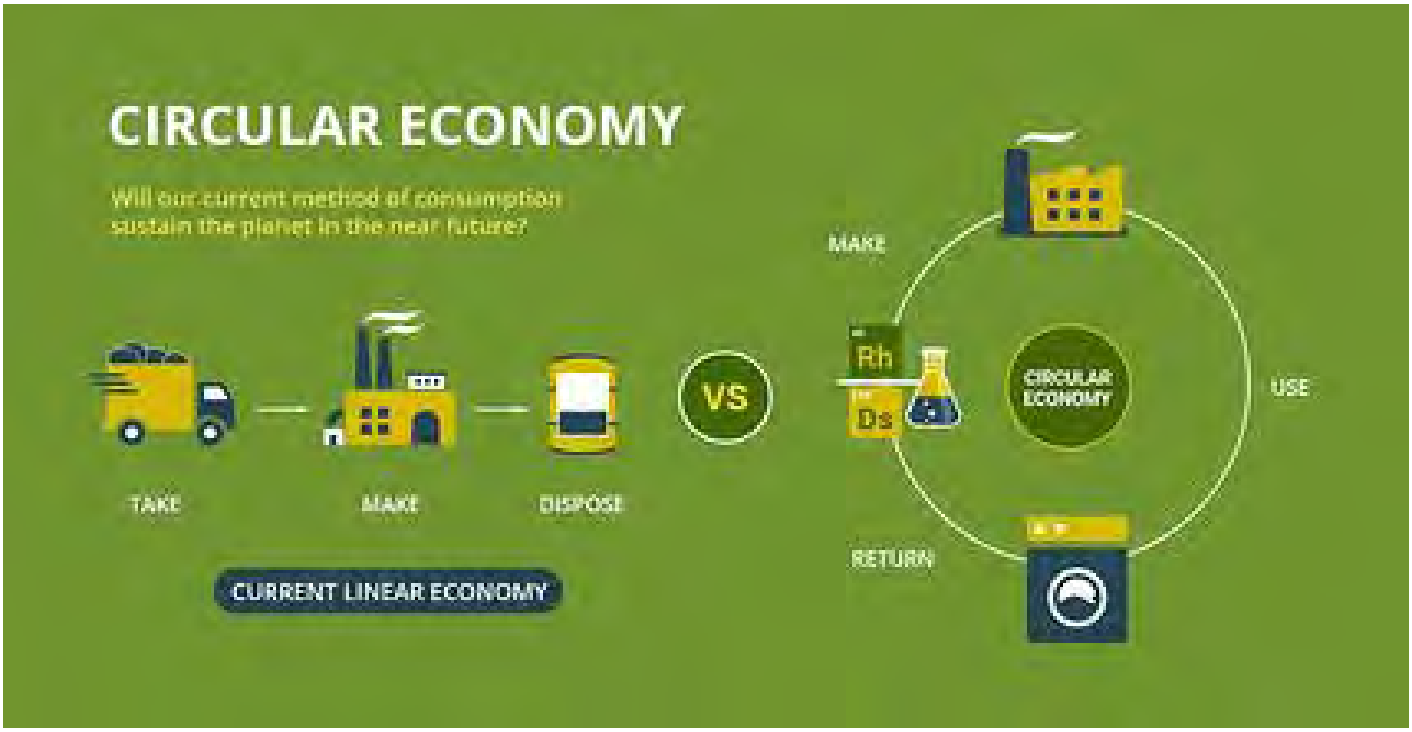
Pyrolysis is a form of gasification that occurs in an oxygen-free environment at lower temperatures than conventional gasification--generally under 750°F. The reaction produces a synthetic gas.

Thermal depolymerization breaks down various waste materials into crude oil products. The waste--the feedstock--is heated under pressure and turned to slurry; the oil is then separated from the water.

These processes can address a crucial problem: What do we do with plastics? Landfills are overflowing with plastic, and some can't be recycled due to contamination or other reasons. For example, plasticulture--plastics uses in agriculture--**often can't be recycled**. But they can be converted into energy through depolymerization and pyrolysis.

Moving Towards the Circular Economy

While waste-to-energy provides a seemingly limitless renewable and clean energy source, there is always an opportunity to reach higher.



Currently, in the United States, spent flammable liquids (industrial solvents) are a leading source of alternative fuel for kilns used in manufacturing cement………but there is a higher purpose available – cleaning the liquids and preparing re-use in industry……. extending the resource lifecycle.

At Temarry, we have created a system that allows us to take spent industrial solvents and recycle them. All waste received by Temarry is recycled, and nothing goes to landfill. Temarry is one of only a handful of facilities serving companies in the United States that recycles flammable liquids combining **solvent distillation** and a **waste-to-energy** in a closed-loop process.

Here's how the process works: Liquids (industrial solvents) are filtered and blended, then directed to a solvent recovery still.

We then take Industrial solid hazardous waste (typical solids that are compatible with the system are rags, organic debris, PPE, and absorbents which are almost always sent to landfills) which is thermally treated at 1500°F to generate steam that powers those stills. This is our waste-to-energy system.

2022 NCF-Envirothon Ohio

Current Environmental Issue Study Resources

Key Topic 5: Human and Animal Waste Treatment

1. Evaluate the differences between municipal waste treatment and home sewage treatmentsystems.
2. Compare and contrast the methods of waste treatment for human waste versus animalwaste.
3. Describe the impacts to ground and surface waters when fecal waste is not effectivelymanaged.
4. Identify innovative methods for managing fecal waste to lessen the impact to naturalresources.

Study Resources

Chapter 10: On-Site Wastewater Treatment – *Centers for Disease Control, 1932/2009 revision* (Pages 129-139)

Animal Manure Management – *USDA NRCS, 1995* (Pages 148-153)

<u>Study Resources begin on the next page!</u>

"Technology has made large populations possible;
large populations now make technology indispensable."

Joseph Wood Krutch, Author, 1932

Introduction

The French are considered the first to use an underground septic tank system in the 1870s. By the mid 1880s, two-chamber, automatic siphoning septic tank systems, similar to those used today, were being installed in the United States. Even now, more than a century later, septic tank systems represent a major household wastewater treatment option. Fully one-fourth to one-third of the homes in the United States use such a system [1].

On-site sewage disposal systems are used in rural areas where houses are spaced so far apart that a sewer system would be too expensive to install, or in areas around cities where the city government has not yet provided sewers to which the homes can connect. In these areas, people install their own private sewage treatment plants. As populations continue to expand beyond the reach of municipal sewer systems, more families are relying on individual on-site wastewater treatment systems and private water supplies. The close proximity of on-site water and wastewater systems in subdivisions and other developed areas, reliance on marginal or poor soils for on-site wastewater disposal, and a general lack of understanding by homeowners about proper septic tank system maintenance pose a significant threat to public health. The expertise on inspecting, maintaining, and installing these systems generally rests with the environmental health staff of the local county or city health departments.

These private disposal systems are typically called septic tank systems. A septic tank is a sewage holding device made of concrete, steel, fiberglass, polyethylene, or other approved material cistern, buried in a yard, which may hold 1,000 gallons or more of wastewater. Wastewater flows from the home into the tank at one end and leaves the tank at the other (Figure 10.1) [2].

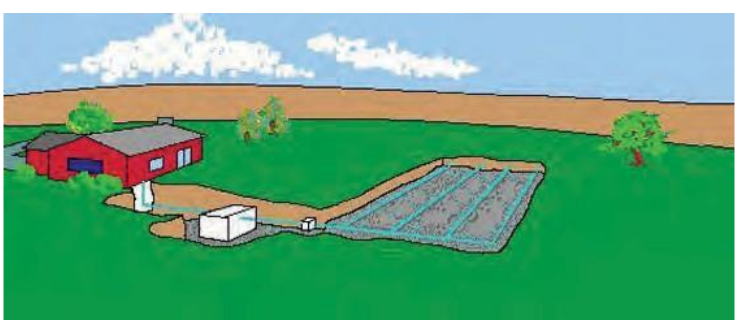


Figure 10.1. Conventional On-site Septic System [2]
Effluent leaves home through a pipe, enters a septic tank, travels through a distribution box to a trench absorption system composed of perforated pipe.

Proper maintenance of septic tanks is a public health necessity. Enteric diseases such as cryptospordiosis, giardiasis, salmonellosis, hepatitis A, and shigellosis may be transmitted through human excrement. Historically, major epidemics of cholera and typhoid fever were primarily caused by improper disposal of wastewater. The earliest epidemiology lesson learned was through the effort of Dr. John Snow of England (1813–1858) during a devastating cholera epidemic in London [3]. Dr. Snow, known as the father of field epidemiology, discovered that the city's water supply was being contaminated by improper disposal of human waste. He published a brief pamphlet, *On the Mode of Communication of Cholera*, suggesting that cholera is a contagious disease caused by a poison that reproduces in the human body and is found in the vomitus and stools of cholera patients. He believed that the main, although not only, means of transmission was water contaminated with this poison. This differed from the commonly accepted belief at the time that diseases were transmitted by inhaling vapors.

Treatment of Human Waste

Safe, sanitary, nuisance-free disposal of wastewater is a public health priority in all population groups, small and large, rural or urban. Wastewater should be disposed of in a manner that ensures that

- community or private drinking water supplies are not threatened;
- direct human exposure is not possible;
- waste is inaccessible to vectors, insects, rodents, or other possible carriers;
- all environmental laws and regulations are complied with; and
- odor or aesthetic nuisances are not created.

In Figure 10.2, a straight pipe from a nearby home discharges untreated sewage that flows from a shallow drainage ditch to a roadside mountain creek in which many children and some adults wade and fish. The clear water (Figure 10.3) is quite deceptive in terms of the health hazard presented. A 4-mile walk along the creek

Figure 10.2. Straight Pipe Discharge
Source: Donald Johnson; used with permission.

Figure 10.3. Clear Creek Water Contaminated With Sewage
Source: Donald Johnson; used with permission.

Epidemiology

John Snow, a London physician, was among the first to use anesthesia. It is his work in epidemiology, however, that earned him his reputation as a prototype for epidemiologists. Dr. Snow's brief 1849 pamphlet, *On the Mode of Communication of Cholera*, caused no great stir, and his theory that the city's water supply was contaminated was only one of many proposed during the epidemic.

