carbonit®

FILTER MADE IN GERMANY

2nd Edition Status: 06/2007

Reverse Osmosis & Co.

Scrutinizing alternative filtration processes

westa-gruppe

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Introduction

The CARBONIT® Filtertechnik GmbH manufactures water filters based on sintered activated block carbon. However, when deciding on a household drinking water filter several processes or methods are available. In this brochure alternatives to activated carbon filtration are exactly described – especially the process of reverse osmosis.

HOUSEHOLD WATER FILTERS IN ORDER TO REDUCE CONTAMINATION LISTED AS DIFFERENT METHODS:

- loose activated carbon, poured/condensed
- activated block carbon, extruded
- activated block carbon, sintered (e.g. CARBONIT® NFP)
- ultra filtration (hollow fibre/capillary membranes)
- reverse osmosis
- steam distillation*

Combinations:

- loose activated carbon & ion exchange** (e.g. jug filter)
- activated block carbon & ultra filtration (e.g. CARBONIT® Clario)

* *Strictly seen we are not dealing with a filtering method here. However, the process is used for the same purpose.*

** *The ion exchange process is not considered a filtration. In order to soften the hard water hard ions are exchanged against other ions.*

Activated carbon

The big advantage of activated carbon for filtration purposes lies in the extremely large inner surface of the porous materials on which a large quantity of adsorbable pollutants can be accumulated. The patented CARBONIT® block additionally provides a reliable maximum pore size so that larger particles and mainly bacteria cannot enter the filtrate (see the brochure "Natural Product Activated Carbon").

Adsorption + mechanical filtering

Apart from the activated carbon, there are three further processes that can be considered when it comes to the after-treatment of drinking water: ultra filtration with capillary membranes, reverse osmosis and steam distillation.

Ultra filtration (hollow fibre/capillary membranes)

Capillary membranes are thin, bendable tubes with a water-permeable synthetic internal wall lining. The capillary effect (in the tube and also within the wall lining itself) ensures a high water flow from the outside to the inside of the membrane. The special interlacing of the synthetic polymer results in a definable pore size. Particles and organisms that are larger than this size cannot pass the wall lining and remain attached to the outside wall. Dissolved substances are usually much smaller and are not filtered out. This method is therefore used here in Germany mainly for sterile filtration (against bacteria, viruses and other micro-organisms). In CARBONIT® IFP Puro and NFP Clario such membranes constitute the second step of complex filtering.

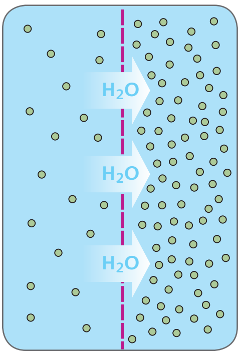
Hygiene filters

Reverse osmosis

Reverse osmosis is a quite fine mechanical filtration process. The membrane of the filter medium is not porous, rather it can take in water in the interspaces of its molecules. On such a flat membrane the natural phenomenon of osmosis occurs. The osmotic pressure counteracts the flow direction of the filter.

Osmosis

Osmosis is the act of motion at semipermeable membranes between aqueous solutions that takes place in nature, e.g. with nearly all animals and plants, at the walls of the cells – between the outer-cellular and inner-cellular solutions: Through the cell wall membrane water molecules move freely in both directions without being affected by any outer influences.



Ill. 1: Osmosis: between unevenly concentrated solutions pure water moves from the side with less concentration to the side with more through a semi-permeable membrane

If there is an uneven concentration (= amount of dissolved salts in the water) of the separated solutions, then an osmotic pressure occurs that acts in the direction of the side that contains the higher concentration level as more water molecules wander through the membrane from the side with the lower concentration level. The osmotic pressure increases in accordance with the difference in concentration of the solutions.

