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Improper Disposal of Household Hazardous Waste: Landfill/Municipal Wastewater Treatment Plant

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Abstract

Household hazardous waste (HHW) is not always separated for proper handling before disposal. When disposed improperly to landfills and municipal treatment plants, these products can have significant impact on the environment. Although HHW is a small portion of municipal solid waste, the presence of HHW in solid management facilities that are not equipped to handle them can have problematic effects, resulting in environmental pollution, damage to facilities, and even injury to workers. In many countries, HHW is not subject to legislation unless separated from other household waste because of its small percentage and the challenge in enforcement. In addition, there is no standard definition of HHW globally; therefore, what constitutes to HHW in one country may not be in another. Government legislation and schemes such as Extended Producer Responsibility play a vital role in encouraging proper disposal among consumers, especially when they are convenient and accessible. In this chapter, hazardous household products in different countries are considered along with common improper and acceptable disposal methods. Furthermore, the impacts of improper disposal on the environment are explored with an emphasis on landfill leachate and wastewater treatment plant effluent. Finally, current legislation and programs that encourage proper disposal are discussed.

Keywords: household hazardous waste, disposal, environmental impact, landfill, wastewater treatment plant, legislation, schemes

1. Introduction

Household waste is something that is common among most, if not all, living residences. Like any industrial facilities that handle potentially hazardous materials, households too dispose and use hazardous substances. The chemical complexion in the waste substances makes it so if disposed improperly, it could ignite, explode, poison, or corrode. Household hazardous waste (HHW) becomes what it is once thrown away. Methods of the waste being improperly disposed is pouring the substance down the drain, into storm sewers, on the ground, and throwing it in

among the trash. It may not be obvious that these substances, once disposed, will be a danger, but particular varieties of HHWs have the prospective to:

- cause somatic injury to sanitation workers;
- if poured down drains or toilets, adulterate septic tanks or wastewater treatment systems;
- pollute—if poured down storm sewers—bodies of water;
- become a danger to young or unknowing children and pets if left open in the house;
- contaminate ground and/or surface water that is used as a way of obtaining drinking water, if directed to exposed landfills.

A big problem that occurs/can occur through improper disposal of HHW would be the deconstruction that the sewage treatment plants are able to obtain. These plants are not able to deconstruct HHW compounds that people would drain or flush, which will end up traveling into lakes and rivers, unprocessed. As a result, one of the main releasers of dioxins and furans was from sewage systems. The substances proved to threaten human health due to the fact that they were highly carcinogenic. Other than the fact of the carcinogenic dangers, interference with the treatments plants could transpire. The toxins that would be processed could poison the microorganisms in the biological process. That would bring us to the position where our water systems would be more susceptible to harmful contaminants.

As a given, hazardous waste is poisonous to all life forms, exposure of such hazardous substances to any living organism (plants and animals) could devitalize it. As a consequence, to the environment, hazardous waste could diminish natural resources and be contaminating to humans. Giving the young/fetuses, whether human or animal, exposure to these hazards would be substantially dangerous, as they are in a process or rapid growth. Introduction to chemicals for the living body would also interfere with biological structure, causing malfunction of organs and limbs.

In addition to the effects to the human and animal bodies, hazardous waste would hinder plant growth. The impeding of plants that are of much use to the human race through manufacturing and consumption would affect our habitat. If the plants were slowly changing, for the worse, it would affect the animals that are needed for food, farm work, and would cause a whole new era of extinction.

If our plant growth can affect our way of living easily, dumping the HHW into landfills gives us a much bigger problem. Landfills that are improperly maintained are major problem; even if they seem to be isolated from any contact, they can contaminate the environment around them. These landfills produce foul-smelling and toxin gases. Along with the gases and toxins, landfills generate leachate, which can travel to our water sources of lakes, rivers, and oceans. This would dig us into a deeper problem of both environmental and human existences. Thereby, leaving HHW unattended and improperly disposed could potentially destroy the ecosystem.

2. Household hazardous waste (HHW)

Separate management of HHW from nonhazardous waste is rare. It is estimated that in countries within the Organization for Economic Cooperation and

Development (OECD), household waste contributes to 67% of 540 million tons of municipal solid waste (MSW). The estimated amount of HHW varies considerably due to an unclear definition of what constitutes household waste as opposed to MSW. In the USA, for the Environmental Protection Agency (USEPA), household products that contain corrosive, toxic, ignitable, or reactive ingredients are considered to be HHW. In general, the HHW is a solid, semisolid, or nonaqueous liquid that can cause or significantly contribute to potential hazard to human health or environment when it is improperly treated, stored, transported, disposed of, or otherwise managed. The portion of HHW in MSW has been estimated to be from less than 0.01–3.4% in several studies. The large variability is due to lack of standard definition as to what constitutes HHW, variability in generation, variability in weighing methods, and limited sample size. Nevertheless, 1% by weight is widely accepted as the fraction of HHW in MSW. Because of this small percentage of HHW produced, households are not practically considered to be hazardous waste producers [1]. While HHW represents a relatively small proportion of current urban solid residues, it is the most toxic part of the waste stream.

HHWs in the household waste are often excluded from management as hazardous waste unless collected separately. However, if these waste materials were generated industrially or commercially, they would be subject to strict disposal guidelines. As a result, HHWs are handled the same way as nonhazardous material with no specific regulation or monitoring. Of recent, this mismanagement constitutes a greater problem as the waste stream not only increases in amount but also becomes more diverse with the introduction of more products into the consumer market.

At the source or point of generation, HHW can be placed in the garbage, down the drain, dumped on the ground, or diverted for reuse, energy recovery, or recycle. No matter where HHW is disposed, due to its toxicity as well as municipal treatment facilities that are not equipped to deal with hazardous material, improper management can adversely impact the quality of the environment:

- Contaminate ground water bodies.
- Contaminate surface water bodies.
- Pollute air.
- Affect the human health (children and pets if left around the house, cause physical injury to sanitation workers).

