Evidence Summary

Approaching the Waste Crisis in Lebanon: Consequences and Insights into Solutions

K2P Evidence summaries use global research evidence to provide insight on public health priority topics that are ambiguous and have important uncertainty. This 3–5 page document informs policymakers and other stakeholders by synthesizing the best available evidence and presenting its relevance to local contexts. Evidence summaries do not provide recommendations but rather articulate evidence in a clear, objective and factual manner.

Evidence Summary

+ Included

Synthesis of evidence on a priority question or topic

Local context

× Not Included

Does not provide **recommendations**

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K2P Evidence Summary

Approaching the Waste Crisis in Lebanon: Consequences and Insights into Solutions

Knowledge to Policy Center K2P

Authors
Nadeen Hilal, Racha Fadlallah, Diana Jamal, Fadi El-Jardali*
*senior author

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Contents

Key Messages

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Problem

- Since July 2015, Lebanon witnessed a waste management crisis with impending disastrous consequences at the health and environment levels.
- Causes of the current problem include political favouritism and the absence of long term planning; while its consequences comprise unauthorized landfills and incineration sites near inhabited areas.
- Time lapse and changes in weather conditions have affected the release of toxins, contamination of food and water, and emergence of infectious diseases; thus necessitating immediate action.
- Alarming air levels of dioxins and polycyclic aromatic hydrocarbons have been identified, rendering this problem nothing short of an emergency

Health Consequences:

- **Landfilling is associated with**
  - Increased risk of cancer with the strongest evidence being for pancreas and skin cancer in males
  - Congenital abnormalities such as non-chromosomal birth defects, nervous system birth defects, hypospadias, epispadias, and low birth weight
  - Increased risk of asthma and increased rate of hospitalization for asthma and other respiratory conditions.
- **Incineration is associated with**
  - Increased risk of cancer with the strongest evidence being for colorectal, larynx, and stomach cancer
  - Congenital abnormalities such as congenital urinary tract defects, spina bifida, cardiac defects, twining, and preferential female births
  - Decrease in respiratory function and an increase in respiratory wheezing in children along with increased respiratory disease mortality
- **Environmental Consequences** include global warming, flammability, toxicity, asphyxiation, decreased agricultural yields, poor soil quality, and increased animal and fish mortality.

What other countries are doing

Countries have adopted different or combined waste management procedures such as source reduction, collection, recycling, composting, incineration, and landfilling based on their income level.

Insights into a solution

- Adoption of the integrated sustainable waste management approach
- Interdisciplinary and multi-sectoral actions are required including political will and informed decision making, municipality support and engagement, health sector alertness, and public awareness.

مقاربة أزمة النفايات في لبنان: تقييم التداعيات الصحية للخيارات واقتراحات للحلول

الرسائل الأساسية

ما هي المشكلة؟

← منذ تموز 2015، يشهد لبنان أزمة إدارة النفايات حملت معها نتائج كارثية على مستوى الصحة والبيئة

← تتضمن أسباب هذه المشكلة المحسوبيات السياسية وغياب التخطيط طويل المدى, في حين ان نتائجها هو الظهور غير الشرعي للمطامر ومراكز حرق النفايات قرب الأماكن السكنية.

← يشكل انبعاث المواد السامة، تلوث الطعام والمياه، وانتشار الأمراض المعدية بعض التداعيات الناجمة عن مرور الوقت وتغير العوامل المناخية، مما يتطلب تحركاً فورياً.

← جعل رصد معدلات مرتفعة من الديوكسينات والهيدروكربونات العطرية متعددة الحلقات في الجو من هذه المشكلة حالة طوارىء.

النتائج الصحية

ترتبط عملية طمر النفايات بالأمور التالية

← إرتفاع خطر الإصابة بمرض السرطان علماً أن أقوى الإثباتات تشير إلى ارتفاع نسبة سرطان البنكرياس والجلد عند الرجال

← ارتفاع نسبة التشوهات الخلقية كالعيوب غير المرتبطة بالكروموزومات، العيوب الخلقية في النظام العصبي، المبال الأسفل، المبال الأعلى، وانخفاض وزن الرضيع عند الولادة

← إرتفاع خطر الإصابة بمرض الربو وارتفاع معدلات دخول المستشفى بسبب الربو وغيره من الأمراض التنفسية

ترتبط عملية حرق النفايات بالأمور التالية:

- ← إرتفاع خطر الإصابة بمرض السرطان علماً أن أقوى الإثباتات تشير إلى ارتفاع نسبة سرطان القولون، الحنجرة والمَعِدة.
- ← تشوهات خلقية كالعيوب في المسالك البولية، السنسنة المشقوقة، مشاكل القلب، بالإضافة الى ارتفاع في ولادة التوائم، وولادة الرضيعات الإناث.
- ← إنخفاض في وظيفة الجهاز التنفسي وارتفاع في درجة الصفير التنفسي لدى الأطفال بالإضافة إلى زيادة الوفيات الناجمةعن الأمراض التنفسية.

أما النتائج البيئية فتتضمن ظاهرةالاحتباس الحراري، القابلية للاشتعال، انتشار السموم، الاختناق، إنخفاض المحاصيل الزراعية، سوء نوعية التربة، وزيادة نفوق الحيوانات والأسماك.

