A CONCISE REVIEW ON SOME FREQUENTLY USED SOLID WASTE MANAGEMENT TECHNOLOGIES AND THEIR EFFECTS INTO THE ENVIRONMENT AND HUMAN HEALTH

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COMO REFERENCIAR ESTE ARTIGO: DINIS, M. A. P. - A concise review on some frequently used solid waste management technologies and their effects into the environment and human health. **Revista da Faculdade de Ciências da Saúde**. Porto : Edições Universidade Fernando Pessoa. ISSN 1646-0480. 6 (2009) 320-330.

RESUMO
Uma revisão sobre alguns estudos epidemiológicos melhorará a compreensão quanto aos efeitos potenciais na saúde da gestão de resíduos e permitirá obter informação importante em termos de trabalho futuro. Alguns estudos mostraram associações significativas entre diversos métodos de gestão de resíduos e impactos potenciais na saúde humana. Noutros estudos as associações foram consideradas inconsistentes ou susceptíveis de conduzir a equívocos, sendo necessários mais estudos epidemiológicos para averiguar as consequências para a saúde humana e para determinar os seus efeitos toxicológicos directos, assegurando assim que a gestão de resíduos representa um risco mínimo para a saúde. Os estudos epidemiológicos devem ser analisados com uma mente aberta, tomando em consideração factores como o estatuto social e a migração das populações.

PALAVRAS-CHAVE
Resíduos, saúde humana, reciclagem, incineração, compostagem, aterro.

ABSTRACT
A review of a few epidemiologic studies will improve the understanding of the potential health effects of waste management and will provide important information regarding future work. Several studies showed significant relationships between several methods of waste management and potential impacts on human health. In other studies associations were found to be inconsistent or equivocal and more specific epidemiological studies must be performed to assess consequences to human health and to determine their direct toxicological effects, thus ensuring that waste management pose minimum risk to health.

KEYWORDS
Wastes, human health, recycling, incineration, composting, landfill.

1. INTRODUCTION

Municipal solid waste (MSW) is in fact the garbage generated by homes, businesses, and institutions. There are many other kinds of solid wastes, including sludge from wastewater and water treatment plants, and air pollution control facilities. Additional discarded materials also include solid, liquid, semisolid, or even containerized gaseous materials from industrial, commercial, mining, and agricultural and community activities (Williams, 2005). Oils and oily wastes, construction and demolition waste and asbestos, and wastes from organic chemical processes are among those taken as hazardous (Rushton, 2003). Solid waste is classified as nonhazardous if it does not pose a threat to the environment or human health (Williams, 2005). However, out of the various categories of the wastes, solid waste contributes a major share towards environmental and human health concern (Misra and Pandey, 2005). The management problem is complicated by the heterogeneity of the waste in terms of chemistry, bioavailability and toxicity. The ranking of wastes according to their degree of associated hazard has advantages when choosing a waste management programme because it will act as a mitigation measure in terms of posterior development of toxicity by mixture with other wastes. Some examples can be found in Misra and Pandey work (Misra and Pandey, 2005). We currently have some major methods of waste management: recycling, composting, sewage treatment, incineration and landfill (Rushton 2003). Some of the advantages and disadvantages of the different methods were outlined by Pheby et al. (2002) in a work where it becomes evident that some of those methods have the same pollutants. Landfilling, incineration and composting processes, for instance, produce dust and particulate matter. There will also be an impact on the population living near, with odours, litter, noise, heavy traffic, flies and birds (Rushton, 2003). On the other hand, the general workforce employed in waste collection, sorting and disposal is exposed to a different amount of exposure and risk from the general population. We will here consider the term incineration as a process of combustion in order to recover energy and reduce the volume of waste which will go to disposal (Domingo and Nadal, 2009). As a consequence of the concern raised by incinerators of MSW, which have been questioned due to the atmospheric emissions, some countries have been carrying out a global planning in terms of MSW management. The aim is to separate recyclable and compostable material, and to considerably diminish the volume of waste to incinerate or to be disposed in landfills. The organic fraction of MSW is reduced through composting, and the resultant compost can be potentially used in several agricultural applications, among several others. Unfortunately, it is also a fact that yearly variations in the properties of compost from the same source does not allow researchers to draw conclusions and, thus, it inhibits research and the correct use of the compost (Mamo et al., 1999).

