detritus | Multidisciplinary Journal for Circular Economy and Sustainable Management of Residues

CISA

Editorial

THE NEED FOR SINKS DURING THE TRANSITION TO A GLOBAL CIRCULAR ECONOMY

In the management of solid waste the deposit on soil has historically played a fundamental role.

This role originates directly from the life cycle of (degradable) products that obey the natural principle of mass balance (in a closed system the mass at any point will be the same) and Lavoisier's Law of Conservation of Mass: (material cannot be lost - it can only be transformed). A general representation of the life cycle is given in Figure 1.

Material resources (renewable or non-renewable, e.g. metals, stones, timber) are withdrawn from a natural pool above the soil or in the subsoil to feed production of goods. Elements and compounds in the material resources are naturally present in a non-mobile form (x) that can be mobilized after the extraction and processing steps necessary to obtain the primary materials for Production. At the end of their Use-life, products will become waste and will enter a Management step (deposit, collection, sorting, transport, preparation for reuse and recycling, etc. – not necessarily in this order).

Non- reused and unrecycled wastes represent residues that need to be disposed of, through Treatment and sometimes, via a Back to Earth deposit.

Along all these steps elements and compounds after extraction are generally in a mobile form(s).

During the different steps, the mobile elements can be emitted (dS/dt)) either legally (emissions respecting limits set by national regulations) or illegally and might give rise to diffused or concentrated unsustainable contamination (pollution).

The general scheme in Figure 1 can represent all the different approaches and strategies developed in different countries over the years. Some steps might be excluded, technological levels might differ significantly, different tools for contamination control might be adopted, some steps (e.g. extraction, waste management, final waste disposal) might be performed in countries different from the ones where goods are produced or used, etc.

The management of all the above influences the sustainability of the system in terms of control of depletion of non-renewable resources, quality of the environment and optimization of the protection of public and ecological health.

We can analyze the development of the scheme under different scenarios:

- Low and middle income countries
- Industrialized countries with a linear approach to municipal waste management
- Actual Circular Economy approach
- Sustainable Circular Economy strategy

Developing countries

In many low and middle income countries, extraction of material resources might be performed without observing the highest technological and environmental protection standards. The most important materials are exported for production in industrialized countries. Waste management is frequently seen as a low priority, largely due to lack of

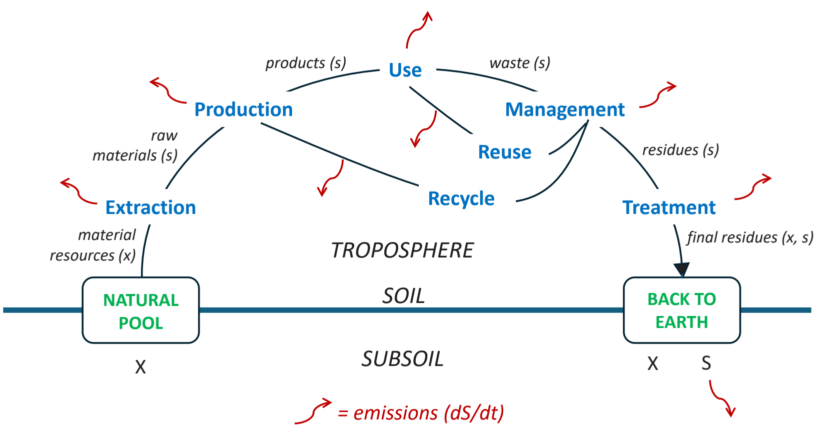

FIGURE 1: Graphical representation of the Life cycle of products and waste. X= non-mobile form of contaminants, S = mobile form of contaminants, dS/dt = emissions of contaminants.

Editor in chief:
Raffaello Cossu
email: raffaello.cossu@gmail.com

Detritus / Volume 28 - 2024 / pages 1-4
https://doi.org/10.31025/2611-4135/2024.19427

financial resource, but it can also be "invisible" (Mukhtar et al, 2018) and/or there can be poor environmental awareness/unwillingness to adopt new technologies amongst politicians and the public (Cossu and Williams, 2015). Waste collection is not implemented consistently or might be carried out in an inappropriate manner. Collected waste is often disposed of in open dumps or poor landfills with no or low emission control. Generally, waste is not adequately compacted, so littering occurs attracting insects, birds, and mammals, increasing risk for disease transmission.

The collection of reusable and recyclable materials is often practiced by the informal sector in communities and on dumpsites. In many cases, these informal systems can be quite effective and economically feasible. However, scavengers working on dumps might subject themselves to injury from falls, fires, toxic fumes, and dangerous waste components.

