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REVIEW ARTICLE

Environmental Impacts and Health Risks of Open Landfills in West African Countries: A Systematic Review of the Literature

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Abstract

In developing countries, despite the fact that most waste is composed mainly of materials of plant origin, the increasing industrialization of communities is increasingly involved in the generation of waste from industrial and agricultural activities and chemical remains. One of the consequences associated with the production of this waste is the emergence of open landfills as a disposal method, which has the effect of releasing several pollutants into the environment, including toxic metals. As waste treatment in landfills varies from region to region, the impact on health and the environment may be different. This systematic review aims to take stock of the situation of open dumps in West Africa and the environmental impacts and health risks associated with these landfills.

Method: After identifying a research question, 21 articles were identified and reviewed using the PICO format to split into concepts and then a keyword for each concept.

The results showed, among other things, the presence of domestic, industrial, electronic, and healthcare waste in several landfills. The trace elements As, Cd, Pb, Hg, Zn and Fe were found at concentrations higher for some metals than those set by the US EPA on metal levels in soils. In addition to metals, organic compounds (PAHs, PCBs, Dioxins/Furans, PBDEs...) have also been found in environmental matrices of some open landfills.

Conclusion: The open landfill approach as a method of solid waste disposal is at an early stage of solid waste management in many parts of the world. The permanent environmental exposure as it exists today in the vicinity of open dumps is likely to accentuate the health risks among the local population. This review contributes to the literature on the environmental and health impact of landfills in West Africa.

Introduction

In developing countries, most waste is almost exclusively generated by domestic activities and is composed mainly of plant-based materials. The increasing industrialization of communities is a factor that is increasingly involved in the production of waste from industrial activities, agricultural activities, chemical remains and the release of toxic metals, etc. Faced with the challenges of disposing of this waste that clogs cities, landfill sites have been set up on the outskirts of large cities to meet this need.

In developing countries (developing countries), land filling has experienced great growth over the last ten years. One of the consequences of this growth is the birth of open landfills as a method of solid waste disposal in many parts of the world [1]. These landfills, which are located and operated to the detriment of environmental protection, are the cause of environmental disasters with significant health risks that are still poorly understood and not well known.

In developing countries, landfills, whether controlled

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or not, are a significant receptacle for the majority of waste, which will lead not only to the risk of biogas emissions from anaerobic biodegradation of fermentable fractions present in waste, but also to the circulation of leach ate that can contaminate both groundwater and surface water [2]. The situation is all the more worrying in countries that do not benefit from any protection and whose landfills are located near lagoons and for which the water table is less than 5 m [3].

From the demographic point of view, some landfills, initially located on the outskirts of large cities, were quickly included in urban areas whose expansion continues to be galloping, this is the case in particular of the Akouédo landfill in Abidjan and that of Mbeubeuss in Dakar [4,5]. In addition, some sites face routing problems and « leakage » flows, sometimes not negligible, which appear despite being located sufficiently away from urban areas [6]. Then there is the use of dangerous waste treatment practices such as the burning of waste which is at the origin of the production of harmful fumes and the release of toxic elements from batteries, batteries, etc. Thus, even after their closures, these landfills will continue to have an insidious impact on health and the environment [6].

However, the scientific literature on the environmental impact and/or health risk of open landfills in some West African countries is limited.

Since waste treatment may differ from one landfill to another because of the different structures set up within each of them, this systematic review aims to take stock of the open landfills in West Africa as well as the environmental impacts and health risks associated with these landfills, based on available work.

Materials and Methods

Sampling strategy

In this systematic review, the method described by Tranfield, et al., 2003 [7] was used. This consists of planning the conduct of the systematic review over a period of time, then carrying out a search based on keywords and then gathering all the known knowledge on a subject and finally, writing a report based on the results obtained during the study period [7]. Specifically, this review relied on data available in the literature on open dumps in West Africa. Furthermore, since the intrinsic nature of their view did not cover human or animal subjects, a consent agreement and submission for an ethical opinion were not necessary.

