Air Pollution by Microbial Bioaerosols around Some Landfills in Bamako

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Abstract: ***In the city of Bamako in Mali, there are more than a dozen waste dumps. These dumps are located in the heart of different neighbourhoods and in the city centre close to homes, shops, markets and other important public places. Within the landfills, the biochemical reactions of the different materials cause several nuisances and pollution, including air pollution by microorganisms. Residents living near landfills are the first identified victims of potential risks from microbial bioaerosols in the air around landfills. This study is consisted to determine the average concentrations of microbial germs contained in the air around some Bamako landfills. Microbial cultures on agar media were carried out in order to count the different microbial concentrations. The highest average concentration of total mesophilic bacteria obtained in the air samples during the two campaigns was 502 CFU/m3. Among the bacteria, the most frequent found in the air with average concentrations above 200 CFU/m3 were Bacillus cereus (354 and 213 CFU/m3), Clostridium perfringens (379 and 367 CFU/m3) and staphylococcus germs (218 and 391 CFU/m3). Only the samples taken during the first campaign have an average Mycobacterium concentration greater than 200 CFU/m3 of air. Low densities of microscopic fungi were also found in the vicinity of landfills. Regardless of their loadings, these microbial bioaerosols cause a threat to public health, especially the health of residents near landfills and workers on landfills.***

Keywords: pollution, bioaerosols, microbials, air, landfills, public health, Bamako

1. Introduction

The severe growth of the city of Bamako is creating difficulties in the implementation of sanitation and solid waste management strategies. The population of Bamako is estimated at 2 million inhabitants. The city is home to more than a third of the city's population and the population growth in Bamako is estimated to be around 5% [1].

The daily production of household waste in the city was 2100 m^3/day in 2005 with a collection rate of 60% [1]. The annual volume of waste produced in 2006 was about 817,600 m^3 (2,240 m^3/day) [2].

Systematic landfilling is the method used in the city. However, the city does not have a suitable landfill for their treatment. The waste after collection is transported and dumped in landfills originally created to serve as intermediate dumps, which, in the absence of functional final landfills, serve as permanent waste storage sites. In the capital city there are a significant number of uncontrolled and poorly managed municipal landfills, located close to homes and businesses. There are, however, a few authorised intermediate storage sites whose management remains a major problem for the municipal authorities. These include the dumpsites of **Badalabougou, Lafiabougou, Medinacoura, and Boulkassoumbougou.**

In addition, several activities are carried out on these dumps by recoverers of end-of-life objects and informal operators. Although landfilling is the most commonly used and considered the most economical way of treating waste, it is not without consequences for the health of the inhabitants and the environment in which they live.

Waste transfers chemical particles and microbes to both air and water. This leads to air pollution and water pollution through infiltration into the subsoil [3]. Among the consequences of poor waste management in Bamako is air pollution that could directly or indirectly affect the population. An increase in the annual average concentration of airborne particles has been recorded in the city, estimated at 331ug/m^3 according to the WHO [4].

Contaminants are aerosols, which are considered small particles that are released into the air chemically or biologically. A large proportion of aerosols are found in or near landfills. In an INRS report, the inhalable (or inhalable) fraction of an aerosol in a workplace like a landfill corresponds to the percentage of particles with an aerodynamic diameter less than or equal to 100 µm. The thoracic fraction is defined as particles less than 10 µm in diameter, the alveolar (respirable) fraction is defined as particles less than 4 µm in diameter [5, 6].

The evolution of waste in landfills and their interactions with the external environment also lead to the dispersion of pollutant flows resulting from physico-chemical and bacteriological reactions between elements. Elkharmouz et al [7]. The smallest particles can reach alveolar cells when in contact with the bloodstream, and are thought to be responsible for some cases of DNA modification [8]. Their aerodynamic diameter is less than 10µm [9]. Among the pollutants we have particularly bioaerosols such as microorganisms. Indeed, a large part of the particles isolated from landfill air are in a range of respirable sizes: 40% of bacteria and 80% of fungi [10]. Microorganisms once in landfills multiply with the favourable growth conditions provided by landfills. Microbes that are frequently implicated in diseases are Mycobacterium, Salmonella, Shigella, Bacillus, Clostridium, and Staphylococus, fungi, viruses and other Enterobacteriaceae [11].

