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Review of Health Impacts from Microbiological Hazards in Health-Care Wastes

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Preface

This document aims at reviewing the scientific literature for findings on health impacts from microbiological hazards of health-care wastes. It also reviews health impacts of similar exposures in similar circumstances, to evaluate health risks by analogy.

Although the available literature is relatively scarce, this document may constitute an initial review, to be updated as additional evidence becomes available.

It is targeted at scientists and public health professionals, and those involved in policy setting around health-care waste management.

1. INTRODUCTION

Health-care facilities, microbiological research laboratories, diagnostic laboratories, pharmaceutical firms, and funeral homes have always generated a wide variety of waste components. The occupational and public health risks associated with the components of the solid waste stream (these types of waste will be referred to as health-care waste or HCW) have not been well assessed. Concern is also raised when the public is visually exposed to HCW, as in the case of health-care waste found washed up along the northeastern US shoreline in 1988[a].

Similarly, public awareness has arisen in other areas of the world. In the state of West Bengale, India, the poor management of health-care waste caused several institutions to consider returning to reusable glass syringes rather than to continue with single-use plastic syringes. The reuse of unsterilized syringes has been estimated to cause 8-16 million cases of hepatitis B (HBV), 2.3 to 4.7 million cases of hepatitis C (HCV) and 80,000 to 160,000 cases of Human Immunodeficiency viruses (HIV) infections per year[1]. Many of these cases could have been prevented through appropriate treatment and disposal of HCW. In addition, although only anecdotal information, numerous needlestick injuries have been reported in the popular press as having occurred to waste workers and children in dumpsites and playgrounds. Recently, children playing in garbage bins near a health care center in Russia found discarded smallpox vaccine ampoules and became infected with the live vaccine strain of the virus.[2]

The response to the potential risks associated with these types of waste and increasing public awareness has been the implementation or strengthening of regulations in many parts of the world. Often, however, such regulatory supervision of the generation, processing, treatment and disposal of HCW has been perceived as too restrictive and costly. As a result, the regulations are often poorly enforced in both high- and low-income countries. This lack of enforcement has contributed to the continuation of unsafe working conditions for waste workers and exposure of the public to the potential health risks posed by HCW.

Though several studies of workers exposed to HCW have documented either increased incidence of disease or direct transmission, the literature contains no evidence of a documented transmission of disease to the general public. However, this literature is not comprehensive and,

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a It was alleged that this waste had entered New York City harbor as a result of illegal disposal activities of one or more solid waste transporters. It was later demonstrated that the wash-up involved little HCW, and that the materials had entered the harbor through the New York City storm drainage system rather than through some form of unlawful activities of waste haulers.

despite several discussion or position papers[3, 4, 5, 6] with limited global relevance, does not permit firm conclusions as to such risks. In fact, these discussions did not always take into consideration the following factors:

- Limited availability of hard data from controlled scientific investigations on the consequences of occupational and accidental exposure to HCW;
- Information restricted to developed country situations, which doesn't reflect exposure, practices and risk situation in low-income countries;
- Actual content of microorganisms, including pathogens, in municipal and health-care waste, and the survival of microorganisms in such waste;
- Survival of microorganisms in landfill sites;
- Airborne transmission of microorganisms in municipal waste sites and during handling of wastes, for example during collection by municipal waste vehicles;
- Public perception of the perceived dangers of HCW and the role this may play in defining regulations.

While the number of scientific reports on the dangers associated with HCW have increased over the last five years, there are limited publications upon which to formulate definitive conclusions with regard to the health risks caused by HCW. The majority of these investigations have focused on occupational risks in high-income countries, especially needlestick injuries.

This report will focus on the following topics related to HCW:

- General risks created by HCW to both workers and the public;
- The chain of events contributing to the transmission of infectious disease to waste workers and the public through exposure to HCW;
- Documentation of the occupational health risks posed by HCW in high-income countries and by analogy, the possible hazards of HCW to workers in low-income countries;
- Potential threat to the public's health through indirect or direct contact with HCW;
- Conclusions and general recommendations.

2. COMPONENTS OF HEALTH-CARE WASTE

In order to assess the impact of the waste generated in health care and other facilities, we have established a working definition of HCW. Only microbiological risks created by HCW will be considered in the following discussions. The following definition (based on reference 7)[7] is proposed for use:

> *Health care waste shall mean discarded (and untreated) materials from health-care activities on humans or animals, which have the potential of transmitting infectious agents to humans. These include discarded materials or equipment from the diagnosis, treatment and prevention of disease, assessment of health status or identification purposes, that*

have been in contact with blood and its derivatives, tissues, tissue fluids or excreta, or wastes from infection wards.

Included under this definition for the purposes of this document are the following component types of waste:

1. Cultures and stocks of infectious agents and associated biologicals, including: cultures and stocks of infectious agents generated in research or clinical laboratories; wastes from the production of biologicals including vaccines, antigens and antitoxins, and sera.

2. Pathological waste, including tissues, organs, and body parts; body fluids that are removed during surgery, autopsy, or other medical procedures; specimens of body fluids.

3. Blood and blood products including discarded liquid human blood; discarded blood components (e.g., serum and plasma); containers with free flowing blood or blood components.

