CHAPTER

1

ADVERSE ENVIRONMENTAL EFFECTS OF OPEN DUMPS

1.1. Introduction

Sustainability of the environment is a major issue with increasing levels of consumption of all resources particularly in the last few decades. This high level of consumption naturally increased the waste amount produced in the towns and cities. Solid waste created by people especially in urban areas is a significant problem all over the world that governments are obliged to solve. According to the Worldbank, the world generates 2.01 billion tons of municipal solid waste (MSW) annually and waste generated per person per day averages 0.74 kilogram but ranges widely, from 0.11 to 4.54 kilograms (Worldbank, 2021). Average waste generation rate is about 1.61 kg/capita/day for Caribbean states, 0.82 kg/capita/day for Pacific states, 1.56 kg/capita/day for Atlantic, Indian, Mediterranean and South China states, and 1.35 kg/capita/day for Organization for Economic Co-operation and Development (OECD) countries (Mohee et al., 2015). Daily waste generation rate in low- and middle-income countries is predicted to increase by 40% or more by 2050 where it is expected to increase by 19% for high-income countries (Worldbank, 2021). It is evident that there is a correlation between income level and waste generation rate. Additionally, by 2050, waste production in low-income countries is expected to increase three-fold according to the Environmental Protection Agency (Environmental Protection Agency, 2020). 1.3 billion tons of solid waste per year was generated all over the world in 2010 and it is expected to reach 3.40 billion tons by 2025 (Worldbank, 2021). The disposal of large amounts of these solid wastes from multiple sources generates a high economic and environmental burden to local governments. If not disposed properly, solid waste causes environmental problems and adversely affects human life. Nowadays, the global COVID-19 pandemic has necessitated the reconsidering of solid waste and open dumps rehabilitation management practices and approaches (Das et al., 2021).

Solid waste management is one of the most important municipal services that is essential to provide for residents by every city government. Demographic characteristics, legislation as well as lifestyle cause the municipal solid waste (MSW) composition to differ according to the region (Reddy et al., 2009). The municipal solid wastes can be disposed of by recycling, composting, incineration and landfilling. Figure 1.1. shows global treatment and disposal of MSW in OECD and European countries according to 2018 statistics. The graph shows that there are significant differences between how European countries handle their MSW. In about half of the countries included in the graph, the most commonly used method for the disposal of solid waste is the landfill method.