A review of the literature has shown that bioaerosol emissions are considerable and can reach a radius of 1000-1200 m from the site [12, 13]. With the action of the wind, they end up in the air we breathe. They interact with their environment (degradation) and with each other (mutation). Once in the body, these particles can enter the bloodstream and cause diseases such as skin infections (wounds), gastrointestinal problems (nausea, vomiting), respiratory problems and allergies (asthma, rhinitis, conjunctivitis) [14]. Respirable fractions are of particular importance in the epidemiology of infectious diseases because of their ease of dispersion and their ability to infiltrate the respiratory system to the pulmonary alveoli. Despite the fact that most people spend much of their time indoors, outdoor air quality can have a significant influence on indoor air quality [15]. Indoor air in buildings located in close proximity to municipal landfills can be polluted by microorganisms emitted from the landfill [16].

Suggestive symptoms such as respiratory or cardiac discomfort (shortness of breath, wheezing or palpitation) appear during pollution peaks, leading to serious illnesses that occur: myocardial infarction, angina pectoris, heart rhythm disorders, stroke, and coronary artery disease [17].

Pathologies such as asthma, allergies, tuberculosis, diarrhoeal diseases and dermatoses) can be of viral, parasitic or bacterial origin. Kayantao et al [18] estimates the frequency of asthma at 14.9% in Bamako. In the same city, 73 cases per 100,000 inhabitants have pulmonary tuberculosis [19]. At the global level, ReMed [20] estimates that the costs associated with asthma exceed those of tuberculosis and HIV/AIDS infection combined. Both diseases can develop in environments such as those in which waste is dumped in Bamako.

The direct targets of these public health threats are the people who work at the landfill sites and the residents and businesses located around the landfills. Microbial bioaerosols from uncontrolled landfills in Bamako can generate health risks (infections, allergies, toxicities, etc.) that can in turn induce major negative impacts on the living environment of the inhabitants of the neighbourhoods in which these sites are located. This study proposes to measure the average concentrations of microbiological agents in the air around a few waste dumps likely to affect the health of the inhabitants.

2. Materials and Methods

2.1 Air sampling on landfills

The "impinger" technique was used for sampling, it consisted of collecting microorganisms (bioaerosol) in a liquid. For the preparation of the stock solution, 40 ml of peptone water was introduced into 50 ml "Falcon" tubes and connected to the air sampling apparatus. After switching on, the machine sucks the air containing microorganisms for 15 minutes into the peptone water contained in one tube. Thus, the microbes in the air were first impacted and then diffused into peptone water. Sampling was therefore carried out in accordance with the instructions in the air sampler user manual described in the SKC, Inc. National Service Center document. At the time of sampling, full tours of the landfills were conducted to capture the bioaerosols contained in the air around the landfills. At the end of the time, the tubes containing the samples were packaged and transported to the laboratory for analysis.

The air samples were taken from four (4) household waste landfills. Eight (8) samples were taken due to four (4) samples per season. Two (2) sampling campaigns were organized. The first samples were taken during the first campaign in the rainy season (month of July 2019) and the second samples were taken during the second campaign in the dry season (month of November 2019).

2.2 Microbiological analyses of samples

The microbiological analysis consisted in searching and enumerating different microbial germs from the inoculation of 1ml of the sample to be analysed on a specific solid culture medium. The culture media that were used for the culture of the microorganisms are:

- PCA agar (Plate Cante Agar) for the enumeration of the total flora 37°C/24h
- Deoxychlolate agar agar for coliform enumeration 44°C/24h
- Chapman (Mannitol Salt Agar) for Staphylococcus enumeration 37°C/48h
- Sabouraud for counting mushrooms 22°C/72h
- Bacillus Cereus Agar for the enumeration of Bacillus Cereus 37°C/24 hours
- Clostridium perfringens Agar for enumeration of Clostridium perfringens 44°C/24h
- Lowestein Jensen Medium Base for the detection of Mycobacterium tuberculosis and other Mycobacteria 37°C/72h
- Coletsos Medium for the confirmation of the presence of Mycobacterium 37°C/72h

The results were expressed in colony-forming units per m3 of air (CFU/m3).

