How to ensure the implementation of a breakthrough technology to solve the water crisis

1. The different stages of a conventional drinking water treatment

1.1 Pre-treatment

The physical processes (screening and sieving) make it possible to retain the waste while the chemical processes (preoxidation by sodium hypochlorite, ozone or potassium permanganate) allow the elimination of iron and manganese, to act on the color of Water (seaweed).

1.2 Clarification

This is an essential step for surface water and karstic groundwater. It makes it possible to obtain clear water by elimination of the suspended matter, and thus turbidity. The clarification may combine the following processes:

Coagulation / flocculation

A physicochemical process whose purpose is to destabilize colloidal matter. Suspended particles smaller than one micrometer and larger than a few nanometers are referred to as colloidal suspension. Clays, metal oxides, carbonates, as well as humic acids, high molecular weight proteins and certain viruses belong to this class colloidal substances These particles do not agglomerate naturally because their surface charges induce electrostatic repulsion forces. The water receives a reagent intended to cause the agglomeration of these particles in suspension into flocculent aggregates, the whole of which forms a mass called "floc". Coagulation involves the addition of chemical substances, capable of canceling repulsive forces. When destabilized, colloidal materials are subjected to the mechanisms of aggregation or adsorption (they agglomerate with one another or are retained on the surface of other molecules). The reagents used are generally salts of iron or aluminum. Since each coagulant reagent is active only in a certain pH zone, it may be necessary to adjust the pH. Under the effect of its own weight, the floc settles slowly.

Filtration

The filtration makes it possible to retain the suspended solids which were not trapped in the preceding steps or which have been formed during the pre-oxidation. It is carried out on conventional materials (sands) or on membranes (the case of groundwater karst). The most common is sand filtration (filter bed): a layer of sand retains the particles and allows the filtered water to pass through. The filter can play a dual role depending on the operating conditions: on the one hand, it retains the suspended matter by filtration and, on the other hand, it constitutes a bacterial support allowing biological treatment, that is to say the consumption organic matter and ammonia, or iron and manganese, by the bacteria which have developed on the sand. The sand filter requires periodic cleaning to remove material between grains that slow down the passage of water. Sand filtration, effective, simple and inexpensive, has become a necessity, due to the enormous volumes of water to be filtered.

1.3 Refining

Refining: results in the oxidation and biodegradation of organic matter and the elimination or absorption of certain micropollutants. In addition, it improves the organoleptic qualities of water (flavor, odor, clarity).

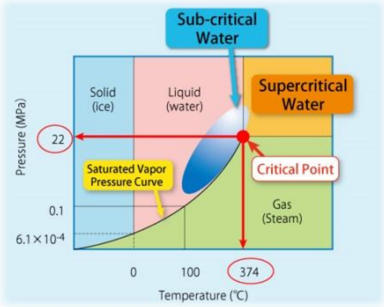
Ozone: in addition to its great disinfecting power (elimination of bacterial viruses and spores), it allows the oxidation of certain organic micropollutants (pesticides, aromatic compounds, etc.) and transforms natural organic matter (which is then eliminated by organic activated charcoal) by increasing their biodegradability.

Activated carbon: a porous material with a very high specific surface area which allows microbiological adsorption and degradation of natural organic matter and organic micropollutants (especially pesticides).

2. The different stages of the innovative drinking water treatment

The water pretreatment step is retained but the clarification is replaced by the heat treatment.

2.1 Thermal treatment



Water exists in solid, liquid or gaseous forms depending on the pressure and temperature conditions imposed on it (see opposite figure). The liquid water subjected to a heat flow reaches its maximum temperature at 100 °C. and cannot go beyond atmospheric pressure without turning into steam. In a confined space, water in its liquid form, heated by the sun's rays, can rise in pressure and remain in liquid form at a temperature above 100 ° C: it is subcritical water.

The majority of so-called persistent substances have a degradation temperature well above 100 ° C under normal pressure and temperature conditions. Thus dissolved in water, the majority of these substances have a boiling temperature well above 100 ° C, which means that they remain dissolved in the liquid water without vaporizing. Several of these persistent substances could be degraded or destroyed by exposure to subcritical water temperature.

- Temperature degradation

Thermal decomposition or thermolysis is a chemical decomposition caused by heat, that is to say a breakdown of the molecules to give less complex compounds, which can be decomposed in turn if the heat increases. Thermolysis is generally an endothermic reaction because of the heat required to break the chemical bonds of the components undergoing this decomposition. The decomposition temperature of a substance is the temperature at which the substance decomposes chemically.

The chemicals used during the pretreatment decompose under the action of temperature.

- Elimination by precipitation

All substances are more or less soluble in water. While there are highly soluble substances, there are no insoluble substances. The solubility of most solids increases with temperature. A saturated solution at a given temperature is a solution that contains the maximum amount of solute that it can dissolve. A saturated solution is, by definition, a solution in dynamic equilibrium with undissolved solute. This equilibrium, however, has a peculiarity: The equilibrium is not modified, if the quantity of the solid part is varied. Indeed, the concentration of a solid is a constant, essentially independent of temperature, pressure and the presence of a solution in contact with this solid.

When a salt containing one of the ions of the aqueous solution is added to the saturated solution of a sparingly soluble compound, the system evolves in the direction which tends to reduce the concentration of this ion, towards the formation of the precipitate by decreasing the solubility of the compound. This decrease in solubility is called the effect of common ions. This property may allow the precipitation of an additional fraction of certain persistent substances which are already very sparingly soluble in water.