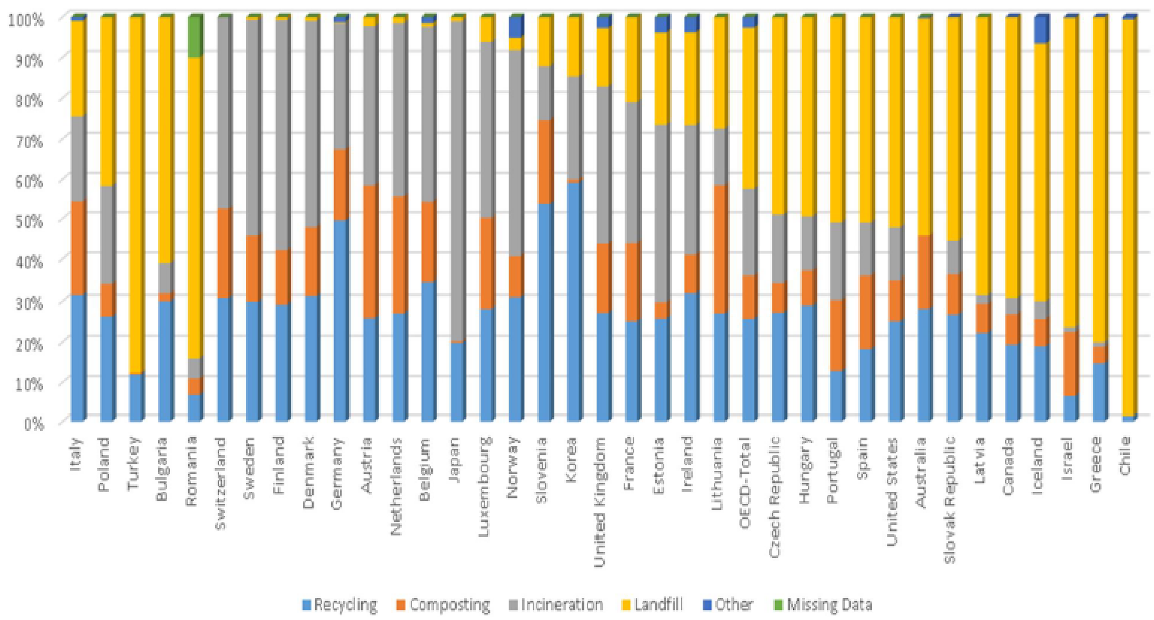

Figure 1.1. Municipal solid waste disposal in OECD and European countries in 2018 (OECD,2021; CEWEP,2020).

Almost 40% of waste is disposed of in landfills around the world. About 19% is processed for materials recovery by recycling and composting, and 11% is disposed of through modern incineration. Though globally 33% of waste is still openly dumped, governments are increasingly realizing the risks and costs of dumpsites and pursuing sustainable waste disposal methods (Figure 1.2.).

Annual budget for the solid waste management is expected to increase to about $375.5 billion in 2025. Waste management budgets can be the highest single item for municipalities in low-income countries with a 20% of municipal budgets. The cost of waste management is more than 10% and 4% of municipal budgets for middle-income and high-income countries, respectively. The solid waste collection and disposal is generally managed by local municipalities with a limited budget and limited capacity for a well-managed disposal strategy in low-income and middle-income countries.

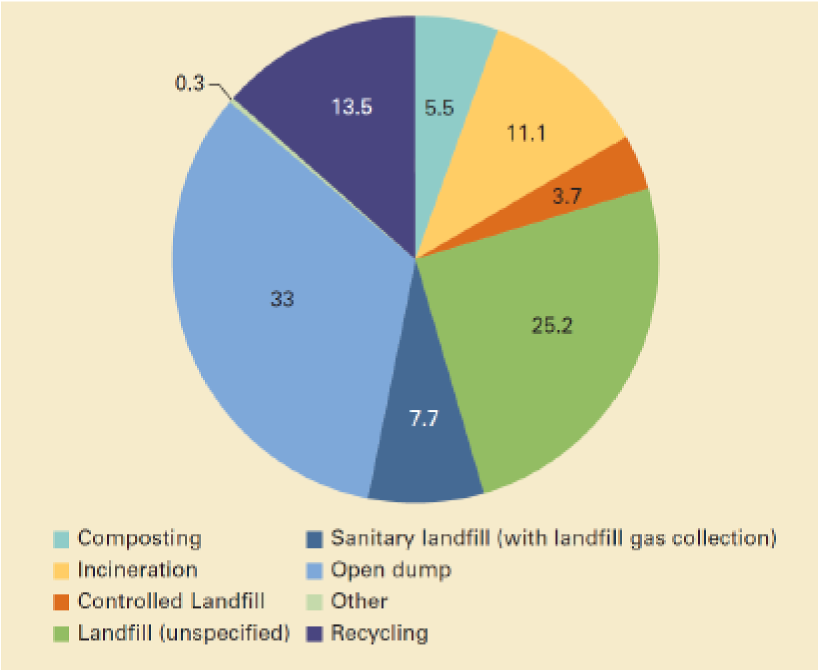

Figure 1.2. Global treatment and disposal of waste in percentages (Worldbank, 2021).

Unfortunately, in order to find a fast and economical solution, these wastes were dumped in open fields without any engineering or environmental considerations and consequently these processes created tens of thousands of open dumps in Europe and around the world. Many developed countries foreseen the environmental impacts of open dumps and left these practices and enforced engineered landfills. Most of these nations followed this more environmentally friendly practice either by voluntarily and/or adapting to, for example, EU legislation. Consecutive directives on solid waste management have strengthened standards and policy guidelines for implementation by EU members, and the EU boosts the sector development to the required standards with grant funding to member states and candidate countries. However, even though those countries constructed and started using engineering landfills, the previous open dumps still existed without any use. Reducing hazards to the environment and water resources by rehabilitating open dump sites that cause serious environmental problems, is still a priority for many governments.

