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Service activities relating to drinking water supply, wastewater and stormwater systems — Hydraulic, mechanical and environmental conditions in wastewater transport systems

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Foreword

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This document was prepared by Technical Committee ISO/TC 224, *Service activities relating to drinking water supply, wastewater and stormwater systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document addresses the hydraulic, mechanical and environmental conditions generally found in wastewater transport and treatment systems (which will be referred to collectively as the “wastewater systems”) based on information that was available at the time of publication.

Wastewater transport and treatment systems have been and are designed to treat sanitary waste streams from toilets and urinals – comprising faeces, urine and toilet paper, along with other sanitary waste streams from bathing, laundry and kitchen activities. Most also treat industrial and commercial discharges containing chemicals. However, in recent years a number of products have been introduced in the market place that are claimed to be compatible with sanitary objectives, which are then either identified as being toilet flushable or which by their location of use and usage, are likely to be flushed down the toilet as the means of disposal. Many of these products are not compatible with current infrastructure.

The principal objectives for managers of wastewater systems are to protect public health and the environment and the occupational health and safety of their workers, along with promoting sustainable development[1]. Management of the wastewater system should also consider impacts on any outputs arising from wastewater treatment. There are many factors that contribute to the successful operation of wastewater systems, including adequate capacity and proper design, along with the necessary capital expenditure and maintenance to maintain and expand the infrastructure as necessary. Another factor for the successful operation of wastewater systems is the prevention of blockages. When blockages occur, there is an unacceptable risk that wastewater may spill from the system and, in doing so, flood property and the surrounding land, and pollute watercourses and the surrounding environment.

A major problem for wastewater operators is the disposal/flushing to sewers of inappropriate and unsuitable items[2]–[4]. Wastewater system blockages and clogged pumps can also come from a variety of sources, including debris and other materials creating barriers to the entry or free flow of water into or through the system including outside drains, industrial and commercial discharges.

Further, there may be fouling and damage to wastewater treatment systems from blocked grilles, gratings, and screens that are intended to:

a) collect and restrict the passage of materials;

b) protect other equipment from being damaged;

c) protect the operation of the treatment systems themselves;

d) minimize the potential for the untreated or partially treated material to enter the environment.

These problems may result in:

— health risk and inconvenience to customers, including that their properties may be flooded with wastewater;

— damage to the environment, including watercourses;

— otherwise unnecessary expenditure in rectifying the issues in order to maintain efficient operations and to prevent sewer backups or sewer overflows;

— exposure of workers to health and safety risks.

The presence of inappropriate materials can compound problems of aging infrastructure and hydraulic capacity of the wastewater infrastructure. It should be noted that sewer overflows may occur for a number of reasons unrelated to blockages, for example: system design constraints; infrastructure failure; and weather.

To protect the wastewater system, a discharged material or product that is disposed via the wastewater system should be able to:

— be flushed from the toilet bowl;

— pass through the drain line (pipes inside/immediately outside property);

— be transported through the wastewater system (sewers and pumping stations);

— not adversely affect the intended performance of wastewater treatment systems;

— not adversely affect the receiving environment when in a disintegrated state.

The physical characteristics that a product should achieve in order to avoid these issues include:

— being able to disintegrate to a sufficient degree and in a timely manner so as to not cause problems in the drain line, sewer system or when passed through pumps;

— to be transported in the flow through the piped system, yet settle in the primary settlement process of wastewater treatment;

— for the material to be compatible with both the wastewater treatment process and the receiving environment.

The conditions listed in this document may be taken into account when designing and evaluating the performance of products which could potentially be flushed via the toilet. It can also assist stakeholders in communicating with consumers and communities about the compatibility of materials flushed via the toilet.

Service activities relating to drinking water supply, wastewater and stormwater systems — Hydraulic, mechanical and environmental conditions in wastewater transport systems

1 Scope

This document details the hydraulic, mechanical and environmental conditions generally found in wastewater transport systems from toilets through to wastewater treatment plants, the general powers of wastewater services to manage discharges to sewers, and the responsibilities imposed on wastewater services by applicable local, regional or national legislation.

