Plastic Materials in Contact with Drinking Water

Hygienic, Mechanical and Corrosion-Chemical Aspects

Wolfgang Werner, TZW Karlsruhe

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NATURAL AND SYNTHETIC POLYMERS

- Biopolymers
  Wood, fur/leather, wool, birch bark tar, caoutchouc (Indian rubber),
  Gum Arabic etc.

- Plastic materials
  Macromolecular organic substances
  Synthesised polymers of different monomers
  + goal-oriented additives

- Plastic materials in drinking water distribution networks
  Since the middle of the fifties: use of PE pipes
  No augmented frequency of damages towards other materials
  [DVGW damage statistics water 1994 – 2004] (high part of external influence)]

- Plastic materials in drinking water installations
  In 2009 a portion of about 65% of plastic and composite pipes related to the complete installation materials

  Random check concerning the procurement conduct of the tradesmen of the association SHK
  [Study Querschiesser Unternehmensberatung GmbH & Co. KG, Xanten]

PLASTIC MATERIALS: COMPOSITION – PROPERTIES

Synthesised polymers based on different organic monomers (originating the names of the plastic materials) . . .

Polymer chains of 1.000 to 1.000.000 molecular units

Linear, branched and cross-linked systems of chains

Structure: amorphous (PVC) to partially crystalline (PE)

Metastable systems

Triggers for transformation (pass to a lower energy state) are mainly increased temperature, oxygen and UV radiation

. . . plus additives (up to a part of 25 %)

- Production aids: nucleation aids, lubricants
- Softening agents, extenders (secondary softening agents)
- Mineral fillers, dye stuffs, optical brighteners
- Stabilizers: thermo stabilizers, antioxidants, UV-stabilisers

- ➢ Great variety due to basic monomers, manufacturing methods and admixing of additives
- ➢ Specific requirements for drinking water systems !!

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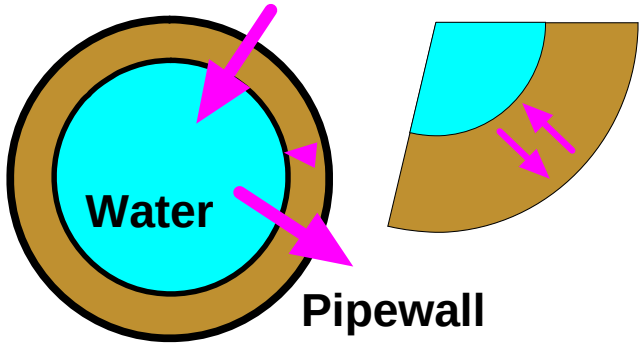
MASS TRANSPORT PROCESSES OF PLASTICS

- Polymers are not diffusion resistant in general
- Mass transport occurs at the interfaces and in the polymer matrix
- Mass transport is controlled by diffusion and solubility

Description of mass transport using Fick‘s second law



$$\frac{\partial c}{\partial t} = D_p \left(\frac{\partial^2 c}{\partial r^2} + \frac{1}{r} + \frac{\partial c}{\partial r} \right)$$

For pipes: cylindric coordinates;
D_p = diffusion coefficient

Migration of substances into the water

Essential parameters:

- Diffusion and distribution coefficients
- temperature
- No influence of the water quality