Snow, however, was able to prove his theory in 1854, when another severe epidemic of cholera occurred in London. Through painstaking documentation of cholera cases and correlation of the comparative incidence of cholera among subscribers to the city's two water companies, he showed that cholera occurred much more frequently in customers of one water company. This company drew its water from the lower Thames, which become contaminated with London sewage, whereas the other company obtained water from the upper Thames. Snow's evidence soon gained many converts.

A striking incident during this epidemic has become legendary. In one neighborhood, the intersection of Cambridge Street and Broad Street, the concentration of cholera cases was so great that the number of deaths reached over 500 in 10 days. Snow investigated the situation and concluded that the cases were clustered around the Broad Street pump. He advised an incredulous but panicked assembly of officials to have the pump handle removed, and when this was done, the epidemic was contained. Snow was a skilled practitioner as well as an epidemiologist, and his creative use of the scientific information of his time is an appropriate example for those interested in disease prevention and control [3].

revealed 12 additional pipes that were also releasing untreated sewage. Some people in the area reportedly regard this creek as a source of drinking water.

Raw or untreated domestic wastewater (sewage) is primarily water, containing only 0.1% of impurities that must be treated and removed. Domestic wastewater contains biodegradable organic materials and, very likely, pathogens. The primary purpose of wastewater treatment is to remove impurities and release the treated effluent into the ground or a stream. There are various processes for accomplishing this:

- **Centralized treatment—**Publicly owned treatment works (POTWs) that use primary (physical) treatment and secondary (biologic) treatment on a large scale to treat flows of up to millions of gallons or liters per day,
- **Treatment on-site—**Septic tanks and absorption fields or variations thereof, and
- **Stabilization ponds (lagoons)—**Centralized treatment for populations of 10,000 or less when soil conditions are marginal and land space is ample.

Not included are pit privies and compost toilets.

Historically, wastewater disposal systems are categorized as water-carrying and nonwater-carrying. Nonwater-carried human fecal waste can be contained and decomposed on-site, the primary examples being a pit privy or compost toilet. These systems are not practical for individual residences because they are inconvenient and they expose users to inclement weather, biting insects, and odors. Because of the depth of the disposal pit for privies, they may introduce waste directly into groundwater. It should be noted that these types of systems are often used and may be acceptable in low-water-use conditions such as small campsites or along nature trails [4–6].

On-site Wastewater Treatment Systems

As urban sprawl continues and the population increases in rural areas, the cost of building additional sewage disposal systems increases. One of the prime reasons for annexation is to increase the tax base without increasing the cost of municipal government. The governments involved often buy into short-term tax gains at massive long-term costs for eventual infrastructure improvements to annexed communities. Installing septic tank systems is common to provide on-site disposal systems, but it is a temporary solution at best. Because property size must be sufficient to allow space for septic system replacement, the cost to the municipality installing a centralized sewer system will be dramatically increased because of the large lot size.

Two microbiologic processes occur in all methods that attempt to decompose domestic wastewater: anaerobic (by bacteria that do not require oxygen) and aerobic (by bacteria that require oxygen) decomposition. Aerobic decomposition is generally preferred because aerobic bacteria decompose organic matter (sewage) at a rate much faster than do anaerobic bacteria and odors are less likely. Centralized wastewater treatment facilities use aerobic processes, as do most types of lagoons. Septic tank systems use both processes.

Septic Tank Systems

Approximately 21% of American homes are served by on-site sewage disposal systems. Of these, 95% are septic tank field systems. Septic tank systems are used as a means of on-site wastewater treatment in many homes, both in rural and urban areas, in the United States. If maintained and operated within acceptable parameters, they are capable of properly treating wastewater for a limited number of years and will need both routine maintenance and eventually major repairs. Proper placement and installation is a key to the successful operation of any on-site wastewater treatment system, but septic tank systems have a finite life expectancy and all such systems will eventually fail and need to be replaced. Figure 10.4 shows a typical rural home with a well and a septic system.

Septic tank systems generally are composed of the septic tank, distribution box, absorption field (also known as the soil drain field), and leach field. The septic tank serves three purposes: sedimentation of solids in the wastewater, storage of solids, and anaerobic breakdown of organic materials.

To place the septic tank and absorption field in a way that will not contaminate water wells, groundwater, or streams, the system should be 10 feet from the house and other structures, at least 5 feet from property lines, 50 feet from water wells, and 25 feet from streams. The entire system area should be easily identifiable. There have been occasions when owners have paved or built over the area. The local health code authorities must be consulted on required distances in their area because of soil and groundwater issues.

Aerobic, or aerated, septic systems use a suspended growth wastewater treatment process, and can remove suspended solids that are not removed by simple sedimentation. Under appropriate conditions, aerobic units may also provide for nitrification of ammonia, as well as significant pathogen reduction. Some type of primary treatment usually precedes the aerated tank. The tanks contain an aeration chamber, with either mechanical aerators or blowers, or air diffusers, and an area for final clarification/settling. Aerobic units may be designed as either continuous flow or batch flow systems. The continuous flow type are the most commercially available units.

Figure 10.4. Septic Tank System [7]

Effluent from the aerated tank is conveyed either by gravity flow or pumping to either further treatment/ pretreatment processes or to final treatment and disposal in a subsurface soil disposal system. Various types of pretreatment may be used ahead of the aerobic units, including septic tanks and trash traps.

The batch flow system collects and treats wastewater over a period of time, then discharges the settled effluent at the end of the cycle [8].

Aerobic units may be used by individual or clustered residences and establishments for treating wastewater before either further treatment/pretreatment or final on-site subsurface treatment and disposal. These units are particularly applicable where enhanced pretreatment is important, and where there is limited availability of land suitable for final on-site disposal of wastewater effluent. Because of their need for routine maintenance to ensure proper operation and performance, aerobic units may be well-suited for multiple-home or commercial applications, where economies of scale tend to reduce maintenance and/or repair costs per user. The lower organic and suspended solids content of the effluent may allow a reduction of land area requirements for subsurface disposal systems.

A properly functioning septic tank will remove approximately 75% of the suspended solids, oil, and grease from effluent. Because the detention time in the tank is 24 hours or less, there is not a major kill of pathogenic bacteria. The bacteria will be removed in the absorption field (drain field). However, there are soils and soil conditions that prohibit the ability of a drain field to absorb effluent from the septic tank.

Septic tanks are sized to retain the total volume of sewage produced by a household in a 24-hour period. Normally a 1,000-gallon tank is the minimum size to use. State or local codes generally require larger tanks as the potential occupancy of the home increases (e.g., 1,250 gallons for four bedrooms) and may require two tanks in succession when inadequate soils require alternative system installation. Figure 10.5 shows a typical septic tank.

Distribution boxes are not required by most on-site plumbing codes or by the U.S. Environmental Protection Agency. When used, distribution boxes provide a convenient inspection port. In addition, if a split system absorption field is installed (two separate absorption trench systems), the distribution box is a convenient place to install a diversion valve for annually alternating absorption fields.

Absorption Field Site Evaluation

The absorption field has a variety of names, including leach field, tile field, drain field, disposal field, and nitrification field. The effluent from the septic tank is directed to the absorption field for final treatment. The suitability of the soil, along with other factors noted below, determines the best way to properly treat and dispose of the wastewater.

Most, but unfortunately not all, states require areas not served by publicly owned sewers to be preapproved for on-site wastewater disposal before home construction through a permitting process. This process typically requires a site evaluation by a local environmental health specialist, soil scientist, or, in some cases, a private contractor. To assist in the site evaluation process, soil survey maps from the local soil conservation service office may be used to provide general information about soils in the area.

The form shown in Figure 10.6 is typical of those used in conducting a soil evaluation.

Sites for on-site wastewater disposal are first evaluated for use with a conventional septic tank system. Evaluation factors include site topography, landscape position, soil texture, soil structure, internal drainage, depth to rock or other restrictive horizons, and useable area. If the criteria are met, a permit is issued to allow the installation of a conventional septic tank system. Areas that do not meet the criteria for a conventional system may meet less-restrictive criteria for an alternative type of system.

Many sites are unsuitable for any type of on-site wastewater disposal system because of severe topographic limitations, poor soils, or other evaluation criteria. Such sites

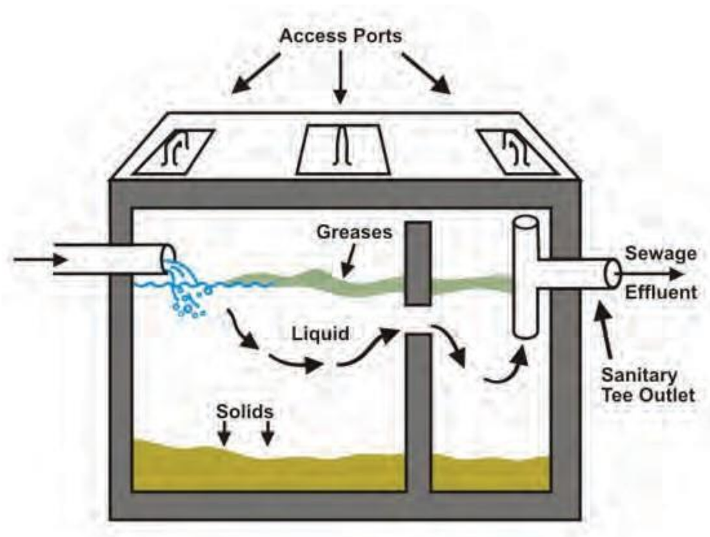


Figure 10.5. Septic Tank [9]

Sample On-site Sewage Disposal System Site Evaluation Form

Location ____________________ Application No. ____________________

Owners Name ____________________ Applicant's Name ____________________

Evaluation Factors	Proposed System Area	Alternative Area 1
1. Topography (slope percent)	S PS U	S PS U
2. Landscape Position	S PS U	S PS U
3. Soil Texture and Group	S PS U	S PS U
4. Soil Structure	S PS U	S PS U
5. Internal Soil Drainage	S PS U	S PS U
6. Soil Depth (inches)	S PS U	S PS U
7. Restrictive Horizons	S PS U	S PS U
8. Available Space	S PS U	S PS U
9. Overall Site Classification	S PS U	S PS U
10. Soil Series (if available)	S PS U	S PS U

S = Suitable PS = Provisionally Suitable U = Unsuitable

11. List site and/or system modifications or alternatives required for site approval and the specific area selected for the system. ____________________

12. Percolation test required Yes____ No____

Figure 10.6. On-site Sewage Disposal System Site Evaluation Form

should not be used for on-site wastewater disposal because of the high likelihood of system failure.