On the other hand, in many third world countries, solid waste management facilities are underdeveloped and sometimes nonexistent. The United Nations reported that between 20 and 80% of all household waste that is generated is often dumped in open spaces, water bodies, drains, and burnt or buried. This creates unsanitary environments leading to health hazards. The portion of HHW in household waste generated by developing countries is much less than in developed countries. The small amount of HHW produced as well as unavailability of funds to direct toward implementing sound practices for waste management has led the United Nations Environment Program to suggest HHW with MSW for disposal in landfills [2]. Regardless of the development level of the country, proper management of HHW can be achieved by understanding the environmental and societal impact of poor practices, HHW contaminants, government legislations, and well-developed schemes.

3. Potential risks of improper disposal of HHW

Unavailable facilities for proper HHW management discourage even their voluntary participation. While the products in the HHW list vary from country to country, below are categories that represent majority if not all products that can be classified as HHW:

- Photochemicals
- Pesticides
- Mercury-containing wastes
- CFC-containing equipment
- Nonedible oil and fat
- Paints, inks, resins, and adhesives
- Detergents
- Pharmaceuticals
- Batteries
- Waste electrical and electronic equipment
- Wood preservatives
- Aerosols
- Personal care products

The risks that a hazardous product poses to the environment depend on certain characteristics of the toxic compounds:

- Solubility
- Mobility
- Persistence
- Degradability
- Toxicity to nonhuman target species
- Potential for penetrating landfill liners
- Potential to be broken down in wastewater treatment system

HHW is likely to be disposed of improperly because residents do not always understand the level, effect, and potential impact of toxicity in the products that

they use. In **Figure 1**, the disposal trend of households in the UK is presented after a survey with 400 respondents was carried out. One can observe that the predominant method for disposing HHW in households is into the garbage in spite of the toxicity level. A large portion of photochemicals and pharmaceuticals are discarded down the drain with little regard for the compounds that they contain and the consequences for this mode of disposal [4].

Since information about the impact of HHW on the environment is not exhaustive and data relating to disposal are not well known, the potential impact of each of these products in the environment and health is considered as well as the amount that is approximately generated by households where available.

On the other hand, **Figure 2** shows a similar study conducted by Statistics Canada in 2009 with over 3800 respondents. While the garbage is still a significant disposal route for HHW, more households reported utilizing drop-off centers and returning products to suppliers and retailers [5].

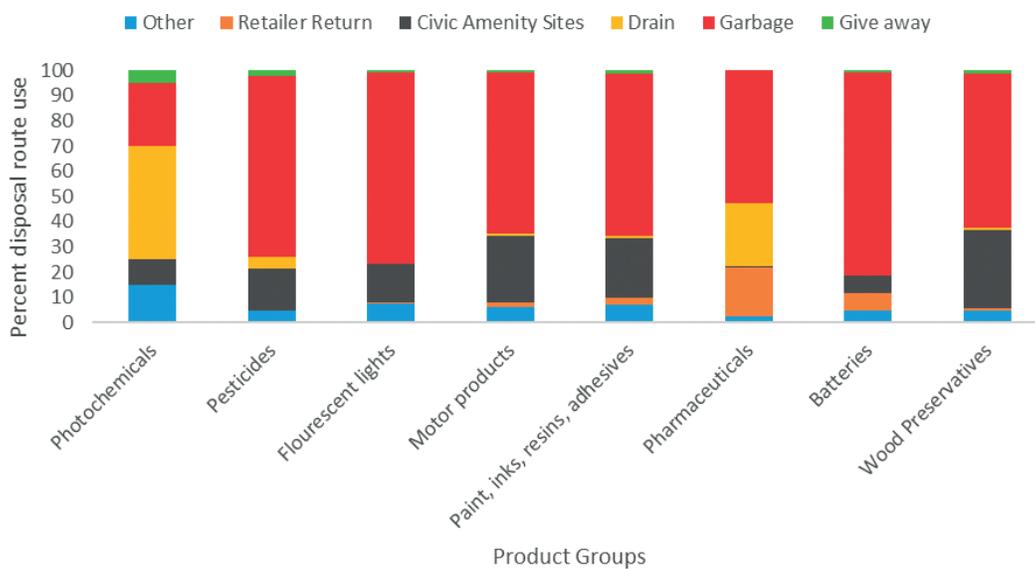


Figure 1. Usual HHW disposal regime of UK households [3].

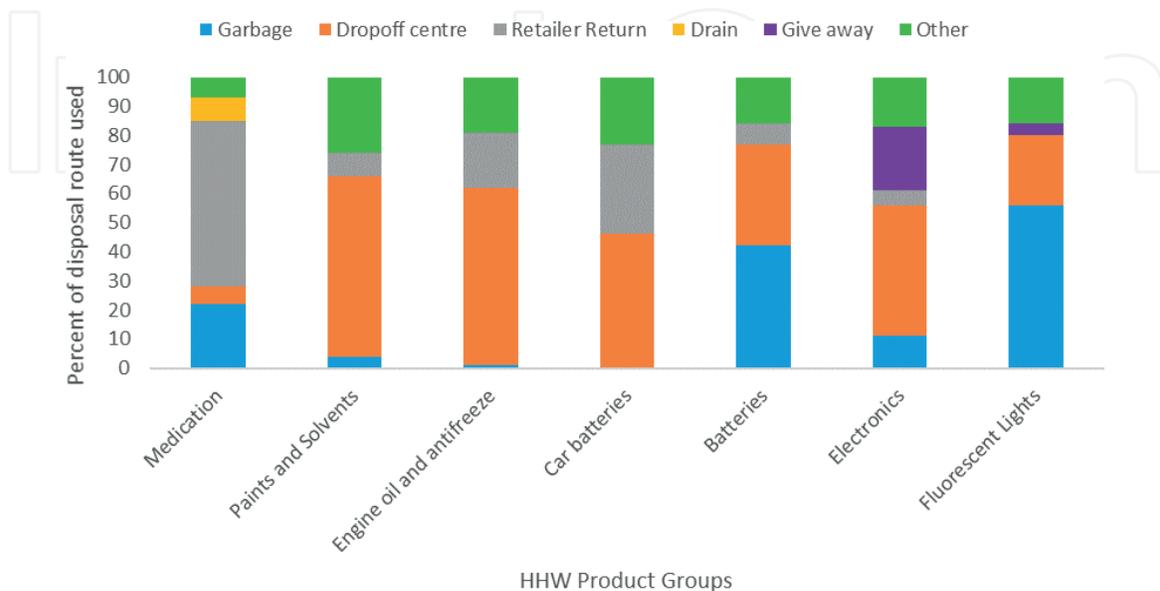


Figure 2. Usual disposal routes in Canadian households (source: Statistics Canada).