Today, the most commonly used method for the disposal of solid waste in developed countries is the landfill method. However, before the landfill applications, solid waste was disposed randomly to any area outside the city by open dumping. Even in the countries which started to use the landfill method, abandoned open dump sites continue to endanger the environment and human health. Figure 1.2 shows global treatment and disposal of waste in the world. Worldbank (2021) states that open dumping accounts for at least 33% of waste in the world -extremely conservatively- not managed in an environmentally safe manner. There are three significant and vital problems in the open dumps: 1) CH_4 gas, a greenhouse gas that's 28 times more potent than CO_2, generated from biodegradable solid wastes in anaerobic conditions. The CH_4 is explosive when present in the range of 5–15% by volume in air and becomes flammable when this rate is higher than 15 %. 2) Leachate and the change in soil properties. Leachate is caused by infiltration of rainwater into the solid wastes as well as by the water content of the solid wastes themselves. Change in the soil properties accelerate the magnitude and speed of the leachates which may contain many organic and inorganic pollutants. This leachate percolates through the soil and reaches the groundwater resulting in a substantial risk to local groundwater resources and to the natural environment. 3) Structural stability in open dump sites. Slope failures at open dumps may lead to serious environmental issues. It becomes more critical especially if the open dumps are close to water bodies. Due to the abovementioned vital problems, open dump sites that are no longer in use need to be rehabilitated and the existing ones should be improved. The European Union has a directive on landfill of wastes (No: 1999/31 / EC), which defines the limitations and procedures to be taken in order to prevent or minimize the threats to the environment. In many countries that are members or candidates of the European Union, open dumps still represent environmental problems.

1.2. Environmental Impacts of Open Dumps

Disposal of solid wastes, especially in urban areas, is one of the major issues to be dealt with. One of the main indicators of the lack of environmental awareness is the use of open dumping as a solid waste disposal method. Open dumping is the most economical disposal method. However, these non-engineered areas, created by dumping waste materials in open lands especially far away from the city, threaten both human health and the environment. Globally, approximately 40% of solid waste is disposed of using landfills, and open dumps are still used as a disposal method in most of the developing or undeveloped countries (Kaza et al., 2018). It is of great importance to abandon the open dumping method and to rehabilitate existing dumpsites, which have many adverse effects. The world produces 2.01 billion tons of urban solid waste every year, 33 percent of which cannot be managed in an environmentally safe manner. While the waste generation rate increases rapidly, the global effects of solid waste are also growing fast. Uncontrolled solid waste disposal contributes to adverse environmental effects such as surface water, groundwater, and soil pollution; air contamination, odors, and green-house gases (GHG) emission; explosion, fire, and other serious environmental risks; vectors of diseases; health risks of scavengers; and visual impacts.

1.2.1. Surface Water, Groundwater and Soil Pollution

Only 2.5% of the world's water bodies are fresh water, and many of these are unavailable; found as locked up in glaciers or inaccessible under the earth’s surface. Therefore, human beings are faced with an increasing water crisis in the world. Groundwater is moving slowly and continuously in geologically forming underground reservoirs called aquifers, whose sources are replenished by the seepage of precipitation. Thus, they are easily affected by human activities. Open dump sites have a direct effect on the pollution of surface water, groundwater and soil. Contrary to the landfills created as a result of engineering studies, leachate management is not generated in these areas. Therefore, leachate with high pollution loads mixes into the water and penetrates into the ground in an uncontrolled manner. Areas close to the open dump sites are more susceptible to the contamination of surface water and groundwater, and there are significant risks for the people living in these areas and using these waters, and for the natural environment.