4. Items or materials contaminated with blood or blood products.

5. Sharps from health care, research, clinical laboratories and blood banks, including but not limited to: needles and syringes, scalpel blades, and broken or unbroken glassware, which were in contact with blood or blood derivatives.

6. Animal waste including carcasses, body parts, body fluids, blood originating from animals from veterinary clinics or research institutes.

Several aspects of this definition of HCW require clarification.

a) Isolation waste is not included as a separate HCW category as its components are found in the types of waste described above.

b) Urine and feces may not be considered to be part of HCW unless it is submitted as a clinical specimen for the purpose of diagnosis, treatment and prevention of disease or assessment of health status. However, if a patient is found to have a disease, which may be transmitted through urine or feces, then the material containing this fluid (including diapers) should be considered HCW.

3. RISKS

The hazardous components of HCW pose physical, chemical, radiological and/or microbiological risks to the public and those involved in their handling, treatment and disposal. In most cases, the concentration of hazardous chemicals present in HCW is generally too low to be considered an occupational problem or a danger to the public. Physical injuries caused by discarded sharps are a more significant risk associated with HCW and may directly contribute to the transmission of microbial infectious agents. In addition, health risks may be generated through the release of toxic pollutants during waste treatment.[8]

The most common and most investigated cause of the microbiological risks associated with HCW are injuries due to needles.[9, 10, 11, 12] Other sharps waste presenting similar risks include glass and plasticware employed in clinical and anatomic laboratories, blood collection systems for obtaining specimens, and scalpel blades from surgical procedures. These sharps may all have been in contact with microbial pathogens. More importantly, sharps can cause percutaneous injuries and thereby create an opening for infectious agents to enter the body. The latter is one of the five essential elements in the acquisition of microbial infections as discussed below.

Most exposures to biological hazards from health-care wastes occur at waste treatment facilities or other locations where workers manually handle untreated waste. Workers may be exposed to blood and body fluids from leaking containers as well as airborne pathogens as the waste enters the treatment process. Again, while such studies analyze developed country situations, little is known of the situation in developing countries, where it can be assumed that exposure is much higher, as are the health risks.

Health-care waste components may also create microbiological risks as a source of infectious aerosols, i.e. droplets of less than 1- 3 microns in diameter, which contain etiologic agents of human and animal diseases. Cultures and stocks from the clinical laboratory contain high concentrations of many infectious agents, e.g. *Mycobacterium tuberculosis,* which is naturally transmitted to their hosts through inhalation,[13, 14] although generally all infectious laboratory waste is treated at the source. Human and animal tissues, organs, and body parts have also been reported in scientific literature as sources of infectious aerosols.[15] Finally, animal bedding materials, which have been saturated with body fluids, blood and excrement, can generate aerosols, which are a potential microbiological risk.

Blood and blood products, as well as various types of body fluids may be capable of transmitting pathogens when brought into direct contact with the mucosal lining of the mouth and nose, the eyes, and areas of the skin containing cuts and abrasions. There are many reports in the literature of the transmission of HIV, HBV, HCV and other pathogens through blood splatters to unprotected mucosal and skin surfaces during emergency or surgical procedures and even in the commercial treatment of HCW.[16, 17, 18, 19]

The following are most likely to come in contact with HCW during its generation, handling, treatment and disposal, and are therefore at greatest risk:

- Health-care personnel
- Laboratory workers
- Waste workers
- Substance abusers
- General public

The general public are certainly the group least at risk, but in certain circumstances contact with HCW may nevertheless occur.

In addition, in low-income countries, the following special groups may be at increased risk from HCW:

- Scavengers sorting HCW and municipal waste containing HCW, frequently without any personal protective equipment or even adequate clothing; and

- Patients, through the re-use of syringes and other forms of medical equipment which has been "recycled" without appropriate treatment.[1, 11]

4. CHAIN OF INFECTION

The microbial agents contained in HCW may contribute to the transmission and acquisition of infectious diseases. Some infectious agents, i.e. microorganisms capable of initiating infections or infectious diseases, are normal constituents of human and animal microflora. However, they may initiate a disease when changes occur in the agent, the host or both. More commonly the agents reside outside the host and must be transmitted from these external sources to the host to initiate an infection. The relationship between the infectious agent, the host and the mechanism through which the microorganism gains access is referred to as the chain of infection.[20] The chain is composed of the following five elements, all of which must be present before an infection can occur:

1. The presence of an infectious agent;
2. A sufficient concentration of the agent to cause an infection (the infectious dose);
3. A host susceptible to the infectious agent;
4. A portal of entry for the infectious agent to gain access to the host;
5. Mode of transmission of the agent to the host.

4.1 Presence of an infectious agent

Humans and animals are always in contact with a vast array of microorganisms from a wide variety of sources, e.g. those forming part of their routine microflora, as well as the microorganisms which can be found in the natural environment in which they live. However, only a very small number of these microorganisms are pathogenic. One of the factors which determines the capability of an agent to cause disease is the virulence of the microorganism. For example, HVC has a relatively high virulence and generally contributes to the development of diseases once the host is infected.[18] In contrast, *Candida albicans* is routinely found associated with human skin, mucosal surfaces and the digestive system, but is not generally the cause of significant disease in healthy individuals. In brief, the pathogenicity of only a few but still significant number of microorganisms can create an infection and possible disease in a susceptible host.