➢ Degradation (aging) of the plastic material by loss of stabilisers

➢ Quality change of the drinking water by migration of additives and monomers

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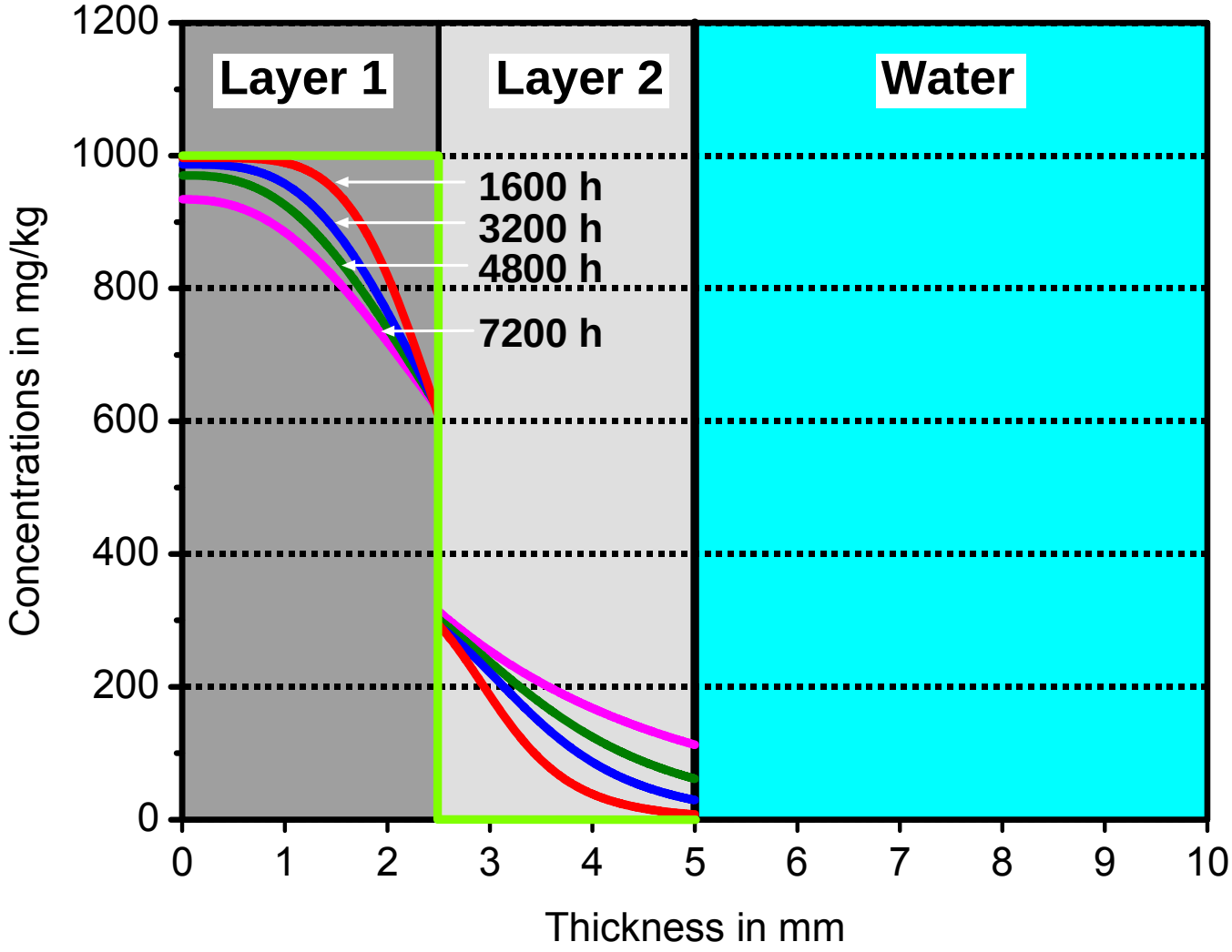
DIFFUSION PROCESSES INSIDE POLYMERS



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PREDICTION OF LIFE-TIME FOR PLASTIC PIPES

In 1957 publication of the first „DVGW bulletin concerning the use of plastic pipes in drinking water distribution networks“

Requirement:

Plastic pipes have to show a sufficient safety against bursting considering an operating pressure of 10 bar and an operating temperature of 20 °C even after an operation time of 50 years.

Internal pressure creep rupture test according to ISO 1167

The time lapse effect occurs in consequence of heightening the test temperature.

The extrapolation is based on the Arrhenius equation:

$$K = A * \exp\left(\frac{-E_A}{R * T}\right)$$

K = rate constant
A und E_A = material dependent constants,
T = temperature, R = universal gas constant

Extrapolation with factor 50 → from one test year to 50 operational years.

