Hyperionised water: filtration, filter media compatibility and detailed physical & chemical explanations

Hyperionised water has a hyperionic state, i.e. a specific physical & chemical equilibrium involving the distribution of dissolved ions, their electrostatic interactions, their solvation (ion-water molecule interaction) and electrochemical parameters (redox/ORP potential, ionic activities, etc.).

This state can be altered when water is circulated through filtration systems designed for "conventional" water, as some filter media do more than simply retain particles: they adsorb, exchange or reconfigure ions at the solid/water interface. In this case, the filter becomes a chemical actor capable of neutralising the hyperionic state.

Summary for the general public
A filter can do more than "filter": certain materials interact with the water and can gradually diminish its properties.

1) The key principle: the hyperionic state is sensitive to solid interfaces

1.1 Water is not «the same» near a surface: the electric double layer

When water comes into contact with a solid, an **electric double layer** (EDL) is formed:

- a layer of ions "bound" to the surface (Stern layer),
- a diffuse layer where ions are distributed according to electrical potential.

This arrangement depends on the water's ionic strength, defined by:

$$I = \frac{1}{2}\sum_i c_i z_i^2$$

where c_i is the molar concentration of ion iand z_i is its charge.

The typical "size" of the electrostatic interfacial region is the Debye length:

$$\lambda_D = \sqrt{\frac{\varepsilon_r \varepsilon_0 k_B T}{2 N_A e^2 I}}$$

ε_r: relative permittivity of water

ε_0: permittivity of free space

k_B: Boltzmann constant

T: temperature (K)

N_A: Avogadro's constant

e: elementary charge

I ionic strength

Interpretation: the more ionised the water (high I), the smaller λ_D: the interfacial effects are highly localised but very intense.

Summary for the general public

On contact with a material, water rearranges itself into a thin «electrical» layer. The more ions the water contains (e.g. seawater), the greater these effects.

1.2 Electrochemical potential: why ionic balance can be «shifted» by a medium

The behaviour of an ion in water is governed by its **electrochemical potential**:

$$\mu_i = \mu_i^0 + RT\ln a_i + z_i F\psi$$

μ_i: electrochemical potential

μ_i^0: reference

R: ideal gas constant

a_i: activity of ion i

F: Faraday constant

ψ: local electrical potential

The activity is:

$$a_i = \gamma_i c_i$$

(γ_i: activity coefficient, c_i: concentration)

Crucial point : close to a surface, $\psi \neq 0$ and the ion distribution changes. If a medium filters, adsorbs or exchanges ions, then c_i, γ_i and therefore a_i change. This shifts the balance that supports the hyperionic state.

Summary for the general public

Certain materials «attract» or «capture» ions: this changes the water's internal balance, rather like removing ingredients from a recipe.

2) Why silica-based media (sand/glass/ diatomite) are incompatible

2.1 Silica and glass: same surface chemistry (silanol groups)

Filter sand (quartz), filter glass beads, diatomite and many related “mineral” media share surfaces rich in **silanol groups**:

$$\equiv \mathrm{SiOH}$$

These groups ionise according to pH:

$$\equiv \mathrm{SiOH} \leftrightarrow \equiv \mathrm{SiO}^- + \mathrm{H}^+$$

When the surface carries $\equiv SiO^-$, it becomes negative and attracts cations:

monovalent: Na^+, K^+

divalent: Ca^{2+}, Mg^{2+}

This attraction creates:

ionic accumulation at the interface,

partial trapping or specific adsorption,

changes in local **activities**,

rearrangement of the interfacial water layer (hydrogen bonding and solvation).

Summary for the general public

Sand and glass are not neutral: their surfaces carry charges that attract ions and modify the water passing through.

2.2 The «total surface area» effect: why a sand filter rapidly neutralises hyperionic water

A filter bed (sand or glass) combines:

a large **specific surface area** (aggregates),

high **contact time** (deep bed),

repeated passes (pool/spa recirculation).

Even if the interaction “per cm²” is low, the total effect becomes dominant, as the number of interfacial sites is enormous.