Various studies have attempted to analyze the content of health-care wastes, in comparison to domestic wastes. Most of them analyzed the concentration of microorganisms, which was found to be comparable in both types of wastes. The number of microorganisms, without identifying them, does not however provide much indication on the pathogenicity of the waste. One study also analyzed the types of microorganisms, and found that health-care wastes contained a greater variety of microorganisms than domestic wastes, which had a greater content of microorganisms of faecal origin.[21]

4.2 Concentration of infectious agent

Of the five factors which contribute to the development of an infection, the most important for the purposes of this report is the concentration of agents required to initiate an infection, namely, the infective dose. This is specific for each agent and may vary depending upon the route and method of transmission.

4.3 Susceptibility of the host

The susceptibility of a host to any given infectious agent is quite complex and dependent upon a number of factors such as the specific microbial agent, its concentration or infective doses, method of entry into the host, etc. The first defensive line of the host is the physical barrier created by the skin and mucosal membranes. Cuts, nicks, abrasions and other forms of breaks in the continuity of these barriers will favor the entry of a pathogen and the potential development of an infection. As noted previously, contact of blood and body fluids with exposed skin has contributed to the transmission of infections to health care workers.[16]. In addition to the skin and mucosal membranes, other determinants, including the host's immunologic status, age, genetics, etc., all contribute to an individual's susceptibility to an infection and subsequent development of disease.

4.4 Portal of entry

The portal of entry for an infectious agent may be broken skin, mucosal surfaces of the mouth, nose or eyes, or the respiratory and gastrointestinal tracts. Many pathogenic microorganisms require some deliberate or accidental break in the skin, such as cuts or intravenous lines, to enter the host.

Alternatively, infectious agents in the form of particulates or aerosols, may be inhaled or accidentally transferred to the eyes, nose or mouth. The size of the particle containing the microorganism or the organism itself will govern the level within the pulmonary tree upon which it will be deposited. Large particles may never be inhaled into the lungs, but remain trapped on the nasal cilia. Small particles which are less than 5 microns in diameter can generally reach the lowest areas within the lungs, where they may initiate infection.

Pathogenic microorganisms often gain access through the host's ingestion of contaminated food or water. In addition, medical procedures such as endoscopy, can introduce infectious agents to the gastrointestinal tract. The catheterization of the host as part of standard medical procedures may lead to infections of the urinary tract and the blood.

Once the pathogenic agent has gained a portal of entry into the host, it may simply colonize the entry site without any evidence of disease. Alternatively, the same agent in contact with a different site may be capable of causing an infection and potentially the development of disease.

4.5 Mode of transmission

There are three probable modes of transmission of infectious agents from HCW to either susceptible members of the public or those that process the waste.

1. ***Direct physical contact***

The host may have direct physical contact with the agent, allowing for the direct transfer (direct transmission) of the microorganism. If the other four elements of the chain of infection have been met, such contact may result in the initiation of an infectious disease. Direct transmission of pathogenic organisms from HCW is most likely to occur with discarded, untreated cultures and stocks generated in clinical microbiology and research laboratories, since the concentration of potential pathogens is far higher than in the natural environment,[13] or by direct exposure to blood or body fluids containing infectious agents.

2. ***Generation of aerosols***

A second means of transmitting potentially pathogenic microorganisms from HCW is through the generation of aerosols, i.e., small particles of from 1-3 microns in diameter which contain the infectious agent. These particles or nuclei may remain suspended in air for long periods of time and can travel for long distances from their initial source. This can occur during the treatment process, (e.g. shredding the waste or chemical treatment). As noted previously, cultures and stocks from clinical laboratories, human and animal tissues and animal bedding materials are components of HCW which may serve as sources of infectious aerosols.[13, 15, 19]

3. ***Vehicle-borne transmission***

Vehicle-borne transmission represents the third possible mechanism for transporting agents from HCW to a susceptible host. In this situation the microorganism is transmitted through contact with contaminated materials or vehicles. Examples of vehicle-borne sources are hollow-bore needles, items soaked and saturated with blood, blood products or other body fluids or any other contaminated HCW component which can act as an intermediate means of introducing the infectious agent through a portal of entry of a susceptible host.[20] Infectious agents may also be transferred to workers' clothing by splashes of blood or body fluids. Such contamination may occur in as many as half of workers in waste treatment facilities.[5]

4.6 Potential of infection from HCW

Considering all the parameters of the chain of infection, a likely ranking of HCW components as potential sources of occupational infection can be made as follows:

1. Sharps
2. Liquid blood and blood components, body fluids
3. Cultures and stocks, contaminated laboratory waste
4. Pathologic waste
5. Animal waste

5. OCCUPATIONAL HEALTH IMPACT OF HCW

5.1 Risks associated with health-care waste treatment plants

A search of the literature revealed only two reports on the possible occupational acquisition of infectious diseases from HCW. The more detailed of the two articles discusses an outbreak of tuberculosis among workers at a commercial HCW treatment site in the United States.[19] The report describes the development of active cases of tuberculosis in three employees and the seroconversion of another ten without evidence of disease. The treatment facility received HCW from medical and dental clinics, commercial clinical laboratories and hospitals. The types of waste processed consisted of cultures and stocks of infectious agents, blood, blood products, body fluids, sharps and a small amount of pathological waste.