Some states and localities may require a percolation test as part of the site evaluation process. As a primary evaluation method, percolation tests are a poor indicator of the ability of a soil to treat and move wastewater throughout the year. However, information obtained by percolation tests may be useful when used in conjunction with a comprehensive soil analysis.

Absorption Field Trench

A conventional absorption field trench (Figure 10.7), also known as a rock lateral system, is the most common system used on level land or land with moderate slopes with adequate soil depth above the water table or other restrictive horizons. The effluent from the septic tank flows through solid piping to a distribution box or, in many cases, straight to an absorption field. With the conventional system and most alternative systems, the effluent flows through perforated pipes into gravel-filled trenches and subsequently seeps through the gravel into the soil.

The local regulatory agency should be consulted about the acceptable depth of the absorption field trench. Some states require as much as 4 feet of separation beneath the bottom of the trench and the groundwater. The depth of absorption field trenches should be at least 18 inches, and ideally no deeper than 24 inches. The absorption field pipe should be laid flat with no slope. There should be a minimum of 12 to 18 inches of acceptable soil below the bottom of the trench to any bedrock, water table, or restrictive horizon. The length of the trench should not exceed 100 feet for systems using a distribution box. Serpentine systems may be several hundred feet long and should be filled with crushed or fragmented clean rock or gravel in the bottom 6 inches of the trench. Perforated 4-inch-diameter pipe is laid on top of the gravel then covered with an additional 2 inches of rock and leveled for a total of 12 inches. A geotextile material or a biodegradable material such as straw should be placed over the gravel before backfilling the trench to prevent soil from clogging the spaces between the rocks.

One or more monitoring ports should be installed in the absorption area extending to the bottom of the gravel to allow measurement of the actual liquid depth in the gravel. This is essential for subsequent testing of the adequacy of the system.

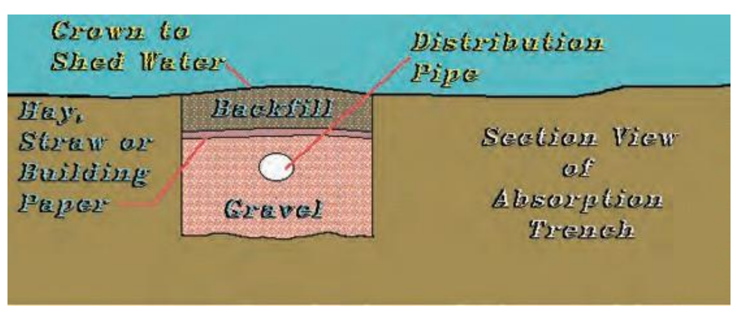


Figure 10.7. Cross-section of an Absorption Field [10]

As a general rule, using longer and narrower trenches to meet square footage requirements produces a better working and longer lasting ground absorption sewage disposal system. Studies have shown that as septic systems age, the majority of effluent absorption by the soil is provided by lateral movement through the trench sidewalls. Longer and narrower trenches (such as 400 feet long by 2 feet wide instead of 200 feet by 4 feet to obtain 800 square feet) greatly increase the sidewall area of the system for lateral movement of wastewater.

Alternative Septic Tank Systems

As the cost of land for home building increases and the availability of land decreases, land that was once considered unsuitable is being developed. This land often has poor soil and drainage properties. Such sites require a considerable amount of engineering skill to design an acceptable wastewater disposal system. In many cases, sites are not acceptable for seepage systems within a reasonable cost. These systems are primarily regulated by state and local government and, before use, approval must be obtained from the appropriate regulatory agencies. Even if a site is approved in one state or county jurisdiction, a similar site may not be approved in another.

The primary difficulty with septic tank systems is treating effluent in slowly permeable or marginal soils. Low-water-use devices, when installed, may make it possible to use a small percentage of septic tank systems in marginal soil. However, low-water-use devices are usually required as part of a larger effort to develop a usable alternative sewage disposal system. Alternative sewage disposal methods that can be used if regular subsurface disposal is not appropriate are numerous [11]. Some of the more common alternative systems are described below.

Mound Systems

A mound system (Table 10.1) is elevated above the natural soil surface to achieve the desired vertical separation from a water table or impervious material. The elevation is accomplished by placing sand fill material on top of the best native soil stratum. At least 1 foot of naturally occurring soil is necessary for a mound system to function properly. Minimizing water usage in the home also is critical to prevent effluent from weeping through the sides of the mound (Figure 10.8).

When a mound system is constructed, the septic tank usually receives wastewater from the house by gravity flow. A lift station is located in the second compartment or in a separate tank to pump the effluent up to the distribution piping in the mound. Floats in the lift station control the size of the pumped effluent dose. An alarm should be installed to alert the homeowner of pump failure so that repairs can be made before the pump tank overfills.

Low-Pressure Pipe Systems

Low-pressure pipe (LPP) systems may also be used where the soil profile is shallow. These systems are similar to mounds except that they use naturally occurring soil as it exists on-site instead of elevating the disposal field with soil fill material. LPP systems are installed with a trenching machine at depths of 12 to 18 inches. The LPP system consists of a septic tank, high-water alarm, pumping tank, supply line, manifold, lateral line, and submersible effluent pump (Figure 10.9).

When septic tank effluent rises to the level of the pump control in the pumping tank, the pump turns on, and effluent moves through the supply line and distribution

Advantages	Disadvantages
May be used in areas with high groundwater, bedrock, or restrictive clay soil near the surface	Must be installed on relatively level lots
Space efficient compared to conventional rock lateral systems	Periodic flushing of the distribution network is required
Allows home building in areas unsuitable for below grade systems	System may be expensive
Water softener wastes, common household chemicals, and detergents are not harmful to this system	System may be difficult to design
	Regular inspection of the pumps and controls necessary to maintain the system in proper working condition

Table 10.1. Mound System Advantages and Disadvantages

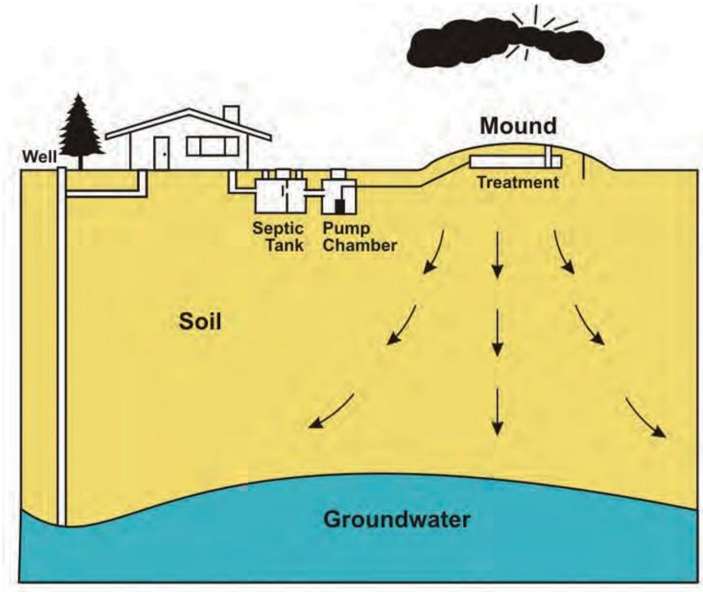


Figure 10.8. Mound System Cutaway [3]

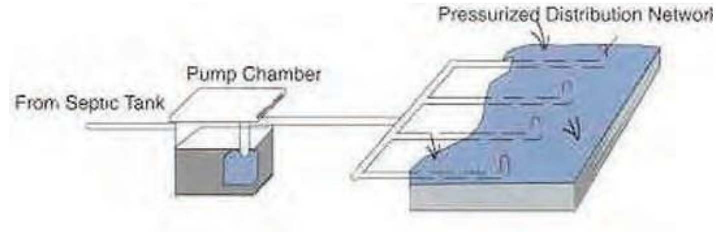


Figure 10.9. Low Pressure On-site System [12]

laterals. The laterals contain small holes and are typically placed 3 to 8 feet apart. From the trenches, the effluent moves into the soil where it is treated. The pump turns off when the effluent falls to the lower control. Dosing takes place one to two times daily, depending on the amount of effluent generated. Pump malfunctions set off an alarm to alert the homeowner. The time between doses allows the effluent to be absorbed into the soil and also allows oxygen to reenter the soil to break down solids that may be left behind. If the pump malfunctions, an alarm notifies the homeowner to contact a qualified septic system contractor. The pump must be repaired or replaced quickly to prevent the pump tank from overflowing. Table 10.2 shows the advantages and disadvantages of LPP systems.

Plant-rock Filter Systems (Constructed Wetlands)

Considered experimental in some states, plant-rock filter systems are being used with great success in Kentucky, Louisiana, and Michigan. Plant-rock filters generally consist of a septic tank (two-compartment), a rock filter, and a small overflow lateral (absorption) field. Overflow from the septic tank is directed into the rock filter. The rock filter is a long narrow trench (3 to 5 feet wide and 60 to 100 feet long) lined with leak-proof polyvinyl chloride or butylplastic to which rock is added. A 2- to4-inch-diameter rock is used below the effluent flow line and larger rock above (Figure 10.10).

Plant-rock filter systems are typically sized to allow 1.3 cubic feet of rock area per gallon of total daily waste flow. A typical size for a three-bedroom house would be 468 square feet of interior area. Various width-to-length ratios within the parameters listed above could be used to obtain the necessary square footage. The trenches can even be designed in an "L" shape to accommodate small building lots.