Leachate is the complex and high pollutants loaded liquids that is generated from the combination of the moisture content of the wastes and rainwater, percolating through the dumpsites and moving into ground (Duran and Cuci, 2016). Leachate can act as groundwater in the aquifer depending on its physical, chemical and biological properties. In soils that are porous and permeable, it is relatively easy for these pollutants to be transmitted to the aquifer. The content of leachate varies according to many parameters such as quality of the dumped solid waste, the age of the dumpsite, the hydrogeological structure of the field, the water content of the solid waste, temperature, pH and climatic conditions, and it contains high amounts of organic matter, nitrogenous matter, heavy metals and organic/inorganic salts (Duran and Cuci, 2016). Biological oxygen demand (BOD) and chemical oxygen demand (COD) are very high in leachates (Christensen et al., 2001).

Heavy metals such as Cd, Cr, Cu, Pb, Ni, Zn and Hg and different organic chemicals in leachate cause serious health problems by polluting surface and groundwater. These pollutants can enter the food chain and bioaccumulate (Long et al., 2010; Sánchez-Chardi and Nadal, 2007) causing malfunctions in the liver, kidneys, the circulatory system, and the movement of nerve signals (Botkin and Keller, 2002). In addition to these pollutants, leachate may contain many different types of bacteria, including fecal coliforms and spore-forming bacteria (Matejczyk et al., 2011). A very small amount of leachate will be sufficient to contaminate large amounts of surface water and groundwater, causing damage to biodiversity and disrupting the food chain (Bakare et al., 2007; Long et al., 2010). Leachate has acidic properties in its initial phase. A seeping at this stage will dissolve the heavy metals in the soil, making them more mobile and more likely to leach into the groundwater (Prechtai et al., 2008). This will be a secondary pollutant source for groundwater. The contamination of surface and drinking water because of the leachate can be treated but this treatment may be lengthy, costly, and thorny. Abandoning groundwater wells that have been affected is often the only thing that is done in this situation. Contamination of groundwater as well as surface water due to polluted water from a facility used for waste disposal is shown in Figure 1.3. (UNEP, 2005).