Measurement of the Oxidation Induction Time (OIT)

Determination of the time of total loss of the system of effective stabilization.

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PROPERTIES OF PLASTIC MATERIALS

Properties compared to metallic material

- low weight
- low slumping and melting temperatures
- low processing temperatures
- high coefficient of thermal expansion
- low heat conductivity and high insulating resistance
- high impact strength
- low mechanical stability (e.g. pressure resistance of pipes)
- notch sensitivity
- low operation temperatures
- good resistance to mineral acidic and alkali caustic solutions
- low resistance to organic solvents and oils etc.

REQUIREMENTS

Requirements for Plastic Materials and for Products Made of Plastic Materials Used in Drinking Water Installations

- Fixing the field of application
- Selection of convenient materials
- Adequate design and construction
  e.g. right diameter section thickness ratio (SDR, Standard-Dimension-Ratio)
- Adequate processing methods
- Adequate joining techniques
  (bonding, welding, compressing, clamping etc., plastic or metallic joints)
- Adequate tool equipment
- Adequate installation techniques
- Adequate environmental conditions
- 50 years of product life-time

GERMAN STANDARDS FOR PLASTIC PIPES AND JOINTS

DVGW W 544

Plastic pipes intended for use in the drinking water installation

2007/05

DVGW W 542

Multi layer composite pipes in the drinking water installation

- requirements and assessment

2009/08

DVGW W 534

Pipe fittings and pipe joints in the drinking water installation

2004/05

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PLASTIC MATERIALS FOR DRINKING WATER PIPES

Drinking water distribution networks

PVC-U Polyvinyl chloride-hard
PE-HD Polyethylene (high density)
PE-LD Polyethylene (low densitiy)