2 Normative references

ISO 24513, *Service activities relating to drinking water supply, wastewater and stormwater systems — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 24513 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
discharged material
material deposited into a toilet as a means of disposal

Note 1 to entry: Some solid materials that are discharged will be contaminated with human excreta such as faeces, urine, vomit, menses, blood, saliva and nasal or throat discharges.

Note 2 to entry: Discharges to wastewater transport systems come also from other sanitary equipment such as showers, laundries, kitchen sinks, and industrial and commercial entities.

3.2
grille
assembly of bars at an environmental exit point from a wastewater transport system to minimise release of solid materials to the environment and exclude entry

Note 1 to entry: In some parts of the world grilles are called grates.

3.3
microplastics
small pieces of plastic less than five millimetres in diameter

Note 1 to entry: Microplastics can be in the form of a sphere (microbeads), or as fibres or fragments.

[SOURCE: Adapted from Gesamp Reports and Studies No. 90 – Microplastics in the Ocean (2015), p.14.]

3.4
plastic
solid material which contains, as an essential ingredient, one or more synthetic organic high polymers and which is formed (shaped) during either manufacture of the polymer or the fabrication into a finished product by heat and/or pressure

[SOURCE: ISO 13617:2001, 3.12, modified — NOTE removed.]

3.5
Reynolds number
R_e
dimensionless ratio of the inertial flow forces to the viscous forces within a fluid

Note 1 to entry: An indicator of the flow characteristics (laminar or turbulent) of a moving fluid.

[SOURCE: ISO 28520:2009, 3.4]

3.6
screen
device of rigid bars, mesh, perforated plate or other configurations installed in wastewater systems

Note 1 to entry: Screens are used to collect solids from within wastewater systems to, for example, protect pumps and downstream infrastructure from clogging or blocking.

3.7
toilet
fixed receptacle into which a person may urinate or defecate, typically consisting of a large bowl connected to a cistern for flushing

Note 1 to entry: Also known as a water closet (WC).

[SOURCE: Adapted from the Oxford English Dictionary. Oxford: OUP; 2018.]

4 Toilets

4.1 General

The purpose of the toilet is to dispose of human excreta (urine, menses, vomit and faeces) by using water to flush it through a drain line to another location for disposal, thus providing safe, sanitary disposal of human waste.

Any material discharged via a toilet should not adversely affect the intended operation of the toilet.

4.2 Typical toilet types

There are a range of toilet configurations found in different parts of the world. Toilet design, configuration and installation may impact on the ability of material to pass through the toilet and into the drain line.

Table 1 shows the commonly found variations in the configuration of toilets as found in a review of the countries listed in 2015.

Table 1 — Typical toilet design configurations in different geographic locations

Country or region	Toilet flush volume	Toilet bowl design
Australia/ NZ	4,5 l and 6,0 l	Wash down
Canada	4,8 l and 6,0 l	Siphonic
Chile	4,8 l to 7,0 l	Siphonic

Table 1 *(continued)*

Country or region	Toilet flush volume	Toilet bowl design
Europe (southern)	3,0 l to 6,0 l	Wash down
Europe (northern)	2,0 l to 4,0 l	Wash down
Israel	4,5 l to 6 l	Wash down
Japan	6.0 l to 10 l	Wash down/siphonic
UK and Ireland	4,5 l to 6,0 l	Wash down
USA	3,0 l to 6,0 l	Siphonic

As indicated in Table 1, there are a range of flush volumes to be taken into account.

For global considerations, a volume for toilets of 4,5 l to 6,0 l may be used as a reference.

4.3 Usage patterns

The frequency and nature of the usage of toilets varies considerably. Some of these uses will involve faecal material and urine with or without toilet paper, others involve urine alone (with or without toilet paper). The sequence of these uses in any one day will depend on the region, the number, gender and age of the persons in the building and the nature of the building.

5 Drain lines

5.1 General

There are a range of drain line configurations found in different parts of the world (see Table 2). Drain line design, configuration, construction and maintenance may impact the ability of waste to pass through the drain line. Typically, material introduced into a drain line moves along the drain line with water from toilet flushing. Failure of flushed material to exit the drain line may result in blocked plumbing and the generation of unacceptable odours or allow material to dry out and adhere to the pipe surface.

