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REVIEW ARTICLE

Environmental Contamination and Public Health Effects of Household Hazardous Waste

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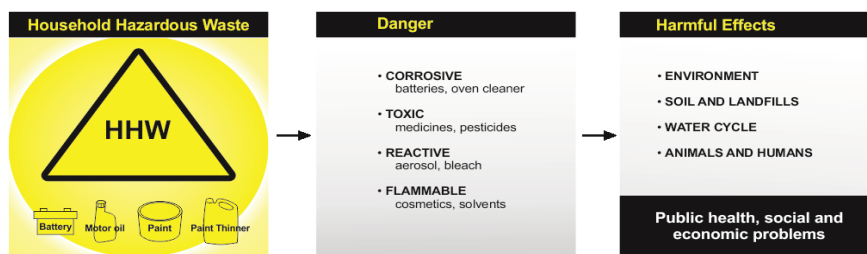
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Abstract

Toxic and hazardous wastes are not only produced by the industries, but also by the household sector. Many household products contain hazardous chemicals and exhibit characteristics that render them dangerous, such as explosiveness, flammability, spontaneous combustion, reactivity, toxicity and corrosiveness. When discarded, these products become Household Hazardous Waste (HHW), which poses a potential threat to human health and the environment. HHW pose a potential hazard to living creatures because they are toxic or lethal, non-degradable or persistent in nature, and may cause detrimental cumulative effects. Even though the overall impacts of household hazardous waste disposal are not fully known but potential concerns include health problems for homeowners, children and pets from improper storage and disposal by the homeowner. Despite the serious threat to public health that it represents, HHW is not perceived as dangerous by a majority of the population. Most of HHW are currently mixed with domestic wastes, which are landfilled, incinerated or composted. If not well-managed, unpredictable negative outcomes of HHW might occur at its source (residential households), waste collection points, during transportation, and after deposit in landfills and/or incineration sites, with the potential to cause permanent damage to the environment and public health. Unfortunately, no establish regulation and standard operational procedure is available for handling HHW in most countries. This review updates the quantity of HHW generated around the world, and the potential and reported environmental and public health effects. Suggestions for reduction of HHW generation and general safety guidelines are also included.

Graphical abstract



Introduction

Household waste means any material, including garbage, trash, and sanitary wastes in septic tanks, derived from households. Among the households are included single and multiple residences, hotels and

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motels, bunkhouses, ranger stations, crew quarters, campgrounds, picnic grounds, and day-use recreation areas. Household wastes include those collected, transported, stored, treated, disposed, recovered (e.g., refuse-derived fuel) or reused. Wastes generated in homes represent two-thirds of all urban productions [1]. Until recently, the presence and management of domestic waste did not present a serious problem for environmental and human health. However, from the last century, changes in societal consumption habits and increase in urban populations have provoked a notable increase in waste generation.

In the flow of domestic waste, certain residues exhibit characteristics that render them dangerous, such as explosiveness, flammability, spontaneous combustion, reactivity with water or air, acute and chronic toxicity, and corrosiveness [2-4]. This waste is known as Household Hazardous Waste (HHW). US legislation has described HHW as household materials which have been discarded and contain toxic, reactive ingredients, ignitable, or corrosive [5]. However, Europe defines the term HHW as such wastes that could potentially increase the hazardous properties of municipal solid waste when landfilled, incinerated or composted [6]. UK National Household Hazardous Waste Forum (NHHWF) provided a broader definition of HHW as “any material discarded by a household, which is difficult to dispose of, or which puts human health or the environment at risk because of its chemical or biological nature” [7].

Some examples of HHW are household cleaners, polishes, drain openers, lighter fluids, cosmetics, fluorescent bulbs, syringes, unwanted medications, home maintenance materials, gardening products, medicines, automobile products, biocides, rechargeable or alkaline batteries, grease and rust solvents, aerosols of various types, latex and oil-based paints, paint thinner and strippers, certain detergents, personal care products, wood preservatives, wood and metal cleaners, glues and cements, solvents, photo chemicals, antifreeze, and electric, transmission fluids, gasoline, carburetor cleaners, and fuel additives, used oil and oil filters, fungicides, insecticides, herbicides, pool chemicals, and electronic wastes [2,8-11].

Rapid global urbanization and increase in living standards in recent decades have led to changes in the HHW generation characteristics due to increase in buying power and easier access to products that are convenient but not always safe. Therefore, people are

exposed to a greater amount of diversified hazardous materials and/or potential hazardous materials, such as phthalates [12], antibacterial agents [13] and monosodium glutamate [14]. However, studies [1,8,15] have indicated that even though HHW comprises 0.5-5.0% of total urban waste, the presence of HHW in disposal sites can cause significant damage owing to its innate characteristics and the manner in which it is treated. Some researchers [1,10] have emphasized the importance of calling more attention to HHW, indicating that in the absence of special collection and treatment programs, many household products containing dangerous chemical substances present potential threats to human health and the environment.

HHW pose a potential hazard to living creatures because they are toxic or lethal, non-degradable or persistent in nature, and may cause detrimental cumulative effects. Household generated hazardous waste such as batteries, paints, solvent and pesticides may threaten individuals and the environment when improperly disposed even though the amount of hazardous waste generated by the household products is only a fraction of that generated by the industries [16]. Collectively, such wastes and the hazards posed are a growing concern. Table 1 shows examples of household products containing hazardous substances. Even though the overall impacts of household hazardous waste disposal are not fully known but potential concerns include health problems for homeowners, children and pets from improper storage and disposal by the homeowner. For example, injuries could happen while waste is being emptied, compacted, or transported. Spills and fire hazards at the collection and disposal sites, and air pollution, groundwater and surface water pollution are all possible outcomes resulting from improper disposal of HHW.