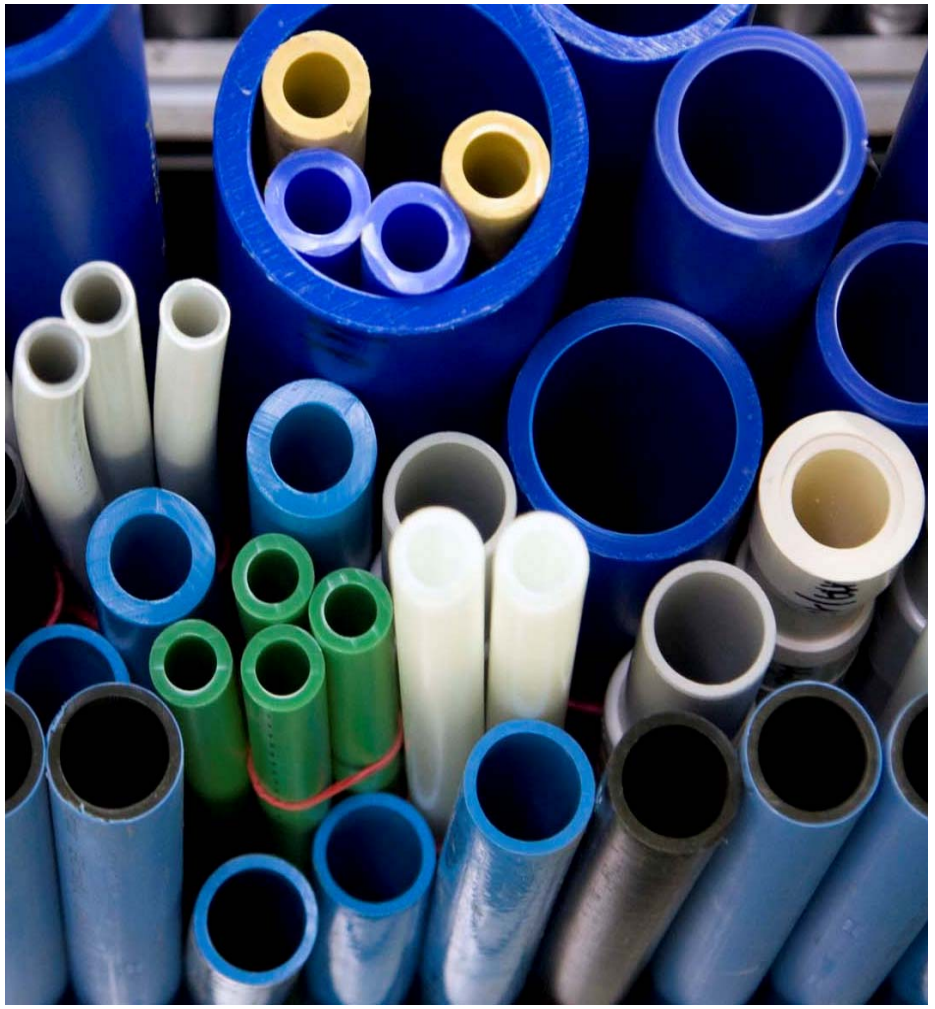
Drinking water installation

PE-Xa cross-linked PE by peroxide
PE-Xb cross-linked PE by silan
PE-Xc cross-linked PE by irradiation
PP Polypropylene
PB Polybutene
PVC-C Post-chlorinated PVC

Composite pipes

e.g. PP/Al/PP

In Germany about
- 100 pipe types with DVGW-Certificate
- 20 composite pipe types
- 50 single pipe types
- 40 manufacturers



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PLASTIC MATERIALS FOR CONSTRUCTION PRODUCTS

PVC	Polyvinyl chloride
PE	Polyethylene
PP	Polypropylene
PB	Polybutene
PA	Polyamide

POM	Polyacetal
PS	Polystyrene
PPE	Polyphenylene ether
PUR	Polyurethane
PPSU	Polyphenylene sulphone

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FURTHER COMPONENTS

- Bonding agents (composite pipes)
- Coating materials, epoxy resin
- Glass fibre reinforced plastics
- Lubricants
- Elastomeres (rubber materials)

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KTW-GUIDELINES / RECOMMENDATIONS

of the Federal Environmental Agency for Hygienic Assessment of Organic Materials in Contact with Drinking Water (KTW-Guidelines)

1977 1st note of the former German Health Authority (BGA)

- Guideline for the Hygienic Assessment of Organic Materials in Contact with Drinking Water (KTW-Guideline)
- Guideline for Hygienic Assessment of Organic Coatings in Contact with Drinking Water (Coating Guideline)

  Enhancement of the Epoxy Resin Guideline. It contains the Positive List of permitted starting substances for the manufacture of the substances and materials (annex 1) and a list of tested products (annex 5).
- Guideline for Hygienic Assessment of Lubricants in Contact with Drinking Water (Sanitary Lubricants) (Lubricant Guideline)
- Recommendation Part 1.3.13 Rubber Materials of Natural and Synthetic Caoutchouc (Rubber Materials)
- Guideline for the Mathematical Estimate of the Migration of Individual Substances from Organic Material in Drinking Water (Modeling Guideline)

TESTING ACCORDING TO KTW-GUIDELINES

Product test !

- Test certificates bound to manufacturer, producing process and producing facility
- Validity of test certificates generally 5 years
- No official validity resp. acceptance of on-site fabrication of commodities (e.g. container coating)
- Verification of the recipe (Positive Lists)
- Exposition of the product in the test water (3 x 3 days)
- Compliance of the basic requirements
  (TOC, Organoleptic (odour / flavour), possibly Cl_2 consumption)
- Compliance of material specific additional requirements, if indicated
- Warm / hot water test, if required
- Different requirements depending on the fields of application
  (pipes, containers, equipment items, gaskets etc.)