3. Result

3.1 Results of the microbiological analyses of the air samples from the first sampling campaign (July 2019)

Table 1: Microbial Concentrations in Air Samples Taken in July 2019

Samples	Microbial concentrations in CFU/m^3 air						
	TAMF	FC	*Bacillus Cereus*	*Clostridium perfringens*	Fungi	Staphylococci	*Mycobacterium*
E_1 : Badalabougou	192	0	376	344	64	564	72
E_2 : Boulkassoumbougou	395	0	364	424	80	88	120
E_3 : Lafiabougou	274	0	384	356	72	37	80
E_4 : Médinacoura	176	0	292	392	144	184	152
Average	259,25	0	354	379	90	218,25	106

Analysis of the results in *Table 1* shows that the ambient air contained several groups of microorganisms. Significant mean concentrations of species such as *Bacillus cereus* (354 CFU/m^3 air) and *Clostridium perfringens* (379 CFU/m^3 air) were found during the rainy season. Fecal coliforms were not found in the analyzed samples, however, significant concentrations of *Staphylococci* (218.25 CFU/m^3 air) were found in the samples.

In addition, the average concentration of enumerated fungi was estimated at 90 CFU/m^3 of air on the Bamako landfills. The presence of *Mycobacterium* (106 CFU/m^3 of air) was confirmed in all air samples analysed.

3.2. Results of microbiological analyses of air samples from the second sampling campaign (November 2019)

Table 2: Microbial concentrations in air samples taken in November 2019

Samples	Microbial concentrations in CFU/m^3 air						
	TAMF	FC	Bacillus Cereus	Clostridium perfringens	Fungi	Staphylococci	Mycobacterium
E_1 : Badalabougou	474	2	80	308	80	72	343
E_2 : Boulkassoumbougou	537	1	398	351	100		403
E_3 : Lafiabougou	511	0	327	474	32	364	368
E_4 : Médinacoura	486	0	48	336	48		311
Average	502	0,75	213,25	367,25	65	391	356,25

The results of the microbiological analyses after the second sampling (*Table 2*) show the average concentrations of the different microbial germs enumerated. The average concentration of the total flora was the highest with 502 CFU/m^3 of air sampled. A very low concentration of Faecal Coliforms (0.75 CFU/m^3 of air) was counted. The mean concentrations of Bacillus cereus species (213.25 CFU/m^3 air) and Clostridium perfringens (367.25 CFU/m^3 air) after the second sampling were also significant compared to the other concentrations. Cultivatable fungi were counted in all samples taken at the different landfills with an average concentration of 65 CFU/m^3 of air.

In the samples, the average concentration of Staphylococci counted was 391 CFU/m^3 of air. The genus *Mycobacterium* with an average concentration of 356.25 CFU/m^3 of air was strongly enumerated in the garbage samples of the second sampling campaign.

3.3 Comparison of microbial concentrations in air around landfills during the two sampling campaigns

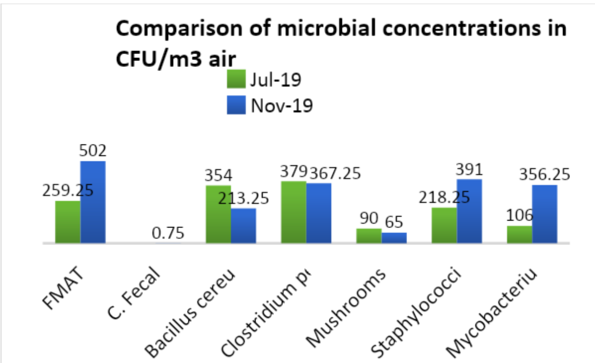

Figure 1: Comparison of different microbial concentrations in CFU/m3 of air

After comparison of the results of the two samples *(Figure 1)*, high concentrations of microorganisms were found in the samples from the first campaign during the rainy season and in the samples from the second campaign.