Given that it is complex to be able to cover a wide range of themes and topics for a single article and in particular for our topic, we have relied on a PICO approach [8,9]. In our PICO format, the “P” refers to the population or problem that for our study refers to open dumps. The “I” refers to the intervention or more precisely to the different exposure actors of our study. The “C” refers to comparison or control, which is an alternative to the “I” intervention or to the exposure actors. Depending on the type of study, it may [8]. Finally, the “O” refers globally to the results and/or the criterion of judgment and here it is the environmental and/or the health risks related to landfills. In order to conduct the review well, it is therefore necessary to ask the question, “For P, am I as opposed to C about to the result O?” following the PICO form [8].

Selection

Once the search question had been defined, the PICO format was used to split it into concepts, and then a keyword was associated with each concept. The keywords were then associated with each other by Boolean operators (and/or) to construct a search equation and query the databases selected for the study. The bibliographic search was conducted during the period from 20 March to 30 September 2021 and the databases “PubMed”, “Science Direct” and “Google Scholar” are the ones that were searched (Table 1). The results obtained at this stage were filtered and a number of references were identified as potentially eligible. The latter were examined when reading the titles and abstracts.

Table 1: Breakdown of the research question into concepts and then keywords.

Environmental impacts and health risks of open landfills in PAOs				
PICO	**P =**	**I =**	**C =**	**O =**
	Population	Exposure factor	Comparison	Outcome
Concepts				
	Open dump	-	-	Environmental Impact, Health Risks
Keywords				
	Waste, disposal, facilities, Landfill, Dumpsite	-	-	Health Risk, Environmental, impact
Research results				
PubMed	(((landfill [MeSH Terms]) OR (Waste disposal facilities [MeSH Terms])) OR (dumpsite)) AND ((health risk [MeSH Terms]) OR (environmental impact [MeSH Terms]) AND (West Africa [MeSH Terms]))			
Google scholar	((landfill) OR (Waste disposal facilities) OR (dumpsite)) AND ((health risk) OR (environmental impact)) AND (West Africa)			
Science Direct				

With the removal of duplicates, references that met the eligibility criteria below were selected for a full-text examination. Thus, the studies selected should be observational studies (case control, cohort study, cross-sectional), studies for both on open landfills, studies of environmental impacts and/or health risks, studies carried out in a West African country.

Following the full-text reading, a number of references, although initially considered relevant, were eventually excluded for non-eligibility under the above criteria.

Result

Selection of publications

The search equations and keywords used in the different databases made it possible to reference 1705 publications. After examining the titles and abstracts, 213 references appeared to be eligible for the selection criteria. Full-text analysis kept 21 of them. The flowchart below summarizes the selection process used (Figure 1).

Characteristics of the different landfills

Landfill is the ultimate outcome for much of the waste in West African countries. The main studies and the characteristics of the landfills of the latter have been identified and are summarized in Table 2 and Table 3. Depending on the site and the region, there are differences between landfills in terms of area, amount of waste per year, etc., and among these, the Mbeubeuss landfill in Senegal seems to be the largest in terms of area (175 ha). This is followed by the Akouédo landfill in Côte d'Ivoire, which has an area of 100 ha (Table 3). With the exception of the Agbogbloshie landfill in Ghana, which specializes in electronic waste, the types of waste found in most landfills are almost similar. These are mainly household waste, industrial waste, agricultural waste and waste from care activities (Table 3).

Environmental impacts of landfills

The authors of the work included in this review noted the presence of heavy metals in the different

