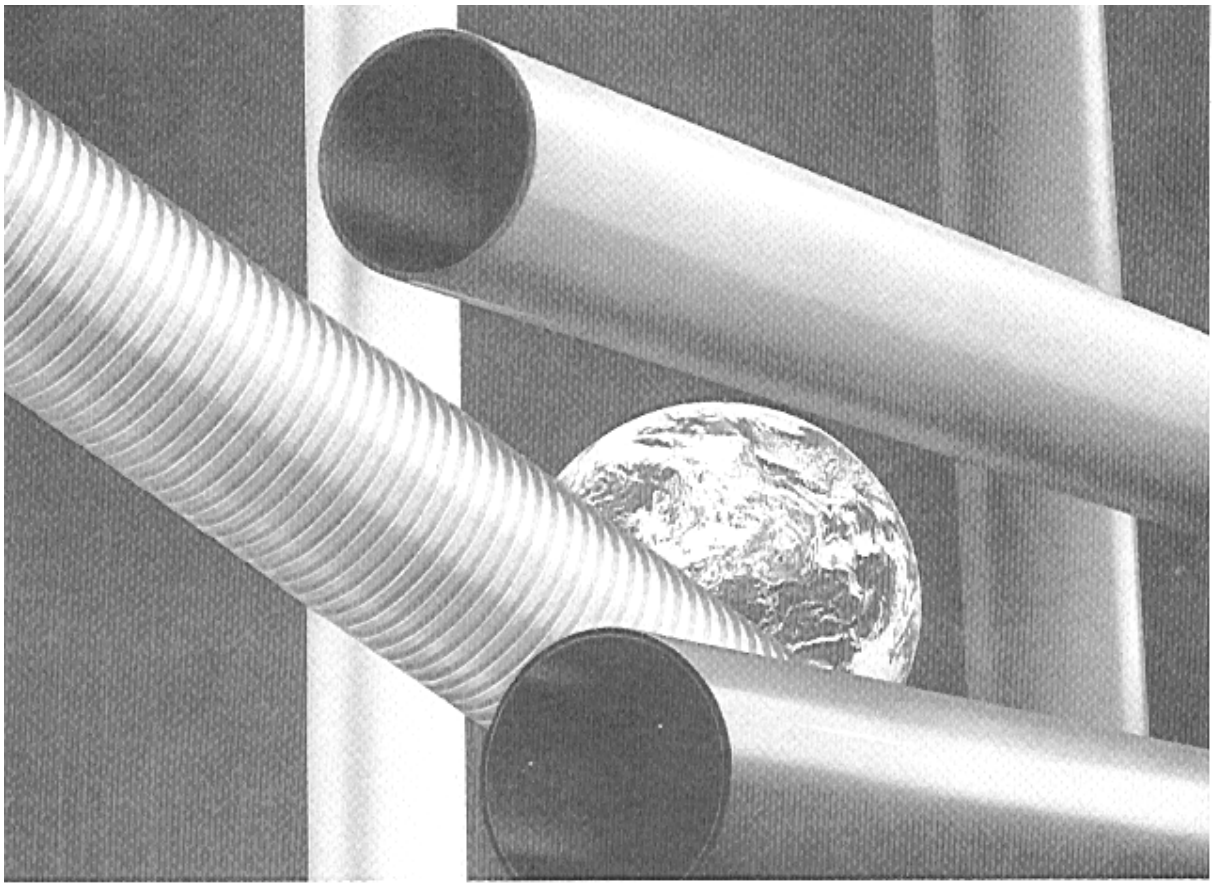
General Information

on the Use of Different Types of Corrosion Resistant Pipe Materials as Inside Service in Buildings



Water Supplies Department
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Preface

These notes are meant to provide consumers with some general information on the corrosion resistant type of pipe materials approved by the Water Authority but are not intended to serve as a design guide or a technical pipe laying manual. It is therefore advisable for the consumers to consult the suppliers on the properties and characteristics of the pipe material should they wish to use any particular type of pipe materials.

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Hong Kong Plumbing & Sanitary Ware Trade Association

Hong Kong Licensed Plumbers Association

The Institute of Plumbing - Hong Kong Council

Hong Kong Plumbing General Union

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I. INTRODUCTION

Discolouration of drinking water, which by no means a new problem, is basically due to corrosion of the internal surface of the galvanized steel pipes (G.I. Pipes) commonly used as the "**inside service**" for fresh water supply in the consumers' premises, resulting in excessive amount of fine iron particles remaining in suspension in the water. This problem is particularly acute when the water has been standing idle in the pipes for some time, or when it is first drawn out from the tap in the morning. Under normal circumstances, the water should become clear after the tap has been turned on for a while.