The mean concentrations of *Bacillus cereus* and Clostridium perfringens species counted after the second campaign were 213.25 and 367.25 CFU/m^3 air, respectively, which were lower than those of the same species counted after analysis of the samples from the first sampling campaign.

The average concentrations of staphylococci and *Mycobacterium* found during the second campaign are the highest with estimated averages of 391 and 356 CFU/m^3 of air than those of the same germs found during the first campaign.

4. Discussion

A significant diversity of germs with varying concentrations was found in air samples taken from landfill sites. The highest mean concentrations of total mesophilic bacteria obtained in the air samples during the two campaigns around the landfills in Bamako do not exceed the highest concentration of total mesophilic bacteria found in the air (105 CFU/m^3) by Rahknen, [21]. Whereas, the concentrations of total bacteria obtained in an open-air household waste composting plant were in the range of 105 to 106 CFU/m^3 [24, 23, 22, and 5]. In Denmark, average concentrations of total microorganisms breathed in by workers collecting and sorting household waste also ranged from 10^5 to 10^6 CFU/m^3 [25, 26].

Although little discussed, air pollution by microorganisms around landfills in Bamako is real and should be addressed. The most frequent microorganisms with average concentrations above 200 CFU/m3 of air are *Bacillus cereus, Clostridium perfringens, Mycobacterium* and staphylococci.

These germs are potentially dangerous and can harm the health of the inhabitants and that of those working on the city's landfills.

Bacillus ceureus is saprophytic in the air which explains their presence in air samples [27]. *Bacillus ceureus* strain ATCC 14579 was first isolated from air in a cow shed in the United Kingdom [28, 29]. The presence of *Bacillus ceureus* in the air around landfill sites in Bamako is not surprising as landfills meet all optimal conditions for proliferation.

The results of the sample analyses revealed high concentrations of bacteria compared to fungi in the air around the landfills in Bamako. The results are in agreement with those of an INERIS study, [30] in which the researchers also discovered from available data that in storage sites for household and similar waste, concentrations of 103-105 CFU/m^3 of air in bacteria and 103-104 CFU/m^3 of air in fungi were found.

Landfills do not contain the necessary humidity for the survival of fungi at all times of the year. The growth of fungi, and in particular moulds in landfills, depends on climatic conditions [31]. Heat and humidity promote the growth of mould in waste. Park et al [32] have shown that mould concentrations in the air also vary according to the activities associated with the waste, thus they obtained concentrations of 4.3.104± 1.4.104 CFU/m^3 of air during waste sorting and 3.7.103±9.7.102 CFU/m^3 of air at the time of waste collection [31, 32]. Moulds in the air release spores that are either deposited on food or inhaled by residents [33]. The fungi Aspergillus, Cladosporium, Alternaria and Penicilium are generally associated with respiratory allergies [31].

Anaerobic sulfite-reducing bacteria such as *Clostridium perfringens* are bacteria that participate in the degradation of organic matter in waste. Their presence in the air is caused by winds that carry them and transport them to potential targets. They participate in the production of methane at landfills.

After calculations of the average concentrations, a low concentration of fecal contaminating bacteria germs was obtained in the samples. The faecal coliforms are derived from the faeces of either animals or humans from sewage sludge dumped in landfills. The prohibition of the dumping of sewage sludge in landfills by municipal authorities limits the spread of fecal coliforms. However, waste stabilization reactions are also limiting the growth of these germs. One study confirms that bacteria of intestinal origin do not tolerate landfill conditions and generally disappear during the first phase of waste decomposition [30]. Most of the literature reports the presence of high concentrations of faecal coliforms rather in composting sites than in landfills. Lacey et al [34] have shown that in composting sites, concentrations of gram-negative bacteria can reach 104 CFU/m^3.