3.1 Photochemicals

These are liquid chemicals used in home developing and printing. Many of the ingredients in these products are toxic solvents and are predominantly disposed of in sewers. The unused portions of these chemicals are hazardous, but also the packaging can be problematic as it can contain some of the chemicals, which end up in the landfill and thus contaminate both soil and groundwater because these chemicals can penetrate the liners transporting to the groundwater and might end up to the surface water through the movement of groundwater. While the amount entering the sewers cannot be estimated, the packaging in the UK is estimated to be about 270 tons/year, most of which will end up in the landfills [6].

3.2 Pesticides

Rapid growth in pesticide use has been observed, and this suggests a proportional increase in the amount that is being disposed of. According to the UK Pesticide Safety Directorate, many of the active compounds have been observed in landfill leachate of which research shows that they pose carcinogenic and endocrine disruptive risks [6]. On the other hand, incineration of pesticides is acceptable, provided that they do not contain mercury or arsenic. In Belgium, around 80% of waste pesticides are collected and incinerated [7].

3.3 Mercury-containing wastes

Household products that contain mercury include fluorescent bulbs, stockpiled paint, dental amalgam, thermometers, and barometers. Of these, fluorescent bulbs contribute the highest amount of mercury waste. However, as the use of these is reported to have better energy and environmental impacts than regular light bulbs, they are so encouraged [8]. Improper disposal of fluorescent bulbs is where the risks lie. In the UK, it is estimated that 80 million are disposed of each year, of which only a small portion are recycled or processed for mercury extraction. In Brazil, lamps containing mercury contribute 1000 kg of mercury disposed of per year. Mercury exposure poses some health risks such as genetic damage and neurotoxicity damaging the kidney, liver, and central nervous system [6].

3.4 Chlorofluorocarbon (CFC)-containing equipment

Refrigeration and air-conditioning appliances/equipment may contain chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) refrigerant. CFCs and HCFCs are ozone-depleting substances (ODS). If they released to the environment, they will destroy the protective ozone layer above the earth and potent greenhouse gases, contributing to global climate change. Examples of these types of equipment include motor vehicle and motor vehicle-like air conditioners, central and room air-conditioning units, refrigerators, freezers, chillers, drinking water coolers, dehumidifiers, research equipment, vending machines, etc. Manufacturing of such freezers and refrigerators has been phased out with the CFC component being replaced. However, disposal of these is still ongoing because of their 8- to 12-year life span leaving 4500 tons of CFC in the UK to be safely disposed of. Disposal of equipment that contains ODS is regulated in the EU by the WEEE directive where separate collection is mandatory [6].

3.5 Nonedible oil and fat

Nonedible oil and fat constitutes to about 15% of HHW in the UK. The waste section comprises mineral oils that often contain additives, which make it hazardous. While they are sometimes collected and re-refined or burned for energy, a significant portion is disposed of by end users down the drain or via oil filters and end up in the landfills. There, the oils can disrupt artificial landfill liners. Preferably, the steel component oil filters can be recycled after the oil is pressed for recovery and processed into fuel by companies [7]. Other examples are maintenance lubricants and greases for vehicles, which contain solvents and hydrocarbons that can be just as harmful.

3.6 Paints, inks, resins, and adhesives

Disposal of paints is the most significant in this category with the solvent-based paints posing the higher risk. In the UK, paints contribute to 17% of the total HHW with large quantities ending up in the sewers or mixed with MSW. However, schemes developed by local charities exist to collect unwanted paint and redistribute them at no charge. This scheme is limited by the quality of paint that can be used and quantity that can be accepted in any given location. Collected paint needs to meet certain criteria to be acceptable for redistribution such as age or packaging. Barely, 1% of the available excess paint is collected due to a small number of collection points [6, 7].

3.7 Detergents

The use of detergents in household is widespread. It has been reported that 5–20% of the phosphate that is found in surface and ground water in northern Europe originates from detergent use. However, not all detergents are classified as hazardous, but those containing acids, bases, and chlorinated solvents are of particular concern [7]. In addition, the biodegradability, the aquatic toxicity, endocrine disruptiveness of the surfactants, and other ingredients in the detergent contribute to its classification as hazardous. When combined, some compounds in detergents can release fumes that affect the eyes and mucous membranes, leading to respiratory failure and death after prolonged exposure [6].

3.8 Pharmaceuticals

In the US, all over-the-counter (OTC) medicines are regarded as hazardous. However, in the EU, only those that are cytotoxic are classified as hazardous. Consumer disposal is not particularly regulated, as it would be problematic, but also due to the relatively low toxicity. As a result of the inability for wastewater treatment plants to remove pharmaceuticals from the waste stream, in many countries, they are now regarded as water contaminants. This is because they eventually make their way into drinking water supplies. They are transferred to sewage sludge during treatment, which is then applied to agricultural land or sent to a landfill [6].

3.9 Batteries

Primary, lead-acid, and nickel-cadmium batteries are those that fall into this category in HHW making up 6–14% of the HHW in the UK. Mercury in consumer

batteries has been banned in Europe and many states in the US. However, many unregulated countries still use batteries containing significant concentrations of mercury, which often ends up in landfills. When buried in landfills, the casing of dry cell batteries can degrade and release heavy metals [9]. Most rechargeable batteries are used in consumer devices and nickel cadmium batteries. In the EU, these types of batteries must be easily removed from electronic devices, and separate collection for recycling is encouraged. However, these end up in MSW where recycling facilities are not well established because it is not mandatory. Cadmium is known to cause health effects like kidney damage. Lead-acid batteries comprise those found in vehicles, or smaller batteries in fire and security alarms. The recycling program for lead-acid batteries in the UK is well established, and 85% collection of the automotive variety has been recorded. However, the batteries from the alarms and from some battery changes carried out at home still end up in MSW. Lead acts as a chronic and acute neurotoxin affecting the kidney [6].