Factors Influencing HHW Generation

The consumption of goods and products lead to the generation of HHW. This condition is influenced by socioeconomic variables such as technological development [21]. Income level determines the capacity of buying and the choice of brands and products, such as cleaning and maintenance products. Similarly, education level influences the choice of purchasing specific products such as books and leisure activities. Other variables such as the weather and the season are known to influence the purchasing of insecticides [22,23]. The overall effect

Table 1: Household products containing hazardous substances.

Product group	Examples	Major components	Hazardous status	Waste	Higher Exposure Route
Mineral oils (natural or synthetic)	Motor oil, Lubricating oil, Hydraulic oil, Gearing oil, etc	Hydrocarbons, Additives	Flammable Potential for water pollution Carcinogen	Waste oil Oil filter from car/trucks Empty bucket and dirty cloths	Waste
Asbestos products	Roofing, slab (Eternit), Flower pots, Insulating panels, Heating blankets, Electric heaters, Brake pads, etc.	Asbestos fiber	Carcinogen	Old household appliances Construction waste	Usage/Waste
Batteries and Accumulators	Car batteries (Lead accumulators)	Lead, Sulphuric acid	Toxic Corrosive	Waste car battery	Waste
	Zinc-carbon and Alkali-Manganese			Waste batteries	Waste
	Mercury batteries	Hg	Toxic	Waste batteries	Waste
	Nickel-cadmium accumulator	Cadmium	Toxic	Waste batteries	Waste
	Lithium batteries			Waste batteries	Waste
Paints and varnishes	Synthetic or Natural varnishes	Pigments containing heavy metals (Cd, Pb) Solvents (ethylene glycol, methyl dipropoxol) Additives (formaldehyde, insecticides, fungicides, biocides, etc)	Toxic Flammable, VOC	Packaging waste Paint residues	Usage/Water/ Waste
	Gloss paint, Acrylic paint	Pigment, Solvent	Toxic Flammable, VOC	Packaging waste Paint residues	Usage Waste
Paints and varnishes	Latex based paint		Toxic	Packaging waste Paint residues	Usage Waste
	Thinner/paint remover	Petroleum distillates, White spirit, Butanol, Xylene, Diacetone, Ethanol	Toxic Flammable, VOC	Packaging waste Product residues	Usage
Wood preservatives		Solvent Salts (Fluorine salt, arseniates) Insecticides, Fungicides (pentachlorophenol, lindane)	Flammable, VOC, Toxic	Packaging waste Waste wood Product residues	Waste wood Product residues Usage Waste
Agents for care and Cleaning	Floor polish	Diethylene glycol, Petroleum distillates, Nitrobenzene	Toxic Flammable Carcinogen	Product residues, Old containers discarded during house clear outs	Usage
	Furniture polish	Diethylene glycol, Petroleum distillates, Nitrobenzene	Toxic Flammable Carcinogen	Product residues, House clear outs	Usage

	Leather care	Solvents	Flammable, VOC	Product residues, House clear outs	Usage
	Shoe polish	Petroleum distillates, Hydrocarbons		Product residues, House clear outs	Usage
	Stain remover	Acetone, Toluene	Toxic Corrosive Flammable Carcinogen	Product residues, House clear outs	Usage
Agents for care and Cleaning	Ammonia based cleaner	Ammonia	Corrosive Toxic	Product residues, House clear outs	Usage
	Scouring agents	Potassium hydroxide	Corrosive	Product residues, House clear outs	Usage
	Disinfectant and bleach based products	Sodium and Calcium hypochlorite, Sodium hydroxide, Antibacterial agents	Corrosive Toxic if swallowed, Irritant	Product residues, House clear outs	Usage/Water
	Cleaning agent oven/grill	Sodium hydroxide	Toxic Corrosive Irritant	Product residues, House clear outs	Usage
	Cleaning agent for pipes	Acid: Hydrochloric acid Alkali: (NaOH, Na ₂ CO ₃ , KOH) Oxidizing agents (NaOCl, H ₂ O ₂), Sodium silicate, Sodium sulphate, Sodium triphosphate	Corrosive Toxic Reactive	Product residues, House clear outs	Usage/Water
	Descaler	Hydrochloric acid Phosphoric acid, Oxalic acid		Product residues, House clear outs	Usage/Water
	Air freshener		Toxic Flammable		Usage
	Bbq lighter fluid		Toxic Flammable		Usage
Solvents	Stain remover, Cleaning products, Paint stripper, Alcohol, Nail varnish, Polish remover, Thinner	Acetone, alcohol, Chlorinated hydrocarbons, Chloroform, White spirit, Toluene, Xylene,	Inflammable, VOC Toxic	Product residues, House clear outs	Usage/Water
Photo lab chemicals	Developer	Solvent (acetone, ethylene glycol) Alkaline solutions	Toxic, Irritant	Product residues	Usage/Water
	Stop bath	Acetic acid, Formaldehyde	Irritant, Carcinogen		Usage/Water
	Whitening bath	Hexacyanoferate, Bichromate	Carcinogen, Toxic		Usage/Water
	Stopping bath	Acetic acid, Formaldehyde	Allergen, arcinogen		Usage/ Water
Mercury containing Products	Fluorescent tubes Low energy light bulbs	Hg	Toxic	End of life disposal	Waste
	Thermometer Barometer, etc	Hg	Toxic	Broken, or Discarded	Waste
Pesticides	Ant poison	Bendiocarb, Pyrethroids	Very Toxic	Product residues, House clear outs	Usage/Waste
	Fungicides	Dichlofluanid, PCP	Very Toxic		Usage/Waste
	Herbicides	Atrazine, Simazine, Acid herbicides, OPs, Organo chlorines, Glyphosate	Very Toxic	Product residues, House clear outs	Usage/Waste
	Insecticides	Pyrethroids, OPs, Arsenic, Organo chlorines	Very Toxic	Product residues, House clear outs	Usage/Waste
Pesticides	Rat poison	Warfrin, Strychnine, Brodifacoum	Very Toxic	Product residues, House clear outs	Usage/Waste

