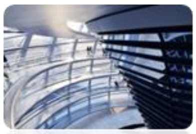
EPOXY RESINS IN WATER PIPES

ASSESSMENT OF POTENTIAL BPA EMISSIONS





The research on the potential emissions of Bisphenol A (BPA) from manufacturing, using and dismissing epoxy resins in water pipes was conducted by Beratungsgesellschaft für integrierte Problemlösungen (BIPRO) on behalf of the Epoxy Resin Committee (ERC). This is part of a series which analyses five key application sectors of epoxy resins in Europe. For more information, contact info@epoxy-europe.eu.

USES & TRENDS

About 80,000 t of BPA-based epoxy resin have been used in water pipe coatings in Europe since around 1990.[1] Roughly 60,000 t are found in underground pipes, while the remaining 20,000 t are in house installations.[2]

Epoxy resin coatings are a preferred choice for rehabilitating water pipes, thanks to their lower market price and low labour requirements. They prevent the complete replacement of deteriorated pipes. New pipes can also be coated with epoxy in their original design for special uses such as waste piping.

MANUFACTURING (LIQUID & SOLID EPOXY RESINS)

About 85% of all epoxy resin produced globally – including those used in water piping - is made by reacting BPA with Epichlorohydrin (ECH). They are used as manufacturing intermediates in the first reaction step to generate epoxy resins. The basic monomer unit of epoxy resin is called BADGE or DGEBA, whose properties (e.g. viscosity, melting point, solubility, etc.) depend on the BPA-ECH ratio. Epoxy used in water pipe linings are liquid epoxy resins (LER) formed from reacting 45% of BPA and 55% of ECH.

BPA assessment: An ERC industry survey detected low average amounts of unreacted BPA in BADGE produced today (<1 ppm). As scientific research demonstrates that BADGE can contain a maximum amount of 10 ppm BPA, the latter figure was used in order to present a highest estimate scenario. Estimating that 80,000 t of BADGE-based LER is found in water pipe linings in Europe, the total maximum amount of unreacted BPA would be equal 2,873 t (29 kg of unreacted BPA used annually).

Additional BPA may be released when leftovers and excessive quantities of BADGE are washed during manufacturing of the Liquid Epoxy Resins. BPA dissolved in water is assumed to be disposed of via the waste water treatment plants and sewages. ERC Members indicated that between 5 and 19 g of BPA per produced ton of epoxy resin were released after on-site waste water treatment in the past ten years, with an efficiency BPA removal rate of 80% to 90% of BPA. Assuming a highest estimate scenario (highest BPA quantity and lowest removal rate), it has been estimated that 304 kg of BPA (or 11 kg annually) would have left the wastewater treatment plant and entered water bodies, possibly dissolving thanks to bacteria or other biological means or degradation through UV-light.

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[1] The analysis considered two different estimations. The first looked at epoxy uses in old pipes (broken or malfunctioning) and in new ones. Industry information revealed that approximately 4,000 t of cured epoxy resin are used in Europe annually for lining broken water pipes, of which 2,667 t is composed of BPA-based epoxy resin (minus hardeners and additives). An additional 206 t is used for direct coating, for a total of 2,873 t. As pipe rehabilitation with epoxy is done since around 1990, the total tonnage used for rehabilitation should be 69,000. This number does not include epoxy in the design of pipes with specific tanks, e.g. wastewater with fat content and house installations, which is estimated to be very limited.

The second estimate took into consideration the location of the epoxy-coated pipes, which in turn informs their diameter (1-3 cm for house installation and 1-1.5m for ground installation) and the other materials used in the pipe. In this case it was estimated that 53,000 t of epoxy resin are currently present in underground pipes in Europe. 17,700 t would be the total for epoxy resin currently used in house installations (about 739 t annually). The number of pipes coated with epoxy since their manufacture was not known although manufacturers confirmed again that they are only used in specific waste water applications.