When material moves down the drain line it may occasionally become snagged on a damaged or broken pipe. Depending on the severity of the damage to the pipe, it should then either self-release, tear off the snag or break up within a certain number of flushes. When such material does not release, tear off or break up, it may result in issues for the drain line. Any material discharged via a toilet should not adversely affect the intended operation of the drain line or sewer system. It should exit a drain line within a timeframe/number of flushes.

5.2 Drain line hydraulic conditions — intermittent flow

5.2.1 General

The hydraulic condition commonly observed in drain lines associated with residences is the intermittent flow of wastewater which influences the motion of solids in the drain line[5].

Solids discharged into drain lines can move by either being entrained in the flush wave or by a sliding dam action. The movement within the flush wave is often short-lived and will only occur close to the discharge point. Further downstream, often after between 5 m and 10 m from the discharge point, the flush wave will have dissipated and any movement will be as a sliding dam as described by Butler[5].

5.2.2 Drain line clearance — stranding

The modes of movement of solid materials in drain lines or small sewers is complex and has been documented extensively by Butler[5]. Material discharged into a drain line will normally move through and exit the drain line driven primarily by the force of the water from the toilet flushes.

Stranding of solids in a drain line may occur for a variety of reasons which can be related to the properties of the discharged material and the drain line. Stranding of solids may be due to 'settling' and 'snagging', which can be related to both the properties of the discharged material and the drain line.

5.2.3 Drain line clearance — settling

The first consideration for drain lines with intermittent flow conditions is whether or not the discharged material will exit the drain line by the simple action of being carried by the flushing water. The weight of some discharged material can increase due to oversaturation with water resulting in it becoming too heavy to move. When this occurs, it is often referred to as settling.

With regards to a toilet flush, the flushing water is separated into two categories: the water which precedes the discharged material and wets the drain line ahead of the discharged material (which reduces friction) and the water which follows the discharged material and creates a hydraulic force pushing the material down the drain line. In most cases, the water surrounding the discharged material passes around and moves ahead of the discharged material. The solid will then settle on the lower surface (invert) of the drain line, until moved along by the next flush – the forces exerted by successive flushes being less as the solid gradually gets further from the discharge point. Further, additional sources of water will also typically be present in the drain line along with water from toilets. These additional flows may provide some additional transit to any solids which remain stationary in the drain line following a toilet flush.

Settling is related to the nature of the discharged material, the volume of the flush, the velocity of the flushed water, the pipe gradient, the length of drain line/distance from discharge point, and the design and installation of the drain line (including size, angle, length, construction material and joint design).

5.2.4 Drain line clearance — snagging

Factors such as the volume and frequency of the flush and the design and installation of the drain line affect whether or not the material being flushed may become snagged to such an extent as to create blockages that adversely affect the system. Most drain lines do not have a continuously smooth interior surface. There will be joints where drain line sections are connected which may create a snagging point, or because the drain line may have become uneven through soil settlement or the build-up of sediment in the drain line. Solids while still carried within the flush wave are unlikely to become snagged. Snagging is far more likely when the solid is being transported by the sliding dam mechanism.

Depending on the condition of the drain line and the nature of the discharged material, some of the discharged material, even if snagged, may:

— start to disintegrate with successive flows of water;

— tear-off and become loose from the snagging point;

— self-release from the snagging point and continue through the drain line.

5.3 Typical drain line configurations

The length of the drain line and number of connections can vary significantly based on the building type and purpose. This information is relevant to the hydraulic conditions within the drain line and compatibility of discharged material. The drain line configuration can impact the ability of a discharged material to pass through the drain line.

Table 2 shows the commonly found variations in the configuration of drain lines as found in a review of the countries listed in 2015.

Table 2 — Typical drain line design configurations in different geographic locations

Country or region	Pipe internal diameter	Pipe gradient	Length of typical drain lines
Australia/NZ	80 mm and 100 mm	1,65 % (Australia)	20 m
Canada	75 mm and 100 mm	2 %	20 m
Chile	100 mm	1 % to 3 %	20 m
Europe (general)	100 mm	1 % to 2 %	10 m to 15 m
Israel	100 mm	1 % to 1,5 %	10 m to 15 m
Japan	75 mm	1 %	10 m
UK and Ireland	100 mm	1,25 %	20 m
USA	75 mm and 100 mm	1 % to 2 %	20 m

As indicated in Table 2, there are a range of geometric parameters to be taken into account.