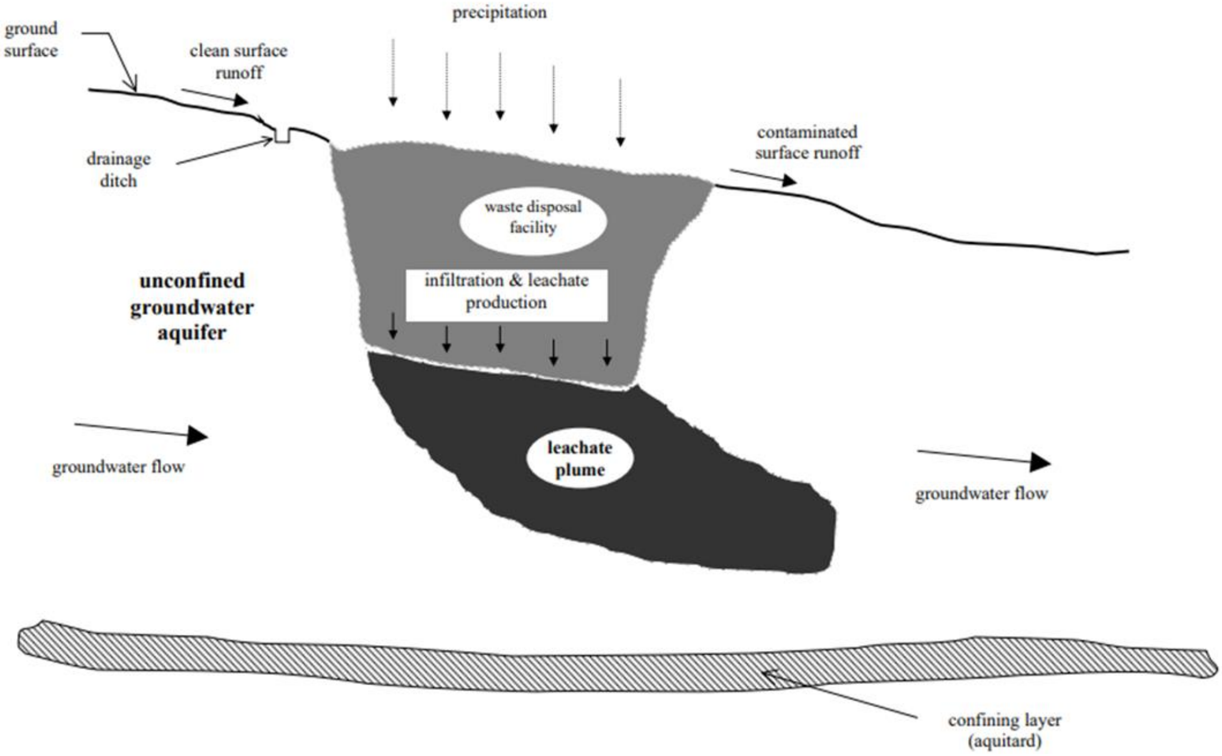

Figure 1.3. Contamination of groundwater as well as surface water due to polluted water from a facility used for waste disposal (UNEP, 2005).

Open dump areas can also change not only chemical but also engineering soil properties. Ukpong and Agunwamba (2011) presented an investigation of three open dump areas in Nigeria in order to determine the impact of the open dumps on soil characteristics. For this purpose, properties of soil approximately 40 m distance from the open dumps were also investigated as the control, and the soil layers for the control were similar to the soil layers in open dump areas. The comparisons showed that the optimum moisture content as well as the liquid limit values for the soil at dump sites were lower than the soil of the control while the amount of lead, iron and zinc, plasticity index, permeability, specific gravity as well as maximum density for the soil under the dumps were higher than the soil under the control.

Kanmani and Gandhimathi (2013) investigated the contamination of heavy metal caused by leachate problem in Ariyamangalam open dump located in India which stores urban solid waste by collecting soil specimens around this open dumpsite. As a result, some heavy metals like Mn, Pb and Cu were observed in these soil specimens. This shows that migration of leachate from this open dump caused noticeable soil contamination.

1.2.2. Structural Stability

One of the major problems with open dumps is possible stability issues such as slope failures. In general, stability problems in landfills may result from soil and waste themselves, and their interactions with liners. In essence, foundation soil, liner system, and cover system should all be considered. In open dump sites, however, the liners are not available, hence the soil and waste and soil-waste interface may be critical. When the slopes in the dumpsite are very steep and unstable, displacement of solid waste masses can occur. Highly saturated ground caused by heavy rains, vibrations created by earthquakes may trigger landslides in these irregular disposal areas. Reducing the slope of the ground will be effective in decreasing the landslide hazards, especially in areas that are close to earthquake zones and receive excessive rainfall (Cointreau, 2006).

Jayaweera et al. (2019) presented a slope failure which took place in an open dump located in Sri Lanka as shown in Figure 1.5. Just before the collapse in this open dump, its height ranged from 20-49 m while slope angles ranged from 20° to 85°.

Figure 1.4. Damage to dwelling units because of the slope failure in Meethotamulla open dump (Jayaweera et al., 2019).