Diffusion

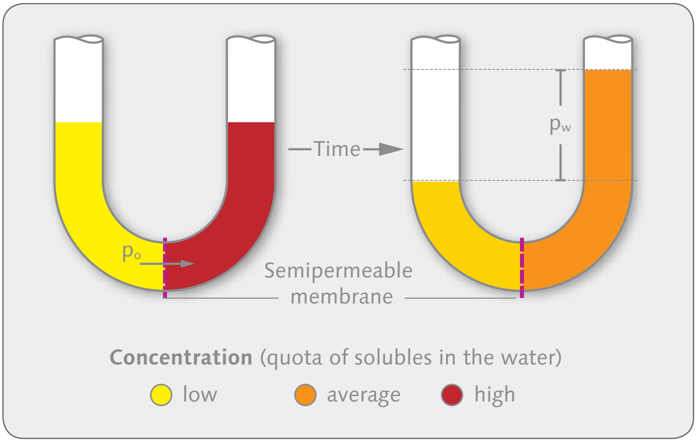
In addition, most of the substances that have been dissolved in water wander through the membrane after a certain time. However, this process is much slower than that for the smaller H_2O molecules. This occurs due to molecular diffusion which is generated through the self-movement of the particles (Brownian Movement). Important: The diffusion of dissolved substances through semipermeable membranes takes place independently of any pressure!

MEMBRANE MOVEMENT RATE & DIFFUSION

The following picture could be of help: Imagine a very thick hedge. When there is a wind lull you can – with a bit of patience – manoeuvre a pencil or a ping-pong ball through it; small birds, caterpillars etc. can also get through by themselves and their own efforts – in both directions. If a storm comes up most of these objects/animals are pressed against the hedge. Onto the other side it is nearly only air that gets through and this air has been slowed down dramatically. The air in this picture symbolises the water; the objects and animals are the dissolved foreign particles.

The effect

If one separates normal tap water (with an average salt concentration[1]) and distilled, i.e. salt-free water, with a semipermeable membrane, then immediately an osmotic pressure of a little less than 1 bar will act upon the direction of the tap water. In seawater approx. 30 bar would be created with which the pure water forces itself through the membrane.



Ill. 2: The water flow, due to the osmotic pressure p_o (at the start at the highest level) ends on the more saturated side if the counterpressure of the water column p_w has reached the same level ($p_o = p_w$). After a certain time the osmotic pressure would sink even further due to dissolved substances that are diffusing to the left. In the end one would have two equal concentrations without any difference in pressure.

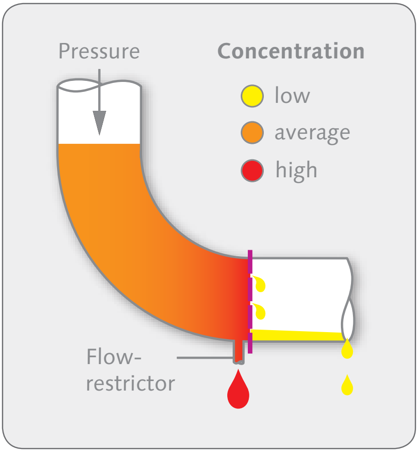
1 *Salts, for example, are the hard water creators calcium and magnesium carbonate but also all other compounds from substances that have been dissolved in water.*

The filter process reverse osmosis

In the 1950s the first successful production of membranes with cell wall-similar features took place and one recognised that through the reversal of the natural flow of water (to the saturated solution) one could produce very pure water.

Functional principle

By pressing raw (i.e. untreated) water against such a semipermeable flat membrane using increased pressure (greater than the osmotic counterpressure), one really does get quite salt-free water (so-called permeate) on the rear side of the membrane – even though this may only be drop-by-drop! The reduction here is approx. 80-97 % with regard to dissolved substances and >99.9 % with all others.



Ill. 3: The principle of reverse osmosis: Through pressure pure water is "pressed out" of the raw water. The remaining, highly concentrated water is discharged into the sewage system.

As the (salt) concentration increases on the inlet side due to the pressing out of the pure water, the osmotic (counter)pressure is also increased. In practical terms, though, only a constant inlet pressure is available (conduit pressure or pressure pump) and therefore the process would come to a standstill (see Ill. 2, on the right). In addition, a solution with too high a level of saturation would hold the risk that the dissolved substances (especially the "lime") would crystallise out and "block" the membrane. In order to counter this, the raw water (the concentrate), which is becoming more concentrated all the time, is constantly being discharged and in return fresh raw water is being channelled to the membrane.

Unlike activated carbon filters reverse osmosis membranes do not hold on to the harmful substances but rather separate "the good from the bad".

Waste water

The controlled discharge of the concentrate into the sewage system occurs with the help of a flow restrictor which is small enough so that it doesn't decrease the pressure on the inlet side yet big enough in order to avoid a blockage taking place and is therefore capable of maintaining a sufficient difference between the inlet pressure and the osmotic counterpressure.