Treatment begins in the septic tank. The partially treated wastewater enters the lined plant-rock filter cell through solid piping, where it is distributed across the cell. The plants within the system introduce oxygen into the waste-

Advantages	Disadvantages
Space requirements are nearly half those of a conventional septic tank system	Some low-pressure pipe systems may gradually accumulate solids at the dead-ends of the lateral lines; therefore, maintenance is required
Can be installed on irregular lot shapes and sizes	Electric components are necessary
Can be installed at shallower depths and requires less topsoil cover	Design and installation may be difficult; installers with experience with such systems should be sought
Provides alternating dosing and resting cycles	
Installation sites are left in their natural condition	

Table 10.2. Low-pressure Pipe Systems Advantages and Disadvantages

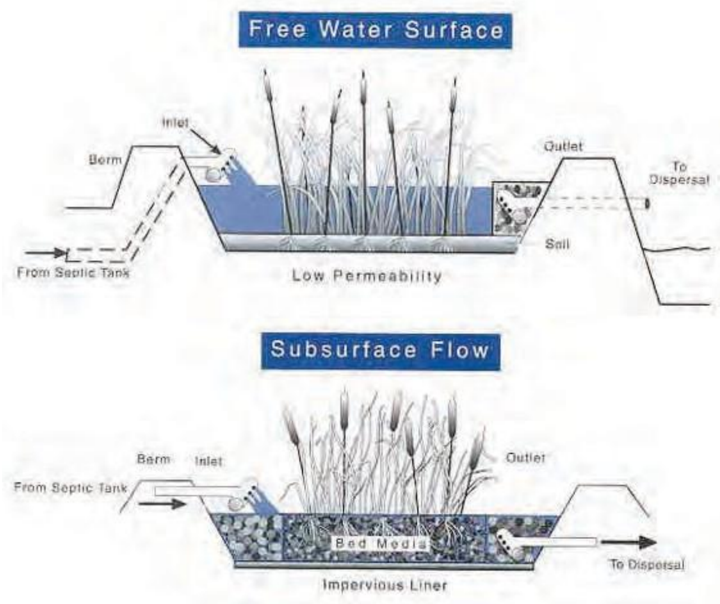


Figure 10.10. Plant-rock Filter system [12]

water through their roots. As the wastewater becomes oxygenated, beneficial microorganisms and fungi thrive on and around the roots, which leads to digestion of organic matter. In addition, large amounts of water are lost through evapotranspiration. The kinds of plants most widely used in these systems include cattails, bulrush, water lilies, many varieties of iris, and nutgrass. Winter temperatures have little effect because the roots are doing the work in these systems, and they stay alive during the winter months. Discharge from wetlands systems may require disinfection. The advantages and disadvantages of the plant-rock filter system are shown in Table 10.3.

Maintaining On-site Wastewater Treatment Systems

Do's and don'ts inside the house:

- Do conserve water. Putting too much water into the septic system can eventually lead to system failure. (Typical water use is about 60 gallons per day for each person in the family.) The standard drain field is designed for a capacity of 120 gallons per bedroom. If near capacity, systems may not work. Water conservation will extend the life of the system and reduce the chances of system failure.
- Do fix dripping faucets and leaking toilets.
- Do avoid long showers.
- Do use washing machines and dishwashers only for full loads.
- Do not allow the water to run continually when brushing teeth or while shaving.
- Do avoid disposing of the following items down the sink drains or toilets: chemicals, sanitary napkins, tissues, cigarette butts, grease, cooking oil, pesticides, kitty litter, coffee grounds, disposable diapers, stockings, or nylons.
- Do not install garbage disposals.
- Do not use septic tank additives or cleaners. They are unnecessary and some of the chemicals can contaminate the groundwater.

Do's and don'ts for outside maintenance:

- Do maintain adequate vegetative cover over the absorption field.
- Do not allow surface waters to flow over the tank and drain field areas. (Diversion ditches or subsurface tiles may be used to direct water away from system.)
- Do not allow heavy equipment, trucks, or automobiles to drive across any part of the system.
- Do not dig into the absorption field or build additions near the septic system or the repair area.

Advantages	Disadvantages
Approximately one-third the size of conventional septic tank absorption field systems	May be slightly more costly to install Disinfection required for effluent discharge
Can be placed on irregular or segmented lots	May not find installers knowledgeable about the system
May be placed in areas with shallow water tables, high bedrock, or restrictive horizons	Life span of the system is unknown because of its relative newness
Relatively low maintenance	Perception of being unsightly to some

Table 10.3. Plant-rock Filter System Advantages and Disadvantages

- Do make sure a concrete riser (or manhole) is installed over the tank if not within 6 inches of the surface, providing easy access for measuring and pumping solids. (Note: All tanks should have two manholes, one positioned over the inlet device and one over the outlet device.)

There is no need to add any commercial substance to “start” or clean a tank to keep it operating properly. They may actually hinder the natural bacterial action that takes place inside a septic tank. The fecal material, cereal grain, salt, baking soda, vegetable oil, detergents, and vitamin supplements that routinely make their way from the house to the tank are far superior to any additive.

Symptoms of Septic System Problems

These symptoms can mean you have a serious septic system problem:

- Sewage backup in drains or toilets (often a black liquid with a disagreeable odor).
- Slow flushing of toilets. Many of the drains will drain much slower than usual, despite the use of plungers or drain-cleaning products. This also can be the result of a clogged plumbing vent or a nonvented fixture.
- Surface flow of wastewater. Sometimes liquid seeps along the surface of the ground near your septic system. It may or may not have much of an odor and will range from very clear to black in color.
- Lush green grass over the absorption field, even during dry weather. Often, this indicates that an excessive amount of liquid from the system is moving up through the soil, instead of down, as it should. Although some upward movement of liquid from the absorption field is good, too much could indicate major problems.
- The presence of nitrates or bacteria in the drinking water well indicates that liquid from the system may be flowing into the well through the ground or over the surface. Water tests available from the local health department will indicate whether this is a problem.
- Buildup of aquatic weeds or algae in lakes or ponds adjacent to your home. This may indicate that nutrient-rich septic system waste is leaching into the surface water, which may lead to both inconvenience and possible health problems.
- Unpleasant odors around the house. Often, an improperly vented plumbing system or a failing septic system causes a buildup of disagreeable odors.

Table 10.4 is a guide to troubleshooting septic tank problems.

Septic Tank Inspection

The first priority in the inspection process is the safety of the homeowner, neighbors, workers, and anyone else for which the process could create a hazard.

- Do not enter septic tanks or cesspools.
- Do not work alone on these tanks.
- Do not bend or lean over septic tanks or cesspools.
- Note and take appropriate action regarding unsafe tank covers.
- Note unsanitary conditions or maintenance needs (sewage backups, odor, seepage).
- Do not bring sewage-contaminated clothing into the home.
- Have current tetanus inoculations if working in septic tank inspection.

Methane and hydrogen sulfide gases are produced in a septic tank. They are both toxic and explosive. Hydrogen sulfide gas is quite deceptive. It can have a very strong odor one moment, but after exposure, the odor may not be noticed.

Inspection Process

As sewage enters a septic tank, the rate of flow is reduced and heavy solids settle, forming sludge. Grease and other light solids rise to the surface, forming a scum. The sludge and scum (Figure 10.11) are retained and break down while the clarified effluent (liquid) is discharged to the absorption field.

Sludge eventually accumulates in the bottom of all septic tanks. The buildup is slower in warm climates than in colder climates. The only way to determine the sludge depth is to measure the sludge with a probe inserted through an inspection port in the tank’s lid. Do not put this job off until the tank fills and the toilet overflows. If this happens, damage to the absorption field could occur and be expensive to repair.

Scum Measurement

The floating scum thickness can be measured with a probe. The scum thickness and the vertical distance from the bottom of the scum to the bottom of the inlet can also be measured. If the bottom of the scum gets within 3 inches of the outlet, scum and grease can enter the absorption field. If grease gets into the absorption field, percolation is impaired and the field can fail. If the scum

Problem	Possible Cause(s)	Remedies
Wastewater backs up into the building or plumbing fixtures sluggish or do not drain well.	Excess water entering the septic tank system, plumbing installed improperly, roots clogging the system, plumbing lines blocked, pump failure, absorption field damaged or crushed by vehicular traffic.	Fix leaks, stop using garbage disposal, clean septic tank and inspect pumps, replace broken pipes, seal pipe connections, avoid planting willow trees close to system lines. Do not allow vehicles to drive over or park over lines. Contact local health department for guidance.
Wastewater surfaces in the yard.	Excess water entering the septic tank system, system blockage, improper system elevations, undersized soil treatment system, pump failure, absorption field damaged or crushed by vehicular traffic.	Fix leaks, clean septic tank and check pumps, make sure distribution box is free of debris and functioning properly, fence off area until problem is fixed, call in experts. Contact local health department for guidance.
Sewage odors indoors.	Sewage surfacing in yard, improper plumbing, sewage backing up in the building, trap under sink dried out, roof vent pipe frozen shut.	Repair plumbing, clean septic tank and check pumps, replace water in drain pipes, thaw vent pipe. Contact local health department for guidance.
Sewage odors outdoors.	Source other than owner's system, sewage surfacing in yard, manhole or inspection pipes damaged or partially removed, downdraft from vent pipes on roof.	Clean tank and check pumps, replace damaged inspection port covers, replace or repair absorption field. Contact local health department for guidance.
Contaminated drinking water or surface water.	System too close to a well, water table, or fractured bedrock; cesspool or dry well being used; improper well construction; broken water supply or wastewater lines. Improperly located wells must be sealed in strict accordance with state and local codes.	Abandon well and locate a new one far and upslope from the septic system, fix all broken lines, stop using cesspool or drywell. Contact local health department for guidance.
Distribution pipes and soil treatment system freeze in winter.	Improper construction, check valve in lift station not working, heavy equipment traffic compacting soil in area, low flow rate, lack of use.	Examine check valve, keep heavy equipment such as cars off area, increase water usage, have friend run water while away on vacation, operate septic tank as a holding tank, do not use antifreeze. Contact local health department for guidance.