The rainy period offers the best conditions for the proliferation of many microbial germs. Indeed, the average concentrations of *Bacillus cereus*, *Clostridium perfringens* and cultivated fungi calculated during the first campaign (rainy season), were higher than those of the same germs obtained during the second sampling campaign. These sprouts are frequently present throughout the year in the air around landfills. Their natural habitat being the soil, some can survive in the waste with little organic substrate. INERIS [30] has reported after analysis of its data that *Clostridium perfringens* can even be identified in 1 to 5 year old wastes. Wastes after a few weeks of decomposition still contain a majority presence of *Bacillus* among a restricted group of germs [35].

Mycobacteria and staphylococci are the bacteria most strongly found in air samples during the so-called dry period (second campaign). During the dry period, there are more aerosols suspended in the air around the landfills in Bamako. However, only microorganisms resistant to hostile conditions in the air such as mycobacteria and staphylococci can live there for a given period of time. For example, spore-forming staphylococci can withstand a temperature of 60ºC for 30 minutes in the air [36].

The staphylococci sought in the air on landfills in Bamako were mostly commensal (coagulase-negative) in the skin and mucous membranes, identical to those found on the site of maturation silos in a composting plant with high concentrations found in the Chapman environment [5, 37].

Lavoie and Lazure [38] found that contamination by inhalation is most important in 65-75% of infections and allergies. *Mycobacterium* contamination occurs by inhalation in most cases. This information is corroborated by Miller et al [39] who state that *Mycobacterium tuberculosis* is transmitted only by air [40]; Miller et al [39]. *Mycobacterium tuberculosis* is the causative agent of tuberculosis. However, some species of Mycobacteria invade the skin causing cutaneous tuberculosis. In a descriptive study in Bamako of 4269 cases, 61 cases of cutaneous tuberculosis were identified [41].
Air pollution damages the respiratory system (respiratory tract and lungs). Workers at waste dumps and/or disposal sites in riverside communities in Mali have reported regular health problems such as rhinitis, conjunctivitis, non-infectious, irritative or allergic rhinopharyngitis [42]. In France, waste microorganisms cause respiratory diseases such as asthma, cough, bronchitis, signs of irritation and allergy in workers collecting and sorting household waste [20].

The average loads of total bacteria and Gram-negative bacteria do not reach the INRS limit values of 10^4 and 10^3 CFU/m^3 respectively. For the fungal flora, the average concentrations obtained are much lower than the INRS limit values (which are between 10^3 and 10^4). Although the average concentrations of *Bacillus cereus, Clostridium perfringens, Mycobacterium* and *Staphylococcus* in the air around landfills are below 103 CFU/m^3, they can be a source of contamination.

Thus, ragpickers, shopkeepers and other residents working on and/or living near landfills may be directly or indirectly infected by bioaerosols.

In Mali, air pollution by microorganisms is not clearly reflected in public health priorities and is of little concern to many people. Their major fear is of foul odours from landfills and the overflow of waste onto vehicle lanes. In some families living very close to landfill sites, there are cases of severe asthma, tuberculosis and skin allergies. However, these people do not link their illnesses to the landfill sites. On the dumpsites, the ragpickers have quickly lost their sense of smell or rather have adapted to it. However, they remain the most convinced that the deterioration of their health is due to the microbes in the landfills. Some of them confuse microbes with insects and other macroscopic parasites. Many of the landfill collectors fear tetanus, which they consider to be one of the most dangerous diseases contracted on landfills.

The negative impact of the former Boulassoumbougou landfill (Figure 2) on the lives of the inhabitants of the neighbourhood is very noticeable. Although it has been decommissioned, it remains a place where strong physicochemical and biochemical interactions between categories of waste take place. Its proximity to the neighbourhood market, which has been installed on part of the landfill, is likely to affect the health of the inhabitants.