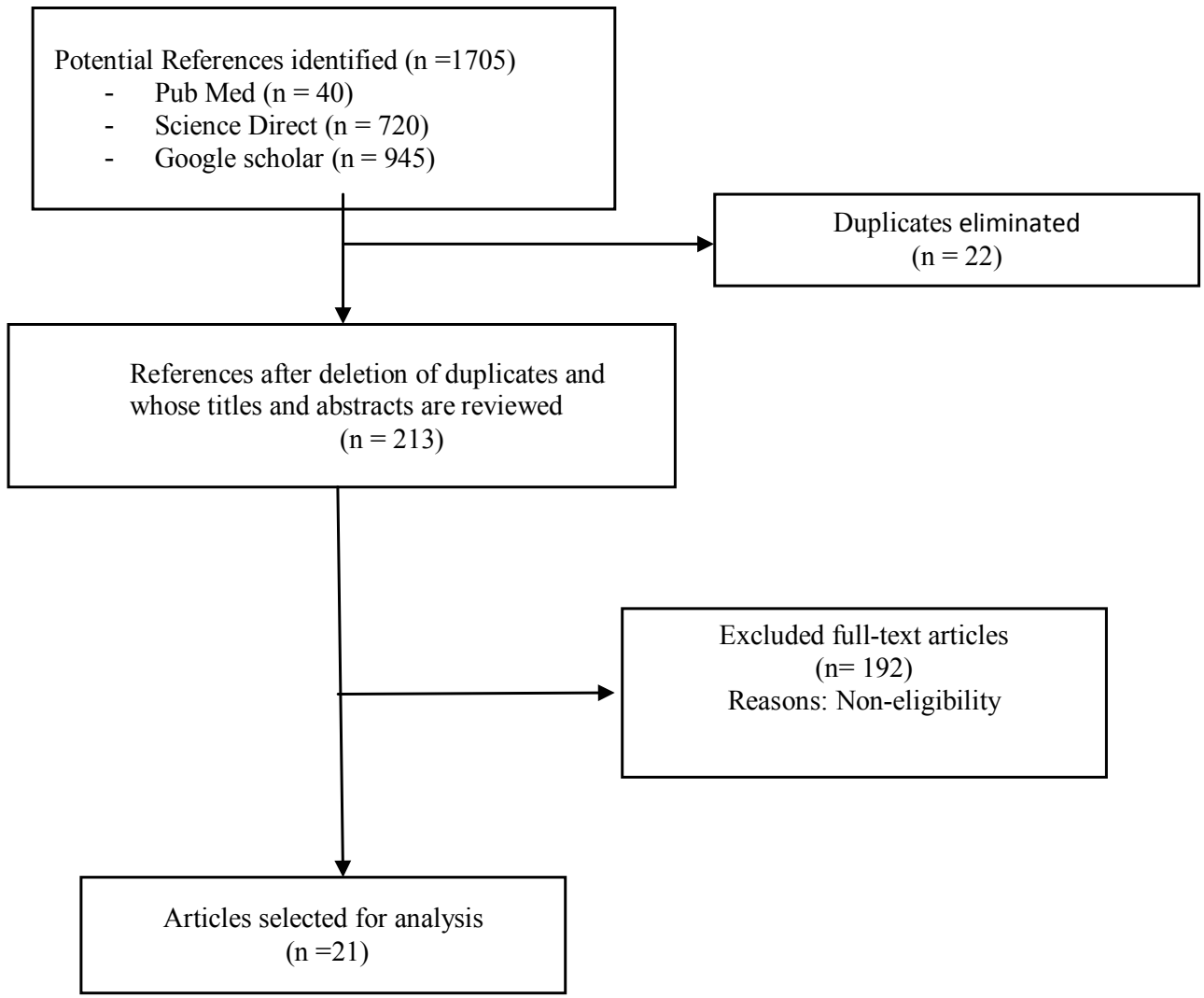

Figure 1: Flowchart of the narrative literature review.

Table 2: List of selected items.