> **EFFECTS ON THE PURE WATER OUTPUT**
>
> - Salt content: the higher, the poorer*
> - Pressure: the lower, the poorer*
> - Temperature: the colder, the poorer*
>
> ** that means that the filtration process is much slower and the more waste water is necessary for the same amount of pure water being produced.*

The necessary relation of concentrate waste water to the amount of produced pure water depends on the salt content of the raw water (indication here can be, for example, the degree of hardness), on the pressure that exists at the inlet and also on the temperature of the water. Through a heated membrane water can be pressed much more easily than through a cold one.

In Germany the manufacturers usually go by approx. the following figures based on experience: Water hardness 20° dH, conduit pressure 4 bar, water temperature 10° C. The reverse osmosis units are adjusted accordingly and they then produce a ratio of 1:3 to 1:4 of pure to waste water (permeate: concentrate). That means for every litre pure water approx. 3-4 litres of waste water are being "used".

The flat membrane

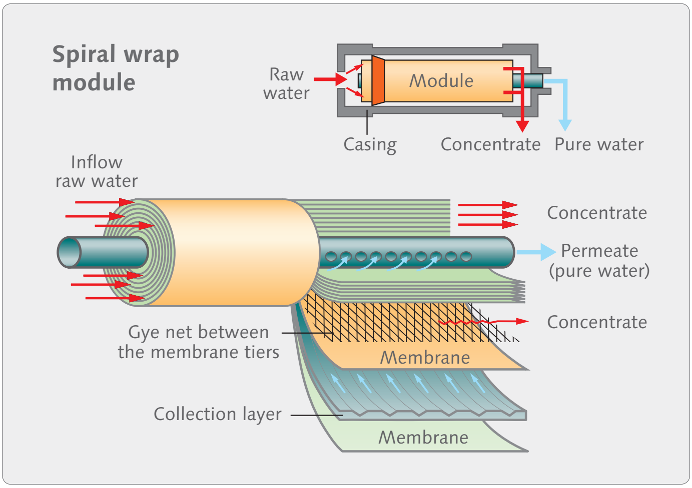
A reverse osmosis membrane is usually a film of interconnected composite synthetic material. "Viewable" pores don't exist, that is why it seems as if the membrane is watertight under zero pressure conditions. The material interspaces (within the micrometre region), however, can take up water as well as other molecules. With increased pressure one can move H_2O molecules to the passage and thereby one can produce near pure water.

> **MEMBRANE QUALITY**
>
> Modern household filters use TFC membranes (= Thin Film Composite). They are made up of polyamide/polysulphones and, contrary to others (e.g. cellulose acetate), are not attacked by bacteria. However, they are more sensitive when it comes to free chlorine.

So that enough pure water can be produced even though the filtering process is very slow, the membrane has to be quite big. For this one uses a special wrapping method with separation tiers on both sides of the membrane.

Contaminant removal

The reverse osmosis is the finest filtration method that can be applied at all. During the operation only H_2O molecules as well as a few dissolved ions are allowed through. The method is therefore



Ill. 4: Spiral wrap module of a reverse osmosis filter. The special structure allows for quite a large membrane surface.

AREAS OF USAGE FOR REVERSE OSMOSIS

- Drinking water processing, centralised as well as decentralised (household appliances)
- Table water production
- Seawater desalination
- Concentrating liquids (juice, wine…)
- Water for laboratory and medical purposes as well as many other technical purposes

used worldwide in both the industrial production of table water ("baby water" etc.) as well as for the processing of seawater (extremely high salt concentration) and much more. A reverse osmosis unit can nearly completely remove all known undissolved as well as dissolved foreign substances, including those that are not adsorbable by activated carbon, such as the hard water creators calcium and magnesium or nitrate and nitrite (reduction 80 % - 95 %). The percentage of dissolved substances in total is reduced by 85 % to over 99 %, the pure water usually has a conductivity capacity of about 10 - 50 μS/cm (water with a high Ohm level, 100,000 - 20,000 Ohm).