We all know that the European waste sector is undergoing unprecedented changes and challenges, driven by business, legislation, public and environmental concern, and government scrutiny (Pollard et al., 2006; Salhofer et al., 2008; Slack et al., 2009). It is important to make clear that environmental pollution plays a significant role in health outcomes. However, and as stated by Briggs (2003), the risk is not equal across the world, and there are severe disparities in the developed and the developing world, between rich and poor, and often between children and adults. It is also important to acknowledge that socio-economic status and the migration of populations are often ignored in the analysis dealing with information related with exposure data (Rushton, 2003). Wigle et al. (2008) identified, for instance, known and suspected relationships between environmental chemical contaminants and adverse pregnancy and child health outcomes, and state that many are supported by inadequate epidemiologic evidence. Many of these risks and health effects are readily avoidable and the need is for preventive action to reduce the emission of pollutants into the environment, and that has been implemented in many developed countries (Briggs, 2003). Knowing that the current pattern of resources consumption is unsustainable, and that the ecological footprint is quite complex, it becomes clear that the way humans deal with nature's ecosystem has severe adverse impacts on human health (Mohan et al,. 2006). Global changes are also a consequence of resources use. The relation between clean technology and waste minimization, associated with coal, in particular (still viewed as the major energy source for centuries to come), is a step ahead in minimizing the production of wastes. Co-incineration and co-combustion are, along with co-composting, alternatives to the conventional processes. Manufacturing goods from recycled materials has to be encouraged, since it often demands less energy (therefore polluting less) and less use of incineration and landfilling must be allowed. The aim of this paper is to review the state-of-the-art of some issues relating current waste management operations, and the evidence of relation with human health.

2. RECYCLING

According to Denison (1996), waste management systems based on recycling offer substantial system-wide or "life-cycle" environmental advantages over systems based on virgin production plus either incineration or landfilling. Only, if when waste management activities are separately analyzed, not accounting for the system-wide consequences do the virgin do material–based systems appear to offer advantages over recycled production plus recycling. Thus, recycling continues to be an indispensable tool in waste management hierarchy. Given the multiplicity of material under the heading of waste, there has to be a considerable potential of hazardous exposure occurrence through the waste management process, no matter the specific method of waste management involved. In recycling, the potential contamination of soil, air and water is a reality and it brings with it the widespread concern of the surrounding community. A study in literature involving work-related effects of dust exposure among recycling workers refers that the longer the worker is in a Material Recovery Facility (MFR) the more likely he is to become affected by various respiratory and gastrointestinal symptoms (Gladding et al., 2003). Literature relating heath problems to which MFR workers are exposed is scarce and does not address all hazards. Accordingly, more specific epidemiological studies must be performed in order to assess potential negative consequences to human health, concerning the exposure to chemical hazards. However, it is true that it is very difficult to establish a relationship since the mixture of so many substances does not allow the drawing of an accurate toxicological profile. Recycling studies involving the exposure of workers to hazards lack in specific information concerning health outcomes, particularly if they are directly reported by workers, as it happens frequently when workers are subjected to inquiries aiming to assess the risks they are exposed to. Appropriate choice of biomarkers (Behnisch et al., 2001) is currently an essential tool for a correct epidemiological design, thus allowing the investigation of interactions between genetic and environmental factors.