Interfacial capture can be represented by simplified adsorption kinetics (schematic):

$$\frac{dq}{dt} = k_a C(1-\theta) - k_d \theta$$

q adsorbed quantity

C solution concentration

θ: fraction of occupied sites

k_a, k_d: adsorption/desorption constants

If the total surface area is large, the filter's effective capacity to "rearrange/ capture" increases sharply.

Summary for the general public
The more surface area in contact (fine sand, large filter, continuous circulation), the more the water is «reconditioned» by the medium... and the more its properties diminish.

2.3 Diatomite: an aggravating example

Diatomite (diatomaceous earth) is a highly **porous** silica with a very **large specific surface area**. Therefore:

more active interfaces,

accelerated capture/rearrangement effects.

Summary for the general public
Diatomite is highly porous, further amplifying interactions with water, making it particularly unfavourable.

3) Zeolites: ion exchange («chemical» media, not just filter media)

Zeolites are microporous aluminosilicates used specifically for **ion exchange**.

3.1 Typical exchange reactions

Schematic examples:

$$Z - Na + K^{+} \leftrightarrow Z - K + Na^{+}$$

$$2(Z - Na) + Ca^{2+} \leftrightarrow Z_2 - Ca + 2Na^{+}$$

This directly modifies:

ionic composition (cations),

ionic strength I,

activities a_i,

balances associated with the hyperionic state.

Summary for the general public
A zeolite acts like an «ion sponge»: it transforms water chemistry by exchanging ions.

4) Activated carbon: massive adsorption + electrochemical impacts (ORP)

4.1 Adsorption: why it upsets the balance

Activated carbon has a very high specific surface area and adsorbs a large number of dissolved species.
Two classic models:

Langmuir :

$$q = \frac{q_{\max} KC}{1 + KC}$$

Freundlich :

$$q = K_F C^{1/n}$$

q mass adsorbed by carbon mass

C solution concentration

K, K_F, n constants

Adsorption removes dissolved species and shifts the solution balances. For a hyperionic state that depends on an ionic/solvation equilibrium, it is structurally unfavourable.

Summary for the general public

Activated carbon is designed to «suck out» what is dissolved. However, to preserve a particular state of the water, you need to avoid a material that constantly removes elements.

4.2 ORP / redox: Nernst relationship

The redox potential follows (for a given pair):

$$E = E^0 - \frac{RT}{nF} \ln Q$$

E measured potential

E^0: standard potential

n number of electrons exchanged

Q reaction quotient

Carbon surfaces can promote certain surface reactions (adsorption + electron transfer), locally modifying Q and therefore E

Summary for the general public
A medium can also influence the «oxidising/reducing» balance of the water: this can contribute to destabilising the desired state.

5) Golden rule: «the more chemically efficient, the more incompatible».

A "high chemical performance" filter medium (adsorption, ion exchange, active surface, microporosity) is not neutral. Hyperionised water needs a hydraulic and filtering environment **that filters without reintroducing chemicals**.

Summary for the general public
Filters that modify water the most (carbon, zeolite, silica) are precisely those to be avoided.

6) Compatible media: neutral mechanical filtration

6.1 PP/PE polymers (polypropylene/polyethylene)

These media (cartridges, bags, filter elements) are preferred because:
relatively neutral surface,
no structural ion exchange,
no massive adsorption,
interception/screening filtration

Summary for the general public
Polymer cartridges retain particles without «capturing» ions: they preserve water better.

6.2 Cellulose (cotton/paper/fibers)

Mechanical filtration media:
effective on particles,
chemical interactions are generally weak compared with active mineral media.

Summary for the general public
Fibre filters act like a «fine sieve» and better respect the balance of the water.

7) Practical recommendations (pool, spa, thalassotherapy facility, seawater)

Pools / spas: PP/PE cartridges and/or cellulose fibrous media are preferred.

Seawater: extra care, as high ionic strength → stronger interfacial interactions.

Domestic water / networks: aim for stability + neutrality, avoid active mineral media.

Summary for the general public

The more salt-laden the water (seawater), the more «neutral» filtration is required.