In order to understand how these workers could have contracted tuberculosis, the processing of HCW in the treatment facility is briefly described according to information provided by the report. The waste is transported to the site in plastic, reusable containers with tight fighting lids. Within the facility, the lids of the plastic tubs are removed and the contents manually dumped into the processing unit through the use of an “in-feed” chute.

After entering the chute, the waste is shredded several times to produce pieces which are less than approximately 5 mm in diameter. The shredded waste is moved by a conveyor into large plastic containers, then compacted and sprayed with water to achieve a 10-15% moisture content. The shredding and compacting process is conducted in an enclosed area which is under negative pressure.

The containers with the moistened and shredded waste are then capped and placed into the actual treatment system where they are heated for 12 minutes to 95^{o}C. To ensure that the required temperature has been achieved, an employee probes each container exiting the treatment system with a thermometer. Following a storage period, the containers are mechanically dumped and the treated and shredded waste is baled into bundles. The treated waste is reduced in volume by about 80%.

The report identified the following deficiencies:

- Failure of the respiratory protection equipment used in the containment area;
- Use of an airline respirator system that did not meet national standards;
- Lack of availability to an appropriately designed changing room for employees exiting the containment room;
- Unavailability of training programs to provide employees with sufficient information regarding decontamination procedures;
- Failure by employees to follow company policies, resulting in the operation of the processing system without particulate filters in place and cleaning of filters with compressed air, the latter creating aerosols of potential infectious agents.

The report further notes that “blowback” frequently occurred, i.e. the air from the containment room would blow back out of the in-feed chute into the main area of the treatment facility when the shredders became clogged. When this occurred, the shredders were manually unclogged, and employees were directly exposed to needles and other sharp objects.

In addition, dye testing of air samples at the in-feed station indicated the potential for aerosolizing of the HCW. Smoke tests revealed that small quantities of air could overcome the capture velocity at the face of the in-feed chute which could result in the potential release of untreated waste. Finally, the investigation demonstrated that the dumping of the waste into the in-feed chute combined with “blowback” could create infectious airborne particulates.

In vitro drug investigations performed by the Washington State Department of Health demonstrate that the etiologic agents recovered from three employees with active cases of tuberculosis had different susceptibility patterns. This evidence virtually eliminated the possibility of person-to-person transmission of the microorganism. Additional epidemiologic studies revealed no other person-to-person sources which could account for the infection of the three employees. Finally, the Department of Health stated that tests confirmed that one of the cases was caused by an isolate of *M. tuberculosis* which had a molecular fingerprint identical to one recovered in culture at one of the health-care facilities that would have sent its cultures and stocks to the commercial treatment facility.

While a direct connection between HCW and the development of occupationally related disease was not established in the second report, the studies did demonstrate that workers at on- and off-site treatment facilities are routinely exposed to blood splashes.[17] The primary objective of the investigation was to survey the workers' environment with respect to safety, aerosol, chemical, blood and microorganism risks associated with four different types of HCW treatment systems at four facilities within the United States. The processing of the waste at all four sites required manual handling of the untreated HCW from primary containers onto conveyors or into larger containers prior to treatment. Furthermore, the type of treatment technology used at the sites was not the only factor contributing to the potential exposure of employees to blood splashes or infectious microorganisms. Policies within the facilities regarding the use of personal protective equipment, uncovered containers for the transport of untreated HCW, and poor working conditions could affect the exposure risk for site personnel.

Work surfaces which employees would come into contact with during the routine processing of waste (e.g. control panels, waste containers, waste probes) were visually inspected for blood contamination and wiped with sterile cotton pads which would be used to detect the presence of hemoglobin. The workers' personal protective equipment was also inspected for obvious blood splashes. In addition, sterile cotton pads were attached to the front and back of the upper torso areas of workers' uniforms. The pads were employed to determine the presence of hemoglobin even when there was no obvious blood stains on the employees' clothing. Finally, at two of the facilities the workers' face shields or protective goggles were cleaned with sterile pads impregnated with sterile buffer and wiped with cotton pads prior to each work shift. At the end of the routine work period, the face shields or goggles were visually inspected for the number and location of blood splashes. In addition, the equipment was wiped with cotton pads for the detection of hemoglobin.

The results of these investigations demonstrated the presence of obvious blood splashes and/or hemoglobin on 61 of the 96 (64%) work surfaces in the waste processing areas at two of the treatment facilities. Eleven of the 128 (8%) pads attached to the upper torso areas of the workers' uniforms in three of the treatment sites were positive for hemoglobin. Finally, hemoglobin was detected on 4 of the 18 (22%) eye protection devices screened during the studies. Controls included the wearing of cotton pads by office workers at each facility; these were all found to be negative for the presence of hemoglobin.