Downtime and hygiene

Contamination by diffusion

As the picture of the hedge has made clear, a reverse osmosis membrane normally functions only under pressure. If no pure water is being produced at the moment, with time mainly small dissolved substances can manage to make their way through the membrane. As the area behind the membrane (the pure water side) contains a quite small amount of accessible water, this effect does not stand out especially negatively when it comes to basic, tank and tabletop devices (see next page): "The first glass" after a longer downtime has a slightly higher percentage of dissolved salts than the following freshly filtered water… This effect is even clearer in direct-flow devices without pure water flush (see page 13).

Bacterial contamination

If the conditions are bad (heat, contaminated raw water) and very long downtimes have occurred, then even bacteria can make their way through the membrane by the process of "growing through" – and then spread out or attach themselves here. Therefore, responsible providers will recommend a prophylactic disinfection at certain intervals (e.g. using hydrogen peroxide or established membrane chlorine compositions).

Several manufacturers of tabletop or pressure tank units are increasingly using especially slow membranes that take longer when reproducing the water withdrawn – but of course not slower than what comfort allows for. Slower membranes increase the water quality and reduce the danger of an occurrence of microorganisms as the downtime here is much less.

MEMBRANE OUTPUT

The filter output and speed of a membrane is given in the name: A 50GDP membrane (or "G50") produces during non-stop operation and under American standard conditions 50 gallons per day, so about 190 litres. Under local conditions here (colder water, lower pressure) it still produces approx. 100 litres. In most cases this much will not be needed!

Change in pH value

"Acidic" reverse osmosis water

The largest part of the dissolved substances in German drinking water of average to high levels of hardness is the "lime": the hard water creators calcium and magnesium carbonate dissolve in a solution with free carbonic acid (made up of carbon dioxide that has been dissolved in water) and make up the water-soluble calcium and magnesium hydrogen carbonate. The reverse osmosis process severs this connection and keeps the "lime" back. The carbonic acid H_2CO_3 can pass the membrane and changes the pH value of pure water despite the small overall amount of 0.5 to 1.5 points less, therefore into the acidic region. Practically all of the very pure, soft waters, no matter what their origin, are thus a bit on the acidic side chemically seen.

Use in household filter devices

In conventional household filter units only approx. 1 to 5 litres of pure water are produced hydraulically (without any additional pumps in use) every hour with the normal conduit pressure in spite of an optimised membrane surface. This flow volume (approx. 15 - 80 ml per minute) is often not enough for the daily consumption requirements: in basic devices the water, for example, has to be collected in a larger bottle during the night…

3 solutions are provided for more usage comfort::

- Pressure tank units,
- Tabletop units,
- Direct-flow units..

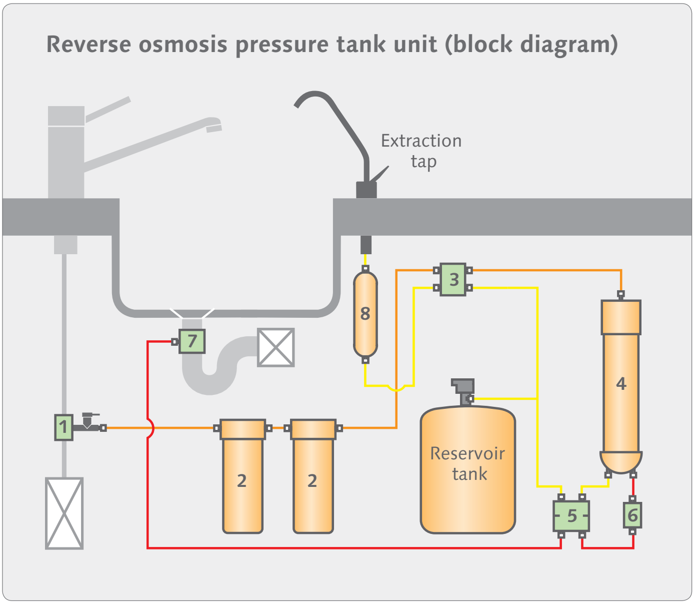
1) Pressure tank units

Pressure tank units

This device type has been on the market since about 30 years and is widely used. The devices that are installed under the table conduct the pure water into a storage pressure tank with an expandable inner tank ("rubber bubble"). If necessary, the collected pure water is drawn over the separate extraction tap directly from the tank with a pressure of approx. 1 - 2 bar. The available volume depends on the size of the tank (mostly approx. 8 - 10 litres).

A pressure tank unit is firmly attached to a cold water supply pipe and to the sewage system. Basic models (without pressure increases and steering elements) operate without electricity – also those that have permeate pumps (see page 12).