By the enactment of the Waterworks (Amendment) Regulation 1994 made on 23 December 1994, the use of galvanized steel pipes which are without proper internal lining as fresh water inside service in all new buildings and upon renewal of the plumbing system in all existing building are prohibited after 23 December 1995.

Apart from the internally-lined galvanized steel pipes, there are alternative pipe materials permitted for use as fresh water inside services and are currently available in Hong Kong. This booklet is to provide some general information on these alternative pipe materials.

II. TYPES OF PIPE MATERIALS

Pipe materials for small diameter pipes of sizes below 100 mm suitable for use as inside service can be grouped as metallic, thermoplastics or a combination of the two.

They include:

Metallic

- Copper
- Stainless steel

Thermoplastics

- PVC-U
- PVC-C
- Polyethylene (PE)
- Medium Density Polyethylene (MDPE)
- High Density Polyethylene (HDPE)
- Crosslinked Polyethylene (PEX)
- Polybutylene (PB)
- Acrylonitrile Butadiene Styrene (ABS)

Composite

- Lined galvanized steel
- Crosslinked Polyethylene/Aluminium/Crosslinked Polyethylene Composite Pressure Pipe (PEX-AL-PEX)
- High Density Polyethylene/Aluminium/High Density Polyethylene Composite Pressure Pipe (HDPE-AL-HDPE)

Copper

Copper pipes complying with **BS EN 1057** are for use in both **hot and cold** water supply. Copper pipes have high pressure rating, good durability and good resistance to corrosion attack in most soil. The smooth surface of copper pipes gives low resistance to water flow. Compression joints and capillary joints are the principal methods for jointing copper tubes and fittings.

Stainless Steel

Stainless steel pipes complying with **BS 4127** are suitable for **hot and cold** water supply. The pipes are jointed by capillary or compression fittings. Stainless steel pipes have high resistance to corrosion attack, high strength and good resistance to accidental damage.

Lined Galvanized Steel (PVC-U/PVC-C/Polyethylene Lining or Epoxy Resin Coated)

Lined galvanized steel pipes are steel pipes with the provision of an internal protection lining to resist corrosion and encrustation. Because of the composite nature of the materials, these pipes possess the rigidity of steel pipes on the external surface and the resistance to corrosion on the internal surface. The lined galvanized steel pipe can be used in vulnerable conditions such as exposure to direct sunlight and traffic loads. Jointing of lined galvanized steel pipes is similar to that of unlined galvanized steel pipes and is therefore readily compatible with the existing mains network.

PVC-U/PE lined steel pipe can withstand a maximum pressure of 9.8 bar at 20°C. For use in hot water supply, PVC-C lined steel pipe can withstand a maximum pressure of 9.8 bar at 82°C.

There is no relevant British Standard for this kind of pipe. However, there are JIS, JWWA, WSP and SS Standards.

Unplasticised Polyvinyl Chloride (PVC-U)

Unplasticised polyvinyl chloride (PVC-U) pipes complying with **BS 3505 for Class D (12 Bar)** are suitable for **cold** water services. PVC-U is a rigid material, light weight and has a good resistance to corrosion attack. As this type of materal has a high coefficient of thermal expansion, PVC-U pipes is thus not suitable for hot water supply.

PVC-U is sensitive to point loading, impact and fatigue loading conditions. So PVC-U pipes are not recommended for use under major carriageways and exposed conditions. PVC-U can be attacked by surface active organic compounds (e.g. detergents) and certain concentrated oxidizing agents (e.g. chlorine gas, concentrated nitric acid) which can increase the risk of brittle fracture. Same as other plastic materials, PVC-U pipes are susceptible to ultra-voilet degradation.

Because PVC-U is not a conductor of electricity, problems of galvanic corrosion do not occur, and the piping system will not suffer from oxidation corrosion. They are jointed

by solvent cement which requires:

(a) Good skill in making a proper joint;

(b) Clean and dry condition for a good bond; and

(c) A drying time of 8 hours before being subjected to the designed working pressure and 24 hours before being tested to 1.5 times the designed working pressure.