Microbial contamination of surfaces in all four facilities was assessed by sampling for two potential pathogens, *Staphylococcus aureus* and *Escherichia coli.* While *S. aureus* was not detected in any of the samples, *E. coli* was found in five samples from three of the treatment sites. With regard to the absence of these two common microbial pathogens on waste surfaces, the authors note "*that inactivation of some human pathogens in medical waste [HCW] begins to occur rapidly after waste generation due to adverse environmental conditions relative to temperature, moisture, and nutrients that [are] encountered during storage and transport. While this can be the situation for some vegetative bacterial pathogens, such results were not necessarily indicative of the absence of more environmentally resistant and virulent pathogens such as M. tuberculosis or a variety of blood-borne viruses*".

The authors concluded from their investigations that blood splashes pose a real and significant health risk to workers involved in on-site and commercial treatment facilities. To assess the risk generated by blood-borne pathogens within the blood splashes, the authors reviewed health risks of workers at sanitary landfills and waste transfer stations as no other applicable data existed. Based upon this assessment, the authors concluded that, under a worst-case scenario, 1 to 4 out of 10,000 workers processing HCW in the studied environments could be expected to develop HIV infections due to their activities.

5.2 Risks associated with sharps

There is little documentation on occupational health impacts associated specifically with processing, treatment or disposal of sharps. Numerous reports however link the development of infectious diseases in health care workers to the contact with sharps or HCW in general, or compile information on needlestick injuries.

Probably the most frequent and intensively investigated risk is created by sharps (including needles, Pasteur pipettes, scalpel blades, blood vials, needles with attached tubing, culture dishes and other glassware) that were in contact with infectious agents.[9, 10, 1, 11, 12, 22] In the United States, it has been estimated that there are over 1 million injuries caused by hollow-bore needles every year among approximately 8.8 million health care workers.[22] However, another report has suggested that this figure represents only about one-half of the actual injuries, as many individuals are reluctant to describe such incidents.[10]

The actual risk of contracting a blood-borne infectious agent through needlesticks depends on a number of variables, including:[23, 11]

- prevalence of the infectious agent in the source (patient) population;
- known or suspected infectious state of the individual patient;
- infectivity or pathogenicity of the virus;
- risk category of the clinical procedure;
- degree of exposure of blood at the time of the incident;
- the provision of post exposure prophylaxis.

A deep needlestick injury involving freshly drawn blood taken from a highly viremic patient with an HBV infection poses a 1 in 3 risk to the health-care worker of acquiring a similar infection. If a similar incident involved HCV, the risk to the worker would be 1 in 30 of developing an infection or disease. Finally, HIV transmission following a single sharps injury presents a 1 in 300 risk to health care personnel. It has been estimated that hepatitis, HIV and other bloodborne infectious agents infect more than 18,000 workers each year, of which approximately 250 die from the resulting disease.[11] Worldwide, a total of 286 staff members of health-care facilities have been reported by December 1997 to have occupationally acquired HIV infection through needlesticks.[16]

A study conducted in the United Kingdom reported that nurses and physicians experienced the highest incidents of needlestick injuries.[11] The article further related that approximately 1% of such events were experienced by porters and members of the housekeeping staff, i.e. those most likely to be involved in the processing of HCW. Since the risks of transmission of HBV, HCV, and HIV through a single needlestick are based upon deep injuries involving freshly drawn blood of highly viremic patients, it is difficult to extrapolate from these figures to risks incurred by those whose needlestick incidents resulted from their work with HCW. However, as there are no other scientific data available, one could infer from the figures of needlesticks discussed above that 40,000 of the 2 million (considering half are unreported) needlestick incidents which occur each year in health care facilities involve those responsible for treatment and/or disposal of HCW. If 1 out of every 3 deep needlestick injuries can result in HBV infections, this could translate to approximately 13,000 occupationally related cases of this viral infection in HCW workers. Similarly, it could be estimated that events involving sharps could contribute to 1,300 cases of HCV infections and 130 of HIV. Therefore, even if the actual rate of occupational acquisition of viral infections from HCW may not be as high as that extrapolated from available data, it is highly probable that needlesticks associated with HCW are potentially a significant occupational health risk.

Isolated reports refer to needlestick injuries related to sharps boxes,[24] and the reduction of such incidents by adequate management of sharps boxes.[25]

Although not necessarily related to HCW, needlestick injuries in the general public have been reported, probably related to IV drug users. A recent survey of police officers[26] reported that 29.7% of a sample of 803 law enforcement officers ever experienced needlestick injuries during their duty. Of this group 27.7% had two or more needlesticks. Risk factors included evening shifts, pat-down searches, patrol duties, male gender and less experience.

A retrospective review of casenotes in the Dublin metropolitan area revealed 52 cases of needlestick injuries between July 1995 and October 1996 alone.[27] Most cases occurred in inner city areas with a recognized high prevalence of IV drug use. Although probably not related to wastes from health care, this reveals a problem related to the use of medical equipment.

As already mentioned, the health impacts from needlestick injuries on waste workers and scavengers have not been sufficiently reported.