	Moth balls	Naphthalene			Usage/Waste
Aerosols	Containing CFC	CFC	Greenhouse effect		Usage/Waste
	Other	Propane, Butane Residues from product (acid, alkali, pesticides, solvents, etc)	Explosive Flammable Greenhouse effect Toxic, Flammable, Corrosive, etc	Product residues, House clear outs	Usage
Medicines	Antibiotics, Hormone replacing drugs, Cancer medicines, Depression medicines, etc		Toxic, Endocrine disrupter	Unused medicines	Water/Waste
Cosmetics	Hair dyes	Pigment, Ammonia		Product residues, Unused product	Water
	Bath salts/bubble bath				Water
	Skin creams	Heavy metal			Water
	Nail varnish	Pigment, Solvent	Toxic Flammable		Usage
	Nail polish remover	Acetone	Toxic Flammable	Product residues, House clear outs	Usage
Chemical for craft and hobbies and car maintenance	Ink cartridge and toner	Alcohol Pigments including: Glycols (e.g. diethylene glycol, tetraethylene glycol) Nitrates Diols (e.g. 1,2-hexanediol, 1,5-pentanediol) Pyrrolidones (e.g. 2-pyrrolidone, N-methyl 2-pyrrolidone) Furans	Flammable Toxic	Waste cartridge, Residues of ink andTon	Waste
	Glue	Xylene, Toluene, etc	Flammable, toxic		Usage
	Text whitener	Solvents	Flammable, toxic		Usage
	Antifreeze, Defroster	Ethylene glycol, Methanol	Flammable, toxic		Usage
	Rust inhibitor	Zn chloride, Chromates	Toxic		Usage
	Sealing compounds	Solvent, PCB	Toxic, Flammable		Usage

Sources: [17-20]

Notes:

Corrosive: Can cause burn and destroy living tissues or other materials, which come in contact

Explosive: Can detonate or explode through exposure to heat, sudden shock, pressure or incompatible chemicals

Flammable: Can be easily set on fire

Toxic: Can cause injury or death through ingestion, inhalation or absorption through skin

Bbq = Barbecue; CFC = Chlorofluorocarbon; PCB = Printed Circuit board.

of the mentioned variables creates a complex mixture that reflects new consumption patterns and lifestyles, both contributing to increase the use of products that lead to the generation of HHW, especially in developing countries.

The middle income group has been reported to generate the highest percentage of hazardous component in their waste as compared to other income groups. The main factor is the power of purchasing goods where consumers from middle income group are able to purchase a greater variety of products, which are of better quality but less environmental-friendly. Surveys indicated that people from the

middle class generally are not willing to pay extra for environmental-friendly products [24]. Therefore, the possibility of them utilizing goods, which contain hazardous compounds of slightly lower prices, is higher. Other contributing factors include lack of awareness on hazardous waste issues and the inefficient waste collection systems [25].

The increasing scale of economic activity, urbanization, industrialization, rising standard of living and population growth, has led to a sharp increase in the quantity of waste generated. In 1997, the total solid waste generated throughout Malaysia was 5.6 million tons or 15,000 tons/day and of this

80 % was domestic waste (about 12,100 ton/day) and the rest (about 3,100 tons/day) was commercial waste [26]. Table 2 shows the HHW generated across the globe.

Household Hazardous Waste and the Environment

Improper disposal of household hazardous waste

Unlike the waste streams originating from industrial sources, hazardous substances in

household waste are not strictly controlled under hazardous waste regulations such as the US Resource Conservation and Recovery Act 1976 (RCRA) [36]. As such, HHW is disposed of to landfill along with general household waste. The amounts and significance of this disposal are poorly understood. Generally, it is assumed that amounts are small and therefore risks of disposal are negligible. The consequences of HHW disposal are therefore obscured in many leachate studies. Where it is possible to differentiate waste sources, leachate composition has the potential to act as a useful tool in HHW risk evaluation. When evaluating the disposal of HHW, the conditions within

Table 2: Hazardous Household Waste (HHW) generation in the world.

Study	Country	HHWs % of the MSW stream	g/person/day
[15]	Mexico	3.49	-
[15]	Northern Mexico	3.70	-
	Southern Mexico	1.03	-
[6]	Switzerland	0.50	-
	UK	0.90	-
	Hungary	0.70	-
[29]	England	5.00	-
[27]	Denmark	-	5.00
[2]	Japan	0.43	5.48
[28]	Argentina	1.00	-
[29]	UK	1.00	-
[30]	Malawi	0.50	-
[31]	China	2.23	6.16
[32]	Vietnam	0.20	0.53
[10]	Nepal	1.00	3.30
[2]	Austria	-	3.84
[2]	Germany	-	6.03
[33]	Ghana	-	0.40
[34]	Palestine (Hebron)	1.00	-
[35]	Czech Republic	2.47	-
[7]	Belgium (2000)	1.00	-
	Finland (1999)	1.17	-
	France (2000)	1.20	-
	Germany (1997)	1.00	-
	Greece (2008)	0.60	-
	Ireland (1998)	0.50	-
	Italy (1997)	1.00	-
	Netherland (2000)	0.40	-
	Portugal (1998)	1.16	-
	Spain (1997)	1.00	-
	Sweden (2011)	0.40	-
	Wales (2007)	0.80	-
	USA (1997)	1.00	-
	India (1999)	0.50	-
	Pakistan (2014)	0.19	-
	Canada (2005)	1.19	-

HHW: Hazardous Household Waste; MSW: Municipal Solid Waste.

the landfill must be acknowledged to determine the nature of the components and the likelihood of occurrence in leachate.

