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# 1. Introduction

The objective of a public drinking-water system is to provide all consumers with a continuous sufficient supply of good quality drinking-water at an affordable price in order to ensure the health and well-being of those served. In general the traditional goal is to develop, when feasible, a system that involves abstraction of water from a source, treatment of the water, and storage and distribution of the treated water through a network of pipes, referred to as mains. The mains should pass within a reasonable distance of the private or public premises that require a drinking-water supply. Maintaining the quality of water within these distribution mains and the delivery of sufficient quantities require continuous supervision by skilled staff. Establishing and maintaining a reliable water system involves recurrent expenditures. In well-managed systems, these costs are normally borne by the consumers in proportion to the quantity of water delivered. Leakage and wastage should be controlled and minimized for safety and for economic and environmental reasons. The collection, transport, treatment and safe disposal of wastewater is also an essential element towards protection of public health.

Systems of management of the mains water system and sewerage system vary widely around the world. The waterworks and sewage disposal operating body (or bodies) may be a local authority, a government corporation or department, or a private company. In the great majority of cases, these bodies have direct responsibility for the water supplied in the mains as far as the property boundary of each individual user. It is the responsibility of the owner of each property, with the help of a competent plumber, to convey the water supply from the distribution mains into their own premises and to safely circulate it to distribution points within the buildings, and to transport liquid waste to the sewerage system. The three roles a competent plumber must assume are:

- to design, install and maintain drinking-water supply and waste removal systems;
- to manage the health and financial risks associated with plumbing;
- to help conserve limited supplies of safe drinking-water.

This publication describes the processes involved in the design, installation and maintenance of effective plumbing systems. It recommends a number of plumbing system design and installation specifications that have demonstrated their

validity from years of experience. It also examines the microbiological, chemical, physical and financial risks associated with plumbing, outlines the major risk management strategies that are used in the plumbing industry and emphasizes the importance of measures to conserve supplies of safe drinking-water.

Good design of plumbing systems is necessary to ensure that the installations are efficient and safe. Good design will also ensure that the installations are appropriate for the different circumstances they serve. The design of good plumbing services must be based on an understanding of the technical requirements and relevant regulatory restrictions.

The publication is aimed at administrators, regulators and plumbers working in areas that are served by a mains drinking-water supply or sewerage system, or are about to install a mains drinking-water supply or sewerage system. It should be of particular value to those working in countries or areas that are in the early stages of introducing effective plumbing systems. While it draws attention to the problems of drinking-water supply and waste removal in developing countries and outlines some of the strategies currently used, it does not systematically cover issues specific to developing countries. The World Health Organization (WHO) has an extensive series of publications and information sheets devoted to improving the quality of water supplies and waste removal systems in developing countries ([http://www.who.int/water\\_sanitation\\_health/en/](http://www.who.int/water_sanitation_health/en/)).

### **1.1 Ensuring water safety in production and distribution systems**

The main strategy for ensuring the microbial and chemical quality of water is the implementation of a water safety plan (WSP), which incorporates a series of “multiple barriers” designed to minimize the transmission of microorganisms and other contaminants from the source of raw water to the user’s tap (see also chapter 4). Part of a WSP involves the regular use of tests to monitor the presence of certain bacteria and chemicals and to validate the performance of the system through their absence at the point of use by the consumer (see section 3.1). The primary series of barriers includes the following:

- protection of water sources from faecal and other contamination;
- storage and settling to remove some microorganisms and particulates;
- coagulation, flocculation and sedimentation to remove colloidal particles and microorganisms;
- filtration for additional microorganism and particulate removal;
- disinfection to inactivate any remaining pathogens;
- protection from recontamination after treatment and during distribution.

The operation of the WSP and the barriers is the responsibility of the water authority, but public health officials and physicians in community practice play a vital watchdog role in the identification of outbreaks that may signal a deficiency in the WSP or result from a breakdown of one of the barriers.

## 1.2 Removal of liquid waste

The continuous supply of adequate quantities of safe drinking-water and the prompt and safe removal of human and domestic wastes are jointly vital for health. Human and domestic waste matter from buildings and houses that is carried away through sewers is known as sewage, wastewater or liquid wastes. The system of pipes for conveyance of sewage and the respective facilities for sewage treatment are known as the sewerage system. In many cases, the sewerage system is managed by a sanitation department or part of community government other than the one responsible for drinking-water. The body that provides the wastewater management service generally funds its activities by collecting fees from its customers.

Liquid wastes are collected through a network of sewers that constitute the limit of responsibility of the management body. It is up to the owners of the properties concerned to collect the wastes within the building in which they were generated and convey them to the public sewerage system. Case study 1 is taken from the Amoy Gardens final report issued in July 2003 by an investigation conducted in part by Health Canada and WHO (WHO 2003).

### CASE STUDY 1. SARS IN HONG KONG

Amoy Gardens is a private residential estate providing living space to approximately 20,000 Hong Kong residents. Around March 20, 2003, an unusual cluster of severe acute respiratory syndrome (SARS) cases was discovered in Block E of the estate with apartment units 7 and 8 mostly affected. The initial epidemiological investigation and the unusual high number of cases affecting these two units prompted the hypothesis that environmental factors may have been involved in the transmission of the infectious agent.