In order to protect the high-grade membrane(s) from particles and aggressive substances (e.g. free chlorine), these devices have one to three pre-filters (sediment and/or activated carbon filters) installed depending on the location they are being used as well as the raw water quality and that have to be replaced at regular intervals. Even though only real foodstuff synthetics are used, the taste can be affected if longer contact periods occur (e.g. within the tank). That is why the pure water is retreated with an activated carbon filter and, if necessary, a sterile post-filter (e.g. those made by CARBONIT®) directly before extraction. This one also has to be replaced at regular intervals. The reverse osmosis membrane itself can work flawlessly for quite a long time; the time period until wear and tear takes place (e.g. cracks) is between 3 and 8 years depending upon the raw water quality, pressure, temperature, maintenance and usage of the unit. Blockages are theoretically possible at any time, for example if for a certain time period very hard or murky water is being filtered.



Ill. 5: Block diagram of a pressure tank unit.
1) Connection to the water conduit
2) Pre-filter (sediment/ activated carbon)
3) Pressure shut-off
4) Membrane module
5) Permeate pump - optional
6) Flow restrictor
7) Waste water connection
8) Post-filter (activated carbon and/or sterile filter)

pure water
raw water
concentrate (waste water)

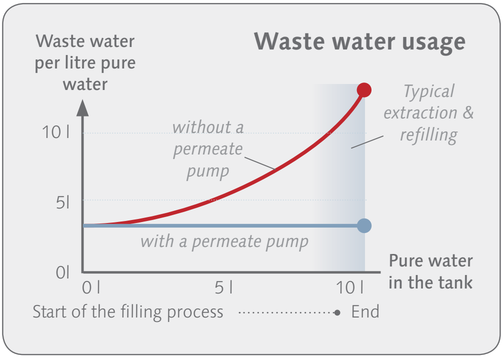
Counter-pressure problem

The pure water volume that is extracted over the separate filter water tap is reproduced automatically and refilled by the unit. Due to the construction, the water pressure rises on the whole of the pure water side together with the capacity of the reservoir tank. This adds itself at the membrane to the osmotic pressure of the pure water and thereby lessens the difference in pressure to the adjacent conduit pressure on the inlet side. Less pressure at the membrane means less pure water production while at the same time the waste water flow remains constant over the flow restrictor. For one litre of pure water, therefore, one does not use 3 - 4 litres of waste water anymore; instead it can be up to approx. 15 litres.

For normal usage this means: The user extracts a litre of pure water from the full tank. The unit automatically starts with the reproduction process until the integrated pressure shut-off senses a preset, minimal difference in pressure and the production is stopped by closing the inflow. This production takes place with a nearly full tank, therefore with a high counterpressure and thus comparatively takes quite a long time. The result is a large volume of waste water with a quite small pure water yield (see the illustration on page 12).

Permeate pump

This effect can momentarily only be avoided with a so-called permeate pump. This pump is operated hydraulically by the flow of the concentrate and "shoves" the produced pure water in portions into the pressure tank. Thereby the counterpressure created here does not make its way back to the membrane and the pure water yield remains constant at approx. 1:3 to 1:4. In order to efficiently operate a pressure tank unit, a conduit pressure of at least 3 bar is necessary. Alternatively an electric pump to increase the pressure has to be installed.



Ill. 6: Waste water usage by pressure tank units without / with a permeate pump

2) Tabletop units

Tabletop units

The first reverse osmosis household filters were tabletop devices with connecting adapters for the sink tap. They functioned just as pressure tank units did, only the filter unit and the reservoir tank could be found in one device "on a table". The permeate is channelled into a zero pressure collector (best to seal it air-tight and light-proof) out of which it is extracted with a tap nozzle. Some of the devices also provide a post-filter in order to improve the taste and/or for hygienic purposes. As the connection (cold fresh water and waste water) is still quite complicated (both pipes have to be mounted through the work surface under the sink or connected to a special faucet valve) and the devices have quite large dimensions in order to store a proper reservoir volume, the total proportion of this device type is comparatively small. However, the counterpressure problem does not occur and a permeate pump is not necessary.