Generally, HHW are directly disposed to the landfill openly and no sanitary. According to USEPA [37], HHWs are sometimes disposed of improperly by individuals such as pouring wastes down the drain, on the ground, into storm sewers, or putting them out with the trash. The dangers of such disposal methods may not be immediately obvious, but certain types of HHW have the potential to cause physical injury to sanitation workers; contaminate septic tanks or wastewater treatment systems if poured down drains or toilets; and present hazards to children, workers, and pets if left around the house. According to Agamuthu [25], more than 64.7% of HHW end up in the garbage bin, 12.7% are poured down the drain, 2.4% are burnt and 20.2% are disposed of by other methods like burying or are just arbitrarily dumped. A variety of studies [38-41] have reported the use of open air burns to control waste levels at disposal sites. This practice promotes the harmful effects of HHWs and other materials, which by themselves do not substantially affect the environment upon disposal.

The disposal methods for HHW in most homes include the following:

Disposal into the trash

Any HHW that gets thrown away with the regular trash is landfilled or incinerated.

Landfills: Landfills are not isolated, they are connected to the environment. Rain, snow, and other precipitation enter landfills and mixed with the landfill contents, including hazardous wastes. If the hazardous waste is water soluble, then it will be dissolved and carried wherever the water takes it. If it is not water soluble, it will probably remain intact and travel suspended in the water. This contaminated water (or leachate) trickles down through the layers of trash and might enter the environment if it does not encounter any type of barrier. Since lined landfills are not designed to treat hazardous waste, some types of hazardous wastes may destroy the synthetic liner, making it ineffective. Leachate contaminated with hazardous waste cannot be completely cleaned at the wastewater treatment facilities to which it is sent. Leachate, contaminated by hazardous waste, may potentially enter the water cycle.

Landfill conditions influence what happens to household hazardous waste. The amount of oxygen

and moisture in the landfill and the surrounding soil characteristics affect how fast HHW containers or metal battery casings will degrade. Water in a landfill may also react with different types of hazardous waste. For example, lithium, found in a type of dry cell battery, may react violently with water stayed in a landfill. Since the chemical makeup is vastly different among the different types of household hazardous waste, a general statement about what happens to household hazardous waste in a landfill environment cannot be made. The long-term effects of HHW in landfills are unknown because studies are very limited. The burial of HHW (without adequate precautions) could contaminate the soil and groundwater, cause fires or explosions, and release toxic fumes.

Incinerators: Although incinerators are equipped with pollution control devices, some pollutants found in HHW are difficult to capture. Some components of the HHW stream are particularly troublesome. For example, at the high temperatures that occur during incineration, mercury (found in some dry cell batteries, fluorescent light bulbs, and old paint) can change into a gas and be emitted through the stack of the incinerator. There are controversies about how effective incinerators are in capturing all pollutants. Some believe that existing air pollution control equipment, such as “scrubbers,” is effective at capturing pollutants before they leave the stack. However, the most efficient technology (spray dry/fabric filter) can only remove 75-85% of the mercury. Airborne mercury is soluble in water and finds its way into lakes, streams, and groundwater, where it can enter the food chain. Also, the ash left over from incinerator burning may contain concentrated amounts of some hazardous chemicals. Once airborne, hazardous substances may react with other contaminants and form a new substance, become dissolved in water droplets, and eventually fall to the earth as rain or as larger particles (dry precipitation). The amount of time a material is in the atmosphere depends on how stable it is. Unstable compounds, such as carbon monoxide, are short lived in the atmosphere. Stable compounds remain in the atmosphere for long periods of time and can cause much damage. The incineration of HHW in municipal waste-to-energy facilities could cause explosions, release toxic fumes into the air, and concentrate toxic substances in the ash.

Dumping on the ground

If dumped directly on the ground, the soil will be firstly affected by HHW. Hazardous materials are

dissolved or suspended into liquid before moving through soil. How thick this solution or mixture is, *i.e.* the viscosity determines how fast the moisture moves. Soil type also influences how fast and how far the moisture travels. Soil characteristics such as porosity (the amount of space between the soil pores) influence the contaminated water's movement. The larger pore spaces found in sandy soils permit easier movement of moisture than do the smaller spaces of clay soils. Geological factors (rock formations, fractures, faults) also affect this movement. Thus, HHW that is dumped may contaminate the surrounding soil or its leachate may percolate down and potentially contaminate groundwater.

Disposal Down the Drain

Any HHW that is poured down the drain enters either a septic system or a wastewater treatment facility and ultimately enters the water cycle.

Septic systems

The septic system treats a building's wastewater before releasing it back into the environment. However, like incinerators and landfills, septic systems are not designed to treat hazardous waste. Hazardous waste, including excessive amounts of drain openers and cleaners containing lye and strong bleach, may negatively affect the system's natural cleansing process by destroying bacteria indispensable to clean the water. Without these bacteria, certain pathogens will travel through the system unchanged. Since the system is not designed to treat chemical waste, HHW passes through the system unchanged and can potentially contaminate ground and surface water. The disposal of HHW down the drains or storm sewers could corrode plumbing; release harmful fumes; create problems in septic systems and in wastewater treatment plants: pollute groundwater, rivers, and streams: contaminate public water supplies; and possibly cause toxic accumulation in food chains.