Figure 2: Satellite image: Boulkassoumbougou landfill, Google Earth, images of 10/16/2018

No measures are taken by the municipal authorities against the various health risks for which microbial pollution is responsible at the landfill sites. Hygiene officials attach little importance to the issue of air pollution by microbial bioaerosols around landfills and have no strategy to deal with this pollution. Diagnoses of infectious diseases during consultations with patients living near landfills do not show a link with the proximity of landfills.

The results of this study provide new information that should enable decision-makers, researchers and the general public to better understand the spread of germs in the air in the vicinity of landfills in Bamako.

5. Conclusion

Landfills in the city of Bamako are major sources of pollution. Average concentrations of microbiological agents in the air around some of the landfills were calculated after enumeration. Germs of *Mycobacterium*, *Staphylococcus* and species such as *Bacillus cereus* and *Clostridium perfringens* were found in the air around the four landfills of the city.

With such average concentrations of enumerated microorganism agents in the air, contamination of people living near landfills and people working on landfills by inhalation or through consumption of contaminated food and water is possible. The different microbes may lead to major health risks. With the emergence of new fatal diseases such as COVID-19, it would be important to control microbial diversity at the level of landfills where the conditions for the anarchic proliferation of mutagenic germs are fairly well met.

Such a study must be carried out in depth in order to identify the microbial strains present in the air around the landfills, to highlight the different infections caused by the different germs at the landfills and to verify the resistance of the germs to medical treatments previously prescribed in health care institutions.

6. Acknowledgments

We thank Prof. Mohamed Sidda MAIGA, Dr. Omar CISSE and Marie L. SAGARA for their guidance during our research work.

References

[1] World Bank Mali. (2011). Environmental analysis of the urban environment, volume 2: environmental profile of the cities of Bamako, Gao, Mopti and Sikasso. Final report number: 60788-ML Africa Region, Sustainable Development Department, 69 p.

[2] Ministry of Health and Ministry of Environment and Sanitation. (2010). Situation Analysis and Needs Assessment (SNA) in Health and Environment [Internet]. Bamako, Mali, 136 P. URL: www.afro.who.int [Accessed 20/03/2016].

[3] CREPA and CIFAL. (2009). Training on waste management in African cities: organisation and financing. "Solid waste management issues in Africa". Ouagadougou, Burina Faso, P48. URL: www.cifal-ouaga.org and www.reseaucrepa.org .

[4] Ministry of Environment and Sanitation. (2010). Study of air quality in Bamako January 2010. P 38

[5] Centre Rhône-Alpes d'Epidémiologie et de Prévention Sanitaire. (2002). Bibliographical study on the assessment of risks related to biosols generated by waste composting. CHU Grenoble - BP 217-38043 Grenoble Cedex 9 tel: 0476511056 fax: 0476510306 email: cantact@careps.org ADAME Centre d'Angers 2 Square La Fayette BP 406 Angers cedex 02. 20p

[6] INRS. (1999). Limit values for occupational exposure to chemical agents in France. Briefing book - Occupational health and safety - Nº 174, 1st quarter 1999

[7] EL KHARMOUZ M., SBAA M., CHAFI A., SAADI S. (2013). The study of the impact of leachates from the former public landfill of the city of OUJDA in Morocco on the physico-chemical quality of

groundwater and surface water, Larhyss Journal, ISSN 1112-3680, no. 16, December 2013, pp. 105-119,

[8] DOUMBIA El Hadji. (2012). Physico-chemical characterization of urban air pollution in West Africa and health impact study. THESE DOCTORAT at the University of Toulouse. p

[9] Record. (2011). Microbiology and waste: health risk assessment. N°09-0669/1A. 100p, URL: www.record-net.org 03/02/2020

[10] Rahkonen P, Ettala M, Laukkanen M, Salkinoja-Salonen M. (1990). Airborne microbes and endotoxins in the work environment of two sanitary landfills in Finland. Aerosol Science and Technology. Taylor & Francis;13(4):505-513.