Table 10.4. Septic Tank System Troubleshooting

is near the bottom of the tee, the septic tank needs to be cleaned out. The scum thickness can best be measured through the large inspection port. Scum should never be closer than 3 inches to the bottom of the baffle. The scum thickness is observed by breaking through it with a probe, usually a pole.

Figure 10.11. Sludge and Scum in Multicompartment Septic Tank [13]

Sludge Measurement

To measure sludge, make a sludge-measuring stick using a long pole with at least 3 feet of white cloth (e.g., an old towel) on the end. Lower the measuring stick into the tank, behind the outlet baffle to avoid scum particles, until it touches the tank bottom. It is best to pump each tank every 2 to 3 years. Annual checking of sludge level is recommended. The sludge level must never be allowed to rise within 6 inches of the bottom of the outlet baffle. In two-compartment tanks, be sure to check both compartments. When a septic tank is pumped, there is no need to deliberately leave any residual solids. Enough will remain after pumping to restart the biologic processes.

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Animal Manure Management

USDA NRCS, 1995

Did you know ...

...that the manure from a dairy milking 200 cows produces as much nitrogen as is in the sewage from a community of 5,000-10,000 people? Or that the annual litter from a typical broiler house of 22,000 birds contains as much phosphorus as is in the sewage from a community of 6,000 people?

...that any increase in animal numbers results in an equal increase in the problems arising from manure collection, storage, treatment, and utilization?

...that beef production in the United States decreased almost 15 percent between 1982 and 1992, while broiler production increased 59 percent and turkey production increased 62 percent, with a corresponding increase in manure and other residual materials?

Words are important!

Richard Kashmanian, in an editorial for BIOCYCLE, stresses the importance of words. He points out that words such as "wastes," "garbage," and "trash" send negative signals to readers or listeners and set in motion a sequence of events that is difficult to reverse.

The following definitions are taken from Webster's New Collegiate Dictionary: "Waste: garbage, rubbish, discarded as worthless, defective, or of no use." Dispose: "to get rid of." Various synonyms listed in Webster's New World Thesaurus for waste are "garbage, refuse, filth, litter, debris, and junk." Not very attractive!

Efforts are underway by various groups to change the vocabulary used to define their products or services. For example, the American Forest and Paper Institute is discontinuing the use of the term "waste paper" when referring to recycled paper. The Water and Environment Federation, formerly the Water Pollution and Control Federation, is using the term "biosolids" to refer to or define the largely organic material commonly called "sludges."

More and more, the agricultural sector recognizes that the reference to livestock manure as livestock "waste" has helped lead to the undervaluation of manure as a source of nutrients, the loss of manure nutrients through mishandling and misapplication, and the overapplication of manure to the land. Understanding that a term's use implies a value, the agricultural sector can replace the use of the word "waste" with "manure," "residuals," or "by-products."

What are organic by-products, and how are they quantified?

Organic by-products, or "wastes," of the livestock industry include a variety of materials such as solid and liquid animal manures, used bedding, spilled feed, and a variety of other substances. Most livestock-associated organic by-products are animal manures.

The amount and consistency of manures varies with animal type, climate, feed ration, animal age and health, and other factors. To compare manure production between animal types or between animals of the same type, manure production is expressed in terms of 1,000-pound animal units. For reference, a single dairy cow weighs about 1,400 pounds, or 1.4 animal units. A typical steer weighs about 1,000 pounds, or 1 animal unit, and most hogs weigh between 200 and 300 pounds, or 0.2 to 0.3 animal unit. A mature broiler, on the other hand, weighs between 4 and 5 pounds, so it takes as many as 250 birds to make up an animal unit.

Manure production and characteristics have changed over time. Livestock tend to be larger and thus produce more manure. Individual herds or flocks are generally larger, and production is tending toward geographic concentrations of specific kinds of animals, such as poultry in the Southeast. Confinement is the rule for most livestock and poultry.

The move to confinement has improved the quality of ration fed to the animals, increased the amount of manure produced, and changed the composition of that manure. For example, the typical daily nitrogen produced in the manure from a dairy cow has increased in the past 20 years from 0.37 pound per day per animal unit to 0.45 pound-an increase of about 20 percent. The increase in the nutrient content of manure, coupled with an increase in the size of the typical dairy animal, increases the potential for environmental degradation.

How much manure can actually be collected?

In the 1970's, Van Dyne of the University of Missouri and Gilbertson of USDA's Agricultural Research Service estimated the portion of livestock manures that could realistically be collected and managed. This "recoverable" manure, by their definition, was roughly equal to the amount of manure produced by livestock in confinement. A broader definition of recoverable manure is now used to account not only for the percentage of manure deposited in confinement, but also for the amount of manure deposited in confinement that can feasibly be collected and utilized.

Responses to a questionnaire completed by Natural Resources Conservation Service personnel as to the percentage of manure that could be feasibly recovered show some differences in recoverable manures from Van Dyne and Gilbertson, but no clear patterns were evident. It is believed that the major differences between the two surveys reflect the movement toward more confinement of all livestock types.

The departure from 100-percent-recoverable manure is largely related to the percentage of animals in confinement; however, location of the facility (climate), the area of confinement, and the methods used to collect the manure are also important factors. Only 90 to 95 percent of the manure can be recovered under the best of circumstances.

How much manure do different types of livestock produce?

Livestock type	Total manure	Nitrogen	Phosphorus
	------- lbs/day/1000-lb animal unit -------		
Beef[1]	59.1	0.31	0.11
Dairy[2]	80.0	0.45	0.07
Hogs and pigs[3]	63.1	0.42	0.16
Chickens (layers)	60.5	0.83	0.31
Chickens (broilers)	80.0	1.10	0.34
Turkeys	43.6	0.74	0.28

[1]High forage diet. [2]Lactating cow. [3]Grower.

Source: USDA Natural Resources Conservation Service. Agricultural Waste Management Handbook (1992)

Recoverable manure, by livestock type

Animal type	West	South Central	South	East	Midwest	Northern Plains
	Natural Resources Conservation Service Region					
	Percent					
Beef (grazing)	5	7	10	10	10	5
Beef (feeder)	85	80	75	85	75	80
Dairy (milker)	80	70	60	80	80	80
Dairy (other)	75	65	50	70	60	70
Hogs and pigs	85	80	65	80	70	75
Layers	90	90	90	95	95	95
Broilers	90	90	95	95	95	95
Turkeys	65	80	85	95	70	75
Sheep	35	35	50	15	35	30

Source: USDA Natural Resources Conservation Service, State animal manure survey.

What natural resource problems are associated with manure management?

Most confined livestock are fed a ration primarily produced offsite. In other words, the feed is brought to the confined animal enterprise, the animal product--whether meat, milk, or eggs--is removed, and the manure remains. The impact of this dislocation of manure from the production area of foodstuffs increases as animal enterprises are concentrated. Land for manure application at agronomic rates is often not available without prohibitive transportation costs, and the tendency to dispose of the manure (as opposed to using its nutrients) increases.
Grazing animals also contribute to natural resource problems when they are allowed access to water bodies. Animals with direct access to streams can degrade water quality partly by dropping manure directly into the water, and partly by destabilizing the streambanks and accelerating the loss of riparian corridor vegetation and buffer strips.

Unmanaged manure contributes nutrients, disease-causing micro-organisms, and oxygen-demanding organics to the Nation's waters. Nonpoint source pollution is recognized as the primary category of water pollution that is not yet controlled, and unmanaged animal manures contribute to nonpoint source pollution in most States.

Surface water pollution is not the only concern. Overapplication of animal manures to the land can degrade soil quality. Increases in nutrients such as phosphorus and potassium in the soil profile are undesirable and in some isolated cases can lead to problems in pasture situations. Excess manure salts in western soils decrease crop yields and can lead to the abandonment of some waste application sites.

Air quality can also be degraded. Historically, the singular air quality issue associated with livestock production was odors. Present concerns continue to focus on odors but include ammonia and methane emissions as well. Ammonia volatilization can contribute to elevated nitrogen in precipitation, which leads to excess nitrogen in water bodies and the acidification of soils. Methane has been identified as one of the primary contributors to the group of greenhouse gases linked to global climate change. Pork and dairy production facilities account for 80 percent of the methane emissions from manure.

What are the trends in manure production?

Trends in manure production mirror the trends in animal numbers. There was a significant increase in the production of poultry for meat in the 1982-92 period, a slight increase in swine numbers, and a general decline in other livestock types. These trends generally reflect changing patterns in demand for meat as a result of the American consumer's move to a healthier, leaner lifestyle.

As important as the increase in poultry numbers is the shift in locations of production, even for those livestock types that are declining in numbers. The changes within the dairy and swine industries are examples (see chart). Increases in dairy numbers in some States are more than offset by a general decline in dairy numbers in most other States, especially those in colder climates; States with declining swine numbers in the 1982-92 period include Florida (-60.3 percent), Georgia (-24.1 percent), and Missouri (-20.0 percent).

Animal population summaries: 1994

Livestock type	Population in 1994*	Change from 1984
	(Millions)	(Percent)
Beef	89.6	-5
Dairy cows and heifers	13.7	-5
Hogs and pigs	60.0	-12
Chickens		
--Layers	290.8	+5
--Broilers	7,017.5	+64
Turkeys	289.0	+69

*Data for dairy and swine as of January 1995.

Source: USDA National Agricultural Statistics Service

What can be done?

The Natural Resources Conservation Service continues to help livestock and poultry operators who voluntarily choose to manage livestock manures. Animal manure management is complex, combining physical aspects of nature such as rainfall, temperature, and soil characteristics; constructed features such as ponds and waterways; and a concerted management strategy to protect or enhance the ecological setting of the animal enterprise. Proper planning and installation of a manure management system open up opportunities for a variety of uses of manure as a source of energy, protein, and nutrients. No system is right or wrong for every situation, but the way manure is handled affects its value as plant nutrients or for other purposes. For example, manure can be kept dry and handled as solids or diluted and handled as liquids, depending on the operator's needs and capabilities. Liquid manure can be covered and anaerobically digested (decomposed in the absence of oxygen) to capture biogas-principally methane-for energy production. The same digestion process *uncovered*, however, releases the biogas (a common "greenhouse gas") into the atmosphere and loses nitrogen through ammonia volatilization. Keeping the manure dry reduces the opportunity for anaerobic digestion but increases the opportunity for the manure to be used as an animal feed supplement, as is being done with poultry litter as a supplement to cattle feed in the Southeast.