Wastewater treatment facilities

Wastewater treatment facilities operate on the same principle as septic systems, except on a much larger scale. Wastewater from residences and businesses is treated at a central location, rather than on site. At the central location, wastewater goes through a series of treatments before it is released into local water sources. Wastewater treatment facilities are not designed to treat hazardous wastes.

Environmental Impact and Public Health Effects of HHW

If not well-managed, unpredictable negative outcomes of HHW can occur at its source (residential households), waste collection points, during transportation, and after deposit in landfills and/or incineration sites, with the potential to cause permanent damage to the environment and public health.

Effects of hazardous household waste on environment

Improper disposal of HHW may change the way the biosphere functions, depletes the ozone layer and causes irreversible damage to domestic water sources. This could result in reduction of the productivity of global ecosystems at a time when millions of people are looking for livelihoods and sustenance to be provided by the environment [42].

Soil and landfills: Studies on the potential adverse effect of HHW on soil and landfill suffer from a common problem: the researchers could not be certain that the landfilled waste from which the leachate was derived did not contain hazardous materials from sources other than households. It should also be noted that some of the contaminants probably come from products not normally categorized as HHW at all, such as inks in paper. HHW also increases in toxicity if Municipal Solid Waste (MSW) landfill leachate comes into contact with hazardous pollutants, which has been widely reviewed as a primary cause of groundwater contamination [1,43]. Substances not found in HHW at disposal can occur in leachate as a result of degradation and other transformations. Quantities of hazardous substances will vary according to landfill conditions, particularly moisture content and ionic strength of the leachate [44].

The quantities of the hazardous chemicals so far detected in leachate from household dumpsites vary from study to study, from trace levels to amounts exceeding established limits. Such variation is the result of differences in disposal practice, levels of regulation, landfill design and ultimately a reflection of the purchasing patterns of consumers, mainly market forces, availability, and culture in different countries. Alternatively, sampling error might play a significant role through the inappropriate application of certain methodologies and analytical techniques [45-47].

There is evidence that HHW disposal to landfill sites contributes toxic substances to the landfill leachate that forms through a process of rainwater infiltration and decomposition of the waste body. Household waste leachate has been shown to contain high concentrations of Pb, Ni, Cd and Hg. Also, increase in physico-chemical parameters such as pH, turbidity, conductivity and phosphate has been reported [48,49]. Mixing HSW compost with HHW would likely cause it to exceed the legally permissible heavy metal limits [50]. Studies on the impact of batteries disposal from household on landfill, in Italy [51], Thailand [52], Iran [53], and in U.S.A. [54] have shown that there is a correlation between batteries disposal on the landfill, increase in heavy metal concentration, environmental damage and public health impact. Exposure to heavy metals can cause serious health problems including cancers, reproductive and behavioral diseases. Persistent substances such as mercury in the environment can accumulate in the fish flesh, plants, fruits, and vegetables making them unsafe to eat and may cause gene mutation, cancer and congenital abnormalities [55]. Lead, which is commonly used in fishing jigs and sinkers, has an adverse effect on the nervous and reproductive systems of mammals and birds, and is poisoning wildlife such as loons and eagles. Various studies conducted on the nature of the leachate from municipal waste landfills, both real and simulated, have revealed that these leachates (even in rural areas) typically contain many hazardous constituents, including organics, such as phthalates, phenol, methylene chloride, trichloroethylene, toluene as well as rests of herbicides/pesticides. Over 200 organic chemicals have been recorded in MSW leachate, a number of which can be assumed to derive from the co-disposal of HHW with MSW [1]. All of these organics are found in consumer products, but this observation does not establish their origin, because they may also be formed in reactions within a landfill, after deposition of the waste. Some of these chemicals have immediate toxic effects while others are toxic only after repeated exposure, i.e. in a long-term exposure. Organochlorine insecticide can accumulate along the food chain, positioning itself in the fat of fish, cattle, poultry and other animals, and breast milk, as well as in plants, fruits and water that have been exposed to these substances, creating ecological and public health problems [56].

Water cycle: The improper disposal of HHW has led to its entrance into the water cycle. Precipitation falls to earth, entering oceans, lakes, and streams or trickling

down through the soil. That water that enters the soil may travel until it reaches an impermeable barrier (such as bedrock). This water collects underneath the earth's surface and is called groundwater. It is stored in the surrounding sand, gravel, or other sediment. Groundwater is not the final resting place for water. Although it moves very slowly, groundwater is constantly on the move. Groundwater eventually flows to the surface (streams, springs, swamps, ponds, or lakes), where it evaporates into clouds or is taken into living things. The whole process then starts over again. It is this constant cycle between surface water and groundwater that spreads water pollution. Groundwater contamination occurs when polluted surface water or precipitation percolates through the soil. Since groundwater constantly interacts with the entire water cycle, contamination spreads easily. Since this cycle is continuous, contaminated groundwater can also feed and contaminate lakes, ponds, and streams.

Scientists worldwide are now detecting household pharmaceuticals in water and soil. In 2002, U.S.A. Geological Survey (USGS) reported pharmaceutical and personal care product contaminants in 80 percent of 139 streams sampled in 30 states [57]. Pharmaceuticals enter wastewater treatment plants through either excretion or flushing of unused medications in households. These pharmaceuticals may not be completely degraded or removed at the wastewater treatment plant. Regardless of the level of treatment, most conventional wastewater treatment cannot effectively eliminate pharmaceutical compounds. Disposal of hazardous household wastes in drains might also pollute drinking water. A gallon of waste oil poured on the ground can contaminate over one million gallons of drinking water. More seriously, hazardous materials spill can also affect sewer systems, causing explosions in pipes and even the overall waste management system [58]. In septic systems, hazardous wastes can kill the organisms that make the system work [59]. This may cause the bulk of untreated wastes to drain into the soil and eventually seep into the groundwater. Sewage treatment systems such as septic systems can be contaminated by improper disposal of hazardous household wastes [59-61]. Most constituents of HHWs are persistent in nature and nonbiodegradable; once released into the environment, they transform from one form into a more toxic form [62-64]. HHW such as cleaning products containing phosphorus or nitrogen can contribute to nutrient loading in water bodies, compromising the water quality [65].

