21 Commissioning of ductile iron pipelines for drinking water

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Drinking water legislation lays down requirements for our most important food – drinking water. Water supply companies are obliged to supply hygienically impeccable water and it is for this reason that comprehensive standards and regulations specifying requirements, test methods and practices are available both for extraction and storage equipment and for distribution networks.

21.1 Preliminary comment

Apart from their fittings and valves, ductile iron pipelines consist mainly of pipes with cement mortar linings. DVGW worksheet W 346 [21.1] describes the handling of pipes and fittings with this tried and tested lining and provides advice on commissioning pipelines and putting them into operation in its two annexes, Annex 1: Changes in the pH value, Annex 2: Flushing and disinfecting.

Formerly, disinfection was the general term usually used for measures for getting the equipment into a hygienically impeccable condition.

Hence the title of DVGW worksheet W 291 "Disinfection of water supply equipment" which appeared in 1986. However experience has taught us that disinfection alone rarely produces the desired result. Preventive measures and cleaning play an important role. The revised edition of DVGW worksheet W 291 [21.2] bears the title "Cleaning and disinfection of water distribution equipment" in order to indicate the importance of careful preliminary cleaning. The worksheet places the emphasis on cleaning, while disinfection is seen as an additional safety measure. In Switzerland this issue is dealt with in the "Recommendations for the cleaning and disinfection of drinking water pipelines", SVGW guideline W1000 [21.3]; in Austria in ÖVGW guideline W 55 "Hygiene in reservoirs and pipeline networks" [21.4].

It is important that no substances should be found in the pipeline which can serve as nutrient substrates for microorganisms. Basically these substrates can originate from inappropriate pipe materials and assembly agents or they can be introduced via impurities.

The first possibility can be avoided if components with DVGW certification, for example, are envisaged right from the planning stage. This requirement is included in e.g. DIN 2000 [21.5] (Section 6.6: Materials, Section 6.6.1: Microbiological and sanitary requirements, Section 6.6.3: Testing and certification). Basically, only materials with valid sanitary certificates should be used. Components with e.g. DVGW certification guarantee that the corresponding qualifications have been met. Also Section 17 of the latest version of the German drinking water ordinance dated 2 August 2013 [21.6] specifies requirements for the extraction, processing and distribution of drinking water. These components are to be planned, constructed and operated at least in accordance with the generally accepted technical rules and standards. The entrepreneur and other owners of equipment of this kind must make sure that only suitable materials and substances are used for new constructions or during servicing and maintenance. The German Federal Environment Agency (UBA) determines assessment criteria so that the requirements can be met in practice [21.7]. For the area of drinking water, accredited certification bodies issue certificates to confirm that these requirements have been met. Similarly in Switzerland, according to SVGW guideline W4-1 [21.8] (Planning, project organisation, construction, testing, operation and maintenance of drinking water networks outside buildings) products with SVGW certification are considered to be suitable for the construction of drinking water supply equipment. In Austria this subject is regulated in Austrian standards B 5014-1 [21.9] and B 5014-2 [21.10].

The second possible means of ingress for impurities arises during the manufacturing of pipeline components, during their handling – including storage and transport – and during their installation. By means of appropriate packaging, for example protective caps for pipes, fittings and valves, the contamination of surfaces in contact with water can be avoided. Instructions for this can be found in EN 805 [21.11] and also in DVGW worksheet W 400-2 [21.12] (Section 5: Incoming goods inspection, transport and storage of parts for pipelines, Section 7.2: Cleaning parts for pipelines) for all pipeline parts during transport and storage, DVGW worksheet W 346 [21.1] for cast iron pipes and fittings and EN 1074-1 [21.13] (Section 8: Packaging) for valves. For fittings and valves, EADIPS®/FGR® standard 74 [21.14] should also be observed.

When installing a new pipeline it should also be borne in mind that, for example, only assembly agents certified according to DVGW test specification VP 641 [21.15] should be used. These are only used for the assembly process itself and must be able to be flushed out. For checking the characteristics of assembly agents in terms of rinsing/flushing them out of valves, DVGW test specification W 363 [21.16], standard Annex A "Checking the rinsing/flushing capability of assembly agents" and [21.17] are applied in Germany. Thread cutting agents must meet the requirements of DVGW worksheet W 521 [21.18] in Germany.

Appropriate cleaning mobilises and removes the unavoidable substances which could adversely affect the quality of the drinking water. Finally, disinfection has the aim of killing or damaging microorganisms which, despite careful cleaning, still remain in the equipment.

For the successful commissioning of a drinking water pipeline there are three terms to be found in DVGW worksheet W 291 [21.2] and similarly in SVGW guideline W1000 [21.3], SVGW guideline W4-3 [21.19] and ÖVGW guideline W 55 [21.4]:

- preventive measures,
- cleaning,
- disinfection.

These terms serve as guidelines and are explained below.

21.2 Preventive measures

A condition for the problem-free commissioning of newly installed drinking water pipelines is compliance with sanitary requirements right from the planning stage and throughout installation. Hence the preventive measures properly begin with the correct choice of pipeline parts along with their storage, transport and installation. Pipes and fittings in ductile cast iron for the production of drinking water pipelines are basically fitted with pipe caps when they leave the production line. The same applies for valves, where foil often protects the packaging units. The caps are there to prevent impurities and even small animals from getting inside the components during storage and transport. Obviously these caps must stay in place until the joints are assembled with the components.

Impurities introduced by personnel, by working materials such as dirty rags for wiping off the sockets and pipe brushes as well as pollutants introduced from the air (the oily mist of exhaust gas given off by 2-stroke pipe cutters!) must be excluded. During breaks in work and overnight the ends of the pipeline need to be sealed to be watertight. There is often a risk that heavy rain or groundwater will inundate the pipe trenches. Soil getting into the pipeline is the main cause of persistent recontamination. The ends of pipelines must be closed off sufficiently tightly so that neither groundwater and dirty water nor animals can penetrate.

21.3 Cleaning measures

The cleaning of pipelines is aimed at getting rid of impurities, deposits and other undesirable substances. Such substances can lead in the long term to the proliferation of micro-organisms on surfaces in contact with water and hence to a multiplication of the colony count in the water or to contamination of the water. The first stage involves mobilising these substances. After that they must be completely flushed out of the system. In no case should they be allowed to be deposited again elsewhere, thereby resulting in further detrimental effects to the water. For cleaning purposes a basic distinction needs to be made between newly installed pipelines and existing ones.