3. COMPOSTING FACILITIES

The diversion of biodegradable waste from landfill is of key importance in developing a sustainable waste strategy for the next decade and beyond (Sykes et al., 2007). The production of a relatively low-cost organic-grade MSW compost for agriculture is gaining popularity due to its positive effects in terms of biological, physical, and chemical soil properties

(Hargreaves et al., 2008; Otten, 2001). It is known that composted materials are remarkably regarded for their ability to improve soil health and plant growth, and suppress pathogens and plant diseases (Ahmad et al., 2007; Hargreaves et al.; 2008 and Jakobsen, 1995). Tourism in general and agro-tourism can also benefit from the use of compost in the improvement of forest and landscape (Manios, 2004). Being known that a compost cannot be considered potentially detrimental or dangerous, for the environment or for the human health, it is also acknowledge that the MSW from which it has been obtained can contain several pollutants that may represent environmental or health risks (Brändli et al., 2007; Veeken and Hamelers, 2002). Critics are apprehensive with often elevated metal concentrations. One of the main concerns has to do with loading the soil with metals which may result in increased metal content of crops and, in other cases groundwater can also be affected (Hargreaves et al., 2008). It is known, for example, that sewage sludge should not be added to the compost at any point since it will raise the metal content of the compost (Richard and Woodbury, 1992). To Domingo and Nadal (2009), health risks of compost are of essentially three main types: a) ingestion of soils, b) contamination through food chain with eventual toxic accumulation, and c) inhalation of dispersed atmospheric dust. Smith (2009) has collected and compiled international data on the total concentrations of heavy metals in MSW and greenwaste compost, which show that all types of compost contain larger concentrations of heavy metals than the background values present in soil, no matter what was the source. Therefore, heavy metals will slowly accumulate in soil, depending on the nature of the chemical association between a metal with the organic residual and soil matrix, the pH value of the soil, the concentration of the element in the compost and the soil, and the ability of the plant to regulate the uptake of a particular element. However, the main sources of contaminants can be removed somewhat effectively by modern mechanical screening processes, as the results compiled by Smith (2009) demonstrate. There is now a general consensus in the scientific literature that aerobic composting processes increase the complexation of heavy metals in organic wastes, thus limitating their solubility and potential bioavailability in soil (Eneji et al., 2003; Smith, 2009; van Herwijnen et al., 2007). Odors, noise, vermin nuisance, bioaerosol generation (organic dust containing bacterial or fungal spores), volatile organic compounds (VOCs) emission and a potential pathway due to its use on land, allowing contaminants to enter food chain, represent some of the drawbacks of this option for waste treatment (Harrison, 2007; Rushton, 2003). Besides odor-related issues, due to VOC emissions, VOC cause nauseas, vomits, hypersensitivity and many other health problems involving general toxicity and carcinogenicity (Kampa and Castanas, 2008; Rumchev et al., 2007). It is well known that benzene can cause aplasic anemia and polycithemia, dichloromethane produces carboxyhemoglobin, dichloromethane, toluene, styrene, trichloroethylene and tetrachloroethylene are neurotoxic, while naphthalene and styrene produce irritations of the mucosal membranes (Domingo and Nadal, 2009). Eitzer (1995), which analysed 8 composting facilities, has discovered that most VOCs are emitted at early stages of processing and that emissions are concentrated at the tipping floors where the waste is dropped off, at the shredder. According to Schlosser and Huyard (2008), bioaerosols in composting facilities may have infectious, allergic and impart toxic effects to humans. Assessment of the risk to workers of inhaling these aerosols is hampered by the scarcity of data available about actual exposure, and by insufficient knowledge about dose-response relationships. Thus, future studies should make an effort to improve exposure characterization and long-term respiratory function monitoring for workers in composting plants, since these individuals are exposed to several general health problems. Domingo and Nadal (2009) have concluded, after reviewing human health risks of composting facilities, that, even if the composting process brings evident ecological and economic advantages, care must be taken when considering occupational problems to the individuals implied in the composting operations, since biological risks exist. Since the compost derived can contain metals, persistent compounds and microbial and fungi toxins, general population must also be informed and compost must only be used in applications where significant increase of human health risks is not at stake. Contradicting Rushton (2003), we can now say that in literature much can be found concerning potential problems about environmental exposure from composting.