5.3 Risks associated with blood

There is very little information in the scientific literature on the hazards posed by blood and blood products on the health of the public and waste workers. The data that are available are restricted to the occupational health impact of this HCW component in its liquid state. Most blood-borne pathogens have a limited ability to multiply and to remain viable longer than a few hours to a few days in dried blood. This accounts for the focus of the few existing studies on liquid blood. As pointed out in Leese, Cole and Jensen's investigations in four commercial HCW treatment sites[17] blood splashes were found on 64% of the work surfaces in the processing areas, 22% of the eye protection devices and 8% of the workers' clothing. The study reports that those directly handling containers of untreated HCW were at risk of exposure to blood-borne pathogens. Utilizing a worse case scenario, they pointed out that 1 to 4 out of 10,000 workers could be expected to develop HIV infections as a result of their daily work activities. Blood splashes have been suspected to have induced the transmission of HCV.[18]

Although the hazard created by liquid blood is primarily associated with health-care delivery, Collins and Kennedy[28] point out that it poses a risk to workers in other areas, such as:

- Chiropodists
- Cosmetic piercers
- Tattooists
- Acupuncturists
- Funeral home workers

While these occupations generally involve exposure to only very small quantities of blood from healthy individuals, there have been no risk analyses or other forms of scientific investigations of the hazards associated with these activities. It is most likely that blood does not pose a serious threat to those involved in these professions, but in the absence of controlled investigations it is difficult to exclude such occupational risks.

If all other parameters of the chain of infection have been met, i.e. presence of an infectious agent in a sufficiently high concentration that when it gains entry to a susceptible host it can cause infection, then vehicle-borne transmission is the most probable mechanism for transporting blood-borne pathogens. As mentioned, hollow-bore needles are the vehicles which account for the vast majority of occupational infections, but hospital bandages or surgical sponges soaked and saturated with blood, medical instruments with dripping blood from surgery or autopsy, and similar HCW components may also be responsible for the transmission of blood-borne infectious agents. Although direct contact with blood may also play a role in the transmission of infectious agents, it is of less importance than needlesticks as a means of transporting blood-borne pathogens.

In high-income countries, waste liquid blood is most often treated and disposed of through the sewage system with its associated treatment.[29] The concentration of blood-borne pathogens is diluted, and their viability is reduced by other constituents in sewage and during treatment. It is unlikely that these pathogens constitute a health threat. No adverse health incidents have been reported as a result of this bulk mechanism of treatment and disposal[19] There are, however, few publications addressing this issue and it is difficult to draw conclusions about the impact of free flowing blood in sewage systems.

5.4 Risks associated with exposure to municipal solid wastes

High-income countries

Because the potential pathways for exposure are similar for workers handling municipal solid waste (MSW) and HCW (provided the management practices are similar), the health impact of working with MSW may be used as an indicator of the effects of exposure HCW workers. Recent reviews of the risks associated with occupational hazards from handling MSW compile main results of related studies.[30, 31] These results are summarized below.

Solid-waste workers, as compared to the general population of these high-income countries, experienced:

- 6.0 times higher risk of infectious diseases (Denmark[32])
- 2.6 times higher risk of allergic pulmonary diseases (Denmark[32])
- 2.5 times higher risk of chronic bronchitis (Switzerland[32])
- 1.2 times higher risk of hepatitis (Italy[33])

The primary factor contributing to pulmonary problems in the workers was bioaerosols containing Gram-positive and negative bacteria, aerobic actinomycetes and filamentous fungi. The Gram-negative bacteria produce endotoxins on their outer membranes which act as pulmonary immunotoxicants. The aerobic actinomycetes (filamentous Gram-positive bacteria) found in MSW are the same as those involved in 'farmer's lung disease', a type of chronic bronchitis. The fungi form spores which are known human aeroallergens, as well as mycotoxins (metabolites formed through the growth of fungi) which appear to suppress the host's pulmonary immune system, contributing to various forms of pulmonary infections and disease. In comparison to ambient air conditions bioaerosol levels in various types of MSW facilities were:

- 2-4 times higher in sanitary landfills (Italy[33])
- 2-10 times higher within material recovery plants (Finland[34])

Although MSW workers in high-income countries generally use some form of personal protective equipment to minimize direct contact with the waste, they still have a higher incidence of infectious diseases. For example, as noted above, investigations in Denmark indicated that MSW workers were six times more likely to suffer some form of infectious disease when compared to Denmark's total work force.[32] Results from other Danish studies indicated that these same workers were exposed to higher levels of airborne pathogens.[32]

Investigations conducted in 1990 in Genoa, Italy demonstrated a higher seroprevalence of hepatitis in the city's MSW workers than found in the general population.[33] Data also indicated the probability of workers contracting HBV increases with their tenure in the MSW facilities. Approximately 20 years ago it was general policy in many high-income countries to collect and dispose of HCW with MSW. As a result, needlesticks were frequently reported by MSW workers. For example, in the early 1970's there were 50-100 needlestick injuries to MSW collectors in New York City. However, no correlation with disease incidence was found.[35]

According to these results, workers in high-income countries involved in processing, treatment and disposal of waste are more likely to be exposed to and contract a greater number of different forms of pulmonary disorders and infectious diseases than the general population. Confounding factors, such as socio-economic status, could cause increased disease rates in waste workers. It would appear, however, that the exposure to such waste contributes significantly to these results, at least in high-income countries. If waste workers are at higher risk of acquiring an infection from pathogens contained in the waste, this has several implications for selecting management options for HCW. This fact should be kept in mind during the decision-making process whether or not to join specific components of HCW to the MSW stream.