Newly installed pipelines contain agents to assist with assembly as well as impurities occurring unintentionally. In all cases these are to be mobilised and flushed away. In the event of “incidents” such as unforeseen and unplanned events like the ingress of mud in bad weather during the

Table 21.1:
Flushing process for pipelines

Flushing process	Description
Flushing water	A simple, conventional process
Flushing with water and air	Flushing with an air/water mix
	Pulsed flushing technique
Combined flushing and pigging	Flushing with water and sponge rubber balls
	Flushing with water and plastic pigs
Special cleaning techniques	High-pressure cleaning
	Cleaning with scrapers

assembly phase, intensive flushing is indicated. The aim is to remove micro-organisms and above all the nutrient substrates for micro-organisms from the pipeline. The more thorough the cleaning, the more effective and likely to succeed the subsequent disinfection measures will be.

The cleaning of water distribution systems (pipelines and reservoirs) is described in DVGW worksheet W 291 [21.2]. ÖVGW guideline W 55 applies in Austria [21.4]. Data sheet no. 7 on the flushing of pipelines in Swiss SVGW guideline W4-5 [21.20] also describes the measures necessary for this. The type of cleaning technique to be used will depend on the nominal size of the pipeline and the level of its contamination. Basically, mechanical cleaning is to be preferred over cleaning with chemicals here. With pipelines it is practically only mechanical techniques which are used. A distinction is made between accessible pipelines with nominal sizes greater than DN 600 and pipelines which are not accessible. In all cases the sections of pipeline to be cleaned must be shut off from the rest of the network before cleaning in order to prevent the flushing water from contaminating the drinking water. In pipelines it is predominantly the flushing techniques described in **Table 21.1** that are used.

21.4 Flushing with water

The simplest cleaning process is flushing with drinking water. For the flushing to be successful it is important that the water in the pipeline achieves a sufficient speed of flow of between 2 m/s and 3 m/s, which is normally possible in pipelines up to DN 150. With larger nominal sizes both the amount of drinking water required and the resulting amount of flushing water are increased. **Figure 21.1** provides information on the water required for flushing pipelines according to the nominal size.

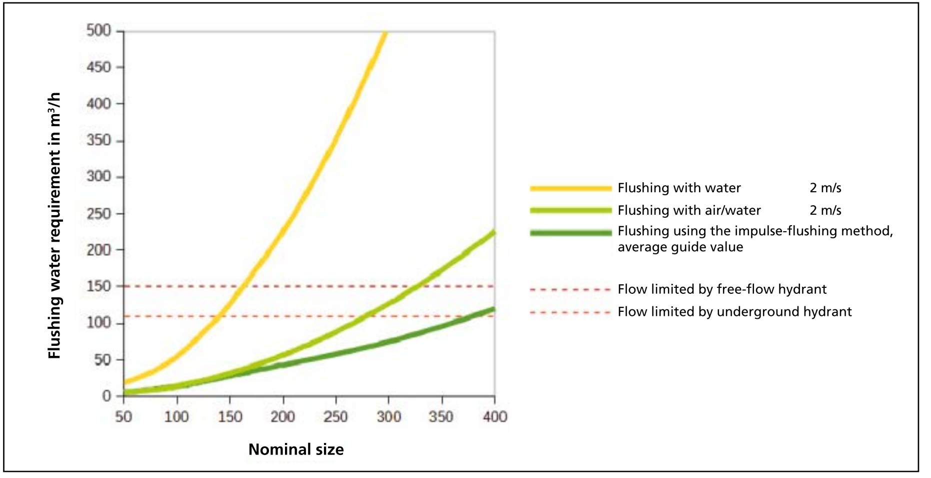

Fig. 21.1:
Water requirement for flushing pipelines where the flow is limited by underground hydrants (source: Hammann GmbH)

Depending on the cross-section of the pipeline, at least three to five times the capacity of the pipeline should be envisaged as the volume of water required. In principle, gravity flow pipelines should be flushed from the top downwards. Effects on the adjacent pipeline network must be taken into account. This means that the supply in adjacent pipelines should not be subject to any pressure drop during flushing. Also the mobilisation of deposits in pipelines upstream caused by a high flow speed should not cause turbidity of the drinking water. When draining off the flushing water local regulations and legislation must be observed. If hydrants are used in the flushing process the capacity of these fixtures needs to be taken into account. With conventional hydrants this is around 110 m³/h and with free-flow hydrants it is around 150 m³/h. Above DN 150 their capacity is no longer sufficient. There are modern techniques available for this, particularly for DN > 150. **Figure 21.1** provides information on the water volume required for flushing with water, with air and water and with the pulsed flushing technique as well as flow limiting by flushing hydrants.

21.5 Flushing with water and air

As compared with flushing with water, the work according to this technique sets high process and safety technology requirements and should only be carried out by experienced experts. Only purified air should be used. It must be oil-free with a low particle and germ count. The flushing water/flushing air ratio is between 1 : 1 and 1 : 3.

The inclusion of air improves the performance of the cleaning process. However, if air bubbles collect in the crown of the pipe, this effect may be limited to the bottom of the pipe only. Uncontrolled pressure surges can cause pipe bursts.

21.6 Impulse-flushing method

An alternative to flushing with water and air is the impulse-flushing method. Purified compressed air is delivered in pulses into a defined section to be flushed, without exceeding the dead pressure of the network **(Figure 21.2)**. This produces high-speed blocks of air and water in the section to be flushed. The turbulent flow covers a broad area and produces locally high forces to mobilise the deposits.

This drastically reduces the amount of water required as compared with flushing with water only **(Table 21.2)**.