4. INCINERATION

Thermal treatments like incineration, pyrolysis or gasification of MSW constitute an important option for its management. Incineration is a controlled process which involves oxidative conversion of combustible solid material to harmless gases suitable for atmospheric release (Misra and Pandey, 2005). Incinerators, in particular, considerably reduce the amount of space necessary for disposal in a landfill (Magrinho et al., 2006; Moy et al., 2008). As already well known, MSW incinerators (MSWI) release atmospheric emissions of acidic gases, heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and also emit potential carcinogenic agents like polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) (Harrad and Harrison, 1996; Magrinho et al., 2006; Meneses et al., 2004; Rushton, 2003, IEH, 1997). In terms of health hazards, Rushton (2003) has said that there is little evidence for an association with proximity to incinerators and reproductive or developmental effects, since corroboration is often absent or equivocal. However, human exposure to heavy metals makes it necessary to monitor those elements in the human body. In Portugal, Alvim-Ferraz and Afonso (2005) have concluded that even when the proper practices for operation and maintenance were used, the incineration of healthcare wastes without control of atmospheric pollutants did not meet the legal emission limits and so there is a need to protect human health and the environment with appropriate equipment to control atmospheric pollution. In order to relate heavy metal exposure to adverse health effects, Reis et al. (2007b, 2007c, 2007d) have biomonitorized Pb, Cd and Hg in blood of population from two areas in Portugal. This biomonitorization took place in people living in the vicinity of solid waste incinerators, in the course of environmental health surveillance programs, aiming at guaranteeing the safeguard of public health in relation to the potential negative impact of incineration processes. The authors concluded for the effectiveness in metal source control in the two incinerators under study, although further investigation should be made in order to clarify the contribution of incineration facilities in the special case of children (Reis et al., 2007d). A general significant trend for reduction in Pb, Cd and Hg levels was observed when compared to the baseline period, thus confirming the impact of a more effective source control. In previous conclusions relative to dioxin exposure, Reis et al. (2007a) had already indicated that dioxin exposure could not be related to the emissions of the incinerators under scrutiny, since dioxin source control seemed to be effective. Also, Elliot et al. (2000) have concluded that evidence linking increased cancer incidence with emissions from incinerators is weak and indirect in Great Britain. In conclusion, and according to Franchini et al. (2004), in most studies health effects that have been associated with incinerators cannot be tied down to a particular pollutant and therefore no causal role can be established, although significant results can be found. More hypothesis-testing epidemiologic studies are needed to investigate the potential health effects of waste incineration on incinerator workers and community residents (Hu and Shy, 2001).