Country	Name of the Landfill	Studies
Ivory Coast	**Akouédo**	1. Characterization of the chemical and microbiological pollution of the environment of the Akouédo landfill, Abidjan-Côte d'Ivoire [15]. 2. Toxicological risks of cohabitation with a landfill: Case of Akouédo in Côte d'Ivoire [5]. 3. Relative mobility of mercury from the Akouédo landfill and risk of contamination of the Continental Terminal aquifer [28].
Nigeria	**Aba-Eku**	Assessment of groundwater pollution near Aba-Eku municipal solid waste dumpsite [38].
Nigeria	**Olushosun**	1. Reproductive toxicity assessment of Olusosun municipal landfill leachate in Mus musculus using abnormal sperm morphology and dominant lethal mutation [31]. 2. Evaluations of groundwater contamination by leachates around Olusosun open dumpsite in Lagos metropolis, southwest Nigeria [17]. 3. An exploratory evaluation of the potential pulmonary, neurological and other health effects of chronic exposure to emissions from municipal solid waste fires at a large dumpsite in Olusosun, Lagos, Nigeria [39].
Ghana	**Kronum**	Distribution of heavy metals in soils from abandoned dump sites in Kumasi, Ghana [35].
Ghana	**Amakon**	Distribution of heavy metals in soils from abandoned dump sites in Kumasi, Ghana [35].
Ghana	**Kpone**	Assessment of heavy metal contamination in soils at the Kpone landfill site, Ghana: Implication for ecological and health risk assessment [13].
Ghana	**Agbogbloshie**	1. Soil concentrations of polybrominated diphenyl ethers and trace metals from an electronic waste dump site in the Greater Accra Region, Ghana: Implications for human exposure [16]. 2. Bioaccessibility and human health risk assessment of metal (loid) s in soil from an e-waste open burning site in Agbogbloshie, Accra, Ghana [18].
Togo	**Agoè**	Assessmentof the quantity of heavy metals in the Agoè landfill (Lomé-Togo): Case of lead, cadmium, copper, nickel and zinc [40].
Niger	**Niamey 2000**	Physico-chemical characterization of landfill leachate: Case of the uncontrolled landfill of Niamey 2000 [25].
Sierra Leone	**Granville Brook**	Environmental and Health Impact of Solid Waste Disposal in Developing Cities: A Case Study of Granville Brook Dumpsite, Freetown, Sierra Leone [26].
Senegal	**Mbeubeuss**	1. Low-level environmental exposure to lead and renal adverse effects: A cross-sectional study in the population of children bordering the Mbeubeuss landfill near Dakar, Senegal [29]. 2. Childhood saturnism near a landfill [41]. 3. Effects of environmental cadmium and lead exposure on adults neighboring a discharge: Evidences of adverse health effects [33]. 4. Renal impairment assessment on adults living nearby a landfill: Early kidney dysfunction biomarkers linked to the environmental exposure to heavy metals [34]. 5. [11] (Cabral 2012). 6. Contamination of chicken eggs near the Mbeubeuss landfill site in a suburb of Dakar, Senegal, with dioxins, polychlorinated biphenyls (PCBs) and hexachlorobenzene [12].
Gambia	**Bakoteh**	Preliminary and detailed engineering design study of the Bakoteh dump Site [24].

environmental matrices around landfills. The toxicity of metallic trace elements cannot be an absolute concept, so it is necessary in such a context to make an analysis taking into account the nature of the environment and its geographical location.

Metallic trace elements in landfill soils: A large part of the studies included in this review found the presence of metals in soils at open landfill sites. Analysis of data on soil trace element contamination shows that the levels found for certain metals are higher than that set by the US EPA on metal levels in soils [10]. Table 4 presents the quantitative data on the levels of arsenic, cadmium, copper, iron, mercury, lead and zinc in landfill soil.

Analysis of these results shows that during the Mbeubeuss landfill, only zinc is found below the US EPA standard of1100 ppm (Table 4). In addition, the levels found by Bodjona, et al. for the Agoé site are generally below US EPA standards, with the exception of cadmium which was 2.51 ppm and which exceeds the value of 0.41

Table 3: Characteristics of open landfills in the study.