ما الذي تقوم به الدول الأخرى؟

اعتمدت الدول إجراءات مختلفة أومجتمعة لإدارة النفايات مثل الحد من إنتاج النفايات من المصدر،الجمع، إعادة التدوير، التحويل إلى سماد، الحرق، والطمر وذلك تبعاً لمستوى دخل هذه الدول.

إقتراحات للحل

- ← اعتماد نهج متكامل لإدارة النفايات بطريقة مستدامة
- ← اعتماد إجراءات متعددة التخصصات والقطاعات بما في ذلك تأمين الإرادةالسياسية، اتخاذ القرارات المستنيرة، دعم ومشاركة البلديات، توعية القطاع الصحي، والتوعية العامة.

Content

Current Problem

Since July 2015, Lebanon has been experiencing a waste management problem. Cessation of waste collection has resulted in its accumulation on streets, neighborhoods, and agricultural and water sites. Unlicensed landfills and incineration sites have emerged in inhabited areas, further adding to the gravity of the situation.

In the absence of any sustainable solution, the waste accumulation problem has reached a critical stage. Time lapse and change in weather conditions have started to affect decay of waste material, release of toxins, contamination of food, leakage into water and food sources, and emergence of infectious diseases.

Due to the acuity and sudden emergence of this problem, locally produced data that can quantify its magnitude, such as the extent of water contamination or the incidence of resultant infectious diseases is still scarce. However, alarming data of air dioxin levels sampled next to a burned dump have recently been identified. In one study, sampling conducted on the rooftop of an inhabited building in an industrial zone in Lebanon revealed dioxin levels 416 times more carcinogenic than those measured in 2014. Dibenzanthracene, another carcinogenic member of the polycyclic aromatic hydrocarbons family, was identified for the first time ever in ambient air in Lebanon. The combined effects of these two toxins have the potential for raising the lifetime cancer risk from 0.1 to 37 per one million adults and from 0.4 to 186 among per one million children. Moreover, these toxins are can adhere to matter for long periods of time, thus imposing lasting ill effects on health and the environment[1]. Therefore, timely intervention is needed; otherwise alarming consequences are expected to ensue.

This evidence summary provides an overview of the consequences of poor waste management with special emphasis on health outcomes. Data from this evidence summary can be used to:

- Explain the consequences of the current deteriorating situation of dispersed garbage and the practice of trash burning
- Evaluate the possible outcomes of potential long-term solutions if the options of landfilling or incineration are to be adopted

Background

Since 1994, the government outsourced waste management to the private firm Sukleen[2], which continued to collect

Background to Evidence Summary

A K2P Evidence Summary uses global research evidence to provide insight on public health priority topics that are ambiguous and have important uncertainty. This document informs policymakers and other stakeholders by synthesizing the best available evidence and presenting its relevance to local contexts.

Evidence summaries do not provide recommendations but rather articulate evidence in a clear, objective and factual manner.

The preparation of this K2P Evidence Summary involved the following steps:

1) *Identifying and selecting a relevant topic according to K2P criteria.*
2) *Appraising and synthesizing relevant research evidence about the problem.*
3) *Drafting the Evidence Summary in such a way as to present global and local research evidence concisely and in an accessible language.*
4) *Undergoing merit review.*
5) *Finalizing the Evidence Summary based on the input of merit reviewers.*
6) *Submitting finalized Evidence Summary for translation into Arabic, validating the translation and Dissemination*

and manage garbage by sorting, composting, recycling, and landfilling until the expiry of its contract in July 17, 2015. Concurrently, the Naameh landfill was long overdue for closure after it had received waste since 1997. Since July 2015, Lebanon has witnessed a trash management problem. In the absence of governmental solutions, municipalities and even local neighborhoods had resorted to primitive solutions. The end result included satellite landfills and incineration sites scattered throughout the country, with grave consequences on health, economy, and the environment.

The absence of long term planning, sectarianism, and political favoritism constitute the roots of the current situation. Efforts to resolve this problem by the government have been futile. Lately, in reaction to the excruciating level of the problem, the Ministry of Public Health has constituted a multidisciplinary national emergency committee to assess the associated health consequences. The committee issued its report by addressing the problem bifurcations and providing recommendations for prevention of its ailments[3].

Problem Consequences

Since unauthorized landfills and incineration sites are dispersed throughout streets, neighbourhoods, water and agricultural sites, it is sensible to address particularly two methods of waste management, landfilling and incineration.

Landfilling has potential impacts on health that arise from inhaled gas and exposure to groundwater contaminated by landfill leachate. The characteristics of such emissions vary considerably across sites, depending on waste composition and the age of the landfill[4].

Incineration, particularly with incomplete combustion, results in the release of toxic gases, one of which is dioxins. In addition to their wide array of adverse health effects, this group of compounds is listed as a human carcinogen[4].