There have been disastrous solid waste slides in the dumpsites with serious consequences. In 2005, a major shift occurred at the Leuwigajah dumpsites in Bandung (Java, Indonesia) after heavy rains, resulting in burying 71 houses and 143 deaths. Another slope failure was observed in Payatas landfill located in the Philippines after several days of exceedingly torrential rain in 2000. The large waste mass slide with volumes of about 13,000-16,000 m^3 occurred, causing 278 deaths (Merry et al., 2005; Lavigne et al., 2014). In Leuwigajah dumpsite located in Indonesia, another landslide happened with the volume of 2,700,000 m3 wastes in 2005. Consequently, there were 147 dead (Koelsch et al. 2005). In addition, a serious disaster occurred in 2018 resulting in the displacement of a very large mass of solid waste from the Hulene dumpsite in Maputo, Mozambique and at least 17 people including children have been killed. It is reported that landslides at dumpsites occurred at very high frequency in 2017, accounting for over 150 deaths in Colombo (Sri Lanka), Addis Ababa (Ethiopia), Conakry (Guinea), and Delhi (India) (Kaza et al., 2018). At Sarajevo, a flow slide occurred in an urban solid waste uncontrolled dump in 1977. The volume of waste moved in this flow was 200,000 m^3 and the flow distance was 1 km. Consequently, 5 houses as well as 2 bridges had damage because of this flow slide (Blight, 2008). Seismic activities affect many structures adversely (e.g., Jinguuji and Toprak, 2017; Toprak et al., 2008; Holzer et al., 2000) and should be considered in risk evaluations. Landfills, including open dumps, are no exception to this. For example, in the 1994 Northridge earthquake, some tears were observed in a geomembrane liner of a landfill (Augello et al., 1995). In the 1989 Loma Prieta earthquake with a magnitude of 7.1, small cracks and little settlement were observed in some landfills (Johnson et al., 1991). After the 1995 Hyogoken-Nanbu earthquake, some waste fills had ground cracks (Akai et al., 1995). Seismic response analyses of the landfills where urban solid wastes are stored are crucial in terms of its serviceability as well as safety evaluations after the earthquakes. Vibration properties of landfills, strong motion as well as foundations, foundation types and landfill stiffness are important parameters in order to assess the landfill seismic response (Choudhury and Savoikar, 2009).

1.2.3. Explosion, Fire and other Serious Environmental Risks

The explosion limit of a gas is the concentration level at which that gas has the potential to explode and is determined by the lower explosive limit (LEL) and upper explosive limit (UEL). These limits are measures of the percentage composition of a gas in air by volume.

Gas at concentrations below the LEL and above the UEL is not explosive. However, a gas in the air between these limits can explode as soon as a present of an ignition source. CH_4 gas, which is formed as a result of the anaerobic decomposition of biodegradable organic materials in the dumpsite, is explosive when mixed with the air at a rate of 5-15% and is a flammable gas when mixed with more than 15% (ATSDR, 2001). Since there is approximately 50% methane gas in open dumpsites, it is not explosive under normal conditions. However, if it migrates and is diluted to a concentration between LEL and UEL, there will be a risk of explosion with the presence of oxygen.

Though not very common, many landfill gas-related explosions have been reported around the world and cause serious damage (such as Keetleman, California in 1988, Cincinnati, Ohio in 1996, and Greece in 2003 (Lavigne et al., 2014)). In Hekimbaşı Dumpsite in Ümraniye, Istanbul, which had been in operation since 1976, 1500-2000 tons of solid waste was disposed daily without any waste compaction. As a result of the explosion of methane gas in the dumpsite in April 1993, 39 people have died after collapsing of too many houses (Figure 1.4). The volume of the waste moved in this flow was 1,200,000 m3 (Kocasoy and Curi, 1995). Incidents around the world related with methane explosions in dumpsites resulting in serious injuries and damages have been reported. Also, a gas explosion occurred in a landfill located in Denmark in 1991 (Kjeldsen and Fischer, 1995).

Figure 1.5. Rescue team search after the explosion in the Hekimbaşı dumpsite.

1.2.4. Visual Impacts

In addition to the environmental and health effects of dumpsite, another problem is visual pollution which causes aesthetic problems. The fact that the waste piles that are randomly stored without any disposal, are in the field of view creates a situation that no one wants to see or live in. There are studies stating that visual pollution is not only an aesthetic problem but also has negative effects on people. Basically, different types of effects such as reducing the value of nearby lands, causing psychological discomfort on people, distracting drivers and encouraging unnecessary consumption have been reported (Wakil et al., 2019; Edquist, 2009). In addition to all other adverse effects, visual pollution is also eliminated with the rehabilitation of open dumpsites by performing landscaping studies properly.