Analysis of the microbiological content of MSW and HCW has shown similar concentrations of microorganisms in both types of wastes.[8] Collins and Kennedy[8] describes studies of health- care waste versus domestic waste and reports that 2% of blood-stained waste was positive for hepatitis viruses and that poliovirus[16] and echovirus[13] were recovered from soiled diapers in domestic waste.

In the course of several studies a variety of pathogens and non-pathogens have been found in solid wastes. Relatively few of these organisms are likely to survive at the temperatures and pH found in health-care and domestic waste. The presence of microorganisms which produce endotoxins may present a health hazard to workers during the handling of waste,[8] as does the presence of vectors such as flies and birds which come in contact with uncovered waste sites.

Low-income countries

There are very few reports on the occupational health risks of MSW in low-income countries. Available studies are generally limited to anecdotal information without any references to control groups or incidence rates in the general population. The few quantitative investigations which have been described in the literature are primarily concerned with waste pickers, or scavengers searching for recyclable materials. Since there is no data beyond anecdotal information indicating the health risks to MSW or HCW workers in low-income countries, it is difficult to estimate the severity of the situation. Waste dumps in low-income countries often contain a mixture of MSW, HCW, and hazardous materials. Scavengers are therefore exposed to a greater variety of risks.

The waste sorting and recycling activities of waste pickers at the open dumps are conducted manually, with minimal washing equipment and virtually no dust controls or personal protection devices. Since the HCW is often present within the same disposal sites as the MSW, the pickers routinely segregate and recycle disposable syringes, other medical devices and cotton bandages.

In addition, studies in several countries have shown associations between working at open dump sites and increased respiratory problems, notably:

- Epidemiological surveys of 400 waste pickers in Calcutta, India showed that 71% of the workers experienced some form of respiratory disease as compared to 34% of the control group;[36]

- 25% of the workers at a dump site in Bombay had coughs and approximately 26% experienced dyspnea;[37]

- Testing the pulmonary function of waste pickers at a dump in Bangkok revealed that 40% were below the normal range;[38]

- Studies of 194 children working as waste pickers in Manila revealed that 23% had chronic coughs and 19% experienced shortness of breath. In only 3% of these children could the symptoms be attributed to pulmonary tuberculosis. In addition, 53% of these waste pickers had decreased pulmonary functions when compared to the city's general population.[38]

Of the 95 waste workers studied at an open dump site in Bombay, 80% had eye problems, 73% respiratory ailments, 51% gastrointestinal ailments, and 40% skin infections or allergies.[37] An investigation of waste pickers who worked at a site in Calcutta revealed that 32% had protozoal and helminthic infections as compared to 12% in the control population of a nearby town.[36] Similar high incidences of infectious and noninfectious diseases among waste pickers and in populations that live near open dump sites in many other low-income countries have been described.

These results may certainly be influenced by several confounding factors. In low-income countries, waste workers are likely to have a low socio-economic status and are usually exposed to many other risk factors and poor living conditions, such as inadequate sanitation, poor housing, unsafe water supply, and restricted access to health care. However, as workers are exposed directly and without adequate personal protection to MSW which includes hazardous substances, a partial contribution to the increased disease rates from exposure to wastes is likely.

6. NON-OCCUPATIONAL HEALTH IMPACTS FROM HCW

6.1 Health impacts from accidental exposure

In this review no scientific reports could be identified that document transmission of infectious disease in a non-occupational setting in high-income countries caused by direct, accidental contact with HCW. This does not mean that such incidents do not occur, but rather that they may simply go unreported. It is extremely difficult and exceedingly costly to conduct controlled epidemiologic investigations of the health impact of HCW in non-occupational settings. For example, it would be almost impossible to know for sure that the infection of a child was acquired as a result of his/her playing with a discarded, untreated sharp or unit of blood. Anecdotal information indicates that these sorts of incidents do occur; but without appropriate reporting and studies, it is difficult to quantify the risk posed by HCW in these situations.

Changes in the delivery of health care also result in increasing quantities of waste, part of which may be generated outside health-care settings. Hemodialysis and chemotherapy are increasingly used in patients' homes. Ventilator-dependent patients are being discharged from hospitals to continue their therapy at home. In addition, illegal intravenous drug users, many of whom have rates of HIV and HBV infections higher than in the general population, frequently discard their utensils and used needles and syringes in public areas.

Although the public may not have direct contact with the HCW from health-care facilities, there is a high probability that members of the public could be affected by the ever increasing volume of HCW created through patient care in the home. It has been estimated that in the USA there are over 1,000 needlestick injuries which occur annually among those that collect MSW from homes.[31] These incidents could, in theory, result in at least two HBV infections per year.

There is anecdotal information of discarded syringe needles, as well as sharps containers filled with used syringes being found in parks, playgrounds and other public gathering places in cities across the United States. Therefore, currently available information clearly indicates that the population of high-income countries can and quite probably does have contact with various components of HCW.

The most recent incident in Russia which involved children in a playground being exposed to discarded smallpox vaccine vials which had not been inactivated is a further example of the potential for exposure of the public to infectious agents from improperly handled HCW. In this particular incident eight children were hospitalized with temperatures of 39 to 40°C and skin eruptions. Considerable difficulty was encountered in identifying the causative agent.