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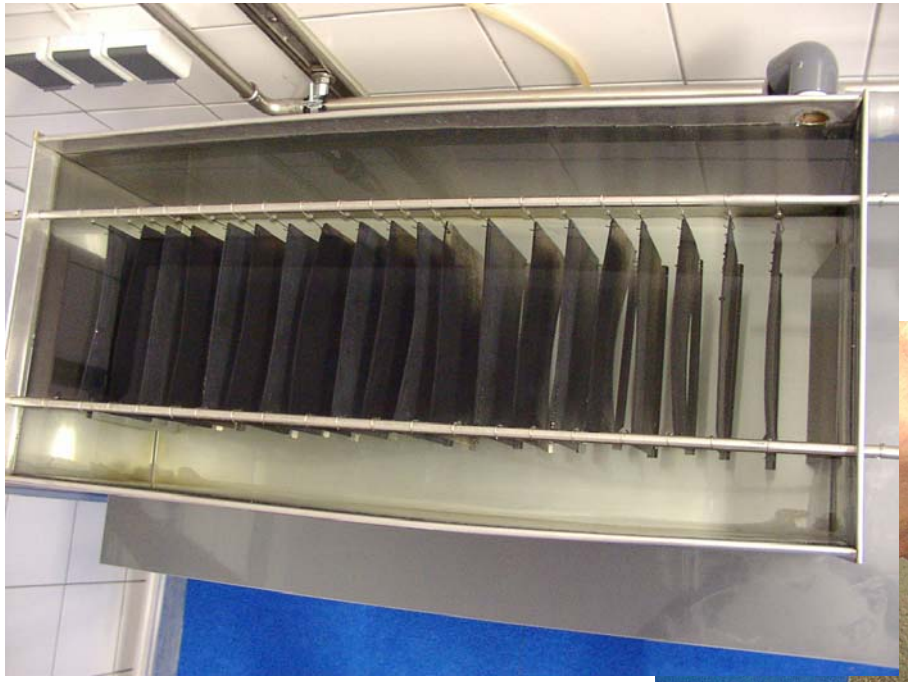
MATERIAL TESTING (DVGW STANDARD W 270)

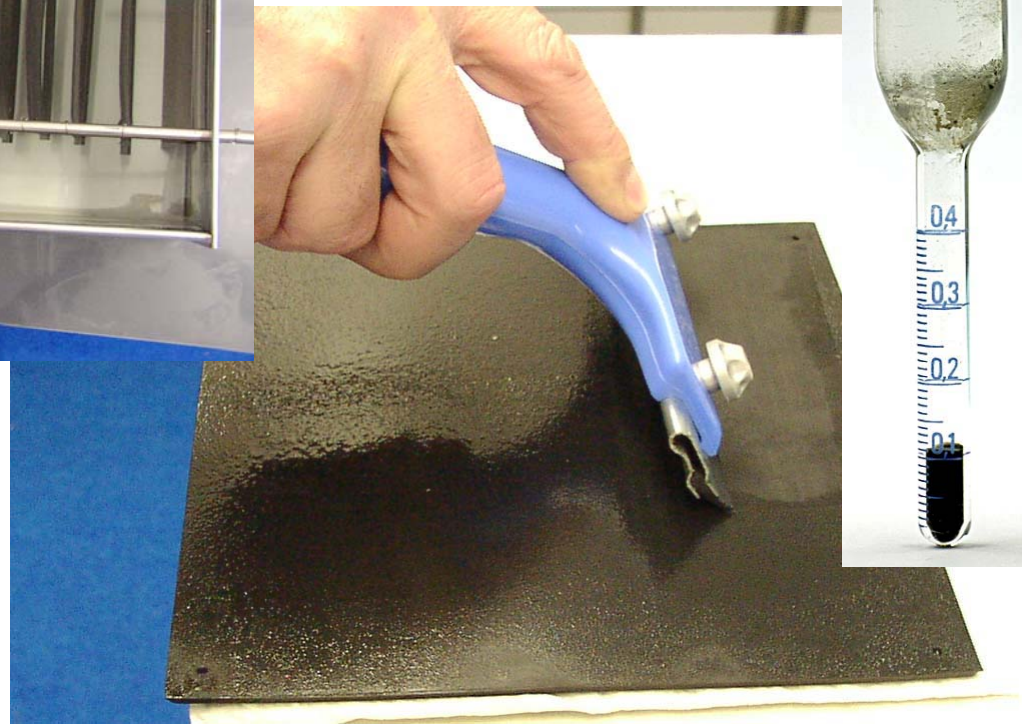
Microbial Enhancement on Materials to Come into Contact with Drinking Water – Testing and Assessment, 2007/11

Material test!