1.2.5. Health Risks for Scavengers

It is estimated that around two million people worldwide support themselves by working as informal scavengers, especially in developing countries where unsustainable waste management is common. Therefore, these people are directly exposed to the adverse effects of solid waste mismanagement and, therefore, encounter serious health problems related with open dumpsites (Hoornweg and Bhada-Tata, 2012). The intensity and type of risks to which scavengers are faced rely on the working conditions, the composition and components of the waste and the exposure time (Gutberlet et al., 2013; Ziraba et al., 2016). Some of these risks are; respiratory system diseases such as bronchitis, asthma, pneumonia caused by exposure to particulates, bio-aerosols and volatile organic substances during waste collection; infectious diseases such as diarrhea, cholera, dysentery, typhoid transmitted through direct contact with disease causing pathogens, and tetanus, hepatitis etc., transmitted through cuts or punctures during waste picking. In addition, as a result of high carbon dioxide (CO_2) and methane (CH_4) gases in dumpsites, headaches and nausea caused by low oxygen conditions are among the health problems that scavengers frequently encounter (Cointreau, 2006).

Although it is not very common, serious injuries and even deaths can occur as a result of the sliding/collapse of the wastes, fires and explosions. During these fires, lead poisoning caused by lead-containing materials such as batteries and paints is among the risks that cannot be ignored. In addition, serious diseases such as HIV and Hepatitis C, caused by exposure to hazardous medical wastes, are among the reported diseases (Cowing, 2013). Moreover, injuries due to accidental falling; dermatological problems; and high rates of reproductive and urinary tract infections among female scavengers, are among the prevalent reported risks (Jayakrishnan et al., 2013).

In order to prevent such problems, the rehabilitation of open dumpsites is the most essential and basic measure that can be taken. Also, to use protective clothing such as gloves and face masks, to train them on hygiene and the problems they may encounter and not to employ children in such places would be effective solutions in order to reduce the damages and injuries for waste scavengers.

Figure 1.6. A female scavenger in an open dump site.

1.2.6. Vector-borne Diseases

Organic materials found in landfills provide an appropriate environment for disease-causing vectors such as flies, mosquitoes and rodents, which pose serious public health problems. Vector-borne diseases continue to represent a significant threat to public health, particularly in developing countries. As reported by the World Health Organization (WHO), vector-borne diseases account for more than 17% of infectious diseases worldwide, resulting in more than one million deaths each year (WHO, 2017). Among the vectors that spread disease, the mosquito is the greatest threat to humankind. Diseases such as malaria and dengue, which cause the death of millions of people each year, are the easiest way to spread through mosquitoes (Tohit et al., 2019). In addition, bacterial infections that spread as a result of houseflies coming into contact with fecal matter in solid waste and carrying it to living organisms are another threat. Rodents can also reproduce and feed very easily in open dumps. Hantavirus is a virus that is transmitted from rodents, especially through inhalation of feces and urine of mice, causing serious diseases (Cointreau, 2006). With the rehabilitation and proper management of dumpsites, the proliferation of disease-causing vectors can be controlled, and health risks can be reduced, especially in developing countries.

1.2.7. Air contamination, odors, and green-house gases (GHG) emission

Landfill gases, that pose significant air pollution problems, are formed by three different processes including bacterial decomposition, evaporation and chemical reactions in the open dumpsites. Mostly, landfill gas is produced by bacterial decomposition that occurs by the breakdown of biological wastes and rotting foods by bacteria found in the waste and/or soil. In addition, some organic pollutants, especially non-methane volatile organic compounds, found in the dumpsite can also be released by evaporation. It is also known that landfill gas is formed as a result of the reaction of some chemicals in the wastes. The factors affecting gas production are the composition of the waste, age of the dumpsite, the presence of oxygen in the site, moisture content and temperature (ATSDR, 2001).

Solid wastes biodegrade over time under aerobic or anaerobic conditions. Depending on the characteristic of the waste in the dumpsite, the end products are CO_2, CH_4 and water, lesser amounts of nitrous oxide (N_2O), ammonia (NH_3), hydrogen sulfide (H_2S), carbon monoxide (CO) and organic compounds such as trichloroethylene, benzene, vinyl chloride are also formed (Barton et al., 2008; Saral et al., 2009). Gas production usually starts 2-6 months after the waste disposal and can continue up to 100 years (Saral et al., 2009).