[11] Caisse Régionale d'Assurance Maladie de l'Ile de France 17-19 avenue Flandre CEDEX 19.

[12] Traversi D, Alessandria L, Schilirò T, Gilli G. (2011). Size-fractionated PM10 monitoring in relation to the contribution of endotoxins in different polluted areas. Atmospheric environment. Elsevier; 45(21):3515-3521.

[13] Fraczek K, Marcinkowska K, Barabasz W, Grzyb J. (2003). Occurrence of fungi in the atmospheric air within the range of municipal waste dump influence in Ujkow Stary, Krakow and Tarnow. Polish Journal of Natural Sciences (Poland).

[14] French Federation of Cardiology. (2015). Air Pollution: A Risk Factor Aggravating Cardiovascular Disease Press Release. CTF Recommendation P 3. URL: www.fedecardio.org last updated 21-08-2019

[15] Shelton BG, Kirkland KH, Flanders WD, Morris GK. (2002). Profiles of airborne fungi in buildings and outdoor environments in the United States. Appl Environ Microbiol. Am Soc Microbiol; 68(4):1743-1753.

[16] Schrapp K, Al-Mutairi N. (2010). Associated health effects among residences near Jeleeb Al-Shuyoukh landfill. American Journal of Environmental Sciences. Science Publications;6(2):184-190.

[17] Fédération Nationale des Activités de la Dépollution et de l'Environnement (FNADE). (2015): Biological risks in waste collection P 11-12-17

[18] Djankiné KAYANTAO, Yacouba TOLOBA, Moussa KAMISSOKO, Bah KEITA, Souleymane DIALLO, Ousmane M'BAYE, Souleymane SANGARE. (2001). Clinical and evolutionary epidemiological aspects of asthma observed in Bamako, Mali. Service pneumo-phtisiologie, Hopital du Point G, Bp 333, Bamako. Volume 11, number 2. URL: www.jle.com/fr

[19] Almahady CISSE (2003). Sanaté-Mali. Tuberculosis, considered a "shameful" disease, is resurfacing. Article published in Inter Press Service, newspaper URL: www.ipsnews.net Posted on 2003-11-04, accessed 2020-03-23

[20] Réseau Médicament et Développement. (2007). Asthma a silent epidemic. ReMed 35, rue Daviel 75013 Paris. 20p. URL: remed@remed.org

[21] Rahkonen P. (1992). "Airborn contaminants at waste treatment plants." Waste Management and Research 10:411-421p.

[22] REINTHALER FF, HAAS D, FEIERL G, SCHLACHER R, PICHLER-SEMMELROCK FP, KOCK M, WUST G, FEENSTRA O, MARTH E. (1999). Comparative investigations of airborne culturable micro-organisms in selected waste treatment facilities and in neighbouring residential areas. Zentralbl Hyg Umweltmed. 1999 Jun; 202(1):1-17.

[23] LAVOIE J, MARCHAND G. (1997). Determination of characteristics to be considered from a worker health and safety point of view in domestic waste composting centres. Études et Recherches : IRSST report, Institut de recherches en santé et en sécurité du travail du Québec, June 1997; 1-37 p.

[24] VAN TONGEREN M, VAN AMELSVOORT L, HEEDERIK D. (1997). Exposure to organic dust, endotoxins and micro-organisms in the municipal waste industry. Int J Occup Environ Health 1997; 3 30-6 p.

[25] Cancer and Environment Unit. (2010). Assessment of health effects related to the management of household and similar waste (HWM). Scientific report of the Centre Léon Bérard and the Rhône-Alpes Regional Health Observatory. 82 p.

[26] Nielsen EM, Breum NO, Nielsen BH, Wurtz H, Poulsen OM, Midtgaard U. (1997). Bioaerosol exposure in waste and seasonal variation. Appl. Occup. Hyg. 1997, 41, 325-344.