Effects of hazardous household waste on humans

As concern about chemicals in household products increases [66], the potential consequences to public health from the disposal of HHW are also moving to the fore. The impact of the resulting chemical mixture of HHW on the public health or the environment is difficult to establish without the availability of reliable risk assessment methods. To overcome the difficulties, several considerations need further research, such as interactions, synergistic and antagonistic effects [67], in addition to the chemical nature and concentration ranges existing in a landfill. Furthermore, when considering public health, it is difficult to assign to each HHW type (or mixture), a representative value to denote the “risk potential”.

The potential for adverse health effects in population contacting hazardous household wastes may involve any organ system, depending on: (1) Dosage, because a large dose may mean immediate effect; (2) Age, since the elderly and children are more susceptible to toxins; (3) Gender, since each sex has hormonally controlled hyper sensitivities; (4) Bodyweight, which is inversely proportional to toxic responses/effects; (5) Psychological status, because stress increases vulnerability; (6) Genetics, because different metabolic rates affect receptor responses; (7) Immunological status and presence of other diseases, because health status influences general metabolism; and (8) Weather conditions, since temperature, humidity, barometric pressure, and season among others potentially affect the absorption rates [19].

Several health effects of primary concern may affect populations exposed to HHW. These include: carcinogenesis (i.e. causing cancers), genetic defects, including mutagenesis (i.e. causing alterations in genes which are transmitted from one generation to another or causing heritable genetic damage), reproductive abnormalities including teratogenesis (i.e. causing damage to developing fetus not necessarily related to toxic effects on mother), alterations of immunobiological homeostasis, Central Nervous System (CNS disorder) and congenital anomalies [19,68].

Systematic documentation of damage due to HHW is scarce. The majority of studies evaluating possible health effects of HHW have revealed that most of the everyday products used at home such as cleaning ingredients and cosmetic products pose

certain types of health risk and hazard. These studies reveal that some ingredients of these products may cause immediate or acute hazards such as skin or respiratory irritation, watery eyes or chemical burns, acid burns from a product like battery acid, or injury by an aerosol exploding close to a stove, headaches, fatigue, burning eyes, runny nose, and rashes [69], while others such as automotive products, solvents, oil-based paints, or pesticides [70] are associated with long-term or chronic harmful health effects such as cancer [69].

Health risks associated with using hazardous household products are of greater concern. Table 3 shows the public health effects of selected household products. A study on chemicals used in household products in New Jersey and Massachusetts showed that in those two states alone, 28 million pounds of chemicals that are known or suspected neurotoxins, carcinogens, or reproductive or developmental toxicants were used in soaps and other detergents. An additional 259 million pounds of these chemicals were accounted for in specialty cleaners and polishers [71]. Table 4 shows the HMIS[®] risk values for typical household products. Humans are exposed to chemicals from various household products through ingestion, absorption or inhalation. This can have both acute and chronic effects on the exposed individuals. Acute effects of some of these products include poisoning by a toxic substance such as antifreeze, injury by an aerosol can exploding close to a stove or acid burns from a product like battery acid. Some HHW have been known to emit toxic gases capable of producing acute reactions such as runny nose, fatigue, burning eyes, headaches, and rashes [69]. Chronic health effects can arise from persistent or recurrent exposure to highly toxic products like oil-based paints, solvents, automotive products, or pesticides [70]. Individuals can be exposed to pesticides through contaminated/polluted indoor and outdoor air (including structural application and agriculture), drinking water, and food. Children are especially susceptible to the negative effects of chemicals from home. When they play, they crawl and put things in their mouths. With their rapidly developing bodies, they are more prone to damage as they have a small fraction of the body weight of an adult, they might process these pollutants differently from adults and can ingest five times more powder-100 mg per day on average [72]. Children may experience neurological effects as well as increased cases of asthma and allergies from exposure to pesticides [73].

Table 3: Potential health hazards of common household products.