Diffusion of contaminants might originate severe environmental impacts and risks for health.

Industrialized countries with MW linear approach

The linear approach ("Take-Make-Waste") prevailed in industrialized countries during the intense industrial development between the 1960s to the 1990s (Cossu and Stegmann, 2018). Material resources were extracted, products generated and used, and wastes were directly disposed of in landfills, without too much care in controlling emissions. In some countries, particularly in megacities, incineration was used, no source segregation and separate collection was generally adopted. Examples of material recycling by manual or mechanical sorting were rarely documented.

Since the 1960s, the use of uncontrolled dumping was gradually replaced by controlled tipping, encoded by the World Health Organization (WHO) in a series of guidelines that represented, over a considerable period, the main technical references in the field (Cossu, 2010). Landfill dominated waste management; for example, although the European Union's Waste Framework Directive (Council Directive 75/442/EEC) introduced the waste hierarchy into European waste policy in 1975, it had little impact until the European Parliament announced a new version to its legislation (Directive 2008/98/EC), which Member States had to introduce into national laws (Williams, 2015).

Landfills were sited in aeras of low permeability where wastes were deposited in thin, uncompacted layers aimed at enhancing the establishment of aerobic conditions. The wastes were subsequently covered with inert materials (preferably clay) to avoid contact between wastes and animals (dogs, birds, rodents, insects, etc.).

Collection of leachate and biogas was not provided for; leachate was allowed to infiltrate into the ground (principle of "dilute and disperse"), whilst biogas production was not contemplated.

The repeated occurrence of noxious situations (odours, leachate ponding around the landfill sites, etc.) and an increased public awareness of environmental issues, jointly with technical and scientific progress in the field, has led since the 1980s to the increasing use of "Contained landfill", based on adoption of physical barriers for controlling emissions. Combined artificial lining systems (clay + synthetic membrane), leachate drainage and collection, heavy waste compaction, anaerobic processing, biogas collection and final capping were the main technical features. The collected leachate was treated with increasing process complexity (from lagoons to sophisticated biological technologies, reverse osmosis, activated carbon absorption, chemical precipitation and oxidation, evaporation, phyto-reduction, etc.)

Biogas was collected and converted to energy with different technologies (production of thermal and electric power, upgrading for domestic use, vehicle fuel, etc.).

Landfilling was driven by technical regulations (Butti *et al*., 2018) in the different industrialized areas of the world: in US the "Resource Conservation and Recovery Act" (RCRA) of 1976 which demanded to the Environmental Protection Agency (EPA) the power to enact specific implementing regulations, in Europe Union the framework Union Directive, 1999/31/EC which was implemented in the different member countries, in Japan the Ordinance No. 1/1977 of the Prime Minister's Office and Ministry of Health and Welfare.

Throughout the years, the "Contained landfill" displayed its numerous limitations. In particular, the potential efficiency of new lining materials has led to an excessive use of them resulting in siting landfill even in vulnerable areas without considering the limited life span of the physical barriers; life spans are largely inferior to the long-term emissions potential of contaminants.

Additionally, the high management costs associated with leachate treatment promoted the tendency to minimize leachate production, adopting low permeable top cover. The consequent reduction of water availability for the attenuation processes (biological stabilization, contaminants flushing, etc.), jointly with several other technical factors (i.e. clogging of drainage systems) resulted in prolonging the long-term negative impacts of landfills (Grossule and Stegmann, 2020).

These kind of landfills are inherently unsustainable for several scientific reasons further to the short- and long-term contamination of water and soil: climate change contribution due to the generation of greenhouse gases during the anaerobic degradation process (methane, CO_2); land space consumption; air quality impact; loss of biodiversity; health risks; waste of material resources; landscape degradation; need for costly long-term monitoring and maintenance; wildlife disruption in term of habitats; displacement of, and behaviour alteration by, animals; etc.

Actual Circular Economy approach

The global economic growth and the increasing need for primary raw materials, jointly with the awareness for environmental protection and resources depletion, have led modern societies to shift attention from the limited and fixed stocks of raw materials to the anthropogenic stocks of materials. This created the base for the development of circular economy as a strategy for recovering of resources from waste (Curran and Williams, 2012). Since the late 1990s and beginning of the 2000s, policies worldwide started to limit the massive landfilling by prioritizing waste management schemes based on waste minimization, reuse, recycle and energy production ("Pollution prevention act" of 1990 in US; "The basic act for establishing a sound material-cycle society" -Act n. 110 of 2000 in Japan; "Waste Directive" 2008/98/EC in the European Union).