1. Health Consequences

There are numerous health hazards for people living close to waste management areas. Key findings from 3 systematic reviews evaluating the health outcomes of two waste management methods: landfilling and incineration. Health outcomes of landfilling inclue[5-7] (Please see Appendix I, Table 1 for more information):

- Increased risk of cancer, particularly pancreatic and skin cancer in males
- Congenital abnormalities such as non-chromosomal birth defects, nervous system birth defects, hypospadias, epispadias, and low birth weight
- Increased risk of asthma and increased rate of hospitalization due to asthma and other respiratory conditions.
- No increased risk was detected for colorectal, liver, bladder, lung, breast, uterus, prostate, stomach or skin cancers

- Mixed or non-significant results were found for lymphoma, kidney, and brain cancers
- Mixed results were found for nervous system birth defects

Health Consequences of Incineration include[5-7] (Please see Appendix I, Table 2 for more information):

- Increased risk of cancer with the strongest evidence being for colorectal, larynx, and stomach cancer
- Congenital abnormalities such as congenital urinary tract defects, spina bifida, cardiac defects, twining, and preferential female births
- Decrease in respiratory function and an increase in respiratory wheezing in children along with increased respiratory disease mortality
- No association was found for myeloma, bladder, cerebral, prostate, or lymphatic system cancers
- Mixed results were found for non-Hodgkin lymphoma, leukemia, sarcoma, soft tissue tumors, breast, lung, colorectal, and liver cancers
- No association was detected for low birth weight, chromosomal or non-chromosomal abnormalities, or spontaneous abortion

2. Environmental Consequences

Landfilling and incineration practices pose a direct threat to diverse components of the environment. This includes the broader elements such as vegetation, ecosystems, and landscape together with the specific impacts on soil, air, and aquatic ecosystems. A review of the literature has addressed these effects. Environmental adverse effects of landfilling and incineration can be summarized as follows[4] (Please see Appendix I, Table 3 for more information):

- Prevents oxygen diffusion into the soil thereby discourages revegetation
- Contributes to global warming through production of carbon dioxide
- Produces toxins which retards plant growth and agricultural yields
- Increases fish mortality through production of toxic oxides
- Affects health of herbivores through ingestion of plants bio-accumulating trace metals

What other countries are doing

Countries adopt waste management methods based on their income level. Although each country and city has their own site specifications, general observations can be made across low-, middle-, and high-income countries, as below[8]. Please see Appendix II for full list of countries according to income level.

Low income countries

- (including Ethiopia, Ghana, Haiti, Liberia, Nepal, and Zimbabwe)
- No organized source reduction programs
- Collection of waste is sporadic and inefficient, service is limited to high visibility areas, the wealthy, and businesses willing to pay (overall collection below 50%)
- Despite their abundance, recycling markets are unregulated and mostly through informal sector
- Composting is rarely undertaken formally even though the waste stream has a high percentage of organic material.
- Incineration is not common, and generally not successful because of high capital, technical, and operation costs, high moisture content in the waste, and high percentage of inerts.
- Incineration is typically adopted by low-technology sites resulting in high levels of pollution to nearby aquifers, water bodies, and settlements.
- Some local governments regulate waste fees, but the fee collection system is inefficient.
- Collection costs represent 80% to 90% of the municipal solid waste management budget with only a small proportion of the budget allocated toward disposal.

Middle Income countries

- (including China, Egypt, India, Iran, Iraq, Jordan, Nigeria, Pakistan, Sri Lanka, Turkey, West Bank & Gaza, Colombia, Mexico, Poland, Romania, Russia, and Venezuela)
- Some discussion of source reduction exists, but is rarely incorporated into an organized program.
- Improved service and increased collection from residential areas (overall collection 50% to 80%)
- Recycling rates are high, more regulated and involve some high technology sorting and processing facilities.
- Large composting plants are often unsuccessful due to contamination and operating costs
- Some incinerators are used, but these experience financial and operational difficulties and are equipped with little air pollution control
- Although sanitary landfills with environmental controls have emerged, open dumping is still common.
- Collection costs are regulated by some local and national governments, represent 50% to 80% of the municipal solid waste management budget, and involve more innovation in fee collection, e.g. included in electricity or water bills.

High Income Countries

- (including Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Italy, Korea, Kuwait, Netherlands, Oman, Qatar, Saudi Arabia, Spain, Sweden, UAE, UK, and the US)
- Organized education programs emphasize the three 'R's' reduce, reuse, and recycle with more producer responsibility and focus on product design.
- Collection rate is greater than 90%, achieved mainly through the use of compactor trucks, highly mechanized vehicles, and transfer stations
- Recyclable material collection services and high technology sorting and processing facilities are common and regulated.
- Composting is popular at both backyard and large-scale facilities and is characterized by source segregation, anaerobic digestion, and critical odor control.
- Incinerators have some form of environmental controls and energy recovery system; about three times the cost of landfilling per ton.
- Sanitary landfills with a combination of liners, leak detection, leachate collection systems, and gas collection and treatment systems.
- Collection costs represent less than 10% of the budget.

Approaching the Waste Management Crisis

Despite this segregation into levels of income, one systematic review concluded that there is no best option for waste management. A reliable approach is to be critical and creative. This can be achieved by starting from the existing strengths of the city and to build upon them and to involve all the stakeholders in designing their own local models[9].