- Microbiological assessment of organic materials foreseen to come in contact with drinking water
- Exposition of the test specimens (plates of 800 cm²) in containers (about 100 L) during slow water flow (20 L/h)
- Control of the surface growth biomass after 1-monthly, 2-monthly and 3-monthly test periods having harvested with a scraper; measurement of volume in glassware for centrifugation
- General use in drinking water in compliance with: surface growth biomass ≤ (0,05 + 0,02) mL / 800 cm²
- Limit value for joints and gaskets of larger surfaces (range of use D1): (0,12 + 0,03) mL / 800 cm²;
- Limit value for joints and gaskets of smaller surfaces (range of use D2): (0,20 + 0,03) mL / 800 cm²

EXPERIMENTAL PROCEDURES (DVGW W 270)





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INFLUENCE OF DISINFECTANTS

Applicated disinfectants:

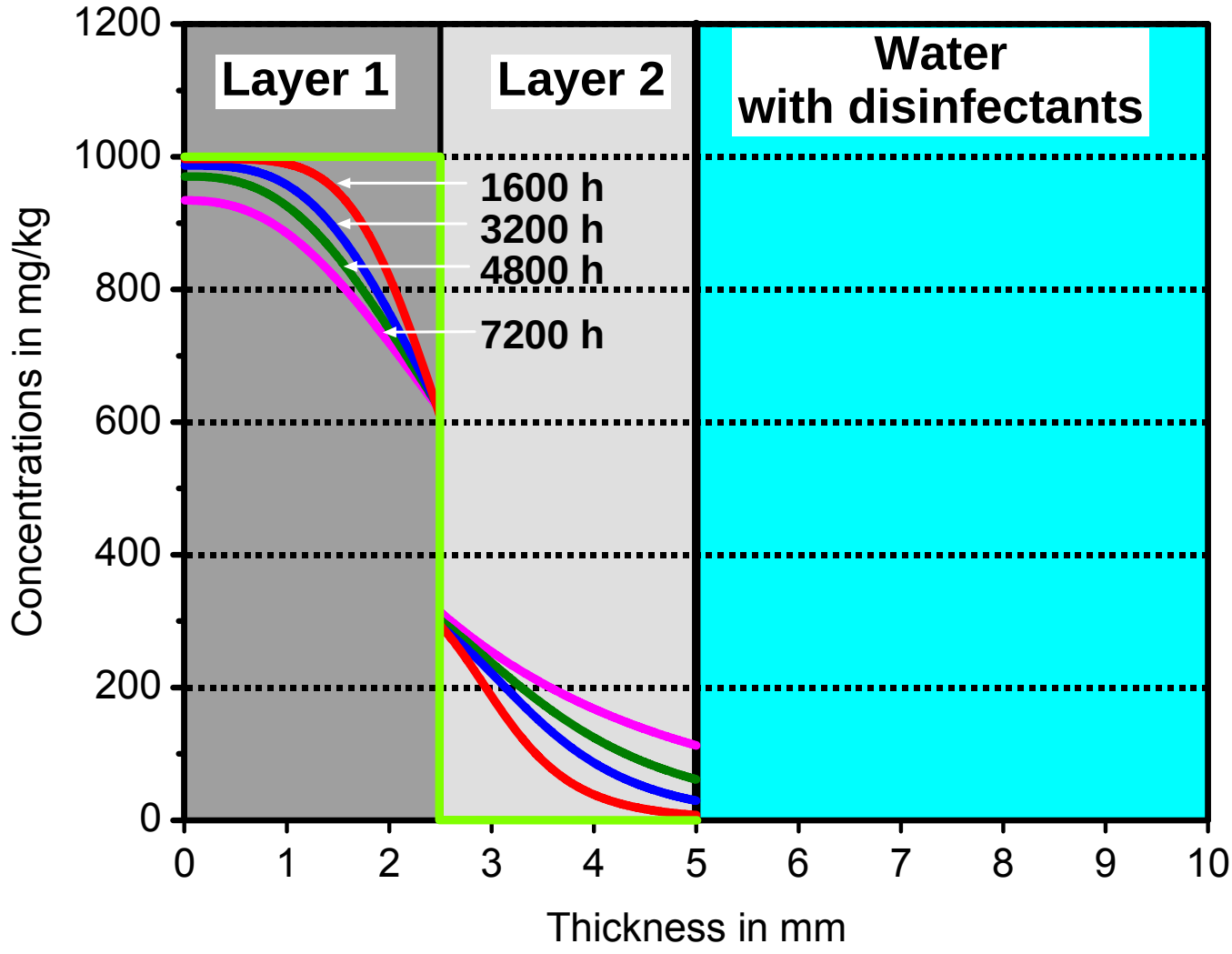
- Chlorine gas, Sodium- / Calciumhypochlorite,
  Chlorine dioxide, Chloramines (not permitted in Germany):
  max. concentration in drinking water after conditioning according to TVO:
  0,3 mg/L free Chlorine
- Ozone