Finally, it should be remembered that it is the condensed water that is subsequently treated to produce drinking water for consumption. After condensation, it is not only sterile but purified because it is freed from any substance whose vaporization temperature is higher than that of water.

2.2 Refining

Ozonation

Ozone is a substance of chemical formula O_3: its molecules are triatomic, formed of three oxygen atoms. Ozone is thus a variety of oxygen, but much less stable than dioxygen (O_2), in which it naturally tends to decompose. At room temperature, it is a pale blue gas, even colorless, which is distinguished by its odor.

At room temperature, ozone decomposes into oxygen (O_2), commonly known as "oxygen": the rapidity of the reaction depends on temperature, air humidity, the presence of catalysts (hydrogen, iron, copper, chromium, etc.) or contact with a solid surface. Ozone is naturally present in the Earth's atmosphere, forming an ozone layer at 13 to 40 km altitude in the stratosphere that intercepts more than 97% of the Sun's ultraviolet rays, but is a pollutant in the lower strata of the Earth atmosphere. It is however used to oxidize organic substances. It inactivates certain pesticides and pathogenic organisms (viruses and bacteria).

The advantage of ozone is that after its action on bacteria, viruses and pesticides, it naturally returns to its original form, that is to say, oxygen. Thus, it leaves no trace in water like most other principles of water treatment. The current technique for contacting the water with the ozone coming from the production installations is carried out in a multi-compartment tank in which ozonized air is pulsed. We propose another technique for the contact between water and ozone to optimize its distribution in water and therefore its efficiency.

Current Ozonation Technique

First, ozone is created through the ambient air. The two main principles of ozone generation are UV lights and corona discharges. The generation of ozone by corona discharge is more common nowadays and has the reputation of having more benefits. Indeed, the oxygen captured passes through an ozone generator where it receives an electrical charge. After receiving an electrical charge, some dioxygen molecules (O_2) will separate to form two independent O atoms. Then, these atoms will attach to O_2 molecules that have not been divided to form ozone molecules (O_3). This technique of making ozone from the ambient air (which contains only 21% of dioxygen) is highly energy-intensive. Moreover, ozone is a very unstable molecule whose half-life is impacted by the presence of water or moisture. During ozonation, the contacting of the water with the ozone coming from the production installations is carried out in a multi-compartment tank in which ozone air is pulled. Energy expenditure and the efficiency of ozonation are intimately linked to the choice of the ozone production technique used.

It is possible to improve the generation of ozone by enriching at a concentration of available dihydrogen subject to UV light, paying particular attention to the emission spectrum of the lamp used in relation to photo-reactions that generate ozone And a control of the water temperature.

Photo-reactions involved:

O_2 + photon $\rightarrow$ 2 O if λ (wavelength of UV radiation) $\leq$ 242 nm; $O_2 + O \rightarrow O_3$

Finally, these oxygen atoms can also react on ozone to form dioxygen according to the reaction:

$O_3 + O \rightarrow 2\ O_2$

Ozone is therefore at the heart of a dynamic equilibrium within which it is continually created and destroyed. It is the Chapman cycle whose balance is the equilibrium: $3\ O_2 \rightarrow 2\ O_3$

The ozonation technique can progress in efficiency by:

- The choice of a less energy-consuming method: Lights emitting 172 nm UV radiations allow breaking a series of molecular bonds and can be an alternative often more profitable to the processes of conventional manufacture by electric charge (corona effect).
- An optimization of the technique of bringing dissolved substances into contact with ozone for a better performance in the desired finality.

Direct ultraviolet radiation

The ozone generating system emits high intensity ultraviolet radiation that cleans and ionizes organic compounds dissolved in water. The latter cause, in addition, the appearance of oxidizing compounds capable of destroying the microorganisms (spores) and certain molecules which would have escaped the previous treatments.

Activated charcoal

Activated carbon is a material consisting essentially of carbonaceous material having a porous structure. Activated charcoal is any coal which has undergone a particular preparation and which therefore possesses, to a high degree, the property of fixing and retaining the fluids brought into contact with it. It is an amorphous structure composed mainly of carbon atoms, obtained after a high-temperature carbonization step, having a very large specific surface area which gives it a high adsorptive power. The activated carbon retains all the molecules resulting from the preoxidation in reducing medium generated by sodium hypochlorite, the thermal degradation resulting from the reactive distillation, the ozonation and the exposure to the ultraviolet rays.

Conclusions and perspectives

This breakthrough technology proposes to recycle water differently, no longer in wastewater treatment plants which involve a centralization of resources whose cost implies large investment in terms of means and skills but directly on the site of its use (which makes it possible to reduce the distribution of a potential pollution during the collection of the waste water). The decentralization of water treatment facilities offers certain advantages from the environmental and economic point of view. Innovative technology compensates for its weakness in handling large volumes by its ability to pool individual production to meet local demand and consequently reduce the carbon footprint linked to the energy expenditure of the treated water transport from the water treatment plant. A management of the drinking water requirement by smart grid is therefore possible and desirable.

The technology also proposes to reduce the bioavailability of persistent toxic substances through innovative heat treatment that can produce natural fertilizers in uncontaminated areas and reduce the risk of waterborne disease dissemination in humanitarian crises through portability of this technology, which can contribute to slowing down the trend of rural desertification and the concentration of populations in urban areas. Since water treatment is particularly energy demanding, this technology makes it possible to separate at the source, untreated water usable for toilets, disinfected water usable for hygiene (shower, laundry) and drinking water which can be consumed to lower energy expenditure.