Insights into a Solution

Based on the Lebanese context and the specific available evidence described in this summary, the following measures can act as a step towards alleviating the anticipated consequences of the waste management crisis:

1. **Adoption of the Integrated Sustainable Waste Management (ISWM) approach**

ISWM is a framework that was first developed during the mid-1980s by WASTE, a Dutch non-governmental organization, and further developed by the Collaborative Working Group on Solid Waste Management in low and middle income countries in the mid-1990s. Since then it has become the 'norm'[10].

The concept of ISWM goes beyond the mere safe disposal of wastes by adopting a holistic perspective to protect public health and the environment, conserve natural sources and contribute to the overall sustainable development. The ISWM includes wide range of concepts such as policy-making, institutional development, and technical design of integrated solutions for the handling and disposal of waste[11].

ISWM aims to achieve a balance between environmental effectiveness, social acceptability, and economic affordability by recognizing three important dimensions in waste management: stakeholders, waste system elements, and sustainability aspects[12,13].

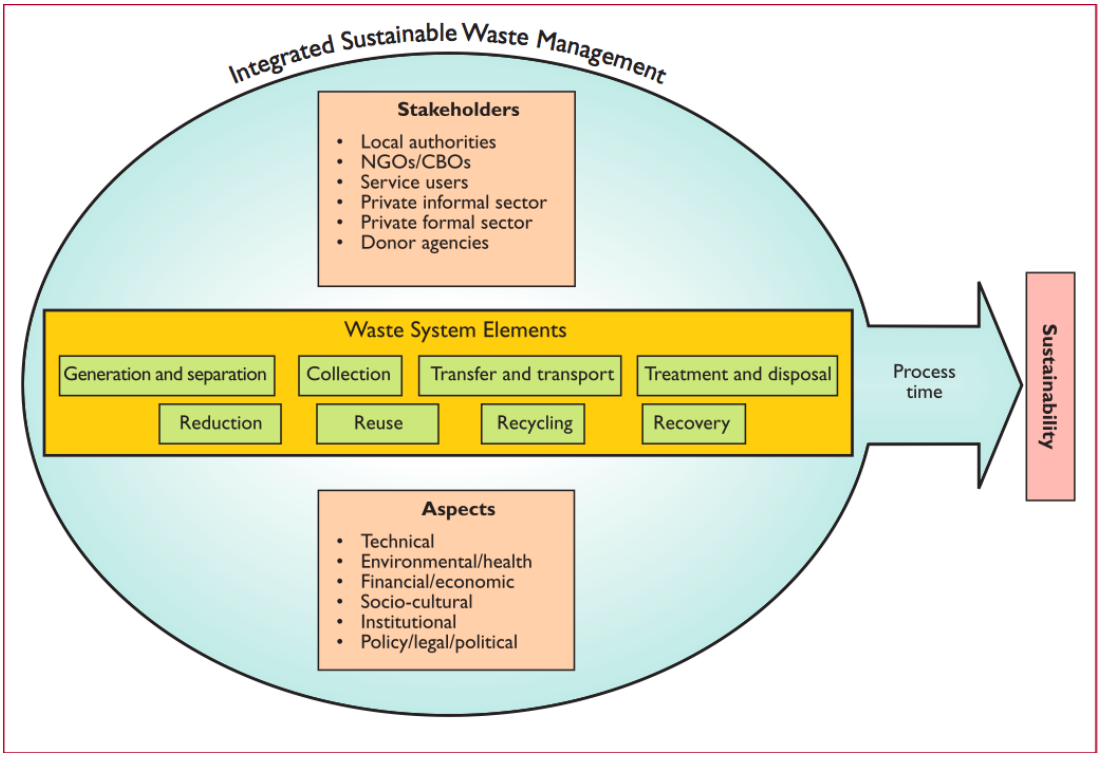

Figure 1 **The integrated sustainable waste management (ISWM) framework** (Source: WASTE, advisers on urban environment and development, Gouda, the Netherlands)

The ISWM approach implies the following implementation hierarchy[14,15]. It should be noted that the ideal tactic requires a top down approach (following the direction of the arrow), whereby controlled incineration and landfilling should be the last resort.