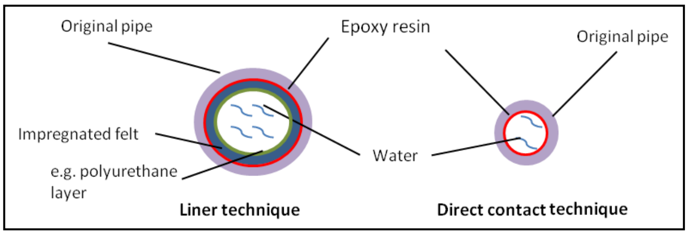
Overall the analysis concluded that around 70-80,000 t of epoxy resin are used in Europe to coat water pipes.

[2] The estimate was deemed to be realistic according to a manufacturer of epoxy resin. The percentage for pipes used in house installations was expected to be 25%.

Vessels used in the production of BADGE are washed with solvents which is then handled as hazardous waste, thus thermally degraded.

APPLICATION STAGE

Epoxy coatings can be applied using two different techniques:



- Liner technique: A new tube made of felt (with a polyurethane layer inside the tube) is applied on the damaged part or section of the pipe. The felt tube is soaked with the epoxy resin and placed inside the damaged section of the pipe using air pressure. On site, the installation of the felt is done by inversion, thus placing the epoxy resin between the new and the old pipe. The epoxy coating acts as a binding agent, meaning it has no direct contact with water during service life.

- Direct coating: A new coating is applied within the damaged pipe. The latter is dried and cleaned, then sprayed with epoxy. Afterwards, the repaired pipe section can resume its original functions. The technique can only be applied to water pipes in house installations as it does not provide the additional stability of the liner technique. The epoxy coating acts as a sealing agent by generating a new layer above the damaged pipe.

BPA assessment: Potential BPA leakage varies depending on the chosen application technique. With regard to the direct contact technique, a German pipe repairer stated that BPA levels in drinking water pipes after lining were close to 0.01 to 0.05 mg/l (an acceptable level by national and international standards, see next section 'Service Life').

With liner application, in principle, BPA losses are minimised by following the exact LER / hardener ratio suggested by the manufacturer in the instruction manual. Thus, when the installation is properly conducted, no BPA release in water can be expected because there is no direct contact of epoxy resin with water.

No information was found about leakages during manufacturing of pipes originally coated with epoxy.

Finally, the waste amount resulting from the coating process is estimated at about 1% of the total base epoxy resin. Therefore a 1 kg bucket used at this stage of the life cycle would have a residual 10 g of resin. Buckets are thermally destroyed; hence no further BPA would be released. No quantification is possible for other residues (e.g. coating tools rinsed with water for cleaning, etc.).

SERVICE LIFE

Pipes coated with epoxy applied by direct coating are frequently exposed to various liquids during service life (acids, bases, salts, germs) at various temperatures. Liner technique pipes are not considered here as they do not have any direct contact with water.

BPA assessment: Hydrolysis or thermolysis of the cured epoxy resin is expected to be low, especially as temperatures in water pipes are expected to remain well below 100°C (thermal stability of epoxy resins is expected below 100°C and up to 200°C in some cases). Physical aging of the cured resin is a more likely occurrence and may include permeability decrease, enthalpy and entropy decrease, relaxation time increase and others. Epoxies may absorb water and cause the epoxy to swell. There is currently no data determining the relationship between BPA levels and physical aging or water diffusion within the cured resin.

Multiple studies have reported the detection of Bisphenol A in drinking water. It is unclear if this is derived from BPA leaching from epoxy pipes. It should however be noted that the European Food Safety Authority and the US Food and Drug Administration have stated that there are no health risks from current uses of BPA (read more).

Existing literature on detectable BPA levels in tap water reflects variable results (including the International Research Centre on Water and the Environment, the Swedish Chemical Agency, the UK Drinking Water Inspectorate). The explanations for this variability mostly depend on the chemical composition of the accessory ingredients in the LER. Both the German association of pipe rehabilitation in house installation companies and ERC (PlasticsEurope) believe that special approvals should be established (e.g. regular testing of potentially hazardous compounds in the original epoxy resin used for the rehabilitation of water pipes). It should be noted that the highest maximum detected BPA levels in surface and groundwater (2.97 µg/l and 2.3 µg/l respectively) are well below the drinking water positive list limit of 30 µg/l set by the German Federal Environmental Agency.