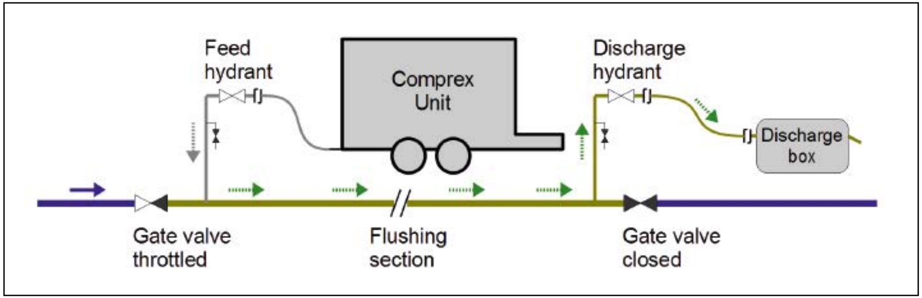

Fig. 21.2:
Cleaning a defined section of pipeline using the impulse-flushing method (source: Hammann GmbH)

This means that negative effects in adjacent networks and pipelines upstream can largely be avoided.

Research projects have enabled the effectiveness of cleaning to be increased while using less water. The blocks of water produced in partially filled pipelines reach flow speeds of more than 15 m/s. A lower water requirement also means less flushing water to be disposed of, which is of particular significance with pipelines of higher nominal sizes.

The advantages of the impulse-flushing method as compared with conventional processes can be summarised as follows:

- more intensive cleaning,
- up to 90 % less water required,
- no turbidity and pressure drops in networks upstream,
- water supply can be maintained outside the section being flushed,
- improvement in the functioning of valves.

Table 21.2:
Water required for flushing with water and for the impulse-flushing method

Nominal size	Water requirement in m³/h			
	Flushing with water at flow speed of		Impulse-flushing method indicative value	
	2 m/s	3 m/s	Low	High
80	36	54	5	15
100	57	85	8	25
125	88	133	10	30
150	127	191	20	38
175	173	260	23	50
200	226	339	35	70
225	286	429	40	80
250	353	530	42	85
300	509	763	50	100
350	693	1039	70	110
400	905	1357	90	150
450	1145	1718	110	190
500	1414	2121	140	230
550	1711	2566	180	280
600	2036	3054	220	330

The pulsed flushing technique is used first and foremost for cleaning drinking water distribution systems. New process techniques in recent years mean that even large transport pipelines with nominal sizes of up to DN 1200 can now be cleaned. In these pipelines, because of the water requirement, cleaning is often only possible using the impulse-flushing method [21.21].

Reducing the amount of water required has gained in importance over recent years. In contrast to drinking water pipelines, in times of low consumption well galleries and raw water pipelines could be cleaned without interrupting their operation and the flushing water purified at the waterworks [21.22].

Persistent impurities can not only form in old pipelines; they can also come about after “incidents”, for example in case of unforeseen and unplanned events during the installation phase of new pipeline sections. The performance of the cleaning process can be increased in such cases with the addition of solids, e.g. pieces of ice.

21.7 Other cleaning techniques

With particularly persistent contaminations, combined flushing and pigging or special cleaning techniques can be used. For pigging, sponge rubber balls or plastic pigs come into use. In both cases equipment needs to be provided for the insertion and removal of the pigs. Hydrants, and preferably free-flow hydrants, are suitable for the sponge rubber balls. With pipelines which need to be cleaned frequently, e.g. for raw or process water, pigging fittings are to be recommended.

Sponge rubber balls are normally used for cleaning pipelines up to DN 150. While more loosely adhering deposits and sediments can be mobilised and flushed out using sponge rubber balls, special pigs can also remove persistent deposits. Attention must be paid to cleanliness during the handling and storage of pigs for drinking water pipelines. During the cleaning process, precautions are to be taken to ensure that the pig does not become stuck in the section being cleaned. And if, for example, pig diameters are too small, water for carrying away the mobilised deposits can get into the section of pipeline to be cleaned.

In special cases, high-pressure cleaning and cleaning with scrapers are methods which are used. High-pressure cleaning can be used regardless of surface quality. However, the cleaning nozzles, pressure and distance from the wall must be adapted to the type of surface in order to avoid damage. Hot water can improve the cleaning. In addition a disinfecting agent can be used sparingly in a targeted manner. Particularly in this case measures should be taken to dispose of or process the flushing water appropriately.

For pipelines which are not accessible, jetting lances are used with the jet directed backwards and a free outflow of the flushing water. In accessible pipelines short sections can be cleaned manually. In this case it is possible to concentrate the cleaning on particularly heavily soiled areas. Safety specifications are to be observed in all cases.

Cleaning with scrapers is predominantly carried out before the renovation of old cast iron pipelines with cement mortar.

21.8 Disinfection process

The simplest process for disinfecting pipelines which is still widely used today is the standing technique. The disinfecting agent is left to stand in the completely filled section of pipeline for at least 12 hours.

With the standing technique, the disinfecting agent gets into the pipeline by adding the solution to be applied to the water by means of metering pumps or injectors providing a constant ratio via a connection piece, an air valve or a hydrant. During the standing time fittings in the section of pipeline being treated, such as valves or hydrants, should be operated so that the disinfectant can also get into areas where the flow is poor.

At the end of the standing time a residual concentration of the disinfecting agent should still be able to be detected in the water.

The standing technique is a static disinfection process. The disinfecting solution stands in the pipeline. Only part of it works on the surface of the pipeline. This means that the concentration of active substance decreases there, while it remains unused on the inside of the pipeline and then has to be disposed of. This disadvantage is ironed out by the dynamic disinfecting process. Here the disinfecting solution moves through the pipeline. In this way no differences in the concentration of active agent occur. With the dynamic disinfecting process, however, particular conditions are required, which are described in **Table 21.3**. With the plug method it is recommended that the disinfecting solution is moved slowly through the pipeline between two pigs.

Table 21.3:
Dynamic disinfection process

Process	Application	Effective use of the agent
Run-through method	Small nominal sizes, short pipe sections, Flushing with disinfecting solution	poor
Closed loop method	Double line or ring line, recirculation of the disinfecting solution	good
Plug method	Large nominal sizes, long pipe sections, plugging with disinfecting solution	good

Ingress of the disinfecting solution into the piping network still in operation is to be prevented by disconnecting the pipeline or by watertight shut-off devices. The shut-off devices must be checked for tightness and identified to prevent them being activated by mistake. The positive operating pressure in the section of pipeline to be disinfected must be considerably lower than that in the adjacent drinking water piping network.

21.9 Disinfection agent

A distinction is to be made between the following disinfection agents:

- commercial form,
- application form or dosage solution (stock solution),
- disinfection solution.