3.10 Waste electrical and electronic equipment (WEEE)

For many years, home electric and electronic equipment has been disposed of in landfills along with their hazardous components. The amount that is being disposed continues to grow as consumer interest in current devices keeps increasing, which leads to discarding of obsolete electronics. WEEEs often have toxic compounds such that special handling is a requirement [8]. Many countries have prohibited the disposal of WEEE in landfills because of the toxicity and the strain of such large quantities of waste on the landfills. In the EU, this group of equipment is regulated under the WEEE directive such that they are collected and treated as hazardous waste. The directive also lists the substances that should be removed and collected from WEEE. Restrictions have also been placed on the use of certain materials in the manufacture of newer equipment [6].

3.11 Wood preservatives

There are three types of treatments that are used to preserve wood, all of which can cause the treated wood to be hazardous, as they have hazardous properties. The types are tar oils, organic solvent-based, and water-based formulations. Creosote, an aquatic contaminant, is often used in tar oils. It is known to be a skin irritant, which causes photosensitivity and skin tumors following long exposure. Tributyltin is an example of organic solvent-based compound that is strictly regulated. A hazardous water-based substance is copper-chrome arsenate (CCA), which contains concentrations of heavy metals that have large health and environmental risks [6]. Arsenate is a priority carcinogenic contaminant of waste, which easily leaches in a landfill and can volatilize during incineration. Landfilling is not acceptable for disposal, and specialized air pollution control equipment is required for incineration [7].

3.12 Aerosols

Aerosols are a large portion of HHW making up 26% of the HHW in the UK. In the past, CFC was widely used in the production of aerosols. However, CFC has been replaced with alternative propellants and solvents, which contribute significantly to the content in HHW. These replacements are often flammable and explosive. Exposure to aerosols can lead to nausea, skin, and throat irritation [6].

3.13 Personal care products

The harmful nature of PCP has been supported by the discovery of certain long-term effects on health and the environment. While most PCP will end up in the sewers, unused products are stockpiled and end up in MSW.

It is important to understand the fate of compounds in HHW when mixed with MSW for disposal. This has led to stricter disposal regulations in many developed countries to improve HHW management [6].

4. Environmental impact

Improper disposal of HHW eventually leads to the presence of hazardous contaminants in the environment. All the facilities that are used to manage discarded HHW are in direct contact with environment media, air surface water, groundwater, and soil (**Figure 3**). These media are in constant contact with each other. As a result, when facilities cannot adequately break down hazardous compounds in HHW, the immediate environment is at risk.

The contaminants enter the water cycle via groundwater or lakes, rivers, and streams traveling through the cycle [10] via different paths:

- Precipitation from the atmosphere
- Percolation through the soil
- Direct disposal from a wastewater treatment plant (WWTP) into a surface water body
- Residents pouring liquids down the stormwater drain that empties into a lake

In addition, toxic gases from HHW can be emitted into the air from the hazardous compounds that are used in producing them during controlled incineration or sometimes, uncontrolled fires [8].

4.1 Landfills

Landfills can be the most economic way for waste management, especially in countries like Canada with large open spaces. However, poorly managed landfills have the potential of causing a number of environmental issues such as contamination of groundwater or aquifers or soil contamination. Modern landfills are not just holes in the ground to be packed with garbage. They can be considered as highly engineered contaminated systems. A modern landfill uses a number of technologies to ensure that the wastes are properly managed to avoid environmental pollution (e.g., ground water contamination, gas emission). **Figure 4** shows schematic of a modern landfill process. Advanced protective liners (both natural and manufactured) are typically used to isolate the waste and leachate from leaking into the surrounding ground or ground water. Single, composite, or double liners can be used depending on the nature of the waste materials being deposited (see **Figure 5**). At minimum, a composite liner should be used for hazardous waste landfill facilities. However, landfills are not usually engineered to handle toxic compounds from HHW [9]. Hazardous liquid waste can be transported from a landfill into the environment if there are no barriers. Leachate that has been contaminated with hazardous material (soluble or insoluble) may destroy synthetic liners and render

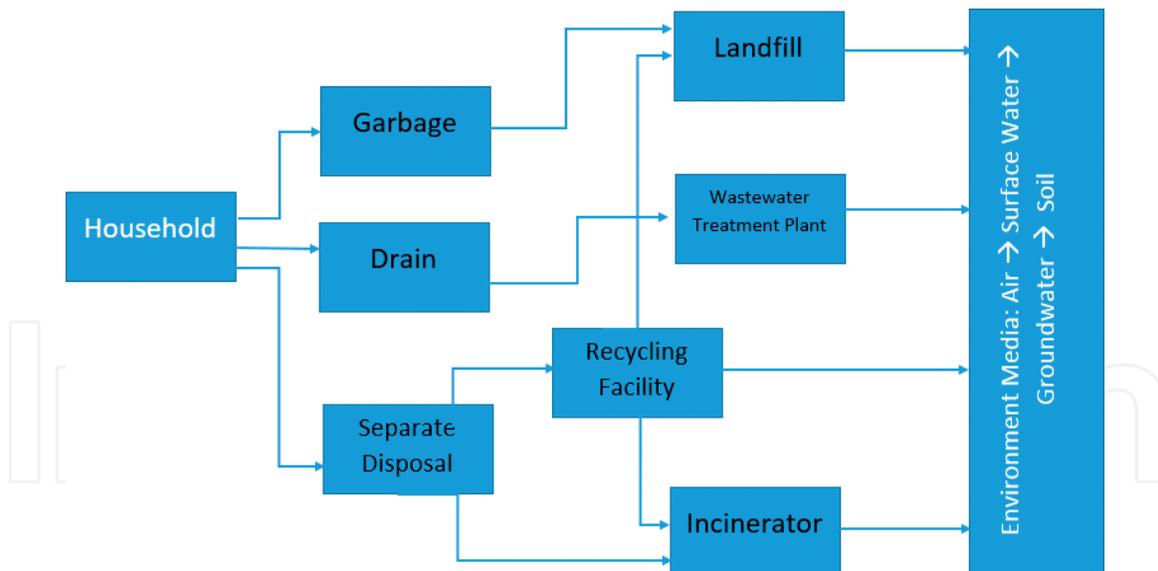


Figure 3.
Improper disposal path of HHW from household to environment.