It should be also noted that ingestion via drinking water represents less than 3% of the total intake of BPA. The German federal government has stated that BPA amounts from drinking water are negligible compared to other known emission paths. Drinking limit values for BPA worldwide remain variable (100 ng/l for the French health authorities; in Japan, the provisional target value regarding drinking water regulation is set at 100 µg).

END OF LIFE

Considering the amount of epoxy resins mentioned above and maintaining a worst case scenario (10 ppm as the maximum residual unreacted BPA), the calculated potential BPA residues are 200 kg for aboveground pipes and 600 kg for underground pipes currently installed in Europe. They are considered in full for this step of the life cycle analysis because no leaks are expected during service life (assuming installation is done correctly and according to manufacturers' instructions). The total tonnage of epoxy in water pipes will enter the waste stage at different times as they have not been installed simultaneously in the past 24 years.

BPA assessment: The disposal of epoxy pipes would be categorised as construction and demolition waste according to existing European regulations. However, the share of plastics in this type of waste is only 0.1 to 2% overall for all types (including epoxy resins). As epoxy resins are thermoset, hence hard to recycle, epoxy resins are not recycled individually.

The remaining considerations about disposal of epoxy resins depend on other pipes' components. In fact, epoxy resin may be decomposed thermally when associated with other materials used in the pipes such as metals (steel and copper) or concrete. These substances are melted during the recycling process and have significantly higher melting points than epoxies. Recycling rates for this type of waste in Europe are highly variable, ranging from 5% in some cases to 40%; hence it is difficult to draw any meaningful estimate for epoxy.

Metal recycling rates from construction waste range from 0.2-4%, thus not a significant amount. General metal waste (not construction only) has much higher recycling rates (about 99%). This estimate includes metal household pipes which would be recycled and degrade up to 196 kg of BPA out of all installed pipes. An additional 6 kg of BPA would be destroyed through recycling metal buckets. Concrete recycling does not necessarily entail heat treatment. After crushing, sorting and removal of metals, the granular product is used as fill material, gravel substitute, sub-base, to produce new concrete or as a surface material in roads. The latter is the main use of recycled concrete and does not involve thermal treatment, hence it is not clear whether concrete coated in epoxy would even be classified as recyclable. Hence, no available data can be taken to estimate a potential recycling quota.

A large number of pipes are potentially left in the ground and their disposal is not controlled. However it is assumed that no fluid would run through the pipes at this stage, implying that BPA release would be minimal (although liquid or heat stress cannot be completely excluded).

Discarded pipes in landfills (without coverage) are likely to experience weathering such as solar radiation, ozone and temperature fluctuation, moisture and photooxidation. Should the epoxy resin polymer matrix break and BPA leach out it is likely to be degraded by sunlight or collect in landfills. In the case of pipes collected at the bottom of disposal sites, BPA may enter municipal wastewater treatment plants and enter water bodies (thus degrading further). A worst case assumption would see the total of 600 kg of BPA from underground pipes potentially leak but it is impossible to predict how much of this remaining quota would be treated as mineral waste and incinerated.

CONCLUSIONS

An estimated 80,000 t of epoxy resins are currently in use in water pipe coatings in Europe today (about 2,873 t annually). The largest BPA release is expected during production and discharged via wastewater, generating a maximum of 304 kg. Losses during service life due to improper installation or maintenance are not possible to estimate and they are likely to be negligible and in any case not a relevant source of potential BPA exposure for humans. At waste stage it is estimated that 200 kg and 600 kg of potentially unreacted BPA is found in aboveground and underground pipes respectively. Part of this amount is expected to be degraded thermally, while the rest would end up as residual waste. Quantification of BPA potentially released at this stage is not possible.

Water pipes

Total epoxy usage mass	**Total BPA releases into environment**				
	Production	**Application**	**Service life**	**Waste**	**Total**
80,000 t	max 304 kg	not determinable	not determinable	not determinable	> 304 kg

Annual epoxy usage mass (2014)	Annual BPA releases into environment				
	Production	Application	Service life	Waste	Total
2,873 t	Max 11 kg	not determinable	not determinable	not determinable	> 11 kg

ANNEX: Life cycle stages and related BPA release for water pipes