Chlorinated Polyvinyl Chloride (PVC-C)

Chlorinated polyvinyl chloride (PVC-C) pipes complying with **BS 7291 - Thermoplastics pipes and associated fittings for hot and cold water for domestic purposes and heating installations in buildings:**

(i) **Part 1. - General requirements**; and

(ii) **Part 4. - Specification for chlorinated polyvinyl chloride (PVC-C) pipes and associated fittings and solvent cement**

are suitable for **hot and cold** water services.
PVC-C pipe is manufactured by the addition of extra chlorine atoms to molecules of PVC and the resultant polymer has a higher service temperature. It resembles PVC in many aspects, except that it may be used in hot water services and has a good resistance to corrosion attack. It is inert to most acids, alkalis, salts and paraffinic hydrocarbon solutions and is often used in chemical plant. However, it is susceptible to permeation/degradation by certain organic contaminants. The inertness of PVC-C, coupled with the smooth bore of the pipe and fittings, almost completely eliminates scale build-up within pipe system. This type of pipe has, however, a high rate of thermal expansion.

It should be noted that the working pressure for which a plastic component is suitable generally reduces relative to an increase in the temperature and/or the duration of use at elevated temperature to which the component is subjected. Therefore, information on the change of pressure rating with temperature for PVC-C pipes must be obtained from the manufacturer or from the applicable product specification.

PVC-C is sensitive to point loading, impact and fatigue loading conditions. So PVC-C pipes are not recommended for use under major carriageways and exposed conditions. Same as other plastic materials, PVC-C pipes are susceptible to ultra-violet degradation.

Because PVC-C is not a conductor of electricity, problems of galvanic corrosion do not occur, and the piping system will not suffer from oxidation corrosion. They are jointed by solvent cement which requires:

(a) Good skill in making a proper joint;

(b) Clean and dry condition for a good bond; and

(c) A drying time of 8 hours before being subjected to the designed working pressure and 24 hours before being tested to 1.5 times the designed working pressure.

Polyethylene, Medium Density Polyethylene (MDPE) and High Density Polyethylene (HDPE)

Polyethylene is a synthetic thermoplastic material produced from the polymerisation of ethylene in a closed loop reactor. The conditions under which polymerisation takes place and the specific catalyst used control the properties of the polymer. A wider range of materials may be produced which can be broadly characterised by their molecular weight, crystallinity and density.

The molecular weight distribution influences both the melt flow characteristics and the toughness of the material. The absolute value of the molecular weight also controls toughness.

The density of the material is closely related to its crystallinity or structural regularity which in turn influences a wide range of physical properties. For example, the increase in the density of the material would improve its short term strength but would trade off its ductility. The lower the ductility of the material the more difficult it becomes in the redistribution of stresses around defects and cracks thus reducing the effective toughness of the material.

Medium density polyethylene (MDPE) specified to **BS 6572 - Specification for blue polyethylene pipes up to nominal sizes 63 for below ground use for potable water or BS 6730 - Specification for black polyethylene pipes up to nominal size 63 for above ground use for cold potable water** is a relatively new pipe material for mainlaying in water industry. Jointing of MDPE pipes may be carried out mechanically or using fusion methods. MDPE pipes made by different manufacturers however may not be compatible for direct fusion jointing although they may be jointed using an electrofusion coupler or a mechanical joint.

There are five methods available for jointing MDPE pipes.

- butt fusion welding
- socket fusion welding
- electrofusion welding
- push-fit spigot and socket joints
- mechanical couplers/compression fittings

MDPE pipes are light in weight, resistant to corrosion attack, weldable and flexible. MDPE has a relatively high coefficient of thermal expansion and is susceptible to UV degradation. It is not intended for above ground and outdoor use. It should be noted that the working pressure for MDPE pipes would be reduced in an increase of the temperature and the duration of its use. Therefore, information on the change of pressure rating with temperature for MDPE pipes must be obtained from the manufacturer or from the applicable product specification.

MDPE pipes can suffer permeation and structural attack by a range of organic and inorganic compounds (such as fuel oil, detergents, chlorine gas, concentrated oxidizing acids, benzene and chlorinated hydrocarbons) so they should not be laid in environment which is contaminated with these compounds or there is a significant risk of spillage of such compounds.

Crosslinked Polyethylene (PE-X)

Crosslinked Polyethylene (PE-X) pipes and fittings complying with **BS 7291 - Thermoplastics pipes and associated fittings for hot and cold water for domestic purposes and heating installations in buildings:**

(i) **Part 1. - General requirements;** and

(ii) **Part 3. - Specification for crosslinked polyethylene (PE-X) pipes and associated fittings**

are suitable for **hot and cold** water services.