Country/city	Name	Surface (ha)	Types of waste	Quantity of waste (T/year)	References
Côte d'Ivoire/Abidjan	**Akouédo**	153	DM, DI, DA, DE, DAS	550,000	[5,15,28]
Nigeria/Ibadan	**Aba-Eku**	10	DM, DI, DA, DE, DAS	990,000	[38]
Nigeria/Lagos	**Olushosun**	42	DM, DI, DA, DE, DAS	1000,000	[17,31,39]
Ghana/Kumasi	**Kronum**	06	DM, DI, DA, DE, DAS	25,000	[35]
Ghana/Kumasi	**Amakon**	10	DM, DI, DA, DE, DAS	40,000	[35]
Ghana/Accra	**Kpone**	18	DM, DI, DA, DE, DAS	1,000,000	[13]
Ghana/Accra	**Agbogbloshie**	-	Of	50,000	[16,18]
Togo/Lomé	**Agoè**	10	DM, DI, DA, DE, DAS	250,000	[40]
Niger/Niamey	**Niamey 2000**	10	DM, DI, DA, DE, DAS	61,500	[25]
Sierra Leone/ Freetown	**Granville Brook**	06	DM, DI, DA, DE, DAS	90,000	[26]
Senegal/Dakar	**Mbeubeuss**	175	DM, DI, DA, DE, DAS	1,000,000	[11,29,33,34,41]
Gambia/Kanifing	**Bakoteh**	18	DM, DI, DA, DE, DAS	52,000	[24]

DM: Household Waste; DI: Industrial Waste; DA: Agricultural Waste; DE: Electronic Waste; SAR: Healthcare Waste.

Table 4: Metal contents of landfill soils.

Landfills	Fe (mg/kg)	As (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	With (mg/kg)	Hg (mg/kg)	Zn (mg/kg)
Akouédo	6754.5	-	9.87	933.37	376.8	4.82	1250.55
Kronum	-	4.2	8.9	11	32	0.04	166
Amakon	-	11	3	288	347	0.19	558
Kpone		390.75	-	351.67	79.87	15.20	1875.75
Agbogbloshie	289	-	0.531	207	222	-	34.7
Agoè	-	-	2.51	66.91	70.24	-	401.13
Mbeubeuss	197690	21	19.7	1129	125.5	-	593
US EPA	-	0.11	0.48	200	270	1	1100

Table 5: Metal contents of landfill leachate.

Landfills	Fe (mg/l)	As (mg/l)	Cd (mg/l)	Pb (mg/l)	With (mg/l)	Hg (mg/l)	Zn (mg/l)
Akouédo	-	-	< 0.02	< 0.2	0.09	-	0.39
Aba-Eku	0.0123	0.0073	0.007	**0.12**	0.4778	0.0008	0.9881
Olushosun	**2.43**	**0.3**	0.19	**0.4**	**11.3**	0.2	-
Niamey 2000	**9.26**	-	**0.19**	-	**2.3**	-	8.75
US EPA	0.3	0.01	0.05	0.015	1.3	-	-

ppm as recommended by the standard US EPA (Table 4). The Kronum, Amakon, Kpone and Agbogbloshie sites all had levels higher than those of the US EPA standards for certain metals such as arsenic, cadmium and even lead which ranged from 4.2 ppm to 390.75 ppm for arsenic, 0.53 ppm and 8.9 ppm for cadmium and 11 ppm and 351.67 ppm for lead, against 0.11, 0.48 and 200 ppm such as the standards set by the US EPA 2002. However, these levels remain lower than those found in the soils of the Akouédo and Mbeubeuss landfills where the lead values were 933.37 ppm and 1129 ppm respectively, and those of cadmium were 9.87 and 19.7 ppm for each of the landfills. In addition, the landfills with the highest mercury levels are those of Akouédo (4.82 mg/kg) and Kponé (15.20 mg/kg).

Metallic trace elements in landfill leachate: Metallic trace elements that have been characterized in soils are also present in leachates. Table 5 presents the metal contents of leachate at selected landfill sites in West African countries. Overall, the metal levels in the leachate of the Akouédo and Aba-Eku landfills are all below the limits set by the US EPA and which are 0.3 ppm for iron, 0.01 ppm for arsenic, 0.05 ppm for cadmium, 0.015 ppm for lead and 1.3 ppm for copper. On the other hand, these landfills at Olushosun and Niamey 2000 are above the same US EPA limits for discharge waters.