[27] Pierre Marie Curie University. (2003). Bacteriology course, DCEM1 level. Service of Bacteriology of the Faculty of Medicine. URL: www.chups.jussieu.fr/ Modified September 23, 2015

[28] Health Canada. (2018). Final Assessment Report for Bacillus cereus strain ATCC 14579 and Bacillus subtilis strain 11685-3 (B. cereus). Environment and Climate Change Canada Cat. No.: En14-326/2018E-PDF. ISBN 978-0-660-27016-6. 90p ec.enviriinfo.ec@canada.ca

[29] Frankland, G. C. and Frankland, P. F. (1887) Studies on some new micro-organisms obtained from air. Philos Trans R Soc Lond B Biol Sci 178, 257-287 p.

[30] INERIS. (2003). Data available for the risk assessment of bioaesols emitted by household and similar waste storage facilities. Final report of the Ministry of Ecology and Sustainable Development. 31p

[31] Jodelle Degois. (2018). Microbial diversity in bioaerosols emitted in waste sorting centres. Evolution [q-bio.PE]. Thesis of the University of Lorraine, French. ffNT: 2018LORR0007ff ffel-01886594f. 162p

[32] Park, D., Ryu, S., Kim, S., Byun, H., Yoon, C., Lee, K. (2013). Airborne bacteria and fungi associated with waste-handling work. International Journal of Occupational and Environmental Health 19:311-318 p.

[33] HealthLink BC. (2006). Indoor Air Quality: Mould and Other Biological Contaminants Number 65b. 2p.URL: www.HealthLinkBC.ca

[34] LACEY J, WILLIAMSON PAM, CROOK B. (1992). Microbial emissions from composts made from mushroom production and domestic waste. In: Composting and compost quality assurance criteria. Commission of the European communities' publisher 1992. EUR 14254 EN. 429 pages: 117-30

[35] GTInVs. (2003). Waste disposal and public health. Coordination InVS participation: InVS, INERIS, ADEME, AGHTM, RSD, SFSP. Provisional version of the contribution on biological risk, URL: www.docplayer.fr/ consulted 24/03/2020

[36] Centre d'Expertise en Analyse Environnementale du Québec. (2016). Research and enumeration of Staphylococcus aureus: Method by filtration on MA limb. 700-STA 1.0, Rev. 5, Ministère du développement durable, de l'Environnement et de la Lutte contre les changements climatiques. 18 p

[37] DELAUNAY N. (1997). An approach to airborne microbiological risk in an industrial household waste composting plant. Doctoral thesis in medicine, Grenoble - France

[38] Jacques Lavoie and Louis Lazure. (1994). Chemical Substances and Biological Agents, Studies and Research. Guide for the prevention of microbial proliferation in ventilation systems. Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), Direction des communications 505; boul. De Maisonneuve West Montreal (Quebec) H3A3C2 1994 ISBN 2-551-13374-2 ISSN 082068395. 88p URL: www.irsst.qc.ca.

[39] Miller JM et al, (2012). Guide lines for safe work practices in human and animal medical diagnostic laboratories: recommendations of CDC-convened, biosafety blue ribbon panel. MMWR Surveillance Summaries, 61 (Suppl.): 1-102

[40] WHO. (2013). Biosafety manual for tuberculosis laboratories. WHO Publishing, 20 Avenue Appia, 1211 Geneva 27 Switzerland. ISBN 978 92 4 250463 7. 66p. URL: www.who.int

[41] Adama DICKO, Ousmane FAYE, Youssouf FOFANA, Moussa SOUMOUTERA, Siritio BERTHE, Saidou TOURE, Bekaye TRAORE, Binta GUINDO, Koureissi TALL, Alima KEITA, Lassine KEITA, Karim COULMIBALY and Somita KEITA. (2017). Cutaneous tuberculosis in Bamako. The Pan African Medical Journal. Last Updated 08/06/2017; 27:102. Article URL: www.panafrican-med-journal.com/ accessed 25/03/2020 doi: 1011604/pamj.08/06/2017.27.102.11577

[42] Ministry of Health and Public Hygiene. (2011). Impact sanitaire de la pollution de l'environnement 2011. P 17