Natural Resources Conservation Service employees are guided in assistance to producers through technical standards contained in the Field Office Technical Guide. These practice standards describe the component or practice to be installed and specify the criteria to be used to ensure the quality of the overall system. Employees also have the 1992 *Agricultural Waste Management Field Handbook* to guide the planning and design of manure management systems. The handbook contains ready references to planning and design parameters and techniques.

Manure management systems encompass six functions: production, collection, storage, treatment, transfer, and utilization. Each function, or combination of functions, is addressed by components specifically designed to meet producers' manure management objectives.

Manure storage ponds or storage structures temporarily store manures or other by-products until they can be safely applied to the land or otherwise used. The storage facility and other appurtenances can be planned and designed to meet the objectives of the producer. Lagoons treat the manure and contaminated wash water, providing the opportunity for odor control and reducing the acreage needed for land application. Lagoons can be covered, which provides the opportunity for biogas capture and use.

Application of manures to cropland and pastureland provides nutrients for plant growth and improves soil tilth. This is by far the most common use of animal manures. The rate and timing of manure applications are key to the protection of soil, water, air, plant, and animal resources.

A typical dairy farm in the upper Midwest might have 50 to 100 milking cows. The herd is totally confined 6 months of the year, and during the remaining months spend part of each day in an earthen lot adjacent to the barn. Manure is collected daily from the barn by means of a tractor scraper. The semi-solid manure is scraped into a low-walled waste storage structure and applied to the land when it can be incorporated into the soil for plant nutrients. Liquids from the dairy, including wash water for milking equipment, are collected in a storage pond with a minimum 180-day storage capacity and applied to the land when the application fits into the overall management of the operation. Rainfall runoff from the earthen lots is also collected in the same storage pond. Clean water is diverted away from the earthen lot, and roof runoff from the barns is carried away from the waste storage facilities.

How does manure management help?

Manure management is as old as human history and as new as the latest adaptation of a time-honored practice. Proper manure management benefits the producer as well as the rest of the ecosystem.

Manure solids are being composted, often with urban residues such as leaves and grass clippings, to produce soil amendments high in organic-matter content. Lagoons are being covered to capture and use methane and other gases, reduce energy expenditures, control odors and methane emissions, and produce a manure product with nutrients that are more readily available for plant growth.

Application of manures to the land at the proper time-using proper management techniques and in proper amounts-recycles the nutrients through the soil profile, reducing the expense of commercial (inorganic) fertilizers as well as the need to add organic matter. Proper manure management improves water quality by preventing pollutants such as nutrients, organics, and pathogens from migrating to surface and ground waters. Soil quality is also improved through the addition of organic materials that improve soil tilth and increase the soil's water-holding capacity. Air quality also benefits from reduced emissions of methane and ammonia compounds, as well as reduced odors.

State Animal Manure Survey

The Natural Resources Conservation Service surveyed the States in 1994 to gain information on how State laws, rules, and regulations affected animal production and the generation, storage, and use of animal manures. Livestock classes considered in the survey were beef cow-calf, beef feeder, dairy cows and heifers, chickens, turkeys, and swine.

The 15-item questionnaire was directed primarily to NRCS State agronomists and State conservation engineers. Forty-one States responded to all or part of the survey. The questions on the survey were designed to maximize the information provided on the laws, rules, and regulations impacting manure management, and to gain as much information as possible about the types of systems used in each State for each livestock type.
The survey will be summarized in Section V of the nutrient portion of the Third Resources Conservation Act (RCA) Appraisal report. For more information, contact David C. Moffitt, environmental engineer, USDA, NRCS, Fort Worth, Texas, (817) 509-3315, or Charles Lander, Agronomist, NRCS National Headquarters, Washington, DC, (202) 690-0249.

In 1980, the owner of a 1,000-head sow farrow-to-finish operation in the West covered a portion of his existing lagoon to collect methane for on-farm energy applications. The collected methane now fuels a 75-kilowatt engine generator, and waste heat is used for space heat and grain drying. **The investment reduced annual operating costs at the facility by $36,000, providing a 34-percent annual rate of return.**

A 100,000-bird broiler producer in northern Florida discontinued all commercial fertilizer use 3 years ago on 150 acres of hayland. All plant nutrient needs are met by litter application. **The hay crop the past two seasons has been at record levels, while the level of nitrates in the shallow ground water has stabilized or declined.**

2022 NCF-Envirothon Ohio

Current Environmental Issue Study Resources

Key Topic Zero Waste /Circular Economy

1. Define Zero Waste and Circular economy
2. Explain the differences between Zero Waste and Circular Economy
3. Explain how zero waste can be integrated into everyday life
4. Explain how recycling fits into Zero Waste and Circular Economy.

Resources -

Zero Waste vs. Circular Economy- Your Guide to Getting in the Loop-Zero Waste

Recycling in Your Community web booklet

Study Resources begin on the next page! →

Zero Waste vs Circular Economy – Your Guide to Getting In the Loop

January 27, 2021
Blog|Business, Lifestyle

Source: timeout.com

Zero waste and circular economy concepts are often mixed up or used interchangeably. While they both have similar goals, they are two different models that take approaches towards sustainability, greenhouse gas emissions reduction, and ultimately, climate change.

The environmental impacts of our existing "take, make, waste" system is becoming more known that generating less waste through more efficient resource management is crucial to our efforts to reduce those impacts. However, where does the circular economy fit into this idea, and how does zero waste complement it?

Read on to learn about the concepts of zero waste and the circular economy, and how they work together for a cleaner and greener future.

What is zero waste?

The **Zero Waste International Alliance** (zwia.org) sums the concept up succinctly. Zero waste focuses on:

“the conservation of all resources by means of responsible production, consumption, reuse, and recovery of all products, packaging, and materials, without burning them, and without discharges to land, water, or air that threaten the environment or human health.”

The goal of zero waste is to design and manage the manufacturing and consumption of products in a way that minimizes waste and recovers as many resources as possible while keeping toxic substances out of the environment.

While the idea of conserving resources and recycling has been around for a long time, the **term ‘zero waste’ and the movement** as we know them today came about in the 1980s as people became conscious of how many resources were ending up in landfill.

What began as a grassroots effort to minimize landfilling and incineration, snowballed into changes in local government legislation and global law over the next few decades.

The buzz around zero waste has grown over the past decade, thanks in part to clear and measurable goals, and because it fits neatly into the sustainability zeitgeist, especially among consumers. This means that many companies have pledged to go “zero waste” by a certain date to show their commitment to sustainability.

However, it’s important to understand the fine print as some businesses are actually implementing **“zero waste to landfill”**. While eliminating waste through reduction, reuse, and recycling is still part of this goal, many operations take a shortcut with materials that are difficult or expensive to dispose of properly, and simply incinerate them instead, in what is called “waste-to-energy” disposal. This doesn’t meet the Zero Waste International Alliance’s definition of zero waste but still allows companies to make sustainability claims.

Another challenge with zero-waste implementation is the burden of properly recycling or reusing a product and its packaging is typically placed on the consumer.

What is a circular economy?

Imagine you have a garden where you plant a variety of fruits, vegetables, and herbs native to your region, along with flowers and plants that naturally repel local pests. To water this garden, you use only greywater from your sink or bathtub, or rainwater that you collect in barrels. When the food is grown and you've consumed it, you compost all garden and food waste putting it back into the ground to provide nourishment for the next growing season, using carefully-maintained tools that are repaired and reused year after year. This could be seen as a small circular economy.

At a simple level, the circular economy is a concept that champions the design of closed-loop systems and the circularity of resources, so that raw materials remain in the supply chain—or the loop as it is otherwise known. The **Ellen MacArthur Foundation**, a nonprofit that promotes the circular economy, defines it as a system that is:

"restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times. … It is a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows."

Circular economies eliminate waste through design by creating more efficient systems that account for the entire lifecycle of a product, ensuring that the waste that does occur is of as high a quality as possible so natural resources can be reused.

The **circular economy concept** first arose in the 1960s when ecologists, economists, and academics concerned with pollution and resource exploitation were discussing ideas related to closed and non-linear systems like those found in nature. These ideas stood in stark contrast to the existing linear economies that manufacturers and policymakers were keen to promote.

One well-known theory that influenced the circular economy is cradle to cradle thinking, originally coined by architect and industrial analyst Walter Stahel in 1976. This and similarly-related concepts—like industrial ecology, regenerative design, and biomimicry—gradually gained prominence in the 1980s and 90s, forming the circular economy framework as we know it today.

A circular economy makes use of many of the strategies we already employ to prevent waste, including reduction, repair, and recycling, while also looking to nature itself for clues to designing **feedback-rich systems** that are robust, adaptive, and promote sustainable functionality that allows **resources to regenerate**. It also emphasizes clean renewable energy and managed water systems to promote healthy ecosystems.

The word "economy" sounds big, but a circular economy can be a system of any size. A garden can be an example of a circular economy that fits in your backyard, while a **company that collects discarded fishing nets** from the ocean and recycles them into consumer products in a green and socially-responsible way has created a business based on the circular economy model.

The ultimate goal of the circular economy movement, however, is a system of a global scale, where we can primarily rely on resources we have already harvested, rather than ignoring recyclables and exploiting raw materials.

Zero waste vs. circular economy – What's the difference?

Source: TerraCycle

So zero waste and a circular economy do have some similarities. They both strive to right the wrongs of our current take-make-waste industrial and economic system, and to eliminate waste. But how are they different?

The differences between zero waste and a circular economy are best explained by looking at the principles of both ideas. Zero waste is guided by principles known as the **Zero Waste Hierarchy**, an inverted triangle that illustrates waste management in order of preference: Reduce through refusal or redesign, reuse and repair, recycle or compost, recover energy, and finally regulated disposal.