Organic compounds in landfills: In addition to metals found at high levels, some authors have highlighted the presence of organic compounds (PAHs, PCBs, Dioxins/

Furans, PBDEs, etc.) in different environmental matrices of open landfills in some West African countries. This is particularly the case with the study conducted by Cabral M. 2012 which found PAH levels of around 888 ug/L in the soil and 111 ng/m^3 in the air around the Mbeubeuss landfill. According to this study, phenanthrene, fluoranthene, pyrene and chrysene were the most represented families of PAHs [11]. A study by the International Network for the Elimination of POPs (IPEN) and Pesticide Action Network (PAN) Africa (2005) also found high levels of dioxins and polychlorinated biphenyls (PCBs) near the site of the Mbeubeuss landfill in eggs of hens raised in the open air [12]. The levels of dioxin found in the eggs sampled from the Mbeubeuss landfill site were 11 times higher than the dioxin limit set for eggs by the EU. In addition, PCB levels exceed the limits proposed by the EU by more than 7 times [12]. High levels of Polybrominated diphenyl ethers (PBDEs) were found by Akortia, et al. in soil samples in the Agbogbloshie landfill with average levels of 54.8 ng.g^{-1} dry weight.

Health risks of open landfills

Table 6 presents the health impacts and the various nuisances documented in the studies selected for this review. The work of Adjiri, et al. (2019) shows an increase in cancer cases in populations living around the Akouédo landfill [5]. Cases of cancer have also been documented by Obiri, et al. 2021, and these are believed to be due to the presence of the Kpone landfill [13]. In addition, pathologies such as kidney damage, respiratory infections or chronic obstructive pulmonary disease have been recorded respectively in populations living near the Mbeubeuss, Bakoteh and Olushosun landfills (Table 6). Of the various landfills studied, three of them recorded cases of diarrheal diseases in the surrounding population, these were the studies on the Kronum, Amakon and Granville Brook landfills. On the other hand, only work on the Agbogbloshie and Mbeubeuss landfills has identified cases of childhood lead poisoning among the population living near these landfills. Neurological damage and malaria prevalence were observedin the Olushosun and Granville Brook landfills respectively.

With regard to nuisances, insect vectors of diseases, the presence of bad odours and coliforms are the main forms of nuisance that have been encountered in these studies, with the consequence of the degradation of the quality of life of the local populations.

Discussion

The analysis of a scientific output may take the form of a literature review, scoping reviews, critical analysis, meta-analysis, or systematic review as presented in this work [14]. Systematic review is considered to be one of the most appropriate tools for evaluating and comparing the work of other researchers.

To carry out the review of this study, a protocol was followed for each step of the process, from the choice of search terms to data extraction.

This study presents a situational analysis of documented cases of many open dump sites in West African countries. Using data from some twenty publications on the environmental impacts and health risks of open landfills in West Africa, we have endeavored after their analysis to discuss them and draw conclusions.

Each of the landfills has its own characteristics. In terms of area, the Mbeubeuss landfill in Senegal remains the largest landfill of 175 hectares. This is followed by the Akouédo landfill located in the capital of the Republic of Côte d'Ivoire even (100 hectares) and other sites with areas ranging from 6 to 42 hectares. This difference in surface area between landfills may, among other things, explain the level of environmental pollution noted at the site level.

From a demographic point of view, some landfills, initially located on the outskirts of the city, were quickly included in rapidly expanding urban areas, such as the Akouédo landfill in Côte d'Ivoire and the Mbeubeuss landfill in Senegal [11,15]. The relocation of certain sites sufficiently away from urban areas is also at the root of

Table 6: Health risks associated with Landfills.

Name	Pathologies	Other nuisances	References
Akouédo	Cancer	Fecal coliforms, faecal streptococci and Clostridiums perfringens	[5]
Olushosun	COPD, neurological impairment	Bad smells	[17,31]
Kronum	Diarrhoeal diseases	-	[35]
Amakon	Diarrhoeal diseases	-	[35]
Kpone	Cancer	-	[13]
Agbogbloshie	Saturnisme infantile	-	[18]
Agoè		Fecal coliforms, Disease-carrying insects	[40]
Granville Brook	Malaria, diarrhoeal diseases		[26]
Mbeubeuss	Kidney damage, childhood lead poisoning	Insectes, badodours, noise pollution	[11,29,34,41]
Bakoteh	Respiratory infections, malaria	Insect vectors of diseases, rodents, bad odours.	[24]

the problems of transporting waste to landfill sites. This phenomenon has the consequence of causing flows of "leakage", sometimes not negligible. In addition, there are certain waste treatment practices such as burning, which is at the origin of the massive production of harmful fumes and the release of toxic elements from batteries, batteries, etc. This is despite the absence of a system for coating or collecting leachate and gases produced [16,17].