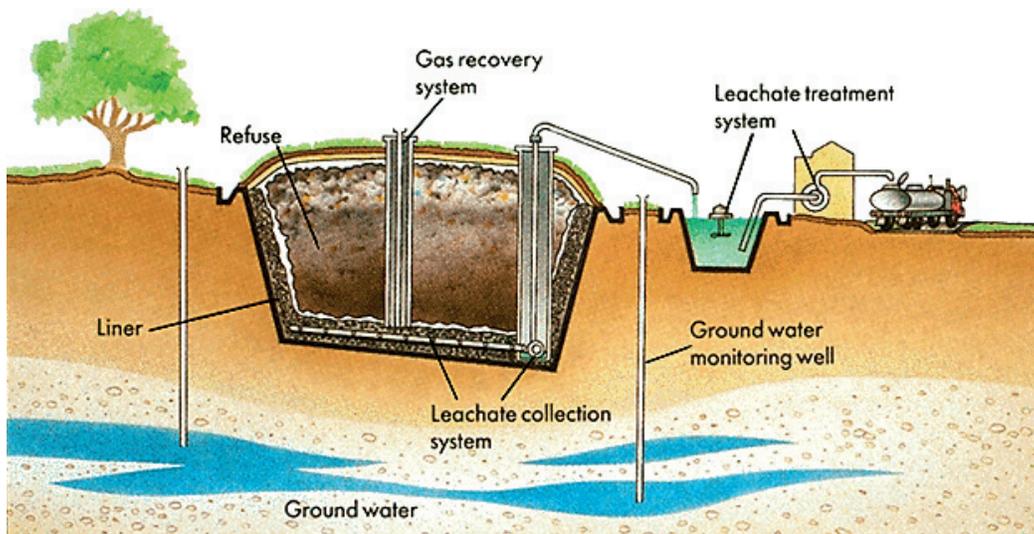


Figure 4.
Schematic of modern landfill process (source: www.oocities.org).

existing barriers ineffective, and thus, the hazardous waste comes in contact with the soil. Its fate is determined by the characteristics of the soil such as porosity, geological factors, and the contaminant like viscosity. The contaminant may percolate downward and affect the groundwater or spread and contaminate surrounding area [10]. Even if the leachate is collected, the treatment plants are not usually equipped to remove hazardous contaminants and end up releasing them into water bodies [11].

In addition, the conditions of the landfill such as the air and moisture content can affect the fate of hazardous contaminants such as the rate of degradation or violent reactions [10]. For example, phthalic acid esters (PAEs) are used as plasticizers that are used in furniture, clothes, food packaging, etc., which are items that will invariably end up in the landfill. While readily degradable under aerobic conditions, those that are found in the landfill environment tend to retard biodegradability of PAEs. When the environmental impact of PAE in a landfill in China was studied, it was discovered the more complex congeners were found absorbed in deeper soils and in the groundwater [12].

Certain volatile organic compounds can be partially degraded and are readily absorbed by MSW in a landfill rather than volatilize. The moisture in the leachate enhances this process. Leachate-containing toxic compounds can be detoxified faster by recirculation within the landfill, which reduces the potential for leakage from the landfill liner. HHWs contribute volatile organic compounds (VOCs) to landfill gases such as benzene, methylene chloride, trichloroethylene, vinyl chloride, etc. VOCs from landfill gases contaminate off-site groundwater through migration [11].

4.2 Incinerators

The quality of air emissions and ash residue is as a result of the fuel being incinerated. Incinerators usually have pollution control devices; however, some of the components that are found in HHW can pose a challenge to be captured. For example, mercury found in dry cell batteries, fluorescent light bulbs, and old paint can be converted to gaseous form and be emitted from the stack. Even the use of air treatment technologies can only remove 75–85%. Once it becomes in the atmosphere, mercury can be solubilized by rain and end up in water bodies. Other contaminants such as hydrogen sulfide and carbon monoxide that enter the atmosphere as gases may react with other compounds to become even more hazardous or remain in the atmosphere if stable, causing damage. Also, toxic metals have been found in the fly ash residue of incinerated MSW containing HHW. Damaging explosions have been reported due to a flammable liquid container being heated, which can lead to a few hours to few years of lost work time [11].

4.3 Wastewater treatment plant

Hazardous material dumped down the drain will end up in the on-site septic system or wastewater treatment plant depending on which system is employed. HHW can enter into wastewater treatment systems through its intended use or as a disposal method. Local governments usually prohibit disposal of HHW into stormwater drains. Recommended disposal may depend on the product and the industry. Some may be dumped down the drain with lots of running water, while others should be kept for collection [11].

Conventional wastewater treatment plants combined physical, chemical, and biological treatment methods depending on the nature of the pollutants and desired level of removal. Modern wastewater treatment process consists of four levels, including preliminary, primary, secondary, tertiary, or advanced treatment, in addition to the solid waste management. Preliminary and primary treatments are mainly physical/mechanical (screening and gravity settling), while secondary and tertiary treatments use combination of biological, physical, and chemical treatment process (**Figure 6**). Preliminary treatment removes larger inorganic materials and floating particles, primary treatment removes a major portion (50–60%) of suspended solids from raw wastewater, and secondary treatment process removes organic matters and suspended solids. Secondary treatment usually consists of biological treatment of wastewater. Most of the WWTPs use aerobic activated sludge process for secondary treatment. The objectives of secondary treatment are to reduce BOD and SS of the effluent to an acceptable level according to the discharge regulation. In some cases, nutrient removal may be also an objective of secondary treatment. Biological treatment processes rely upon the ability of the organisms to utilize the contaminants as substrates and results in the generation of new biomass and biodegradation by-products.