Further to the traditional fractions of MSW normally considered in source segregation programs (plastics, paper, cardboard, glass containers, cans, putrescibles , etc.), other waste streams have been increasingly considered for recycling, such as waste from electrical and electronic equipment, end-of-life vehicles, scrapped tires, construction and demolition waste, combustion residues, food waste, batteries, road sweeping waste, water treatment sludges, exhausted oils, old landfilled waste, residues from food industries, slags and other industrial waste.

These materials can alternatively be used to obtain different kinds of products, such as secondary raw materials, building materials, fuel and biofuel, composites, fertilizers, etc. and regulations are continuously implemented for qualifying the passage from waste to product ("End of Waste").

So far, the Circular Economy concept is expanding successfully in several other areas of our society (i.e. sustainable architecture and recovery of buildings), but in routine waste management some issues are becoming increasingly critical and problematic:

- Modern products are continuously introduced in the market without caring about the environmental impacts (related to quality and quantity) when they will become waste (e.g. smart phones, composite plastics);
- Minimization is detrimentally influenced by a continuous production of goods with planned obsolescence (electronics, appliances, fast fashion garments, children's toys, etc.);
- Products that are introduced daily into the market contain a wide range of substances and additives (particularly non-degradable organics, nanoparticles, metals) which could present problems either in terms of impairing the recycling process (e.g. elastane and electronic components in textiles) via accumulation of contaminants in the recycled products and related release during use (e.g. microplastics, various xenobiotics) and by concentration in the residues to be disposed of;
- Even after recycling a considerable amount of waste (unrecycled, residues from different recycling loops, recycling process, etc.) remains, and are disposed by landfill or incineration;
- Landfilling of untreated waste, particularly in Europe, has been banned without a clear communication towards the citizen and visions about the need of closing the material balance in waste management where deposit on soil might still be necessary;
- Some phases of the circular economy are carried out in countries where environmentally sustainable standards in extraction of resources, manufacturing processes, recycling and waste management/disposal are not observed.

Landfilling for residual waste still maintains the main technical characteristics of the "contained landfill", despite regulations that have occasionally been updated to reduce the volumes of waste conferred, to prevent waste of resources, to minimize the production of greenhouse gases and, in general, to lower environmental impacts and risks. Moreover, most industrialized countries have introduced criteria for the monitoring of landfills during the post-closure phase, proposing the principle of financial provision and responsibility for landfill operators if the landfill continues to constitute a risk for the environment.

However, the evolution of the contained landfill into a residual landfill did not develop at the same pace as the need to respect environmental sustainability, aimed to avoid leaving the future generations to manage unacceptable burdens.

Although present measures applied to control long-term impact (post-closure care, environmental long-term operator responsibility) are adopted by regulations, the appropriate tools for their implementation are still lacking. Indeed, termination of post-closure care is defined according to time rather than environmental performance and no criteria have been established to define acceptable conditions on which to assess operator responsibility. Furthermore, as mentioned previously, residual landfills are largely based on the technology applied for contained landfills, thus featuring the same negative characteristics ranging from the deterioration of lining and leachate drainage systems to the adoption of leachate minimization measures and related negative consequences.

Lastly, a landfill for residual waste might require greater technical and environmental care than traditional landfills due to different analytical composition and mechanical properties of the materials to be buried: contaminants mobility could result enhanced and mechanical stability could be impaired.

Global world with a sustainable approach

The critical issues present in Circular Economy implementation can be substantially summarized in the increasing production of fast-moving goods and in the poor control of the mass balance which drives material flows (i.e. quality of goods, circulation and diffusion of contaminants, sustainable management of residues).

Possible solutions could be the following:

- Manufacturer responsibility for the products should be extended and more severely enforced to control quality and quantity of waste.
- Symbiosis between producers and recyclers should be stronger and more systematic to increase recycling capability and to control the removal of detrimental substances ad contaminants along the recycling processes (e.g. ban use of non-recyclable plastics in short-lifetime, consumable products);
- Residual wastes should be managed with the view to provide a safe and permanent sink for contaminants, closing material loops.

The sinks should be designed to convert mobile contaminants into stable substances that do not pose harm for the environment and the health of people and animals. Sinks can be represented by treatment technologies, based on thermal, biological, chemical, or physical processes (e.g. incineration, composting, inertness, washing, etc.) and by natural or anthropogenic “back to earth” recipients, where substances should be in a non-mobile form, in an equilibrium with the environment.