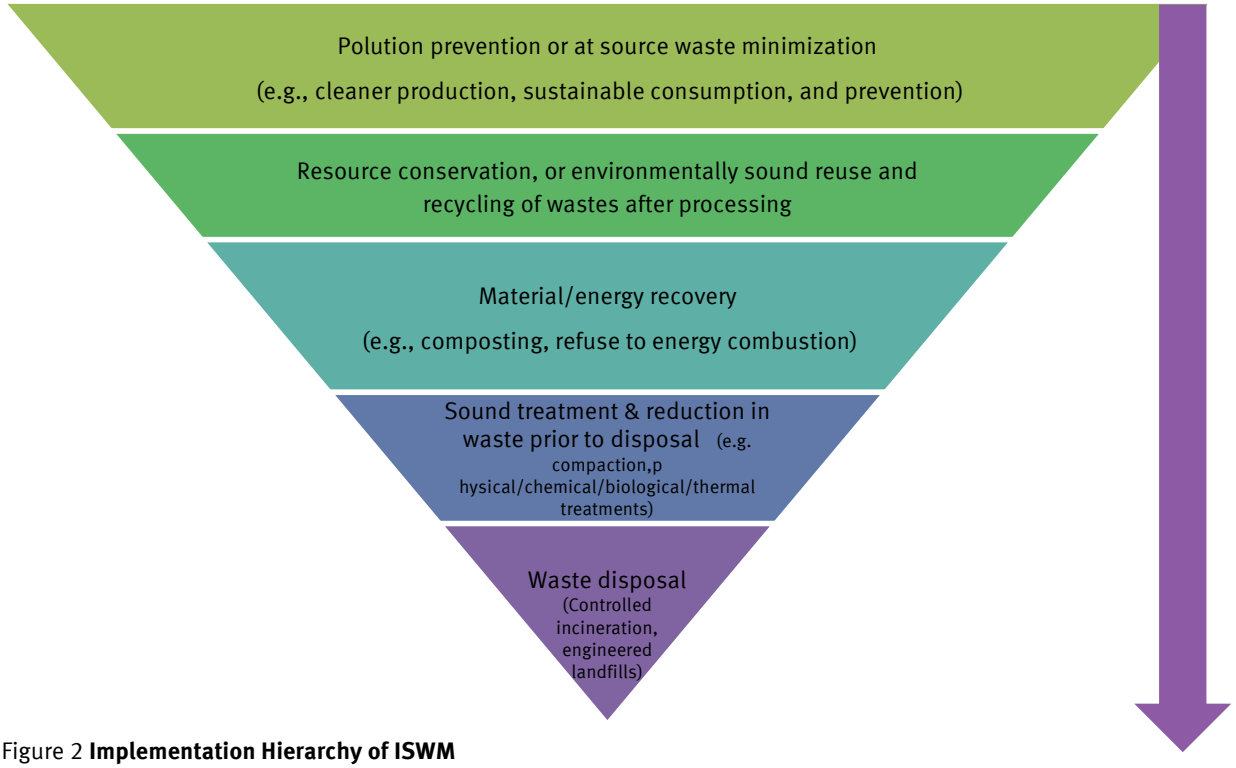

Figure 2 **Implementation Hierarchy of ISWM**

2. Interdisciplinary and multi-sectoral collaborations

Proper management of solid waste is a complex undertaking that entails appropriate technical solutions, adequate organizational capacity, and cooperation across a wide range of stakeholders.

At the government level

The government should have the political will to raise this emerging public health problem above all other considerations, recognize that inaction will lead to disastrous effects at the health and environment level, and find a solution before detrimental health and environment consequences emerge.

This can be achieved by

- Consulting with the needed technical, health, economic, and environmental expertise to analyze the current situation and decide on the best waste management option (or mixture of options)
- Considering the option of delegation of the waste management responsibility to local municipalities; and concurrently strengthening the capacities of the latter through providing them with the necessary technical, financial, and decisional support

At the municipality level

- Creation of well-designed landfills or incineration sites as far as possible from inhabited areas, preferably more than 10 km away, as determined by multiple environmental reports
- Avoiding contact of trash piles with water sources or agricultural lands
- Routine measurement of toxins released and testing water for possible contamination
- Encourage citizens to segregate waste and adopt the option of recycling
- Financial and technical collaboration with the government, NGOs, or other organizations for better achievement of the above objectives
- Public engagement in decision-making and implementation of solutions

At the health system level

- More vigorous surveillance of diseases particularly those at expected increased risk of emergence
- Keeping an open eye for increased trends in specific diseases particularly infections on the short term and cancer and congenital abnormalities on the longer term
- Timely reporting of specific infectious diseases for prompt intervention in an attempt to avoid emergence of epidemics
- Public education about the importance and application of hygienic measures

At the citizens' level

- Economizing on the production of trash, which results in decreasing the volume of scattered waste
- Sorting out of trash for potential recycling of some categories such as paper, plastic, glass and metals
- Avoiding individual acts of incineration
- Following strict hygienic measures particularly with food preparation through sanitization of fruits and vegetables, deep cooking of meat, and use of water from reliable resources
- Avoiding contact with infected persons, to prevent further transmission of microorganisms.

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Annexes

Appendices

Appendix I: Summary of Key Findings

Table 1 **Health outcomes of exposure to landfills**

Health Outcome	Number of Studies	Countries	Exposure	Impact
Cancer				
Colorectal[16,17]	2	Finland; Australia	Inhabitants of houses built on a former dumping area or districts around the boundary of disposal depot	No increased incidence
Liver[18-20]	3	Italy; Canada; Brazil	Various distances evaluated	No increased liver cancer mortality in a community living in an area containing a landfill No significant increased trend in populations living at various distances.
Bladder[17,19,21]	3	UK; Australia; Brazil	Within 2 km of source or districts around the boundary of disposal depot	No association detected
Larynx[17,20]	2	Italy; Australia	Up to 10 km or districts around the boundary of disposal depot	In one study a significant decrease of mortality rates was detected as the distance from the sites increased. No association was detected in the second study.
Lung[16,17,20]	3	Australia;	Inhabitants of houses built on a	No increased