The circular economy model instead has **three main principles** that are more like pillars that work in tandem: designing out waste and pollution, keeping products and materials in use for the entire lifespan, and regenerating natural systems. While zero waste focuses on keeping waste out of the environment, a circular economy goes one step further by striving to regenerate the environment.

Another slightly more abstract way to think of it is that zero waste is a set of principles that guide us towards a goal, while a circular economy is a model that provides a systematic framework. We can also think of zero waste as a goal, and a circular economy as a means to get there.

In this way, we can see that these two concepts are different yet complement each other in multifaceted ways.

There are also practical differences in the way these two concepts are applied. Going back to the "zero manufacturing waste to landfill" issue, under the definition of zero waste, a company can claim that they have achieved this goal by making their processes more efficient and diverting from landfill through recycling and reuse.

They pass a certain amount of waste onto the consumer, for example, with single-use plastic bottles, which may then end up being incinerated or in landfill. If the company were to take this packaging back for reuse or remanufacturing, or if dedicated recycling systems were in place that redirected these resources back into the loop, then it could be said that they have contributed to a more circular economy.

Our role within a circular economy – Incorporating circular economies into daily life

For the general public and businesses in the US, it's a lot easier to incorporate zero waste principles into daily life than it is to construct a circular economy. While some of the methods involved—reduce, reuse and repair, and recycle—are a part of both, for the most part, it's not realistic for a single person or a family to develop their own circular economy.

Yet while economies happen on a larger scale than what occurs between our own "four walls", we as individuals are an essential part of them and have an important role to play in advancing the new business models that promote more circular approaches. We can, and of course should, reduce our consumption and reuse or recycle whenever possible, but how about borrowing and sharing too?

Source: Loop

Another tenet of the circular economy concept is selling services instead of things. This has a variety of applications, one of which is selling the rights to use goods, but not the goods themselves. You may already be familiar with this in the form of libraries or renting power tools for a home improvement project rather than buying them yourself.

There is also a growing number of local initiatives around the world aiming to wean humanity off single-use plastics by creating systems where reusable containers and packaging are rented. One great example is **the startup Loop**, which has partnered with major brands and supermarkets to offer popular products in reusable containers.

Anyone can even participate in a circular economy with goods already owned. Gadgets and technology are a great place to start: Why not get broken screens repaired locally? When it comes time to upgrade, **recycling old smartphones** or donating is an option instead.

Although the concept of a circular economy is indeed complex and difficult to tackle, unlike zero waste, there are still plenty of ways businesses and consumers can participate in and promote circular systems. Check out what kind of circular initiatives exist locally, or look into ways a **circular economy can be integrated into your business**. Alternatively, **subscribe to our blog** to stay in the loop and learn more about how you can use zero waste and circular economies to help build a more sustainable future.

Guidelines for Recycling in Your Community

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Bureau of Waste Management

Guidelines for Recycling in Your Community

This booklet is a simple guide to help residents and businesses understand recycling in Pennsylvania. The Pennsylvania Department of Environmental Protection (DEP) is committed to supporting successful recycling programs in local communities and encourages everyone to find ways to reduce their waste streams, reuse materials, recycle what they can, and properly dispose of what they must.

DEP has overseen Pennsylvania's statewide recycling program since 1988, when the Municipal Waste Planning Recycling and Waste Reduction Act, known as Act 101, took effect. Among other measures, Act 101:

- Requires larger municipalities to offer curbside recycling programs to residents and businesses*;
- Establishes a statewide fee on waste disposal to fund local recycling programs; and
- Requires each county to develop municipal waste management plans and update them every ten years.

While DEP administers the statewide program, in Pennsylvania, **all recycling is local!** Many Pennsylvania municipalities and counties manage local recycling programs, complemented by recycling services offered by private and non-profit organizations. Local recycling programs are all unique: The collection systems, acceptable materials, and local rules are all determined by the entity that operates the program.

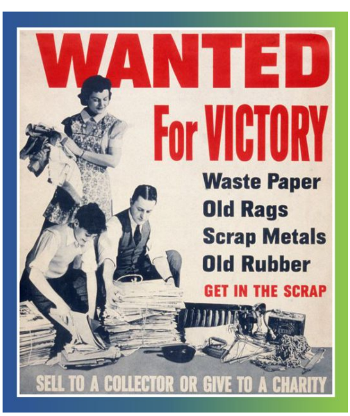
Factors that influence a recycling program include:

- The community's population size and density
- The mix and quality of waste materials generated
- Proximity to recycling markets (buyers for recycled materials)
- Funding and staffing levels available to operate recycling programs

While recycling programs in PA are locally controlled, they are all influenced by national and global trends. The sustainability of recycling programs in Pennsylvania requires regular adjustments to these local rules to meet the ever-changing needs of recycling markets.

This booklet will help you recycle the right way in PA by finding recycling programs in your area, learning your local rules, and following them. Read on for steps you can take to maximize the social, environmental, and economic benefits of recycling!

**Any municipality with a population greater than 10,000 residents must provide curbside recycling service. In addition, any municipality with a population between 5,000-10,000 residents and a population density of more than 300 residents per square mile must also provide curbside recycling service. These programs must collect at least three (3) materials from a list of eight (8) provided in Act 101. In addition, all mandated programs must collect leaf waste as defined under Act 101*.



Americans have been recycling since before the dawn of the modern environmental movement. During WWII, the federal government promoted recycling on the homefront as a way to help support the war effort and make good use of scarce materials.

Guide to Recyclable Materials

Learn to identify and prepare commonly recycled materials in PA to maximize your recycling and reduce costly contamination.

In Pennsylvania, under Act 101, larger municipalities must offer curbside recycling programs that accept at least three of the following eight categories of recyclable materials, along with leaf waste, as defined by Act 101.

Should you combine these materials or separate them? It varies based on the rules of your local recycling program or hauler. Whether you single-stream all materials into one bin, separate each into its own container, or some combination, remember: Learn your local rules and follow them!

Did You Know?

About 4 in 5 Pennsylvanians are served by municipal curbside recycling programs.

Recyclable	Commonly Accepted Items	Commonly Not Accepted Items
Aluminum	Aluminum cans	Scrap metal, car parts, appliances

Check if your program allows: Aluminum foil, pans, trays*

Other information: Local scrap dealers or landfill may accept more items*

Steel and Bimetallic (Tin) Cans	All cans other than aluminum	Scrap metal, car parts, appliances

Other information: Local scrap dealers or landfill may accept more items*

Plastics	#1-#7 rigid plastic containers	Shrink-wrap packaging, unnumbered plastic, toys

Check if your program allows: Check with your local program for what they accept*

Other information: Local retail and grocery stores may accept plastic bags*

Clear Glass	Clear glass bottles and jars	Broken glass, glassware, window panes, mirrors, light bulbs
Colored Glass	Green, brown, blue, or other color glass bottles and jars	Broken glass, glassware, window panes, mirrors, light bulbs
High-Grade Office Paper	Standard white printer/computer paper	Heavily soiled papers, or papers with bindings or clips attached

Check if your program allows: Unwanted mail, stationary, mixed papers*

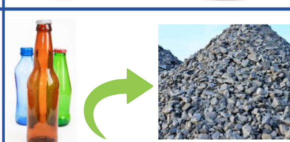
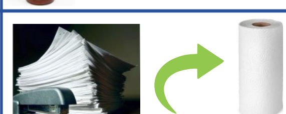
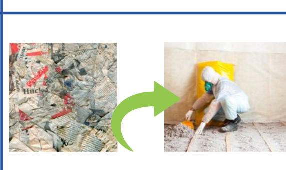
Newsprint	Newspapers, including advertising inserts	Soiled newsprint

Check if your program allows: Unwanted mail, magazines, other paper products*

Corrugated Paper (Cardboard)	Corrugated boxes (cardboard with alternating ridges/grooves)	Soiled containers, such as greasy pizza boxes

Check if your program allows: Smooth cardboard such as cereal boxes*

*For additional information contact your County Recycling Coordinator (see page 11)

How to Identify/ Prepare	Transforms into these Recycled Products	
Aluminum items will not stick to a magnet	Bicycle frames, window frames, appliances, computer parts, new beverage cans	
Steel and bimetal items will stick to a magnet	Steel beams, rebar, car parts, appliances, new food and beverage cans	
Look for recycling triangle with plastic # on bottom of con-tainer; only include plastics accepted by your recycling program	Plastic lumber, carpet, fleece clothing, backpacks, toys, insulation, new plastic containers	
Separate clear glass from other colors if required by local program	Fiberglass, road aggregate, new bottles and jars	
Separate glass by color if required by your local program	Fiberglass, road aggregate, new bottles and jars	
Stapled papers are usually acceptable	Tissues, paper towels, toilet paper, new computer and notebook paper	
Rain-soaked newspapers can be recycled once dry	Building insulation, sheetrock, countertops, cat litter, egg cartons, newspapers, ceiling tiles	
Break down cardboard boxes flat to dimensions required by local program	Paper bags, paper towel rolls, new cardboard containers	

***Rinse clean all metal, glass and plastic containers.**

Frequently Asked Questions & Common Misconceptions

Q: What harm could it do to put my single-use plastic bag in the bin that says no plastic bags, for example? Won't they have to just recycle it anyway?

A: Sending non-recyclable materials to your local recycling program contaminates the material stream. This is called “wish recycling” or “aspirational recycling.” Your single-use plastic bag, also known as “film” to the recycling industry, will NOT be recycled. Instead, a worker will likely remove your un-recyclable item at the sorting facility, slowing down the process and increasing the cost to run the recycling program. It may get caught and jam up or damage recycling equipment. Picture hair wrapped around a vacuum cleaner roller, but on machinery so big that a worker has to walk inside it to fix it.

If your plastic bag isn't caught and removed, it can result in the entire load of recyclable materials being rejected by the buyer and landfilled instead. Buyers of recycled material streams have lowered the thresholds for allowable contamination in recent years, making each consumer's actions to properly sort and clean recyclable materials even more vital to the success of a recycling program.

Also, don't put recycled materials in bags unless your municipality allows it.

Remember: **When in doubt, leave it out!** Even one bad decision can spoil everyone's recycling efforts.