3) Direct-flow units

Direct-flow units

These units (mostly installed "under tables") deliver freshly filtered pure water "with the press of a button". Thereby they have quite large (approx. 50 to 100 times the surface area!) or a bit more permeable membranes at their disposal as well as having an integrated pressure increase. Under normal conditions, such filter devices can produce approx. 1 - 3 litres per minute. They don't need a reservoir and thereby avoid the problems with regard to tank and counter-pressure that are connected with this.

Diffusion problem

The quality of the pure water during operation is very good even when "more porous" special membranes are used and comparable to that of tank and tabletop devices. A problem does occur during periods of non-operation. During the downtime periods (longer than with pressure tank units as production only takes place during the extraction process) a diffusion of considerably more foreign substances in a much shorter time takes place through the more porous membrane material into the pure water side. Due to the large membrane chamber the entire pure water area is much larger than in other devices. Up to 3 litres of "not so pure" pure water have to be extracted until the optimal, freshly filtered water comes out of the tap. At times a special pure water flush tank method is optionally provided in order to fill the entire unit interior with pure reverse osmosis water after the extraction process has been completed. Smaller extraction volumes, however, hereby lead to a very high water consumption.

DECEPTIVE SALES ARGUMENTS

When looking for arguments in favour of their own treatment method, vendors also make use of untrustworthy and dubious methods. Especially the reverse osmosis dealers use a device time and time again that produces coloured, foamy outfall with the help of a current flow in normal tap water. In water that has been filtered with reverse osmosis, this does not occur. The cause of this effect, however, does not lie in the contaminant level but rather in the varying conductivity of both waters. The foam is mainly being produced by the two metal rods that are being held into the water through electrochemical corrosion as soon as a current flows between the two. Pure water – as water after reverse osmosis – cannot conduct any electricity as it does not contain any (or very few) salts/minerals. That is why the metal rods cannot react. Trustworthy vendors show the change in conductivity, i.e. the reduction of the dissolved substances, with the help of a measuring device. The problem is: numbers are not as spectacular as unsightly foam.

Distillation

Steam distillation

Steam distillation basically copies natural purification (evaporation). In a boiler water is heated to approx. 80° C. During the evaporation process all of the substances of the water remain in the boiler except for volatile organic compounds that are then filtered with a basic activated carbon filter. One gets fully desalted, pure water that is very similar to condensed, rain or dew water – almost free of any foreign substances. The remaining percentage of dissolved substances is below 1%, the conductivity capacity is about 5 - 10 µS/cm.

Steam distillers are electrical household appliances that, for example, in the 800 W version completely evaporate 3 litres in approx.

4 - 5 hours. The boiler has to be regularly cleaned of the residue left behind (that can be up to 1g per litre!). The energy consumption produces costs of about 15 to 20 €-Cent per litre.

Note...

... on the suitability of reverse osmosis or (steam) distilled water as drinking water.

Steam distilled water is drinkable

First, the misconception that water that has a very low mineral content (therefore, as an example, distilled water) is acutely dangerous to one's health has to be disagreed with. In nature, surface as well as spring or rock water contains quite varying levels of minerals. Since eons many of these have been used for human consumption: Rain water, melted snow and ice or condensate with an extremely low level of dissolved minerals as well as spring, rock or well water with a at times very high concentration.

Steam distilled water, however, cannot be put on a par with commercially available distilled water for such things as batteries, irons and steam cleaners. This water is not produced in order to be consumed as a foodstuff and should therefore – amongst other reasons due to the technical residues from the desalination process – not be drunk.

Main task of the water

When judging the health value of the minerals that are taken on by water, the experts have quite different opinions. Important, though, is the recognised view that the main task of potable water is not the adequate supply of nutrients but rather serves to compensate the lost amounts of liquid (over the respiratory and excretion functions). The – as far as is possible – comprehensive elimination of harmful and dangerous substances is our focal point. This is surely true for all other manufacturers of high-quality household filter devices.

We hope that with this brochure we have been able to give you an objective overview of the alternative filter methods for homeowners and private households.

We are of course also open to criticism. We would be delighted to receive your suggestions and supplementary comments.

Imprint

Publisher:
CARBONIT® Filtertechnik GmbH,
Salzwedel, Germany
www.carbonit.com

Compilation:
Roman Rossberg, Wasserladen GmbH
www.wasserladen.de

Design/Layout:
zwoplus, Berlin
www.am-gruppe.net

Translation:
Marc Heinitz, Berlin
www.proz.com/profile/70143

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