Health Outcome	Number of Studies	Countries	Exposure	Impact
		Italy; Finland	former dumping area Up to 10 km distance from site Districts around the boundary of disposal depot	incidence
Kidney[16,18]	2	Italy; Canada	Up to 10 km from site	Modest non-significant increase in risk
Lymphomas[17,18,20]	3	Canada; Australia; Italy	Up to 10 km from site or districts around the boundary of disposal depot	One out of three studies found a significant association
Leukemia[17,19-21]	6 (2 in children and 4 in adults)	UK; Brazil; Australia; Italy	Up to 10 km or districts around the boundary of disposal depot	No association
Brain[17,21]	2	UK; US	Within 2 km from site or districts around the boundary of disposal depot	No association was found in one study, while increased risk in males living in the proximity was found in the other
Other cancers [16-18]	3	Australia; Canada; Finland	Inhabitants of houses built on a former dumping area or districts around the boundary of disposal depot	No association was found for breast, uterus, prostate, stomach, and skin cancers Increased risk for pancreatic cancer Another study found an increased risk for skin and pancreatic cancers only in males
Birth defects and reproductive disorders				
Birth defects in	11	UK; Belgium;	Various distances	Mixed results where

Health Outcome	Number of Studies	Countries	Exposure	Impact
general [19,22-31]		Denmark; France; Italy; Ireland	assessed	six studies found statistically significant associations while five other studies did not
Non-chromosomal birth defects[32]	1	Belgium; Denmark; France; Italy; UK	Within 7 km	-Increase in risk of non-chromosomal birth defects (neural-tube defects, malformations of the cardiac septa, and anomalies of great arteries and veins) in people living at less than 3 km from landfills containing both urban solid and industrial or toxic wastes.
Nervous system birth defects[23,33,34]	3	UK; US	Various distances used	Mixed results: Two studies confirmed association and one study denied any association
Cardiovascular defects oral defects[33]	1	US	Up to 1 mile	No increased risk
Hypo- and epispadias[35]	1	US	Proximity and chemical leaks	Higher risk of hypospadias and epispadias was detected in children living close to industrial toxic wastes
Down syndrome[36]	1	UK	Within 2 km of site	No association
Sirenomelia and cyclopia[37, 38]	2	Colombia; South America	Cases captured in 1 hospital Within 2 km of site	Four cases of sirenomelia and four of cyclopia were born in one hospital within a 165 days were

Health Outcome	Number of Studies	Countries	Exposure	Impact
				identified. However this study could not conclude if these incident cases reflected increased risk.
Low birth weight[24,27,39-41]	5	Alaska; UK; Canada	Various distances used or as per exposure zones	Four out of five studies demonstrated Increased risk
Respiratory Diseases				
Asthma incidence[16,26,42]	3	Finland; UK; US	Inhabitants of houses built on a former dumping area or comparison of health data of a zip code containing a hazardous waste site to other zip codes	Increased incidence of asthma and increased hospitalization for asthma and respiratory diseases
Total Mortality				
Total mortality[17,26,43,44]	4	Australia; UK; Italy; US	Based on districts around the boundary of disposal depot or former canal residents or former residents of nearby landfill	Two studies reported an association while the remaining two studies denied any association.

Table 2 **Health outcomes of exposure to incineration sites**

Health Outcome	Number of Studies	Countries	Exposure	Impact
Cancer				
All cancers[45-49]	4 in adults; 1 in children	UK; France; Italy	Various distances used or according to dioxin exposure	Mixed results in adults: Two studies reported an association while two other studies denied any association No excess risk of cancer mortality was found in children aged less than 5 years.
Non-Hodgkin lymphomas[45,46,48-52]	7	UK; Italy; Brazil; France	Various distances used or according to dioxin exposure	Mixed results: Three studies reported a positive association with dioxin exposure whereas four studies found no association
Sarcoma and soft tissues[45,47,49,51-53,55,56]	9	UK; France; Italy	Various distances used or according to dioxin exposure	No association was shown in five studies. The other four studies reported significant risk increase associated with living less than 2 km from the site and significant risk increase by level and duration of exposure. This association was particularly observed in women.
Breast[47,49,57]	3	France; Italy	Based on dioxin exposure zones, or within 3.5 km radius around incinerator	One out of three studies found a small association
Lung[45,46,48,49,58,59]	6	UK; Italy; Brazil	Various distances used or according	Three studies reported risk excess

Health Outcome	Number of Studies	Countries	Exposure	Impact
			to dioxin exposure	in people living close to the emission site. Three other investigations, with better exposure measurement, found no association.
Colorectal[45,46,49]	3	UK; Italy	Various distances used or according to dioxin exposure	An increased risk with distance from the site was reported in one study, but the authors suggested possible overestimation due to poor control of confounding factors. Another study with a good outcome measurement found no increased risk. Another study found higher mortality in men and higher incidence in women, but the increased risk was found at heavy metal exposure levels of 1–2 ng/m3 and not at higher levels.
Liver[19,45,46,48,49]	5	Italy; Brazil; UK; France	Various distances used or according to dioxin exposure	Three studies found no association. One investigation found a significant increase in risk associated with smaller distances from the sites. Another study carried out in rural deprived areas found an association, but flaws