Q: I've visited places where I could recycle items that I can't recycle at home. Why can't we just recycle everything, everywhere?

A: For a material to be recyclable, there must be a demand for the material and a cost-effective way to transport and transform it into a new product. Many recycling programs struggle to find markets for certain materials, so they must limit their programs to accepting what they can recycle without significant financial loss. Some communities can accept a wider array of recyclable materials because they are closer to recycling markets, have specialized sorting equipment, or have made a conscious decision to subsidize their recycling programs.

Whether traveling or at home, always pay attention to signage and follow the local recycling rules.

Q: Why do recycling programs change the rules about what can be recycled, what can be combined or separated, etc.?

A: Local rules for recycling are often changed when a modification is made to the recycling program's equipment, such as bins, trucks, or sorting machinery. Sustaining a local recycling program also requires regular adjustments to the rules to meet the ever-changing needs of recycling markets. The demand for recyclable materials continuously responds to national and global industry trends, economic fluctuations, and changing consumer preferences. Your local recycling program must periodically change its rules to adjust to these forces.

Q: What should I do with a heavily soiled but otherwise recyclable item?

A: If a recyclable item can be easily cleaned at home, rinse it and put it in the bin. But if an item is heavily soiled, trying to clean it may waste water and energy, eliminating any environmental benefit of recycling it. Some dirty items can't be cleaned at all, even in commercial recycling facilities (for example, paper and cardboard that is saturated with oil).

Heavily soiled recyclables threaten to foul the entire load, which could cause it to be rejected and sent to the landfill instead. So if your pizza box is stained with grease, you spilled coffee on the newspaper, or that peanut butter won't stop clinging to the jar, throw it away with a clear conscience.

Q: Why do recycling programs cost money? Shouldn't it be free?

A: Recycling is just another method to handle unwanted materials, and it is not free. When items can be recycled into new products, it's better for the planet and your community. However, there are many costs associated with the process of recycling, from the point of collection to the creation of a new product. These costs include maintenance of drop-off facilities and trucks; cleaning, sorting, storing, and transporting recyclable materials to markets; processing those materials into new products; and more. Some recyclable materials are in higher demand by recycling markets because they cost less to recycle than to create from new raw materials, but in other cases, the reverse is true. Local communities have a vast array of scopes and costs for their recycling programs, determined by applicable regulations and the needs of residents.

Q: How do I know what I put in the recycling bin is actually being recycled?

A: In Pennsylvania, it's illegal to dispose of source-separated recyclable materials in a landfill. If you suspect a waste hauler or anyone else is improperly disposing of recyclables, call your regional DEP office and file a complaint. All complaints are investigated and will be kept confidential.

Q: I can't recycle much or anything where I live. I want to. Is it illegal to drop off my recycling in a nearby municipality?

A: Contact the operator of the recycling program where you wish to drop off materials. They can advise you on their local rules. If recycling drop-off facilities are limited to residents of a certain county or municipality, please do not violate their rules. It could be prosecuted as illegal dumping.

Other Tips To Reduce Waste

- **Buy Recycled:** Look for products made with recycled materials when you shop, to help create a market for recyclable materials.
- **Reduce, Reuse, and then Recycle:** Reduce your waste stream by making thoughtful decisions about what you buy and reusing what materials you can, to minimize what you recycle or send to landfills.

Questions to ask yourself when making a purchase:

-Was this product made from recycled content?

-Is the packaging or container recyclable?

-Does this item contain environmentally friendly ingredients?

-Do I need to take a bag for this purchase?

-Can I buy this item in bulk?

- **Think Recycling Beyond the Kitchen:** Recyclables generated in other areas of the house, such as shampoo bottles in your bathroom or papers in your home office, are often cleaner than food containers, but these can be forgotten. To encourage a comprehensive recycling habit, keep a marked recycling bin on each floor or section of the house. It will be more convenient to carry recyclables to a central collection point in the kitchen or garage.

- **When in Doubt, Throw it Out:** If you're not sure something is recyclable, the best choice is to throw it in the trash. This eliminates potential contamination of recyclable materials, which could cause a much greater increase in unnecessary waste than just trashing your borderline item.
- **Pennsylvania Recycles!** Pennsylvania recycles approximately 7 to 8 million tons of resources each year. This cuts 10 million tons of carbon dioxide emissions from the air (equal to taking 2 million cars off the road) and saves enough electricity to power 1.5 million homes.

  Did you know that about 19 out of 20 Pennsylvanians have access to some form of recycling program in their community? This includes approximately 1,050 municipal curbside pickup programs and 870 drop-off programs, which extend recycling opportunities to Pennsylvania's rural areas.

  Recycle Everywhere: To recycle materials not widely accepted by local municipal recycling programs, look for other opportunities to recycle in your community. Many businesses and some non-profit organizations offer recycling programs. Try taking your:

  - Single-use plastic bags to grocery and big-box stores
  - Used tires to tire stores
  - Used motor oil, transmission fluid and oil filters to auto parts stores and garages
  - E-waste to electronics stores
  - CFL bulbs to home improvement stores
  - Motor vehicle and other lead acid batteries to any retailers that sell them (Act 101 requirement)
  - Used clothing and household goods to charitable organizations

Other resources to help you reduce, reuse, and recycle may include:

- Your electricity provider may offer rebates and haul-away programs to replace older appliances with more energy-efficient models.
- Non-profit organizations take clothing and household items and distribute them to needy families or sell them, either in thrift stores or to textile recyclers, to raise funds for their charitable programs.
- Local police stations, county sheriffs, pharmacies, and hospitals offer secure drug-drop off sites for expired, unwanted, and left-over prescription drugs; find a location at ddap.pa.gov/drugtakeback
- Compost at home or find a farm or community garden that will accept compostable materials.
- Local scrap businesses will accept metals, which are typically among the most valuable recyclable materials.
- Watch out for special recycling events for hard-to-recycle materials in your area, such as electronics, appliances, and tires.
- Try to reduce your unwanted mail by registering for "Do Not Mail" lists and converting as many bills and newsletters to electronic versions as possible.

Remember: Recycling Works in Pennsylvania!

Contact Page

To learn more about Recycling in Pennsylvania, visit:
https://www.dep.pa.gov/recycling

To learn more about recycling in your county and get involved, contact your County Recycling Coordinator: dep.pa.gov/countyrecycling, or the DEP Recycling Coordinator in your region.

Find your DEP Regional Office here: dep.pa.gov/regions

Visit the DEP website at http://www.dep.pa.gov

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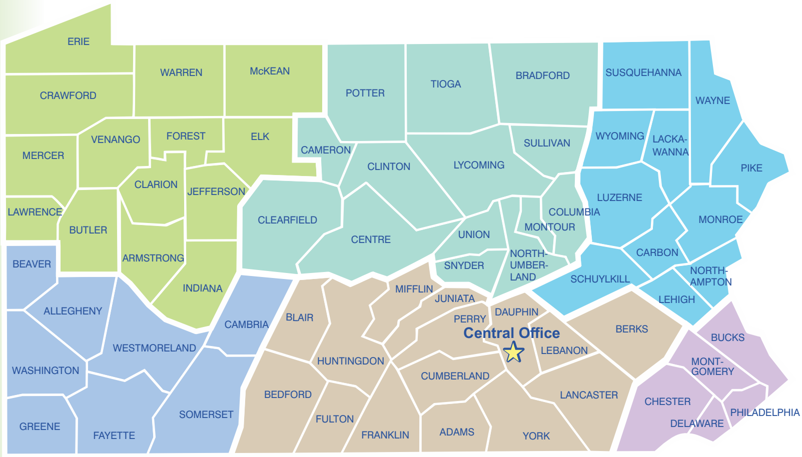
DEPARTMENT OF ENVIRONMENTAL PROTECTION

PA Department of Environmental Protection Regional Offices

Northwest (Meadville) Regional Office
230 Chestnut St.
Meadville, PA 16335-3481
Telephone: 814.332.6945

Northcentral (Williamsport) Regional Office
208 W. 3rd St., Suite 101
Williamsport, PA 17701-6448
Telephone: 570.327.3636

Northeast (Wilkes-Barre) Regional Office
2 Public Square
Wilkes-Barre, PA 18701-1915
Telephone: 570.826.2511



Southwest (Pittsburgh) Regional Office
400 Waterfront Dr.
Pittsburgh, PA 15222-4745
Telephone: 412.442.4000

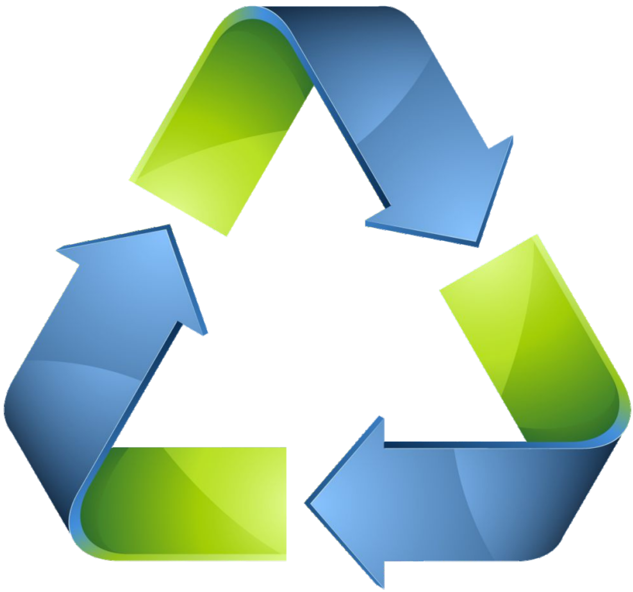
Southcentral (Harrisburg) Regional Office
909 Elmerton Ave.
Harrisburg, PA 17110-8200
Telephone: 717.705.4700

Southeast (Norristown) Regional Office
2 East Main St.
Norristown, PA 19401
Telephone: 484.250.5900

BENEFITS of RECYCLING

Environmental

(Saves energy; reduces greenhouse gas emissions and waste)



Economic

(Conserves resources; increases jobs, wages, sales and revenues)

Social

(Improves communities and quality of life; builds environmental ethic)

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