Chlorine and hydrogen peroxide are available as ready-to-use dosage solutions. Commercial chlorine bleaching agent has a chlorine content of 130 g/L to 150 g/L. Solutions of hydrogen peroxide often have a content of 30 % or 50 %. Chlorine bleaching agent and hydrogen peroxide solutions are to be stored in the dark, cool and tightly sealed. Light, heat and impurities accelerate deco position. Hydrogen peroxide solutions often contain stabilisers.

Chlorine dioxide solution can easily be produced on site with two components with good storage stability. The ready-to-use dosage solution usually has a chlorine dioxide content of 3 g/L. It is stable for weeks if stored correctly. Meanwhile single-component products are also available for producing chlorine dioxide solutions. Calcium hypochlorite and potassium permanganate are solids from which dosage solutions can be produced before use.

In recent years the use of disinfecting agents based on chlorine and hypochlorite has been decreasing. Reasons for this are, among other things, the restricted area of application, the production of undesirable by-products and the expense of disposal. Modern disinfecting agents are based on hydrogen peroxide or chlorine dioxide. Calcium hypochlorite and potassium permanganate do not play any significant role in pipeline disinfection.

DVGW worksheet W 291 [21.2] dedicates a special section to disinfection agents. Advice on the choice of disinfection agent and safe working practices can also be found there. The relevant table provides information on chemicals for disinfecting equipment and gives a summary of the commercial form, storage and application concentrations. Special sections deal with the individual disinfection agents including their chemical properties and fields of application. The application concentrations recommended in DVGW worksheet W 291 [21.2] for the major. disinfection agents for pipelines are:

- chlorine/hypochlorite 50 mg/L
- hydrogen peroxide 150 mg/L
- chlorine dioxide 6 mg/L

The efficacy of the disinfection agent depends essentially on the pH value. With pH values < 8 the disinfection solutions with the concentrations recommended in DVGW worksheet W 291 [21.2] work well. However at higher pH values the effectiveness of chlorine/hypochlorite and hydrogen peroxide quickly subsides. Such conditions can arise with construction components in cementitious materials and/or soft water. DVGW worksheet W 346 [21.1] provides information in its Annex 2 on the efficacy of disinfection agents with pipelines lined with cement mortar depending on the type of water. In pipelines with untreated cement mortar lining the pH value can increase considerably with soft water of water types $W_{KS}I$ and $W_{KS}II$ and hence the efficacy of chlorine/hypochlorite and hydrogen peroxide decreases. **Table 21.4** provides information on essential content in a simplified form.

Table 21.4:
Efficacy of different disinfection agents with pipelines lined with cement mortar based on DVGW worksheet W 346 [21.1], Annex 2

Cement mortar	without pre-treatment			with pre-treatment [1]		
Water typw	W_{KS}I	W_{KS}II	W_{KS}III	W_{KS}I	W_{KS}II	W_{KS}III
$K_{S\,4,3}$ in mmol/L	< 0,5	0,5 bis 2	> 2	< 0,5	0,5 bis 2	> 2
Chlorine/hypochlorite	–	0 [2]	+	0 [2]	0	+
Hydrogen peroxide	– [2), 3)]	0 [2]	+	0 [2), 3)]	0	+
Chlorine dioxide	+	+	+	+	+	+

\+ good
0 adequate
– poor

1) If applicable water treatment with W_{KS}I and with W_{KS}II
2) High disinfection agent concentration and long working time
3) Improves efficacy with addition of 1 % phosphoric acid

The redox voltage or oxidation-reduction potential (ORP) is often used for estimating efficacy. The ORP is the mixed potential of all oxidation and reduction reactions (redox reactions) occurring in the water, where the substances contained in the water and in the material as well as their possible chemical reactions are not known. Therefore the redox potential cannot be calculated from the concentration of disinfection agent alone. Added to this is the fact that many redox reactions are dependent on the pH value. **Figure 21.3** shows the correlation between redox potential and pH value for the major disinfection agents.

In order to achieve a germicidal effect there should be an ORP of $E_H > 800$ mV. These conditions apply not only to the water but they must also be ensured at the water/material phase interface. If soft, slightly buffered water is used for filling a pipeline which has a fresh, untreated cement mortar lining then, as a consequence of the increase in the pH value, the ORP required for disinfection of $E_H > 800$ mV cannot be achieved with many disinfection agents, or can only be achieved with high concentrations and long reaction times. Among these disinfection agents are, for example, the frequently used chlorine/hypochlorite which, at pH values above 8, increasingly causes difficulties with disinfection. To be recommended in these cases are disinfection agents with an ORP which has a zero or low dependency on the pH value, such as chlorine dioxide for example.

If a cement mortar lined pipeline is put into operation with sufficiently hard water, then surface layers are formed on the surface of the mortar.

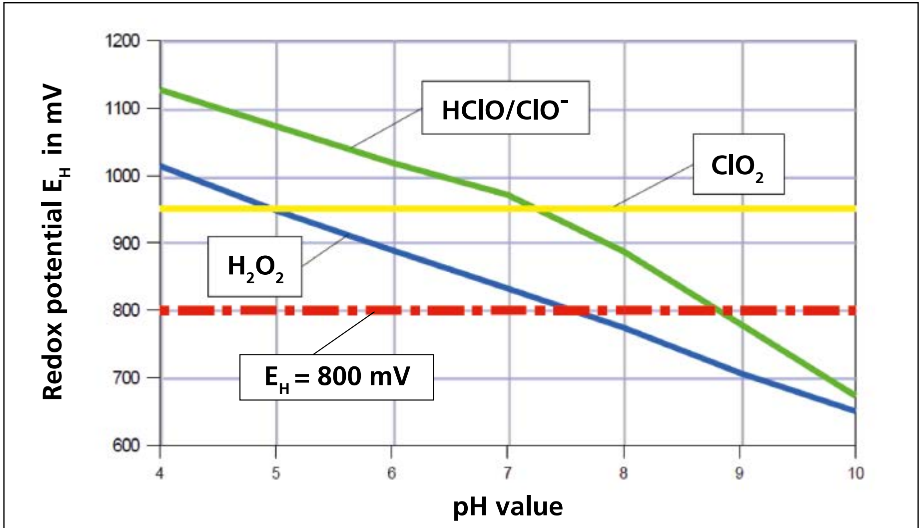

Fig. 21.3:
ORP of the disinfection agents chlorine (hypochlorous acid)/hypochlorite ($HClO/ClO^-$), hydrogen peroxide (H_2O_2) and chlorine dioxide (ClO_2) depending on pH value [21.23]

Good buffering of harder water alleviates the increase in the pH value. Accordingly, surface layers and good buffering of the water favour the achievement of the necessary redox potential.