Landfill gas generated in dumpsites contributes to climate change, which is one of the most challenging problems of today. Increasing the amount of solid waste due to rapid population growth also causes an increase in greenhouse gases, which contribute significantly to climate change. Mismanagement of solid wastes is shown as the main source for this increase (Tian et al., 2013). Among these landfill gasses, which are accepted as one of the important causes of climate change, methane gas is the greenhouse gas that is even more potent. According to the Environmental Protection Agency's (EPA) report in 2006, developing countries are responsible for 30-40% of methane gas emissions generated from dumpsites for the year 2000 (US EPA, 2006). Moreover, in the Intergovernmental Panel on Climate Change (IPCC) assessment report (AR5), it was stated that CH_4 is 28 to 36 times more powerful greenhouse gas than CO_2 in terms of its global warming potential due to higher ability to absorb heat in the atmosphere (IPCC, 2014).

As it is the easiest, effective and cheapest solution to reduce waste volume conveniently and to free up the space at dumpsites, open burning is a frequently applied method. It is estimated that 41% of global waste is burning in an open and uncontrolled manner (Cogut, 2016). As a result of this uncontrolled burning of wastes, various toxic pollutants and greenhouse gases are released into the atmosphere such as CO_2, CH_4, particulate matter, persistent organic pollutants (POPs) such as polycyclic aromatic hydrocarbons (PAHs), dioxins and furans. It is estimated that 270,000 premature deaths occur annually (Cogut, 2016) due to the burning of waste in dumpsites, and these processes are thought to contribute to approximately 5% of global greenhouse gas emissions (William et al., 2018). Considering the current situation, solid waste-related emissions are projected to rise to 2.6 billion tons of CO_2 equivalent by 2050, if no further management strategy is implemented (TheWorldBank, 2018).

As mentioned above, CH_4 is a flammable gas when mixed with the air of more than15%. If the wastes are not appropriately compressed in the dumpsites, the air may penetrate into the waste and mix with the methane gas, causing spontaneous ignition. Whether spontaneous or man-made, these fires cause serious air pollution. It is estimated that a large amount of the world's garbage is burned intentionally or spontaneously and causes emissions above the values revealed in the regional and global inventories (Wiedinmyer et al., 2014).

Odors have a psychological effect on humans even at very low concentrations, and exposure to such substances can decrease quality of life, leading to many health problems such as headache, loss of appetite, digestive system disorders, sleep disorders, shortness of breath and allergic reactions (Lee et al., 2013). Therefore, odor pollution has become a type of pollution subject to regulations and control in many countries (Capelli et al., 2013). Previous studies have shown that highly offensive odorous compounds are emitted from the open dumps and causing serious problems and complaints for people living nearby (Dincer et al., 2006). The amount of waste generated has also increased with the growing population, causing an increase in the odor problem with the additional impact of unsuitable site selection such as canyon-valley like topography that restricts the local winds. According to epidemiological studies, there are serious correlations between air pollution and human health (Ancona et al., 2015). It has been reported that dumpsites are among the high-risk sites including respiratory, neurotoxic, carcinogenic and teratogenic risks, especially for people living around these areas (Aderemi and Falade, 2012; Durmuşoğlu et al., 2010). Hydrogen sulfide (H_2S) and ammonia (NH_3) gases that are produced during the degradation of wastes, are primarily responsible for the odor pollution. NH_3 has a strong pungent odor, while H_2S has a characteristic odor with rotten egg smell. Humans can detect the odor of these gases even at very low levels in the air. In the study conducted by Ding et al. (2012), 68 different volatile organic compounds that cause odor problems were identified in the open dumpsites and it was reported that NH_3 and H_2S constitute almost 95% of them. Additionally, inorganic compounds, halogenated compounds, volatile fatty acids, aromatic compounds, aldehydes, ketones and esters, hydrocarbons and other sulfurous and nitrogenous compounds were also found, but in lesser amounts. It was also stated that odor emissions were influenced by environmental factors and in high temperature, high humidity, low wind speed and low air pressure conditions, their emissions were found to be worse (Ding et al., 2012).

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