Other factors such as the type of waste received by landfills may also be involved. With the exception of the Agbogbloshie site in Ghana, which is a landfill mainly intended for waste electronic equipment, the landfills listed in this analysis receive for the most part all types of waste (household, industrial, agricultural, care activities, etc.). [18]. Unlike household waste, electronic waste is characterized by a high metal load and is present in mixed landfills. As a result, the composition of the waste is an important parameter that can explain the level of contamination of the sites and the type of pollutant encountered. In addition, the proximity of residential areas to e-waste sites is a much greater health risk factor for children and pregnant women [19-23].

The open landfills found in most of the West African countries studied are also important sources of pollution of environmental matrices (air, water and soil). Metallic trace elements (lead, cadmium, arsenic, etc.) and organic compounds (PAHs, PCBs, dioxins/furans, PBDEs) are the families of pollutants most encountered in landfills. Organic compounds PAHs, PCBs, Dioxins/ Furans, PBDEs... which were found had high levels in the various environmental matrices of the landfills and mainly in the Mbeubeuss and Agbogbloshie landfills [11,16,18]. Thus, according to the authors, the presence of organic compounds at the various sites is partly due to the phenomenon of open incineration of waste on these sites.

In addition, most of these landfills are located in unfavorable areas, such as the Mbeubeuss, Akouédo, Niamey 2000, Olushosun, Bakoteh and Granville Brook landfills, which are located in areas where the water table does not exceed 10 m [11,15,17,24-26]. One of the consequences of this small distance between the water table and the surface is in particular the risk of infiltration of surface water and groundwater by waste percolation water (leachate). Depending on the porosity, composition and thickness of the pile of waste, rainwater and the moisture contained in the waste is likely to pass through the aquifer with a fairly variable speed and flow. This flow mechanism also promotes the biodegradation of fermentable organic matter and loads the water with microorganisms, organic and mineral substances. It is also this "waste juice" that is called leachate and which can be defined as a complex effluent specific to the landfill from which it comes [27].

The various landfill sites studied have overall metal concentrations significantly higher than the standards set by the US EPA. On the other hand, the metal contents (Cd, Pb, Cu, Zn) in the Akouédo landfill reported by Adjiri, et al. 2009 are below the standards set by the US EPA for discharge water. In their study of the Aba-Eku landfill, Aromoloran, et al. 2019 report metal levels below the US EPA standard values, with the exception of lead which had a value above the norm (0.12 versus 0.015). In addition, the Olushosun and Niamey 2000 sites had metal content in leachate upto US EPA standards [17,25]. The high levels of metal in the leachate of these landfills and the level of the water table relative to the soil surface suggest a high risk of contamination of surface and groundwater.

The comparison of the different levels of heavy metal pollution for the sites studied shows the Mbeubeuss landfill in Senegal as the most polluted site. The levels of iron, cadmium, lead for this site were higher than those of other sites and US EPA recommendations [5,11,15,28,29]. The Mbeubeuss landfill thus preceded that of Akouédo [5]. In addition, cadmium, lead, arsenic and mercury were the most implicated in the pollution of the sites.

In view of the contamination data of the various environmental matrices by heavy metals and organic compounds, there is no doubt that the population bordering these landfills has been exposed with a significant health risk that can be correlated with the toxicity of these different compounds.