21.10 Handling and disposal

Information on the storage, handling and disposal of disinfection agents can be found in the manufacturer's data sheets and safety data sheets. DVGW worksheet W 346 [21.1], Annex 2 offers advice here.

All disinfection agents have a tendency to decay, light and dust as well as heavy metal compounds and organic materials have an accelerating effect. Therefore disinfection agents, and above all their dosage solutions, must always be stored in cool and dark conditions. Only the equipment recommended by the manufacturer is to be used for handling them. If too much dosage solution is taken out of the storage container it must not be put back.

Dosage solutions should not be stored for too long. The manufacturer's instructions must be followed. The free chlorine content of commercially available chlorine bleaching agents diminishes constantly depending on temperature. DVGW worksheet W 229 [21.24] provides information on this correlation. This disintegration also produces undesirable by-products. Therefore it is essential that the content of free chlorine is checked after longer storage times.

In contrast to hydrogen peroxide and chlorine dioxide solutions, sodium hypochlorite solution is alkaline (chlorine bleaching agent) with pH values between 11.5 and 12.5. After it has been added, the pH value of the treated water inevitably rises. With soft water this affects the efficacy of the disinfecting solution and with very hard water it can lead to the precipitation of calcium carbonate. Reducing the pH value by mixing the solution with acids is to be discouraged because chlorine gas can escape and this may trigger an incident.

Disinfection solutions containing chlorine should basically be treated before they are introduced into the sewage system or into bodies of water. The possibilities here are dilution, chemical neutralisation with e.g. sodium thiosulphate or filtration through activated carbon filters.

Disinfection agents based on hydrogen peroxide are available under various trade names. As an dosage solution they have hydrogen peroxide concentrations of around 35 % or 50 %. For spray application there are e.g. pump sprays with hydrogen peroxide concentrations of around 3 %. These allow parts or joints to be disinfected on site.

DVGW worksheets W 291 [21.2] and W 346 [21.1], Annex 2, ÖVGW guideline W 55 [21.4] and SVGW guideline W 1000 [21.3] all provide information on the disposal of water containing disinfection agents.

21.11 Inspection and release of the pipeline

After disinfection, the disinfection solution is flushed out of the pipeline and it is filled with the water to be transported subsequently. No more disinfection agent should be able to be detected in the last filling of water. Approximately two to three times the pipeline capacity is necessary for the flushing. At the end of the flushing process water samples are to be taken from the pipeline for microbiological examination. This is done at the end of the pipeline or, with longer pipelines, also on partial sections. It is essential that the measures stated in e.g. standard ISO 5667-5 [21.25] – also included in the German standard method for the analysis of water, wastewater and sludge; general information (Group A); (A 14) – are taken into account when taking the samples. This includes run-out, cleaning and flaming of the extraction valves.

The success of cleaning and disinfection measures is to be checked by microbiological examinations. Basically, pipelines should only be put into operation once corresponding test results produce evidence of complete microbiological safety and the limit values specified for chemical substances are respected. Inspections with limit values and tests are based on the drinking water regulations. If the result is not satisfactory the measures must be repeated.

It should be mentioned that, on the basis of microbiological examinations after thorough cleaning, e.g. using the impulse-flushing method, there may be no need for disinfection [21.21]. This is of particular interest if there is not enough water available or there are large flushing volumes to be disposed of. The impulse-flushing method reduces the amount of water required for cleaning and can save the need for subsequent disinfection and rinsing of the pipeline.

21.12 Measures for existing cast iron pipelines

After repairs and other work on a pipeline, the sections of the pipeline need to be put back into operation as quickly as possible. Therefore there is no time left for standard disinfection and sampling with the issuing of a release. In this case it must be ensured by other means that the drinking water pipeline is in perfect condition from the hygiene viewpoint after completion of the work. Particular attention is to be paid here to clean practices when carrying out the work. It is recommended that the components are checked for cleanliness and disinfected with spray solution before their installation. After the end of the work the section of pipeline is to be thoroughly flushed through with water, if possible at high speed. By adding disinfecting agents, disinfection can be achieved if necessary during the flushing process. In all cases the instructions of DVGW worksheet W 291 [21.2] are to be observed.

It happens time and again that water quality is adversely affected by malfunctions, exceptional events or emergencies. Examples are failures in water purification, the ingress of impurities into the drinking water pipeline via leaks, or an unintentional connection with pipelines which do not carry drinking water. The Federal environmental agency gives recommendations on provisions for a sufficient disinfection capacity in such cases [21.26]. After disinfection of the specific area of drinking water using mobile equipment, it is above all essential to understand the cause of the problem. After remedial measures, the drinking water supply system in question must be thoroughly cleaned. As this normally involves impurities which are difficult to remove, highly effective cleaning measures are indicated. The impulse-flushing method has proved itself here. Its efficacy can be increased by the injection of solids.

Raw water pipelines have a tendency to incrustation, particularly with high iron and manganese contents. Depending on the operating method and type of raw water it can happen that, because of traces of dissolved oxygen, oxidation and precipitation already occur before treatment of the water. It is currently being investigated whether and to what extent microbial iron ochre formation is a cause of the negative impacts [21.27].

In order to safeguard the performance capability of these pipelines, regular maintenance is necessary, for example by flushing with rubber balls or pigging. By contrast, compressed air “pigs” fit every pipe cross-section and reliably carry the mobilised deposits away. The causes of deposits in raw water pipelines as well as measures for avoiding and removing them, above all using the impulse-flushing method, are described in [21.28].

21.13 Summary

When planning, constructing and commissioning new pipelines, attention needs to be paid to aspects of hygiene. **Table 21.5** provides information on work before, during and after cleaning and disinfection. Preventive measures take account of sanitary aspects during the planning and construction of pipelines. After disinfection, arrangements need to be made for the proper elimination of the water containing disinfecting agent and for putting the pipeline into operational condition by flushing it with drinking water. Microbiological testing provides information on whether the measure was completed successfully. The pipeline may only be put into operation once the release has been given.