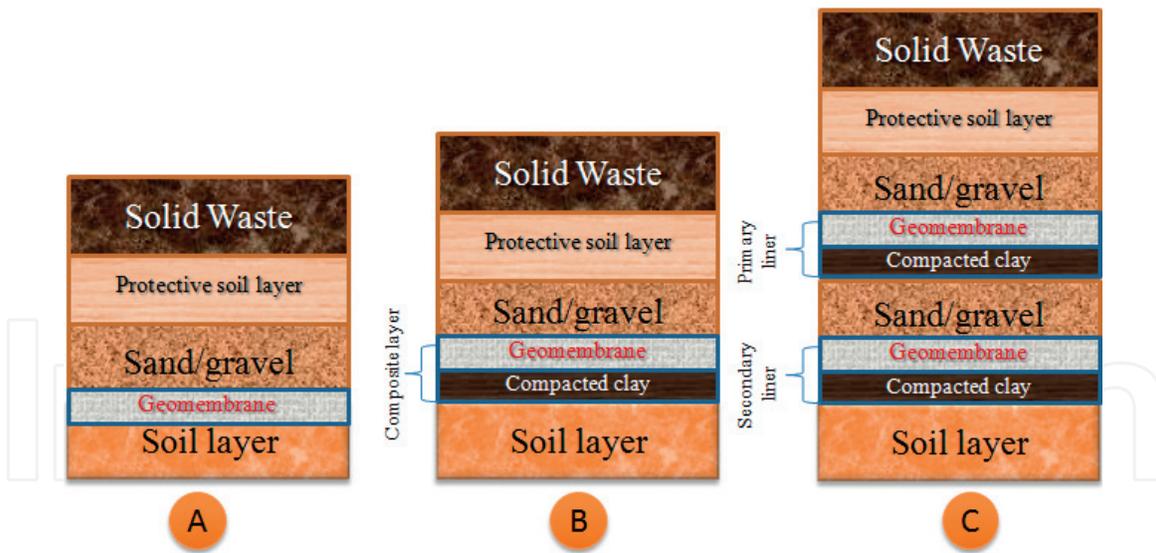


Figure 5.
 (A) Single liner, (B) composite liner, and (C) double liner system.

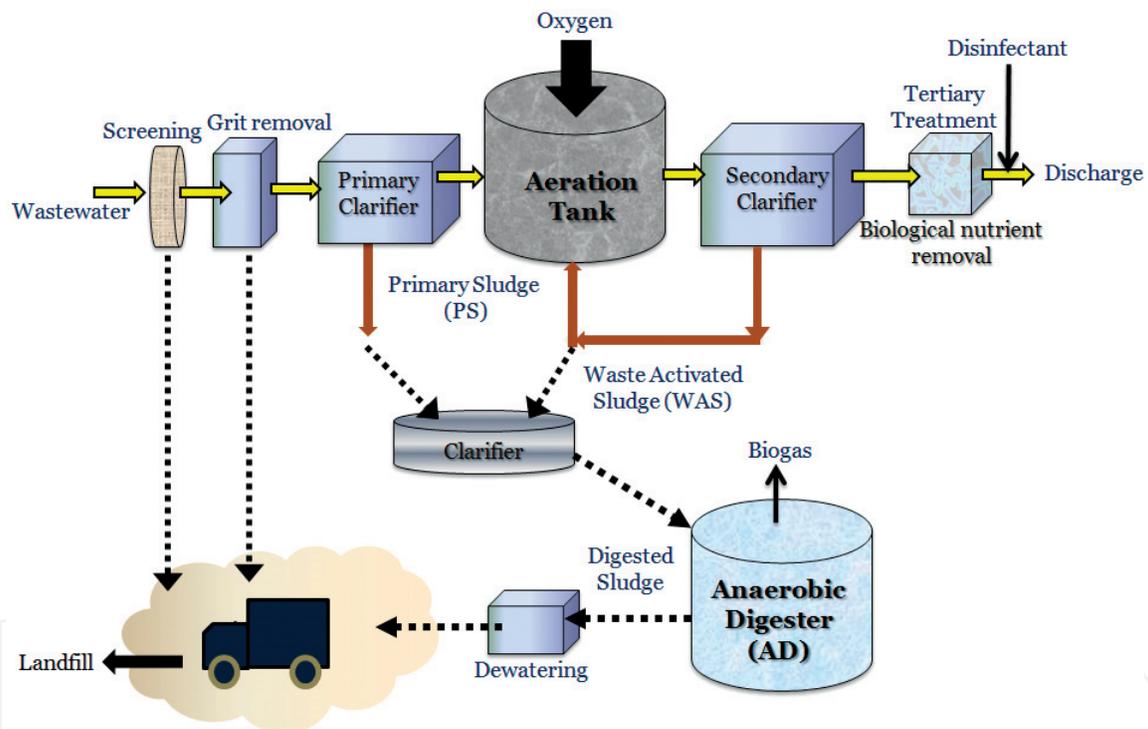


Figure 6.
 Typical municipal wastewater treatment process.

Lye and bleach found in cleaning products and other hazardous components can hinder the bacteria that are utilized in the biological treatment processes and will significantly affect the process efficiency. This will cause wastewater to pass through the system without treatment and ultimately will reach the groundwater and/or surface water [10]. This can contaminate aquatic life; nitrates, and phosphates can cause eutrophication (algal bloom), leading to the use of more herbicides for control.

Excess loading of nutrients like nitrates and phosphates results in the uncontrolled growth of phytoplanktons and macrophytes. The growth and subsequent death of these organisms form a greenish slime layer at the surface of water bodies. This slime layer reduces the amount of sunlight that can penetrate through and the oxygen that can be replenished into the water. In addition, the excessive

growth causes high competition for resources among aquatic organisms and death such that the biodiversity in the water body may be severely affected over time. This is the water pollution phenomenon known as eutrophication. Aside from the negative effects on water esthetics, eutrophication can hamper recreation activities, navigation, and aquatic life [13].