5. LANDFILLS

Disposal of the wastes is the final process in any waste management programme. There are geologic factors responsible for optimum attenuation of the wastes and decomposition products. These are listed by Misra and Pandey (2005), and include seismic stability, topography and many other parameters. Due to the easiness of operation and due to low economic costs in many cases, landfills have, for many years, been among the most used forms of disposal of MSW. El-Fadel et al. (1997) considered that about 95% of the generated MSW in 1997 on world-wide scale was still being disposed in landfills. Things have certainly changed somewhat since then. However, Mohan et al. (2006) stated in 2006 that the UK sent most of its waste to landfill. It is thought to be unsustainable to continue to landill such large amounts of waste and, thus, wastes are expected to be diverted from landfilling, recurring to solutions like incineration when nothing else appears to be able to be done instead. It is well known now that the disposal in landfills brings with it inevitable consequences like gas generation and leachates, mainly due to microbial decomposition, and also to the different climatic conditions to which landfills are continuously exposed (Domingo and Nadal, 2009; El-Fadel et al., 1997). Gases emitted from landfill sites consist primarily of methane and carbon dioxide, with other gases being emitted at low concentrations, as with hydrogen sulphide and mercury vapour. VOCs comprise about 0.5% (Rushton, 2003). As in incinerators, PAHs and PCBs must also be considered, besides chlorinated hydrocarbons, metals, pesticides, dioxins and pathogens, among others (WHO, 2000). Other important environmental questions include groundwater contamination and atmospheric pollution (Domingo and Nadal, 2009). The potential for environmental damage by lanfilled hazardous wastes will differ depending on the composition and quantity of that waste (Misra and Pandey, 2005). According to Rushton (2003), a raised incidence of low birth weight births has been related to residence near landfill sites, as also congenital malformations. Elliot et al. (2001), Goldman et al. (1985), and Vianna and Polan (1984) found increased incidence of low birth weight in population living near landfill sites. On the contrary, Shaw et al. (1992) and Sosniak et al. (1994) found no association between residence and exposure measurements. Also, Redfearn and Roberts (2001) refered that well-managed landfill sites are unlikely to cause adverse health effects, especially if prior to landfilling wastes are submitted to pre-treatments like encapsulation, detoxifications, chemical fixation, etc. There have been several comprehensive reviews of epidemiological studies of populations living nearby landfill sites, since some of the problems of chemical leaking in homes (Rushton, 2003) in the USA happened in the 1970s. Houses were built in the 1950s around the landfill sites built in the 1930s and 1940s. Vrijheid (2000) concludes there might be real risks associated with residence near certain landfill sites, although biases and confounding factors cannot be excluded from the analysis. Problems like respiratory symptoms, skin, nose and eyes irritation, gastrointestinal problems, fatigue, headaches and allergies and psychological problems related in interviews could be related with people being worried about pollution.

CONCLUSIONS

Waste is a very complex mixture of substances and the health impacts of waste management technologies will require further assessment and monitoring in order to assess human health hazards and risks. The findings for a clear interaction between chemical hazards presented by wastes and human health outcomes are inconsistent in most cases, and do not allow to establish a clear association between them. As it becomes clear in the majority of the referred literature, the investigations indicate that further research into the potential environmental and health risks of waste management methods must be accomplished. A more accurate characterization of individual exposure together with improved information of chemical and toxicological data on specific compounds should contribute to improve our current understanding of more complex interactions among chemicals involved. Studies lack on more powerful statistical data on large populations, in order to allow the drawing of conclusions on general and specific human health risks, entering with the influence of confounding factors and bias. It can be said that it is because scientific understanding of the health effects of waste installations is insufficient, being difficult to determine their direct toxicological effects, that waste management is an important public health issue and it is a concern for the public. Thus, and whenever possible, a complete heath impact assessment, enabling to know, either quantitatively or qualitatively, the potential impacts of a waste management site upon the health of a local community, followed by possible mitigation measures must be considered. Those measures might involve community representatives in decision making regarding waste management installations, ensuring that waste management installations work at the standards imposed by law to protect human health. Namely involving equipment of quality control of gases and effluents, for example, and also minimizing the distance between the source of production and the point of management, thus reducing the impacts on populations. The decision about the most sustainable mean of waste management depends on many factors and it requires life cycle assessment, in order to study the environmental impacts of a product during its entire life. Whenever appropriate, risk assessment must be carried out, and it will help to improve the strategy to use in waste management to minimize human health impact. Being clear that appropriate locations are chosen in terms of economic, environmental and social criteria, inequalities happen and communities must not suffer disproportionately adverse impacts. Mitigating health impacts may also be accomplished with traffic calming, reduction of noise and odour. The community must have the opportunity to raise their concerns to site operators, which will be given the chance to mitigate adverse impacts. These are examples of good practices and social responsibility, since even the most advanced treatment methods result in residues that are no longer amenable to cost-effective treatment. The progress to achieve better industrial waste management practices, in order to protect human health and the surrounding environment, can be performed with continuous auditing operations that will ensure a reduction in the potential impact from the waste.

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