Strong oxidants!

2003 in Southern France damages at domestic connection pipes made of PE were found caused by disinfection with chlorine dioxide.

- Investigations of Suez Environnement with 4 mg/L ClO_2 at 40 °C revealed strong attacks of chlorine dioxide on pipes of standard PE80.
- Loss of mechanical stability was confirmed by another investigation with pipes of PE80 and differently stabilized material of PVC up to 8 mg/L ClO_2 at 40 °C. Under these conditions only minor attacks on the PVC pipes were found (PVC4pipes).
- Currently at the center for plastic material SKZ (Kunststoff-Zentrum at Würzburg, Germany) and at the Austrian research institute for chemistry and technique ofi (Österreichisches Forschungsinstitut für Chemie und Technik at Vienna, Austria) research is being done concerning the influence of disinfectants on the chemical resistance of plastic and metallic materials.

TRANSPORT OF SUBSTANCES INSIDE POLYMERES



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SUMMARY

Since the mid-fifties of the last century plastic pipes have been operated successfully in drinking water distribution networks. Presently the first installed pipes have reached their predicted product life time of 50 years. Many of these pipes can be used for some more decades because of proven mechanical stability.

Currently produced pipes for drinking water distribution networks are dimensioned for a product life time of 100 years.

In 2009 plastic pipes have a market share of about 65% of all new piping in drinking water installations.

Following the codes of practice pipes and fittings as well as other CPDWs made of plastic materials show the same usability and stability as products made of metallic materials. This is valid within the postulated life-time of 50 years. Above all, based on their properties plastic materials have enabled the creation of new products and production processes as well as new applications.

An essential precondition for the maintenance of the actual quality level, the improvement of existing and the development of new products is the existence of a certification system including a qualified product surveillance. That is one the reasons why in the past in Germany most of the problems with plastic materials had been detected and solved in a short time.

Many problems are caused by incorrect handling or improper operation. Being aware of this it is obvious that manufacturers, plumbers, pipe layers, installers etc. are to be instructed well by training them regarding the development of the current technology.

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Many thanks for your kind attention!

Technologiezentrum Wasser Karlsruhe (TZW)

Abteilung Prüfstelle und Korrosion

Wasserwerkstrasse 4

76137 Karlsruhe

http://www.tzw.de

Dr.-Ing. Wolfgang Werner

+49 721 93163 18

wolfgang.werner@tzw.de

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