On the other hand, heavy metals are toxic, persistent, and mobile and tend to accumulate. They generally have very low acceptable concentrations in drinking water standard. In WWTP, low-concentration volatile solvents can evaporate from the aeration tank and become air pollutants. However, high concentrations, acids, bases, poisons, and solvents can affect the WWTP workers' safety and effluent quality and contaminate the sludge. Even if the wastewater flow does not contain HHW, leachate from landfills and combined sewer flow can introduce contaminants from pesticides and motor oil, which originate in the households of which even a small amount of pesticide concentration can cause a WWTP to fail toxicity test [11].

4.4 Recycling centers

Majority of the e-waste collected in the US and other developed countries end up in developing countries in Asia and Africa, which often have less than adequate concern for the environmental impacts of the primitive recycling activities that are conducted. Illegal e-waste recycling activities in Guiyu, China, have led to the release of hazardous chemicals into the environment. Harmful concentrations of heavy metals and compounds such as polybrominated diphenyl ethers (PBDEs) were reported in local children and workers of the recycling facilities likely due to open dumping activities that contaminated the soil and river sediments. Polychlorinated biphenyls (PCBs) released during manual dismantling of electronics and from open combustion of the waste material resulted in the presence of significant concentrations in the local residents as a result of bioaccumulation in fish and inhalation [14, 15].

5. Proper disposal methods

5.1 Source separation

Proper disposal of HHW starts with differentiating between hazardous household products and nonhazardous waste products. Mixing of household waste at the source must be addressed and banned. By collecting similar HHWs together, they can be more efficiently managed with regard to environmental safety, human health, and costs. When separated, arsenic-treated wood can be incinerated using proper pollution control technologies reducing any form of carcinogenic environmental impact, which may otherwise be present if it had been landfilled. Even more popular in developed countries is the separation and collection of cleaning products and pesticides. Majority of which can be incinerated according to best practices unless they contain mercury [7].

5.2 Recycling and repurposing

Some HHW products can be of value as they can be recycled for a different purpose or may contain material, which can be extracted for use in manufacturing other products, as in the case of antifreeze, which can be repurposed as an engine coolant. Another example is waste motor oil, which can be refined as lubricating oil

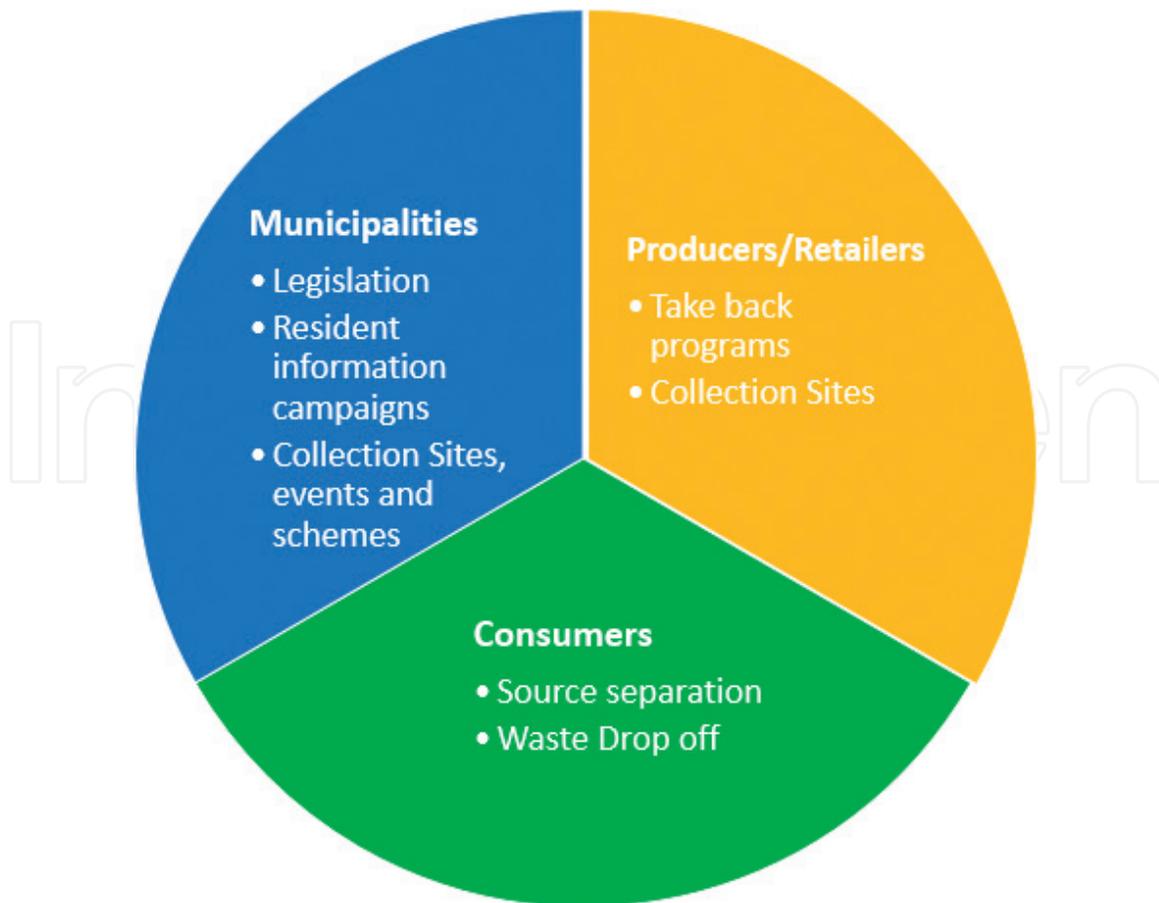


Figure 7.
Collaboration between municipalities, producers, and consumers for proper HHW disposal.

or processed as low-grade fuel oil. Lead-acid batteries contain lead, which can be extracted to produce new batteries. Dry cell batteries, on the other hand, contain many different heavy metals, which may pose a problem for extraction. By collecting a significant amount separately, they can be disposed of more cautiously as hazardous waste [10]. Many EU states collect and recycle fluorescent tubes; however, in Germany, all the components of fluorescent tubes aside from the fluorescent powder have been reported to be reused [7].