21.14 Closing comments, additional information and prospects

21.14.1 European rules and standards

In contrast to DVGW rules and standards, to date European rules and standards do not contain any particular standard for the commissioning or the cleaning and disinfection of pipelines.
EN 805 [21.11] only provides information on disinfection in Section 12. Here, flushing with drinking water without any disinfection agent with or without the addition of air is considered as part of disinfection. Annex A.28 together with Table A.3 offers advice on the selection of the disinfection agent.

21.14.2 Research projects

In recent years a number of research projects have helped with a better understanding of connections in terms of cleaning and disinfection. The results are published in the form of thesis papers [21.35], [21.36]. There is now some important new knowledge available about biofilms in systems carrying drinking water, in particular regarding the VBNC state of bacteria. VBNC means viable but not culturable. The disinfectant influences the transitions between the culturable and VBNC stages of certain bacteria. It can alter the populations and favour fast-growing bacteria. Cleaning does not mean the same thing as disinfection. Effective cleaning is a precondition for the success of disinfecting measures.

In the explanations it is clearly described what cleaning means – namely removing impurities, deposits and other undesirable substances from the pipelines. In this process all loose deposits are to be mobilised and carried away. In no case should they be deposited again elsewhere, thereby leading to further detriment to the drinking water. The removal of deposits reduces the possibility of the implantation of micro-organisms and optimises the operating condition of the drinking water system.

Table 21.5:
Sanitary aspects when planning, constructing and commissioning pipelines

Measure	Work	Standard work/reference
Preventive measures	Selection of materials according to generally accepted technical rules and standards	Guideline 98/83/EC [21.29], Deutsche TrinkwV § 17 [21.6], DIN 2000 [21.5], Section 6.6
	Use of tested materials	Federal environment agency guidelines [21.7], DVGW worksheets W 270 [21.30], W 347 [21.31] and W 348 [21.32] SVGW guideline W4-1 [21.8] OENORM B 5014-1 [21.9] and OENORM B 5014-2 [21.10]
	Use of tested aids; flushing-out capability	DVGW test specifications VP 641 [21.15] and W 363 [21.16], Annex A, plus [21.17], DVGW worksheet W 521 [21.18]
	Use of certified products when available	DVGW index of products for the water industry [21.33]
	Avoidance of impurities during production, storage and transport; closure with caps, packaging	EN 805 [21.11], Section 10.1.3, DVGW worksheets W 400-2 [21.12], Section 5, and W 346 [21.1], EN 1074-1 [21.13], Section 8 SVGW guideline W4-3 [21.19], ÖVGW guideline W 55 [21.4]
	Cleanliness during installation; avoidance of impurities e.g. mud, dirty rags	DVGW worksheets W 346 [21.1] and W 400-2 [21.12], Section 7.2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]

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Measure	Work	Standard work/reference
Cleaning	Removal of unintentional foreign matters; removal of assembly agents	DVGW-worksheets W 291 [21.2] and W 346 [21.1], Annex 2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]
Disinfection	Killing/damaging micro-organisms; compliance with fields of application	DVGW-worksheets W 291 [21.2] and W 346 [21.1], Annex 2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]
Measures after disinfection	Flushing, taking water samples; disposal of water containing disinfection agents	DVGW worksheets W 291 [21.2] and W 346 [21.1], Annex 2 SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]
Inspection of measures	Microbiological testing; measuring the pH value	EN 16412 [21.34] Deutsche TrinkwV [21.6] SVGW guideline W4-3 [21.19] ÖVGW guideline W 55 [21.4]

Simulated calculations show areas where there is insufficient flow. Such areas in joints and components can result in an increased biofilm formation during operation and must be constructively minimised. Also the length of little-used outlets should be limited to a maximum of three times the internal diameter. In the event of contamination, areas of low flow can only be reached by means of intensive cleaning processes such as the pulsed impulse-flushing method. Simulated calculations have already helped with the optimisation of components with the aim of reducing problems with increased biofilm formation during operation, as well as improving cleaning and disinfection.

21.14.3 DVGW worksheet W 557 [21.37]

While DVGW worksheet W 291 [21.2] concerns water distribution systems, rules were needed for drinking water installations inside buildings as a result of different operating conditions, nominal sizes, materials, components and apparatus.

Based on DVGW worksheet W 291 [21.2] and as a supplement to EN 806-4 [21.38], DVGW worksheet W 557 [21.37] was produced. In fact pipes and fittings in ductile cast iron according to EN 545 [21.39] are normally only used outside buildings, but this worksheet nevertheless contains information on the operation of distribution networks of such outstanding importance that it is worth mentioning here.

DVGW worksheet W 557 [21.37] was published in October 2012 with the knowledge available at that time but it did not yet take account of the results of the latest research project [21.36]. In its structure it reflects the three themes of DVGW worksheet W 291 [21.2]:

- preventive measures,
- cleaning,
- disinfection.

DVGW worksheet W 557 [21.37] emphasises the importance of cleaning before disinfection. This advice applies equally for water distribution, in particular for impurities and contamination.

The first step in eliminating impurities is always cleaning. This also applies for microbial contaminations. Microorganisms embedded in particles or corrosion products are not really killed with the help of disinfection agents as these do not reach the microorganisms. Therefore the particles or corrosion products have to be removed by flushing or other cleaning measures. System disinfection may be necessary as an additional safety measure. Deposits favour the growth of microorganisms, which can then result in adverse microbial effects. In order to prevent this, cleaning is necessary whenever there is a presence of deposits. Where the quality of the drinking water has been adversely affected by microbial action, cleaning must be carried out as the first measure. In these cases, additional disinfection of the system may be necessary after cleaning.

The worksheet refers to the stress on materials due to disinfection. Each system disinfection places stress on the materials and components of the drinking water installation, meaning that damage may occur to the drinking water installation. Repeating system disinfection at regular intervals in order to prevent contaminations is not to be recommended for this reason.

21.14.4 Revision of DVGW worksheet W 291 [21.2]

After more than 15 years the revision of DVGW worksheet W 291 [21.2] is pending. Work begins in 2015.