The health risk assessment of an open landfill located in a region of central Italy showed for different scenarios and for carcinogenic and non-carcinogenic effects, risk indices (IR) whose order of magnitude was lower than those accepted by the main international agencies such as the WHO and the US EPA [30]. Also in 2014, the presence of unpleasant odours from landfill sites is likely to alter the quality-of-life of the local population. The work of Peter, et al. 2018 on particle emissions from an old landfill located in Chennai in India, also highlighted high-risk indices (IR) of occurrences of pathologies such as cancers and respiratory infections such as those found by the various authors of this review [5,13,17,24,31]. According to Peter, et al. 2018, the occurrence of these pathologies is strongly related to emissions of fine particles (PM2.5) containing metallic trace elements (As, Cr, Cd, Ni and Pb) [32]. There is also a limited amount of data on the health impacts of open dumps in the West African zone.

In addition, the occurrence of non-carcinogenic pathologies such as renal damage, childhood lead poisoning, respiratory infections and neurological damage observed in the residents of the various landfill sites that were observed was cored to the presence of landfills and after evaluation of lead and cadmium biomarkers of effects and impregnation [11,29,33].

The results of recent work by the same author have shown cellular disturbances in the nephritic segments rather than irreversible damage to the kidneys [34]. Other pathologies such as diarrheal diseases, malaria which according to the authors are very common among residents of landfill sites are mainly linked to the state of insalubrities encountered all around the sites [15,24,26,35]. The health impact of landfills on populations is difficult to highlight. This is all the more linked to the existence of several factors which can contribute to bias in the analyses and in particular the interpretation. The absence of a rich bibliography of the health risks of landfills can also be explained by the difficulty of being able to establish the direct causal link between the pollution from these landfills and the diseases found among the local population. In addition, the diffuse impact is difficult to study. The health risk presented by most of the authors stems from a state of scientific knowledge at the moment, which in the same momentum sets reference values on the basis of toxicological or epidemiological data established or strongly suspected. The aim of such an approach, however, is to enlighten the public debate on the reality and also on the extent of the health risks associated with the pollution of open landfills in West African countries.

In the industrialized countries, the model of open landfills has gradually been rehabilitated, or even definitively closed following the results of the numerous works carried out on the environmental impact and on the health, risks associated with it [36,37].

Nevertheless, it appears from our analysis that the continuation of environmental exposure as it exists today in the vicinity of these landfills is likely to accentuate the impregnation of local populations with the various pollutants, which a priori may lead to an increase in the risk of death.

This various works made it possible to present the level of pollution of certain sites of open landfills by organic compounds.

Conclusion

The aim of this study was to assess the situation of many landfills in West African countries in order to contribute to improving the state of knowledge on the various environmental contaminants and the health risks associated with open landfills in this part of the world. It was based on a collection of data from three major databases, 21 publications reporting on the environmental impacts and/or health risks of open dumps in West Africa.

The open landfill approach as a method of solid waste disposal is at an early stage of solid waste management in many parts of the world. It is one of the most poorly provided services by municipal authorities in developing countries where this management model thus applied has no scientific value, seems outdated and especially ineffective given the context of globalization. Several of these sites in the West African region have been located both inside the cities and on the periphery. The increase in the world's population and the ever-increasing demand for nutrition, as well as the need for essential products, are at the same time factors that can promote the massive production of waste in households across these different countries.

Thus, the huge quantities of unsorted waste received by these landfill sites increase the impact on the environment, which has the consequence of creating an excess of risk to the health of the populations living near these sites.

In order to improve the environmental status of West African cities, the construction of new sites for the storage and disposal of household waste such as technical landfills or incinerator plants, in accordance with the law, is proving to be an imperative. In addition, it is also wise to put in place a better management and collection plan for household waste in order to put an end to and/or limit the proliferation of open landfills that do not bobstay contribute to increasing the level of pollution in these cities. A permanent environmental exposure as it exists today in the vicinity of open dumps is likely to accentuate the health risks among the local population. Therefore, peremptory measures should be considered in the sense of contributing to a better living conditions of living populations near landfills in West Africa.

Competing Interest Statement

The authors declare no conflict of interest.

Author Contributions

All authors contributed equally to the development of this manuscript and have read and accepted the published version of the manuscript.

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