For global considerations the following drain line parameters may be used as a reference:

a) a length of 10 to 20 m;

b) a diameter of 75 to 100 mm;

c) a slope of 1 % to 2 %.

6 Wastewater transport systems

6.1 General

The design, layout and configuration of wastewater transport systems vary significantly depending on the municipality served, its geographic and topographic features, and climatic conditions[6]–[10].

Pipes are required to convey the wastewater from drain lines to the wastewater treatment plant. The wastewater transport system includes pipes of various diameters, along with manholes and other hydraulic structures, storm water grilles or grates. Wastewater may flow through the pipes by gravity or under pressure from a pump.

Pumps are required where there is a need to overcome an elevation difference to pump to a level from which gravity can then be used to facilitate the transport of flows. This can occur anywhere from the end of the drain line to any point within the transport system.

Screens or grinders may be installed ahead of the pumps or other downstream infrastructure including overflow outlets and immediately prior to the influent point of the treatment system in order to protect them from becoming blocked with inappropriately discharged material.

Grilles are installed at environmental exit points from the wastewater networks to minimize release of solid materials to the environment. Gratings are installed in stormwater channels (typically in roads) to prevent the entry of large solid materials into stormwater sewers.

The issues which may occur from the discharge of inappropriate materials into a wastewater transport system include:

a) clogging or fouling of pumps;

b) settlement or snagging in pipes;

c) blinding of grilles and screens by accumulated materials.

6.2 Typical transit times in transport systems

There is great variance within the wastewater transport systems with respect to the distance travelled or duration before contacting screens and pumps, depending on topographical situations. In this context, it was recognized that a time frame should be established for the likely duration of transport prior to the discharged material encountering a screen or a pump.

Based on expert views and a survey undertaken, the typical duration to the first grille or pump is considered to be between 30 min and 6 h, although it may be longer. The transit time to a wastewater treatment plant can range from 30 min to several days.

For global considerations a transit time to the first grille or pump of 30 min to 6 h may be used as a reference.

6.3 Typical hydraulic conditions in flowing pipes (Reynolds number)

The Reynolds number can be used to indicate the hydraulic conditions within pipe. The Reynolds number can be used to describe these conditions in sewer design and laboratory testing. The Reynolds Number for a flowing sewer can vary by orders of magnitude depending on multiple factors including pipe diameter, material, age, and slope, along with the volume and nature of wastewater being transported.

Sewers are designed to maintain a velocity necessary to transport solids to prevent deposition and decomposition in the sewer. A minimum velocity in a sewer of 0,3 m/s will stop settling of suspended solids, and a velocity when flowing full of 0,6 m/s will facilitate self-cleaning of the sewer via resuspension of settled solids[11].

The Reynolds number for wastewater flow in all sewers will vary over the course of a day as a result of diurnal flow variation. The Reynolds number for diurnal flows in a typical 200 mm diameter wastewater pipe may range from 11 000 (150 l/min) to 29 000 (600 l/min).

For global considerations for low volumes of flow in small-diameter gravity sewer pipes, an indicative Reynolds number (Re) of between 11 000 and 29 000 may be used as a reference.

7 Screening

Screens are designed to protect pumps and downstream infrastructure from issues such as clogging and blocking. Materials greater than a certain size can blind screens and grilles, resulting in an elevated load of solid waste to landfill, increased maintenance or potential blockages leading to sewer overflows and flooding. The screens in wastewater transport and treatment systems can have a apertures ranging from 0,3 mm to approximately 144 mm[12]. The typical configuration of wastewater treatment plant screens, depending upon the treatment process, is for screens of 2 mm to 25 mm.

The interpretation of EU directives[13],[14] in a number of Northern European countries (and subsequently adopted elsewhere) is typically to install 6 mm perforated plate screens[14],[15] at the inlet to the wastewater treatment plant.

For global considerations, a screen aperture of 2 mm to 25 mm may be used as a reference.

8 Treatment processes

8.1 General

Organisations operating wastewater treatment plants have an obligation to minimize the impact on the environment. This can be explicit in legislation or expressed in a licence condition.

Treatment plant processes are designed to remove settleable and floatable materials, and biologically degrade or treat material that remains in the liquid stream. Some are also able to remove nutrients