Product Type	Class	Possible Hazardous Ingredients	Hazardous status	Potential Health Hazards
Air fresheners	II	Formaldehyde	Toxic	Carcinogen, irritates eyes, nose, throat and skin; nervous, digestive and respiratory system damage
Bleach	V	Sodium hypochlorite	Corrosive Toxic	Causes burns; mixing with ammonia creates a deadly gas, nervous, digestive and respiratory system damage
Disinfectants	V	Phenols Ammonia	Toxic Flammable Toxic	respiratory, circulatory, or cardiac damage Vapor irritates skin, eyes and respiratory tract
Drain cleaner/ oven cleaner	V	Sodium or potassium hypochlorite	Corrosive	Causes severe burns and tissue damage if swallowed, nervous, digestive and respiratory system damage
Floor cleaner/wax	V	Diethylene glycol	Toxic	Central nervous system depression, kidney and liver damage
Furniture polish	V	Petroleum distillates	Flammable	Some are carcinogens
Spot removers	V	Perchloroethylene, Ammonia hydroxide	Corrosive	Suspected carcinogen Irritates skin, eyes, respiratory tract
Window cleaners	V	Ammonia	Toxic	Vapor irritating to lungs, eyes, and skin
Flea powder	IV	Carcaryl Dichloropene Chlordane/other chlorinated hydrocarbons	Toxic Toxic Toxic	Irritates skin; causes nervous, respiratory and circulatory system damage Irritates skin; causes nervous and digestive system damage Irritates eyes and skin; causes respiratory, digestive and urinary system damage
Paint thinner	III	Chlorinated aliphatic hydrocarbons Esters Alcohols Chlorinated aromatic hydrocarbons	Toxic Toxic Flammable Flammable Toxic	Causes digestive and urinary system damage Irritates eyes, nose and throat Nervous system damage, irritates eyes, nose and throat Digestive system damage
Paints	II	Ketones Aromatic hydrocarbons Mineral spirits	Flammable Toxic Flammable Flammable	Respiratory system damage Carcinogenic; irritates skin, eyes, nose and throat; respiratory system damage Irritates skin, eyes, nose and throat; respiratory system damage
Pool sanitizers	V	Calcium hypochlorite Ethylene (algaecides)	Corrosive Flammable Toxic	Irritates skin, eyes, nose and throat; if ingested causes severe burns to the digestive system Irritation of eyes, mucous membrane and skin, affects Reproductive system; probable human carcinogen of medium carcinogenic hazard
Toilet bowl cleaner	V	Sodium acid Sulfate/oxalate/ hypochloric acid Chlorinated phenols	Corrosive Toxic Flammable Toxic	Burns skin; digestive and respiratory systems damage Respiratory and circulatory system damage
Motor oil	I	Heavy metals Hydrocarbons	Toxic Flammable	Nerve and kidney damage; carcinogenic Carcinogenic
Batteries (car, boat, tractor)	IV	Sulfuric acid Lead	Toxic Corrosive Toxic Corrosive	Severe skin burns and blindness Nerve and kidney damage, carcinogenic
Windshield washer fluid	I	Methanol Ethylene glycol Isopropanol	Flammable Toxic Flammable Toxic Flammable	Can damage the nervous system, liver, kidney; inhalation can Cause lung disease Can cause severe damage to the heart, kidney and brain; Inhalation can cause dizziness Irritation of the mucous membrane; ingestion results in drowsiness, unconsciousness and death
Laundry detergent	V	Cationic, anionic or nonionic solutions	Reactive	If swallowed, cationic detergents can cause nausea, vomiting, shock, convulsions, and coma. Nonionic detergents can irritate the skin and eyes

All-purpose cleaners	V	Ammonia Monobutyl acetate	Toxic Toxic	Fumes can irritate eyes and lungs, can cause burns or rashes on skin; can produce deadly chloramine gas if mixed with chlorine-containing products Inhalation can cause dizziness
Insecticides	IV	Organophosphate and carbamates	Toxic	Can cause headache, dizziness, twitching, nausea; carcinogenic in animals
Household foggers	IV	Pyrethrins Permethrin Methoprene	Toxic Toxic Toxic	Can cause severe allergic dermatitis, systemic allergic reactions; large amounts may cause nausea, vomiting, tinnitus, headache and nervous system disturbances Can cause itching and burning of the skin and eyes; irritates the upper respiratory tract Can irritate skin and eyes
Swimming pool chloride tablet	II	Sodium/calcium hypochlorite	Corrosive Reactive	Corrosive to skin and lining of nose, mouth and throat; fumes irritating to eyes and respiratory tract
Insect repellants	IV	Butopyronoxyl Dimethyl phthalate Diethyltoluamide (DEET)	Toxic Toxic Toxic	Can cause mild necrosis in liver and kidney in animals Can cause central nervous system depression if swallowed Can irritate sensitive skin and respiratory tract tissues; loss of coordination, anxiety, behavioral changes and mental confusion
Weed killer	IV	Diquat, 2,4-D, and glyphosate	Toxic	Can irritate the eyes and skin; can cause abdominal pain, nausea, vomiting and diarrhea
Rodent control	IV	Warfarin	Reactive	Causes internal bleeding if ingested in large amount
Rug, carpet, upholstery cleaners	V	Naphthalene	Toxic Reactive	Can damage liver; prolonged vapor exposure can lead to Cataract formation

Source: [77-81,53,61].

Table 4: HMIS® risk values for typical household products.

Product	Health rating	Flammability	Reactivity
Household maintenance	2	4	1
Insecticides	4*	4	4
Self care	0	1	0
Cleaning	3	1	1

HMIS®: 0-minimal; 1-slight; 2-moderate; 3-serious; 4-severe; *Cancer risk (HMIS®; [82].

Also, antifreeze or engine coolant contains ethylene glycol that tastes sweet to children, and if accidentally ingested might cause serious and harmful effects. Symptoms of antifreeze poisoning include severe diarrhea and vomiting in children.

Hazardous cleaners in aerosol form are of particular concern. A person using an aerosol spray is surrounded in a fine mist of the hazardous product. The mist can remain airborne for hours and can easily be inhaled into the lungs. If the aerosol spray is misdirected, it can result in chemical burns and eye injuries. Data from the American Association of Poison Control Centers indicates, household cleaners were the third largest category of substances associated with calls to poison control centers, with over 218,000 calls made

in 2005 [73]. Over half of those calls (121,000) were made in response to an incident involving children ages six and under [74]. Study [75] has shown that frequent use of household products is associated with persistent wheezing among pre-school age children and exposure to household cleaning chemicals has been reported to increase the likelihood of asthma among children [76].