The base material of a PE-X pipe is high density polyethylene of high molecular weight, with organic peroxide serving as the cross-linking agent. There are various cross-

linking methods for PE moulding or extrusion either alone or in combination with other plastic materials. The polymer chains are linked together under pressure to form a three-dimensional structure.

It should be noted that the working pressure for PE-X pipes would be reduced in an increase of the temperature and the duration of its use. Therefore, information on the change of pressure rating with temperature for PE-X pipes must be obtained from the manufacturer or from the applicable product specification.

On account of its high coefficient of expansion, the pipe must be installed in such a way that temperature-induced linear expansion and contraction can be accommodated.

In case of exposed installation, the pipes must be encased to provide protection against UV degradation.

PE-X pipes cannot be jointed by direct fusion jointing or electrofusion coupler. They must be jointed by mechanical couplers/compression fittings.

Crosslinked Polyethylene/Aluminium/Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe and Polyethylene/Aluminium/Polyethylene (PE-AL-PE) Composite Pressure Pipe.

PEX/AL/PEX or **HDPE/AL/HDPE** pipe is a co-extruded crosslinked polyethylene or high density polyethylene composite pressure pipe with a welded aluminium tube reinforcement between the inner and outer layers. The inner and outer layers are made of crosslinked polyethylene or high density polyethylene and are bonded to the aluminium tube by a melt adhesive. Pipes may be in coils for small sizes or in straight lengths.

As cross-linked polyethylene pipe can withstand higher temperature than ordinary polyethylene pipe, it can be used for above-ground **hot and cold** water services at operating pressures up to 10 bar at a temperature up to 95°C(short term 110°C) whereas the pipe with high density polyethylene material is suitable for above-ground **cold** water services.

PE-X/AL/PE-X or HDPE/AL/HDPE are semi-rigid and light in weight. Copper pipes are 3-4 times heavier for the same application and galvanized steel pipes are 15-17 times heavier.

Polyethylene material is UV-degradable and is therefore not suitable for use in installations exposed to direct sunlight. Pipework system should be protected against

freezing. However, they can normally withstand several freeze/thaw cycles without bursting.

Installations containing PE-X/AL/PE-X or HDPE/AL/HDPE pipes cannot be used as an electrical earth point.

There is no British Standard Specification for this kind of pipe material and they shall comply with the relevant American Standards and Canadian Standards.

Polybutylene (PB)

Polybutylene pipes and fittings complying with **BS 7291 - Thermoplastic pipes and associated fittings for hot and cold water for domestic purposes and heating installations in buildings:-**

(i) **Part 1. - General requirements**; and

(ii) **Part 2. - Specification for polybutylene (PB) pipes and associated fittings**

are suitable for **hot and cold** water services.

Polybutylene is synthesized by the polymerization of butylene isomers. The resultant polymer has a variety of side branches, which give it better protection against oxygen when exposed to sunlight when compared with other polyolefins. However, when Polybutylene pipes are to be installed outdoor exposed to direct sunlight, the types with proper oxygen barrier should be preferred.
It should be noted that the working pressure for PB pipes would be reduced in an increase of the temperature and the duration of its use. Therefore, information on the change of pressure rating with temperature for PB pipes must be obtained from the manufacturer or from the applicable product specification.

Polybutylene pipes can be jointed by fusion welding techniques and compression fittings. In consideration of the high coefficient of thermal expansion of polybutylene, measures should be taken to make allowance for expansion in hot water system.

Acrylonitrile Butadiene Styrene (ABS)

ABS pipes are made from an Acrylonitrile Butadiene Styrene formulation and can withstand a minimum continuous working pressure of 10 bar at 20°C. These pipes are

jointed by cold solvent welding (solvent cement). The material is tough and has high impact strength and good chemical resistance.

ABS pipes and fittings are accepted by WRc. There is yet no British Standard Specification and other National Standards to cover this kind of pipe material for domestic use. However, **BS 5391 - Specification for acrylonitrile-butadiene-styrene (ABS) pressure pipe, Part 1 - Pipe for industrial uses** is available.