Health Outcome	Number of Studies	Countries	Exposure	Impact
				in the study design diminish its validity
Larynx[45,46,48,49]	4	UK; Italy; France	Various distances evaluated	All four studies demonstrated convincing evidence of association.
Leukemia[46,48,49,60]	4 (2 adults and 2 children)	Italy; Brazil; UK	Various distances evaluated	One study found a modest increase in risk in residents between 2 and 3.5 km from the site, but not at shorter distances; suggesting that this risk is hardly linkable with the distance from the site. Another study in adults failed to demonstrate an association. Two studies in children found contradictory results, with the study reporting an association having mixed exposure (incinerator and industrial combustion)
Stomach[45,49]	2	UK; Italy	Various distances evaluated	One study found a significant increase in risk associated with the distance from the site, but control of confounding factors was poor. Another study reported an increased risk for women exposed to heavy

Health Outcome	Number of Studies	Countries	Exposure	Impact
				metal levels of 1–2 ng/m3, but not for those exposed to higher levels
Bladder[45,49]	2	UK; Italy	Various distances evaluated	No association was found in both studies
Cerebral, myeloma, lymphatic system, prostate[49]	1	Italy	3.5 km radius from incinerators	No association was found between incidence and mortality for these diseases and living nearby incinerators
Birth defects and reproductive disorders				
Orofacial defects[61-63]	3	Sweden; France; Netherlands	Various distances evaluated or according to Dioxin exposure	Mixed results: Two studies detected an increased risk whereas no increased risk was found in the remaining study
Urinary tract defects[64]	1	France	Dioxin exposure	An increased risk was found for congenital urinary tract defects when women were exposed to atmospheric dioxin and dioxin deposits in the ground during the first months of pregnancy. Authors also suggest a possible role of the dioxin in contaminating locally produced food
Spina bifida, cardiac defects, and renal dysplasia[61,65]	2	UK; France	Dioxin exposure	Modest risk increase of spina bifida, cardiac defects, and renal dysplasia were demonstrated

Health Outcome	Number of Studies	Countries	Exposure	Impact
Low birth weight[67]	1	Japan	Dioxin exposure	No significant association
Chromosomal and non-chromosomal anomalies[68]	1	UK	Up to 7 km	No significant association
Spontaneous abortion[68]	1	Italy	Dioxin exposure	No significant association
Births sex ratios[69]	1	Italy	Using 3-D mapping techniques, in the residential areas at risk from airborne pollution	Increased occurrence of female births
Twining[70]	1	Scotland	Rates in areas exposed to airborne pollution from incinerators were compared with the background rates present in neighboring areas	Increased occurrence of twining
Respiratory Diseases				
Respiratory function, wheezing, chronic respiratory symptoms, respiratory disease mortality[49,71-74]	5	China; Japan; US; Italy	Children of the primary schools in 3 polluted areas Up to 3.5 km radius from incinerators Mean PM10 level Distance of the public schools from municipal waste incineration plants	Two studies reported a decrease in respiratory function and an increase in respiratory wheezing in children Increased prevalence of chronic respiratory symptoms was detected in two other studies In one study, a higher respiratory disease mortality was found in

Health Outcome	Number of Studies	Countries	Exposure	Impact
				men exposed to heavy metals levels of 0.5–1 ng/m3; with no risk detected in individuals exposed to higher levels. That same study found no difference for total mortality and hospitalization for respiratory diseases.
All-Cause Mortality and Cardiovascular Disease				
All-cause mortality and cardiovascular diseases[49]	1	Italy	Up to 3.5 km radius from incinerators	One study found that total mortality in women was associated with the presence of an incinerator at any level of exposure to heavy metals Same study found an increase in cardiovascular disease mortality in women, in hospitalization for chronic cardiac insufficiency and acute myocardial infarction in men in the mid-category exposure (0.5–1 ng/m3) to heavy metals, but not for the highest (higher than 2 ng/m3)
Skin Diseases				
Atopic dermatitis[72]	1	Japan	Mean PM10 level	One study found no association with atopic dermatitis, but a reporting bias and poor control of

Health Outcome	Number of Studies	Countries	Exposure	Impact
				confounding factors indicate an unsatisfactory quality of the paper.

Table 3 **Environmental Consequences**

Pollutants	Main impacts	Description of Impacts
Methane	Global warming Vegetation dieback	Converted to carbon dioxide (CO2) in the atmosphere, but has a short-term 'greenhouse factor' 30 times that of CO2 Prevents oxygen entering soil, thus discouraging re-vegetation of landfills
Carbon dioxide and Carbon monoxide (CO)	Global warming Flammability Toxicity Asphyxiation hazards	Partly responsible for atmospheric greenhouse effect causing climate change Elevated CO2 levels may stimulate weed growth Inhalation of CO causes deprivation of oxygen to brain and heart tissues
Nitrogen oxides (NO2)	Photochemical ozone formation Nutrient enrichment	NO2 participating in the photochemical smog can result in secondary production of the pollutant ozone (O3) NO2 is a plant-growth retardant and can cause decreases in agricultural yields Eutrophication of oligotrophic aquatic and terrestrial ecosystems Loss of habitat, disappearance of flora and fauna
Organic compounds Volatile organic compounds	Toxic and potentially carcinogenic Forms ozone and peroxyacetyl nitrate through photochemical	