Study [83] has shown an association between mothers' exposure to phthalates during pregnancy and adverse effects to their male children. Another study reported a correlation between levels of phthalates in house dust and allergic symptoms and/or asthma in children in those homes [84]. HHW has the potential to cause danger for waste workers

and harm trash collection personnel. Inappropriate HHW classification management, such as improper disposal of aerosol cans, might lead to serious accidents (fire and explosion) that are destructive to transfer station equipment and hazardous to employees [82,85]. Improper disposal of used or unwanted “sharps” (needles, syringes, lancets and other sharps items) can cause serious injury and pose health risks to the public and waste workers. Waste workers are exposed to potential needle stick injuries and potential infection when inappropriate containers break open inside garbage trucks or sharps become exposed when sent to recycling facilities. Housekeepers and janitors may also be injured when loose sharps poke through trash bags. Used needles may also cause painful infections and transmit serious diseases, such as HIV and hepatitis. Galvin and Ridgley [86] cites a study about Los Angeles city that found chemicals implicated in 158 injuries in waste collectors during 1980 to 1985. However, more extensive documentation is lacking. Furthermore, the insurance industry does not maintain data in a form that would allow one to examine the level of HHW-related claims by refuse workers.

Effects of hazardous household waste on animals

Glycol ethers are a large group of organic solvents widely used in cleaning chemical formulations for both industrial and household applications [87-89]. Animal studies have reported testicular damage, reduced fertility, maternal toxicity, early embryonic death, birth defects, and delayed development from inhalation and oral exposure to the glycol ethers [90]. Ethylene glycol present in antifreeze or engine coolant used in homes tastes sweet to animals but is toxic. For example, in animals, as little as a teaspoonful might be fatal to a cat, and four-tea spoonfuls might be dangerous to a dog. Phthalates from HHW have been shown to induce developmental, reproductive (such as male sexual characteristics, reduced sperm count and abnormal sperm cells) [90] and organ damage in animals [91]. A volatile chemical from cleaning products, 2-butoxyethanol, which usually evaporates into the air during usage, has been shown to be easily absorbed by the skin from the air, aside inhalation [92]. Study has found reduced fertility among female mice exposed to 2-butoxyethanol, and lower birth weight in their offspring [93] and it is reported to be the most potent glycol ether in terms of red blood cell damage, which can lead to anemia [94,95]. Researchers suspect that hormones and pharmaceutical compounds of

household origin, which have polluted the water bodies may be responsible for effects on wildlife, including feminization of male fish, sluggish activity or reduced appetite, decreased reproduction rates, slower development rates and additional appendages.

General Safety Guidelines for Household Hazardous Products

At times it is unavoidable to use a product with hazardous ingredients, however the risks can be minimized. To use products that contain hazardous ingredients at home, the user should be aware of the following safety rules:

- a. Read labels: Although product labels do not always give complete information, some precautions may be listed. It is important to understand the directions before using a hazardous product.
- b. Wear protective clothing: Gloves, safety glasses, and respirators may be required in order to safely use a hazardous product. It is advisable to wear clothing other than everyday clothes when working with hazardous products. Also avoid wearing soft contact lenses while using volatile solvents. These lenses can absorb the chemical and hold it next to the eye, causing irritation, burns, or extensive damage. Volatile substances are liquids that evaporate easily into a gaseous form.
- c. Habit: It is good to avoid eating, drinking, or smoking when using hazardous products.
- d. Never mix chemicals: It is not good to think that combining two different extra-strength cleaners will produce a super cleaner. Manufacturers are not required to list the exact chemical ingredients on the label; therefore, one can never be sure what it is that one is mixing.
- e. Always replace the caps on containers while using products: Many products may contain chemicals that are extremely volatile and evaporate quickly into their surroundings. Airborne fumes can be harmful to human and animal health.
- f. Clean up after using the product: The rag used to clean up spilled hazardous product at home contains those same chemicals. They should be stored in a covered metal container

for protection. Rags used to soak up solvents become fire hazards.

- g. Keep products in their original containers and out of the reach of children: The container provides necessary information about the product's use and storage. If placed in another container, the product has a high potential of becoming a "mystery" product. Such mysteries are dangerous. Storing hazardous products in former food containers increases the likelihood of accidental poisonings.
- h. Use aerosols with caution: Do not puncture aerosol's can, as this may cause an explosion. Never place the can near a high heat source. Do not throw a partially full or full can in with regular trash; it may explode in a garbage truck when compacted.
- i. Use it up: It is important to be sure the entire contents are used up before throwing hazardous products away. If this cannot be done, it is advisable to call the solid waste authority for information on household hazardous waste collection in the community.

Suggested Ways to Reduce the Generation of HHW

The best way to deal with HHW is to avoid creating it. This can be achieved by:

1. Purchase Less: People should buy only the amount needed, even if a larger container offers a price discount.
2. Use it up: Use up all of the products you have before you buy any more. Most products do not expire.
3. Give it away: Find someone or any charity that can use your excess material.
4. Simplify: Use multi-purpose cleaners rather than having a full collection of specialized products.
5. Use safer alternatives: Buy less-toxic alternatives. Avoid the ones with the words "poison" or "danger" on the label.
6. Recycle everything you can: check with the nearest transfer station or hazardous waste collection site

Conclusion

Hazardous house waste has the potential to contaminate the environment and cause serious public health effects. The constituents are sources of hazardous chemicals into the environment with potential deleterious effects. There is limited information in the literature about the toxic/harmful effect of this type of waste. Because of the composition of this waste stream, the disposal and management require stricter regulations and policies.

Further work is required to quantify the amounts of hazardous substances emitted from MSW landfill and ascertain the links to HHW disposal. Leachate concentrations can potentially act as a guide to amounts of the hazardous substances disposed in household waste and provide an indication of the chemical pathways operating/occurring within the landfill body. The risks from the release of such substances into the surrounding environment, either as a result of leakage or through insufficient leachate treatment, require assessment to evaluate the potential harm to health and the environment from continued disposal of HHW to landfill.

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Conflict of Interest

The authors declare no conflict of interest.

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