21.14.5 Cleaning and maintenance

Cleaning is not only necessary at the time of commissioning in order to expel impurities and assembly agents but also plays a major role in the maintenance of pipelines. It ensures a hygienically impeccable condition and security of supply. Particularly with raw water pipelines, regular cleaning is necessary if, for example, the pipeline is affected by iron ochre formation [21.23].

The new DWA rules take account of the maintenance of wastewater pressure pipes. Here cleaning is possible by means of pigging, flushing with compressed air or the impulse-flushing method. The corresponding insertion equipment or pigging traps need to be envisaged during planning and construction. Static compressed air flushing should prevent deposits while the impulse-flushing method can target the cleaning to sections of the pipeline where it is needed. Both processes normally work online and use accumulated water for cleaning.

21.15 References

[21.1] DVGW-Arbeitsblatt W 346
Guss- und Stahlrohrleitungsteile mit ZM-Auskleidung –
Handhabung
[DVGW worksheet W 346
Cast iron and steel pipes and components with cement mortar lining –
Handling]
2000-08

[21.2] DVGW-Arbeitsblatt W 291
Reinigung und Desinfektion von Wasserverteilungsanlagen
[DVGW worksheet W 291
Cleaning and disinfection of water distribution systems]
2000-03

[21.3] SVGW-Richtlinie W1000
Empfehlungen für die Reinigung und Desinfektion von Trinkwasserleitungen
[SVGW guideline W1000
Recommendations for cleaning and disinfection of drinking water pipelines]
2000-03

[21.4] ÖVGW-Richtlinie W 55
Behälter- und Rohrnetzhygiene
[ÖVGW guideline W 55
Hygiene in reservoirs and
pipeline networks]
2012-05-01

[21.5] DIN 2000
Zentrale Trinkwasserversorgung –
Leitsätze für Anforderungen an
Trinkwasser, Planung, Bau, Betrieb
und Instandhaltung der
Versorgungsanlagen
[Central drinking water supply –
Guide lines regarding requirements
for drinking water, planning,
construction, operation and
maintenance of plants]
2000-10

[21.6] Deutsche Trinkwasserver-
ordnung in der Fassung der
Bekanntmachung vom
2. August 2013
http://www.gesetze-im-internet.de/
trinkwv_2001/BJNR095910001.html

[21.7] Leitlinien des Umweltbundes-
amtes (Übersicht)
http://www.umweltbundesamt.de/
themen/wasser/trinkwasser/trink-
wasser-verteilen/bewertungs-
grundlagen-leitlinien

[21.8] SVGW-Richtlinie W4-1
Richtlinie für Wasserverteilung –
Teil 1: Allgemeines
[SVGW guideline W4-1
Guideline for water distribution –
Part 1: General]
2013-03

[21.9] OENORM B 5014-1
Sensorische und chemische Anforde-
rungen und Prüfung von Werk-
stoffen im Trinkwasserbereich –
Teil 1: Organische Werkstoffe
[Organoleptic and chemical require-
ments and testing of materials in
contact with drinking water –
Part 1: Organic materials]
2000-11-01

[21.10] OENORM B 5014-2
Sensorische und chemische Anforde-
rungen und Prüfung von Werk-
stoffen im Trinkwasserbereich –
Teil 2: Zementgebundene
Werkstoffe
[Organoleptic and chemical require-
ments and testing of materials in
contact with drinking water –
Part 2: Cementitious materials]
2011-12-15

[21.11] EN 805
Water supply –
Requirements for systems and
components outside buildings
[Wasserversorgung –
Anforderungen an Wasserversor-
gungssysteme und deren Bau-
teile außerhalb von Gebäuden]
2000

[21.12] DVGW-Arbeitsblatt W 400-2
Technische Regeln Wasserverteilungsanlagen (TRWV) –
Teil 2: Bau und Prüfung
[DVGW worksheet W 400-2
Technical rules for water distribution systems –
Part 2: Construction and testing]
2004-09

[21.13] EN 1074-1
Valves for water supply –
Fitness for purpose requirements and appropriate verification tests –
Part 1: General requirements
[Armaturen für die Wasserversorgung –
Anforderungen an die Gebrauchstauglichkeit und deren Prüfung –
Teil 1: Allgemeine Anforderungen]
2000

[21.14] EADIPS®/FGR®-Norm 74
Formstücke und Armaturen aus duktilem Gusseisen –
Verpackung von Formstücken und Armaturen
[Ductile iron fittings and valves –
Packaging of ductile iron fittings and valves]
2013-06

[21.15] DVGW-Prüfgrundlage VP 641
Gleitmittel für Steckmuffen-Verbindungen in der Wasserversorgung –
Anforderungen und Prüfungen
[DVGW test specification VP 641
Lubricants for push-in joints in water supply –
Requirements and testing]
2009-06

[21.16] DVGW-Prüfgrundlage W 363
Absperrarmaturen, Rückflussverhinderer, Be-/Entlüftungsventile und Regelarmaturen aus metallenen Werkstoffen für Trinkwasserversorgungsanlagen –
Anforderungen und Prüfungen
[DVGW test specification W 363
Isolation valves, check valves, air valves and control valves made of metallic materials for drinking water distribution systems –
Requirements and testing]
2010-06

[21.17] DVGW-Prüfgrundlage W 363-B1:
1. Beiblatt zu DVGW-Prüfgrundlage W 363 –
Absperrarmaturen, Rückflussverhinderer, Be-/Entlüftungsventile und Regelarmaturen aus metallenen Werkstoffen für Trinkwasserversorgungsanlagen –
Anforderungen und Prüfungen
[DVGW test specification W 363-B1:
Supplement 1 to DVGW test specification W 363 –
Isolation valves, check valves, air valves and control valves made of metallic materials for drinking water distribution systems –
Requirements and testing]
2014-09

[21.18] DVGW-Arbeitsblatt W 521
Gewindeschneidstoffe für die Trinkwasser-Installation – Anforderungen und Prüfung
[DVGW worksheet W 521
Thread cutting agents for drinking water installation – Requirements and testing]
1995-12

[21.19] SVGW-Richtlinie W4-3
Richtlinie für Wasserverteilung – Planung, Projektierung, Bau, Prüfung sowie Betrieb und Instandhaltung der Trinkwasserverteilung außerhalb von Gebäuden – Teil 3: Bau und Prüfung
[SVGW guideline W4-3
Guideline for water distribution – Planning, project development, construction, testing as well as operation and maintenance of drinking water distribution systems outside buildings – Part 3: Construction and testing]
2013-3