In this regard, any sort of the landfill model which has been experienced so far (uncontrolled, contained, residual, etc.) cannot effectively act as a sink.

While landfills might accumulate some organic carbon, they cannot be regarded as an anthropogenic sink due to incomplete decomposition and the natural carbon storage capacity of ecosystems like peatlands or forests are much more efficient. Biological stabilization such as Anaerobic digestion and Composting would represent a more efficient way to sequester organic carbon in the agricultural soil.

However, landfills may act sinks for inert and inorganic carbon which includes materials like non-recyclable plastics, glass, treated wood, and minerals/aggregates. Unlike organic carbon, which decomposes into gases, inert carbon remains relatively stable over time. Some inorganic materials, such as glass and ceramics, have a long lifespan and do not readily break down. When these materials are disposed of in landfills, they effectively store carbon for extended periods.

Inert plastics, although technically organic, degrade very slowly in landfills due to their chemical composition. Plastic items, such as bottles and packaging, can remain largely intact for decades or even centuries. During this time, they effectively trap carbon.

Inorganic contaminants in landfills particularly under anaerobic conditions (e.g. ammonia, heavy metals) can leach for centuries. This is the same for persistent organics, such as halogenated solvents.

Something like a Back to Earth Sink (BES) has been proposed in the past with the term of “Sustainable Landfill” (i.e. Grossule, 2020), which, particularly for the population might be considered as an oxymoron due the negative experiences associated with landfilling thus far. It is similar to designing a modern house respecting all the environmental requirements, and to present it with the term of “sustainable hovel”. To move toward the implementation of BES, it would be necessary to ban not only landfilling, but also the term itself and the related existing regulations. New regulations should be urgently agreed and issued. In addition, an extensive communication campaign would be of paramount relevance as people everywhere are against landfilling and widely convinced that Circular Economy is equivalent to “Zero Waste”.

Conclusions

The use of an acceptable “Back to Earth” (BES) sink is crucial during the global transition to a circular economy. Firstly, a BES would minimize environmental impacts by reducing greenhouse gas emissions and leachate production, which can contaminate soil and water. Secondly, a BES can provide a safe disposal method for non-recyclable and hazardous waste, ensuring public health and safety. Thirdly, the use of BES would give countries time to plan and resource their move towards circular economy practices by promoting waste avoidance, reuse, segregation, recycling, and composting whilst still recognizing the practical realities involved in this process. We suggest that Back to Earth Sinks are going to be a vital component in the development a circular economy, and that their implementation is urgent.

Raffaello Cossu
University of Padova, Italy
raffaello.cossu@gmail.com

Ian Williams
University of Southampton, United Kingdom
i.d.williams@soton.ac.uk

REFERENCES

Butti L., Peres F., Lops, C. (2019) Legal framework of landfilling in different areas of the world. In Cossu R., Stegmann R. Solid waste landfilling : concepts, processes, technologies, Elsevier. ISBN 978-0-12-818336-6.

Cossu, R. (2010). Technical evolution of landfilling. Waste Management 30(6):947-8 https://doi.org/10.1016/j.wasman.2010.03.003

Cossu R and Stegmann, R. (2019) Waste management strategies and role of landfilling. In Cossu R., Stegmann R. Solid waste landfilling : concepts, processes, technologies, Elsevier. ISBN 978-0-12-818336-6.

Cossu, R. and Williams, I.D. (2015). Editorial: Urban Mining: Concepts, terminologies, challenges. Waste Management, 45, 1-3. http://doi.org/10.1016/j.wasman.2015.09.040.

Curran, and Williams, I.D. (2012). A zero waste vision for industrial networks in Europe. J Hazardous Materials, 207-208, 3-7. https://doi.org/10.1016/j.jhazmat.2011.07.122.

Grossule, V. (2020). Final quality of a sustainable landfill and post-closure management. Detritus, 13, 148–159. https://doi.org/10.31025/2611-4135/2020.13999

Mukhtar, E.M., Williams, I.D. and Shaw, P.J. (2018). Visibility of fundamental solid waste management factors in developing countries. Detritus, 01, 162-173. https://doi.org/10.26403/detritus/2018.16.

Williams, I.D. (2015). Editorial: Forty years of the waste hierarchy. Waste Management, 40, 1-2. http://dx.doi.org/10.1016/j.wasman.2015.03.01.