Pollutants	Main impacts	Description of Impacts
	reactions	
Sulphur oxides	Affects lichens at a concentration 6x lower than that affecting human health	Synergistic effect in combination with smoke Lower agricultural crop yields
NOx and SOx	Acidification	Affects poorly buffered soils Decline in coniferous forestry Increased fish mortality Metal corrosion
Hydrogen fluoride	Toxicity in plants Affects dairy cattle	Cause blight in maize Lowers citrus productivity Cattle grazing on exposed herbage suffer fluorosis (loss of teeth, bone growth at joints, lameness)
Trace metals	Toxic to plants and affect animal health	Some are potent catalysts and can contribute to the post-incineration formation of dioxins Herbivore health affected through ingestion of plants bio-accumulating trace metals
Chlorinated organic compounds (dioxins and furans)	Lipo-soluble, persistent, and bio-accumulative in different components of ecosystems	
Ammonia	Toxicity to fish and disturbed behavior in horses	Affects oxygen demand in exposed water
Salt e.g. sodium chloride	Ecological toxicity Alters soil conductivity and ionic exchange	

Appendix II: List of countries by income level[8]

Lower Income (LI)	Lower Middle Income (LMI)	Upper Middle Income (UMI)	High Income (HIC)
Chad	Bulgaria	Colombia	Barbados
Comoros	Cameroon	Costa Rica	Belgium
Congo, Dem. Rep.	Cape Verde	Cuba	Brunei Darussalam
Eritrea	China	Dominica	Canada
Ethiopia	Congo, Rep.	Dominican Republic	Croatia
Gambia	Cote d'Ivoire	Fiji	Cyprus
Ghana	Ecuador	Gabon	Czech Republic
Guinea	Egypt, Arab Rep.	Georgia	Denmark
Haiti	El Salvador	Grenada	Estonia
Kenya	Guatemala	Jamaica	Finland
Lao PDR	Guyana	Latvia	France
Liberia	Honduras	Lebanon	Germany
Madagascar	India	Lithuania	Greece
Malawi	Indonesia	Malaysia	Hong Kong, China
Mali	Iran, Islamic Rep.	Mauritius	Hungary
Mauritania	Iraq	Mexico	Iceland
Mongolia	Jordan	Myanmar	Ireland
Mozambique	Lesotho	Namibia	Israel
Nepal	Macedonia, FYR	Panama	Italy
Niger	Maldives	Peru	Japan
Rwanda	Marshall Islands	Poland	Korea, South
Senegal	Morocco	Romania	Kuwait
Serbia	Nicaragua	Russian Federation	Luxembourg
Sierra Leone	Nigeria	Seychelles	Macao, China
Tanzania	Pakistan	South Africa	Malta
Togo	Paraguay	St. Kitts and Nevis	Monaco
Uganda	Philippines	St. Lucia	Netherlands
Vanuatu	Sao Tome and Principe	St. Vincent and the Grenadines	New Zealand
Vietnam	Solomon Islands	Suriname	Norway
Zambia	Sri Lanka	Tajikistan	Oman
Zimbabwe	Sudan	Uruguay	Portugal
	Swaziland	Venezuela, RB	Qatar
	Syrian Arab Republic		Saudi Arabia
	Thailand		Singapore
	Tonga		Slovak Republic
	Tunisia		Slovenia
	Turkey		Spain
	Turkmenistan		Sweden
	West Bank and Gaza		Switzerland
			Trinidad and Tobago
			United Arab Emirates
			United Kingdom
			United States

Appendix III: Glossary of terms

Term	Definition
Neural-tube defects	Any of various congenital defects caused by incomplete closure of the neural tube during the early stages of embryonic development
Hypospadias	An abnormality of the penis in which the urethra opens on the underside
Epispadias	A congenital defect in which the urethra opens upon the upper surface of the penis
Sirenomelia	A congenital malformation in which the lower limbs are fused
Cyclopia	A developmental anomaly characterized by the presence of a single median eye
Sarcoma	A malignant tumor arising in tissue of mesodermal origin (as connective tissue, bone, cartilage, or striated muscle) that spreads by extension into neighboring tissue or by way of the bloodstream
Spina bifida	A neural tube defect marked by congenital cleft of the spinal column usually with hernial protrusion of the meninges and sometimes the spinal cord
Renal dysplasia	Abnormal growth or development of kidney
Twinning	The bearing of twins
Atopic dermatitis	A chronic eczematous skin condition marked especially by intense itching, inflammation, and dryness
PM 10	Particulate matter up to 10 micrometers in size

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Knowledge to Policy (K2P) Center
Faculty of Health Sciences
American University of Beirut
Riad El Solh, Beirut 1107 2020
Beirut, Lebanon
+961 1 350 000 ext. 4689
www.aub.edu.lb/K2P
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