Given the increasing volume of such waste and number of possible sites at which the public could contact the waste, it is almost impossible for members of the public not to be affected by HCW. As noted above, the absence of studies on infections in the public resulting from HCW does not mean that they do not occur.

6.2 Health impacts from non-accidental exposure

Non-accidental exposure to HCW mainly occurs in developing and transitional countries, by intentional re-use of disposable medical equipment, in particular plastic "single use" syringes. An important body of evidence suggests that in such countries where hepatitis B and hepatitis C lead to a high burden of chronic liver disease, re-use of injection equipment without sterilization causes a high proportion of new cases of infection.[13] Each year, re-use of injection equipment in the absence of sterilization causes an estimated 8 to 16 million HBV infections, 2.3 to 4.7 million HCV infections, and 80,000 to 160,000 HIV infections,[40] costing 1.3 million future early deaths, 26 million of years of life lost, and US$ 535 million direct medical costs.[8] Among reported breaks in infection control practices, the failure to dispose of disposable syringes in order to re-use them in the absence of sterilization is one of the most common.

Little evidence is available on the health impacts of other re-used medical devices, but there is documentation on the re-use of bandages and other medical items.

Re-use of disposable injection equipment in the absence of sterilization is caused by[39] an absence of awareness among patients and healthcare workers that re-use of dirty injection equipment can transmit infections,[40] shortages of injection equipment, and[41] a failure to adequately dispose of injection equipment at the point of use. Of the observed re-use of injection equipment, the available evidence does not allow calculating the proportion of re-use that is attributable to lack of awareness, shortages of supplies, or poor waste disposal. However, the only way to ensure that disposable syringes and needles are not re-used and do not lead to accidental needlestick injuries is efficient, safe, and environment-friendly sharps waste management.

7. DISCUSSION AND CONCLUSIONS

The information presented in this report is compiled from the few controlled studies and qualitative observations of the occupational and public health impact of microbiological hazards in HCW. Because of the lack of adequate documentation in this area it is difficult to draw firm conclusions. In developing countries, the evidence suggests that inadequate management of infectious health-care waste has a low probability to result in incidents, but which may be associated with relatively serious consequences. In developed countries, in particular where health-care waste is disposed of in uncontrolled waste dumps and where scavenging, waste sorting or recycling is involved, it is likely that a significant health impact is caused on those exposed.

During waste treatment, the acquisition of active tuberculosis by workers in a commercial treatment facility, the high number of potentially infectious blood splashes occurring during on and off-site HCW treatment, the greater incidence of infectious and noninfectious diseases among workers at MSW landfills, and the increased volume of HCW components in the MSW stream as a result of the rise in home care, indicate that poor management of HCW can have a significant impact on the health of the public and workers.

The impact of HCW in low-income countries is very likely to pose a great risk to workers and the public due to poorer practices of waste management and personal protection of workers. In addition, the consequences of the hazards posed by HCW in low-income countries may be more significant due to limited availability of immunization against infectious diseases.

The occupational and non-occupational health risks from microbiological hazards in HCW are created by the following components:

- Sharps (e.g. hypodermic needles and syringes, Pasteur pipettes, scalpel blades, lancets, blood vials) as they can cause physical injury and thereby create a portal of entry for the transmission of infectious agents. It is therefore important that these items be isolated by collecting and storing them in puncture-proof containers and be treated or isolated safely, and rendered either inaccessible or decontaminated and unusable.

- Blood and blood products (e.g. discarded serum and plasma, containers with free flowing blood, surgical sponges saturated to the point that the blood is free flowing or dripping) are potential reservoirs of infectious agents. As a precaution, these components of the HCW stream should be treated or disposed of adequately, and not merged with the municipal waste stream.

- Cultures and stocks (e.g. cultures of infectious agents from research and clinical laboratories, live and attenuated vaccines, antigens and antitoxins) may contain relatively high concentrations of agents known to be pathogenic to man and animals. These materials should be treated at the site of generation to limit the hazards. When this is not possible, they must be appropriately packaged and transported to commercial treatment facilities.

- Some HCW treatment systems create potential microbiological hazards by creation of aerosols, by blood splashes during handling or by airborne endotoxins from microorganisms in the waste. The provision of respiratory protections and protective clothing minimizes these exposures to workers.

- Microorganisms, including human pathogens, have been shown to remain viable in

HCW. Conditions in such waste however usually do not favour growth or survival.

- Health care waste workers should wear adequate protective equipment. They must be fully trained in handling potentially infectious wastes.

- Segregation and treatment of HCW at the source of generation will minimize the amount of potentially infectious materials which reach landfills and open dumps, and reduces potential exposure of waste workers, scavengers and the public.

Review of the published information on the microbiological hazards associated with HCW have shown that there are several areas of concern for the potential transmission of human pathogens to the public and waste workers. If HCW are separately and adequately packaged, stored, transported, handled and treated, the hazards are minimal.

Further scientific information on the risks from exposure to the various components of HCW would be useful in defining best practice and precautionary measures. In developing countries, a number of measures are immediately necessary and could be readily implemented in order to reduce an important disease burden.

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