III A Summary of the Advantages and Disadvantages of the Different Types of Pipe Materials

Pipe Materials	Advantages	Disadvantages
Copper	- High pressure capability - Good formability - Good corrosion resistance - High strength and durability to withstand external loading - Ease of jointing - Suitable for conveying hot water - Readily available in local market	- Soft water can cause internal corrosion attack of copper pipes giving rise to 'blue' water
Stainless Steel	- High pressure capability - Good corrosion resistance - High strength and durability - Ease of jointing - Suitable for conveying hot water	
Lined galvanized steel (PVC-U, PVC-C, PB, polyethylene or epoxy resin lining)	- Good resistance to internal corrosion and encrustation - Smooth internal surface to give better flow characteristic - Readily compatible with existing commonly used unlined steel pipe	- Heavy weight - Susceptible to impact damage, greater care required in handling - The cutting, threading, chamfering and jointing of the piping system demands higher skill and is susceptible to poor installation practice.
PVC-U	- Good corrosion resistance - Light weight - Ease of jointing - Low cost - Smooth internal surface giving low frictional resistance and preventing scale build-up - Readily available in local market	- Brittle, susceptible to impact damage - Long drying time of solvent cement in jointing - Low abrasion resistance - Susceptible to permeation /degradation by certain organic contaminants - UV degradation on prolonged exposure to direct sunlight

Pipe Materials	Advantages	Disadvantages
		- Susceptible to poor installation practice
MDPE	- Good corrosion resistance - Good formability - Fusion and mechanical joint available - Low frictional resistance - Strong and tough - Flexible and durable, light and easy to handle - Good resistance to impact - Light weight	- Fusion jointing requires skilled installers and special equipment (electricity supply is required) - Subject to creep - Strength decreasing with time though at a very slow rate - MPDE pipes made by different manufacturers may not be compatible for direct fusion jointing - Susceptible to ultra-violet degradation on prolonged exposure to direct sunlight - Susceptible to permeation /degradation by certain inorganic and organic contaminants
PVC-C	- Good corrosion and chemical resistance - Light weight - Smooth bore giving low frictional resistance and preventing scale build-up - No galvanic or oxidative corrosion - Can be connected to other materials easily - Suitable for conveying hot water	- Brittle, susceptible to impact damage - Long drying time of solvent cement in jointing - Can be flammable - Reduction in strength and rigidity with increase of temperature - Susceptible to permeation /degradation by certain organic contaminants - Susceptible to ultra-voilet degradation on prolonged exposure to direct sunlight - Susceptible to poor installation practice

Pipe Materials	Advantages	Disadvantages
PE-X	- Light weight - Good corrosion and chemical resistance - Smooth bore giving low frictional resistance and preventing scale build-up - Can withstand an excessive temperature of up to 120°C for a short period - Flexible, can be cold bent - Suitable for conveying hot water	- Subject to creep - Susceptible to ultra-voilet degradation on prolonged exposure to direct sunlight - Can only be jointed together by mechanical jointing - Can be flammable
PB	- Good corrosion and abrasion resistance - Flexible, can be cold bent - Durable, light and easy to handle and repair - Smooth internal surface giving low resistance to flow and preventing scale build-up - High temperature resistance - Can be welded to form a leak free system (the British Standard has not yet been amended to include this aspect) - Suitable for conveying hot water	- Susceptible to ultra-violet degradation on prolonged exposure to direct sunlight - Susceptible to corrosion attack by organic solvents - Reduction in strength with increase of temperature - Subject to creep
ABS	- Ability to absorb impact energy without failure - Ductile compared with PVC-U and PVC-C - Light and durable - Good resistance to corrosion - Smooth internal surface giving low resistance to flow and preventing scale build-up - No galvanic or oxidative corrosion	- Reduction in strength and rigidity with increase of temperature - Susceptible to slight surface degradation on prolonged exposure to direct sunlight - Susceptible to corrosion attack by organic solvents - Susceptible to poor installation practice - Long drying time of solvent cement in jointing

Pipe Materials	Advantages	Disadvantages
PEX-AL-PEX composite pipe	- Can be exposed to direct sunlight (black pipe) - Can withstand an excessive temperature of up to 110°C for a short period - Light weight - Can be cold bent to a minimum of five times of its diameter - Smooth internal surface giving low resistance to flow and preventing scale build-up - The pipe is not permeable to oxygen which cannot thus enter recirculating water and be deleterious to other system components - Suitable for conveying hot water - No galvanic or oxidative corrosion	- Can only be jointed together by mechanical jointing - Susceptible to corrosion attack by organic solvents - Susceptible to ultra-violet degradation (except black pipe) on prolonged exposure to direct sunlight
PE-AL-PE composite pipe	- Light weight - Good corrosion and chemical resistance - Smooth bore giving low frictional resistance and preventing scale build-up - Can be cold bent to a minimum of five times of its diameter - No galvanic or oxidative corrosion	- Susceptible to ultra-violet degradation on prolonged exposure to direct sunlight - Can only be jointed together by mechanical jointing - Susceptible to corrosion attack by organic solvents