The areas of investigation centred on the plumbing and ventilation systems. There was a potential of plumbing and ventilation system interaction that could have promoted the transmission of an infectious agent. To prevent a free flow from the plumbing system to the indoor environment, water traps are installed to ensure waste containment. Amoy Gardens has all the necessary plumbing features for such containment. The containment would be maintained, provided that the plumbing system is operated as per design intent, with all traps sealed either by a water seal or by a solid, gas tight plug. However, if the traps were left without water and without a plug, this would establish an open path for waste, in the form of sewer gas and aerosol/droplets, to enter the occupancies. A strong vertical distribution of infectious material was obvious in unit 7 and particularly in unit 8 apartments leading to the hypothesis that unprotected occupants could have been infected by contaminated droplets drawn from a waste pipe previously used by an ill person residing in a living unit above or below, who was shedding infectious material. A transfer of particles from the water pipe system to the occupancies was tested and proven possible. The floor drain traps in many apartments seemed to have not been primed on a regular basis and thus had lost their sealing function. Thus aerosol and

droplets generated within the plumbing system had access to the bathroom through the unsealed floor drains. The inside apartment testing revealed that the bathroom fan created a vacuum inside the bathroom when the door and window were closed. This is most likely the case if an occupant uses the toilet or takes a shower. Thus infectious material could have been sucked into the bathroom from the waste stack system and exposed the occupant.

In conclusion, the environmental investigation supports an accumulation of different events that together could have mediated the epidemic in Block E of the Amoy Gardens Estate. The shedding of infectious material from several patients into the sewer system may have exceeded the critical mass needed to generate hazardous aerosols/droplets in the wastewater system. The open floor drains in combination with the overpowered exhaust fans of the bathrooms may have then sucked infectious material into the occupancies and in this way exposed people to infectious aerosols/droplets or contaminated surfaces through droplet settling.

Source: Adapted from WHO 2003.

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### **1.3 Risk of contamination through cross-connections**

Inside many properties there are, in effect, two distinct systems of pipes, one conveying drinking-water and the other wastewater. These pipes, internal and external to the building, together with the fittings themselves, are the plumbing systems of the property. The two systems of pipes pass underground to reach the building, and they come close together at sanitary fittings and fixtures such as water closets, sinks or baths. The proximity of the drinking-water supply and waste disposal systems means that there is a risk that liquid waste might contaminate the drinking-water supply system. The minimization of this risk is one of the prime objectives of a well-designed and properly built plumbing system.

Effective plumbing technologies and practices ensure that when properly applied there is no cross-connection between the drinking-water supply and the waste removal systems. The risks of cross-connection are usually greater in public, industrial and commercial premises, where dual water systems, circulating pumps, toxic wastes and other factors have to be managed. There are also risks in multi-storey buildings where booster pumps are employed to increase the mains pressure, and in special systems used in hospitals and in dental and veterinary surgeries. However, even standard single-family domestic buildings present health risks to both occupants and neighbours if faulty plumbing is installed or if plumbing is not maintained.

The ill effects of a cross-connection may not be confined to the premises concerned, but may be transferred to the mains supply system to which the plumbing is connected. In these cases, the health of a whole community may be threatened. The risks of mains contamination are greatest when the supply

pressure fluctuates or the service is intermittent. Some water supplies are intermittently shut off in the mistaken belief that this will reduce consumption. The deliberate interruption of supply is regarded as a dangerous practice, to be avoided at all costs by a well-managed water authority. However, even in a well-managed public drinking-water supply, circumstances will arise where mains must be shut off for cleaning, maintenance or repair, causing a lowered or negative pressure in the services connected to them. Pressure drops can also occur in an undersized system when large amounts of water are used in firefighting in the water system. The danger of mains contamination from pressure drops is serious and disease outbreaks in many parts of the world have been traced to this source.

The advent of technology providing for the injection of fertilizer or drench chemicals into irrigation or stock-watering systems creates another risk of contamination in both urban and rural situations. Protection against backflow, caused by backpressure or backsiphonage, along with the avoidance of all cross-connections, are essential to safeguard consumer health.

#### **1.4 Periodic inspection**

Risk minimization also depends on maintenance of equipment. In the case of large or complex systems, or where public use or the handling of food for sale is involved, the health (or other) authority may require periodic inspection and retesting as a condition for approval. The owner of any plumbing system, irrespective of its size or purpose, should be obliged to identify and to promptly repair any fault that may develop, whatever its cause.

An essential feature of risk minimization strategies is that they are regularly monitored and maintained. As part of its responsibility for protection of public health and safety, the authority must make certain that plumbing systems are assiduously maintained at the standard required in the plumbing code of practice (see chapter 7). Ensuring ongoing compliance with the code of practice through a process of periodic inspection of installations is costly, so appropriate priorities need to be set.

For systems that have the potential to pose a serious risk to public health (such as premises where food or drink is processed, hotels and lodging houses, and industrial premises) it may be a condition of the authority's approval that the plumbing system should be retested at specific intervals (such as every two years), and that such tests should be witnessed by the inspector. The inspector should also be satisfied that no cross-connections or other violations of the code have occurred since the previous inspection and test. Work completed under a system of self-certification may also be subject to periodic audit by the authority and the ability to issue future self-certification may be withdrawn in the light of any problems arising from the audit.