5.3 Give out

Rather than discard surplus products in the garbage or down the drain, items such as paint and wood preservatives can be given out to those who require them when in good condition. Charities that facilitate these have been established in certain countries.

6. Legislation and policies

For any management system to be successful, efforts from the municipalities, manufacturers, and residents must be combined. Legislation that assigns responsibility for hazardous components and clarifies handling requirements of household hazardous products encourages manufacturers to consider sustainable methods of recycling waste from their products. Collection programs and proper management schemes fostered by municipalities and industries working together can reduce the amount of HHW that is discarded dangerously. At the core of these programs is the

voluntary source separation by residents within their households. The participation of municipalities, manufacturers, and retailers is also required for these programs to be successful at HHW management (**Figure 7**) [1].

6.1 European Union

The member states of the European Union (EU) are subject to the Waste Framework Directive (WFD) or the Directive 2008/98/EC of the European Parliament concerning general requirements for waste management. Established in 1975, this directive has been substantially amended with the latest revision provided in 2008. HHW is covered in article 20 of this directive, and as with previous directives, it is excluded from the definition of hazardous waste, while it is mixed with other types of household waste. The exclusion also applies when HHW has been separated from mixed household waste and remains until it has been collected properly. Under this legislation, there is no guidance to the management of HHW or legal obligation to the house owners [1, 16].

Directives exist for specific categories of hazardous waste. These documents provide some direction for member states on collection and disposal of the waste and encourage the education of householders on the importance of separating HHW from mixed municipal waste and of the collection and recycling programs that are available to them. The categories include waste from electrical and electronic equipment (WEEE), batteries and accumulators, and waste oils.

Waste oils are covered under the WFD directly in article 21. About 3 million tons of waste oil need to be managed annually in the EU that can severely damage soil and water. The directive prohibits any type of disposal that may adversely affect the environment and human health, discourages mixing of different types of waste oils, and encourages separate collection. The directives for 'batteries and accumulators' and WEEE call for accessible and free collection points and requires producers and distributors to take back waste batteries, accumulators and electrical and electronic equipment (EEE). However, while the disposal of industrial and automotive batteries and accumulators in landfills and incinerators are prohibited, no such legislation is put forth for household batteries. On the other hand, disposal of WEEE is prohibited until proper treatment has been carried out [17].

6.2 North America

HHW in the US is regulated under Subtitle D of the Resource Conservation and Recovery Act as solid waste. It is excluded from hazardous waste, provided that it is material from a permanent or temporary residence [18]. However, since solid waste is regulated by the state and local authorities, some states have more stringent regulations for the management of HHW.

An example is Hawaii. Many of the items that are on the federal list as HHW are the same in Hawaii. However, lamps that contain lead and/or mercury and lead-acid batteries are managed more strictly. In addition, an electronic bill was passed that required computer manufacturers to establish recycling programs. There is also a prohibition on placing motor oil on the ground, in the drainage ways, in sewers, or into water bodies [19].

In Canada, the disposal of solid waste falls under the care of the municipalities with the provinces monitoring operations. While HHW is limited to paint, aerosols, solvents, pesticides, and other products containing hazardous properties, the Waste Diversion Act sets the requirements and guidelines for management of HHW, WEEE, and waste oils in Ontario. Under this act, manufacturers are financially responsible for HHW program, which was developed in 2006 to manage waste

from their products. Similarly, WEEE management is mandatorily funded by industry though some retailers charge consumers an environmental fee at the time of purchase of electronic equipment. However, recycling of mercury-containing lamps is voluntary for consumers [20].

6.3 Schemes and programs

Municipalities may establish frequent HHW curbside pickup as part of the general waste collection program. While convenient for households, this mode can be expensive and time-consuming for waste management authorities [1, 19]. Other options include less frequent collection such as biannually, residents requesting special wastes pick up or personal drop-off at central locations. Such programs for proper disposal and recycling are well established in many countries including the US, Australia, Germany, Denmark, and Sweden [1, 7].

The Extended Producer Responsibility (EPR) is a government policy approach that places the main responsibility of managing a product on the producers or manufacturers. The EU's WEEE directive and Hawaii's computer recycling program are primary examples of such a legislative approach. Companies within an industry can collaborate to develop initiatives for handling waste from their products. The Rechargeable Battery Recycling Corporation (RBRC) is a company that was created by the efforts of battery manufacturers in North America. RBRC is responsible for collecting and processing certain types of batteries in order to extract metals that can be used in manufacturing new batteries [11].

Very similar to the EPR is the Product Stewardship (PS) approach. The manufacturers, retailers, and consumers share the responsibility for the end of life management of a product. The EU has programs similar to these for the management of pesticides and air fresheners [11]. The US also has a well-established PS system and enforces these programs in some states through laws, subsidies, fees, and mandatory take-backs [1]. The retail take-back system provides a setting for retailers to collect waste materials from consumers whether for exchange or refunds. It is particularly attractive because retailers tend to be within reach and more convenient for consumers. However, there is the potential for such a program to place financial burden on the retailers due to handling and storage requirements. In North America, it has been used successfully for the management of all kinds of waste including automotive batteries, fluorescent lamps, mercury thermostats, etc. Likewise, Japan has a take-back program for home appliances, but it is mandatory and requires consumers to pay the retailer for the waste handling [3].

7. Conclusions

In this chapter, the adverse impacts of improper disposal of HHW on the environment were discussed. Improper disposal of HHW introduces harmful compounds, which cannot be removed by treatment facilities into the environment, and these chemicals end up in human, animal, and plant tissues. What constitutes inadequate disposal varies from pouring down the sink or drainage, dumping in the garbage or even out on the ground outdoors. Even when proper disposal routes are provided by municipalities such as drop-off centers are available, many classes of HHW are still disposed in the garbage. Public education, source separation, and

recycling are key strategies to reducing the quantity of HHW stream into municipal facilities and by extension of the environment. The success of these strategies for HHW disposal requires voluntary action from residents, legislation from governments mandating manufacturers to take better responsibility, and schemes that make proper disposal more accessible to residents.

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