[21.20] SVGW-Richtlinie W4-5
Richtlinie für Wasserverteilung – Planung, Projektierung, Bau, Prüfung sowie Betrieb und Instandhaltung der Trinkwasserverteilung außerhalb von Gebäuden – Teil 5: Praxisunterlagen, Themenblatt Nr. 7: Rohrnetzspülung
[SVGW guideline W4-5
Guideline for water distribution – Planning, project development, construction, testing as well as operation and maintenance of drinking water distribution systems outside buildings – Part 5: Practical data sheet, data sheet No. 7: Network flushing]
2013-3

[21.21] Bernemann, M. und Farke, O.:
Bau einer Trinkwassertransportleitung DN 700 in Paderborn
[Construction of a drinking water-main DN 700 in Paderborn]
bbr – Fachmagazin für Leitungsbau, Brunnenbau und Geothermie
2007-02, S. 16 ff.

[21.22] Immel, S., Schimmelpfennig, S., Klein, N., Utke, C., und Gnirss, R.:
Brunnengalerien und Rohwasserleitungen online reinigen
[Inline cleaning of well galleries and raw water pipelines]
wwt – Wasserwirtschaft Wassertechnik,
Heft 1–2,
2014, S. 15 ff.

[21.23] Klein, N. und Rammelsberg, J.:
Inbetriebnahme von Rohrleitungen mit Zementmörtel-Auskleidung
[Commissioning of cement mortar lined pipelines]
3R international (48),
Heft 3-4,
2009, S. 144 ff.

[21.24] DVGW-Arbeitsblatt W 229
Verfahren zur Desinfektion von Trinkwasser mit Chlor und Hypochloriten
[DVGW worksheet W 229
Disinfection procedures of drinking water with chlorine and hypochlorite's]
2008-05

[21.25] ISO 5667-5
Water quality –
Sampling –
Part 5: Guidance on sampling of drinking water from treatment works and piped distribution systems
[Wasserbeschaffenheit – Probenahme –
Teil 5: Anleitung zur Probenahme von Trinkwasser aus Aufbereitungsanlagen und Rohrnetzsystemen]
2006

[21.26] Bundesgesundheitsblatt – Gesundheitsforschung – Gesundheitsschutz
Empfehlung des Umweltbundesamtes
Vorhalten einer hinreichenden Desinfektionskapazität nach § 5 Abs. 4 TrinkwV 2001 für außergewöhnliche Vorkommnisse oder Notfälle
2004-11
https://www.umweltbundesamt.de/sites/default/files/medien/374/dokumente/desinfektions-kapazitaet_2004_11.pdf

[21.27] Mikrobielle Verockerung in technischen Systemen
http://www.anti-ocker.de/

[21.28] Klein, N. und Hammann, H.-G.:
Reinigen der Rohwasserleitungen sichert die Trinkwasserversorgung
[Cleaning of raw water pipelines secures drinking water supply]
Energie | wasser-praxis, Ausgabe 06
2008, S. 24 ff.

[21.29] Richtlinie 98/83/EG
Richtlinie 98/83/EG des Rates vom 03.11.1998 über die Qualität von Wasser für den menschlichen Gebrauch
[Directive 98/83/EC
Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption]
1998-11-03

[21.30] DVGW-Arbeitsblatt W 270
Vermehrung von Mikroorganismen auf Werkstoffen für den Trinkwasserbereich – Prüfung und Bewertung
[DVGW worksheet W 270
Microbial enhancement on materials to come into contact with drinking water –
Testing and assessment]
2007-11

[21.31] DVGW-Arbeitsblatt W 347
Hygienische Anforderungen an zementgebundene Werkstoffe im Trinkwasserbereich –
Prüfung und Bewertung
[DVGW worksheet W 347
Hygiene requirements for cementitious materials intended for use in drinking water supply systems –
Testing and evaluation]
2006-05

[21.32] DVGW-Arbeitsblatt W 348
Anforderungen an Bitumenbeschichtungen von Formstücken aus duktilem Gusseisen und im Verbindungsbereich von Rohren aus duktilem Gusseisen, unlegiertem und niedrig legiertem Stahl

[DVGW worksheet W 348
Requirements of bituminous coatings of ductile iron fittings and in the jointing area of ductile iron pipes and unalloyed and low-alloyed steel pipes]
2004-09

[21.33] DVGW-Verzeichnis wasserfachlicher Produkte
http://www.dvgw-cert.com/?id=34
http://mycert.dvgw-cert.com/verzeichnisse/index/

[21.34] EN 16421
Influence of materials on water for human consumption – Enhancement of microbial growth (EMG)
[Einfluss von Materialien auf Wasser für den menschlichen Gebrauch – Vermehrung von Mikroorganismen]
2014

[21.35] Erkenntnisse aus dem BMBF (Deutsches Bundesministerium für Bildung und Forschung) – Verbundprojekt „Biofilme in der Trinkwasser-Installation“
http://www.biofilm-hausinstallation.de/dokumente/Thesenpapie_2_0.PDF

[21.36] Erkenntnisse aus dem Projekt „Biofilm-Management“ Erkennung und Bekämpfung von vorübergehend unkultivierbaren Pathogenen in der Trinkwasser-Installation
http://www.biofilm-management.de/sites/default/files/Projektmeetings/Bonn_2014/Thesenpapier/Thesenpapier%201.1.pdf

[21.37] DVGW-Arbeitsblatt W 557
Reinigung und Desinfektion von Trinkwasser-Installationen
[DVGW worksheet W 557
Cleaning and disinfection of drinking water installations]
2012-10

[21.38] EN 806-4
Specifications for installations inside buildings conveying water for human consumption – Part 4: Installation
[Technische Regeln für Trinkwasser-Installationen – Teil 4: Installation]
2010

[21.39] EN 545
Ductile iron pipes, fittings, accessories and their joints for water pipelines – Requirements and test methods
[Rohre, Formstücke, Zubehörteile aus duktilem Gusseisen und ihre Verbindungen für Wasserleitungen – Anforderungen und Prüfverfahren]
2010