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Supplement

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Research & Development

Why does tap water have a taste or smell?

Contents

Odorless or tasteless water does not exist, neither does chemically pure water in its natural state. Water can be tasted like wine, its taste and smell can be enjoyed, sought out and compared as is illustrated by the recent opening of water bars. Yet, saying that tap water has a taste or smell would imply that it has a bad taste or a bad smell, which would lead to reluctance to drink it and fear for one's health. However subjective these sensory perceptions may be, the dissatisfaction which they cause is nonetheless real. According to a recent parliamentary report in 2002, 40% of the French population found that water had an unpleasant taste. What makes water taste unpleasant? For over 5 years, researchers at Veolia have been working towards finding an explanation. They have been breaking down, identifying, characterizing and finding the sources of compounds contained in water in order to neutralize them and give water a pleasant taste.

INTERVIEW

« In the absence of adequate tools, studies on the organoleptic characteristics of water have recently started. »

David Benanou,
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While 15 % of humanity has no access to drinking water, isn't a luxury to be concerned about how water tastes?

« It is a luxury in that healthy water flows from taps. In Western countries, essential needs are covered, but comfort needs are evolving. Not long so ago, in France, the indication "water and gas on all floors" could be seen in buildings. Running water at home was seen as a comfort good. Today, consumers are more demanding and complain when water is not to their taste. But when drinking water has such an unpleasant taste that it is undrinkable, it is no longer a case of luxury. Warm countries, in which water is scarce and seldom renewed, have all the conditions for this resource to give off smells. For instance, water in a certain Australian town has a septic tank smell. This water, which is naturally rich in algae, has a content in certain odor compounds 1000 times higher than that in French towns where there are complaints about water having a moldy smell. Furthermore, concerns about bad taste in water not only affect rich countries. During its last conference, the International Water Association brought together researchers from 75 countries, including Chile, Brazil and Sri Lanka. »

"In the absence of regulatory criteria, Veolia intervenes when dissatisfaction arises"

Does a bad taste indicate a health risk?

« It is hard to convince the public that drinking water is safe if it has a bad taste or smell. It would be seen as unsafe, and yet the concentration levels of odor compounds observed in water networks do not pose a health risk. »

What is tasty water?

« There is no criteria to define the taste and smell that water should have. Based on French regulations, water should be clear, limpid, balanced in mineral salts and pleasant to drink. Looking into the taste of water and the pleasure it brings to consumers, means leaving the field of sanitary quality, which can be measured using tests, and entering into the more subjective field of taste quality. Despite the absence of assessable regulatory criteria, Veolia intervenes when dissatisfaction arises. »

Since when have researchers at Veolia been working on the taste of water?

« For several years now. Before, it was hard to respond to complaints: the measurement chain for odor compounds, (from drawing samples to the laboratory, to handling samples) was ill-adapted to the problem, especially since in most cases bad taste in water is fleeting. Capturing, isolating and identifying volatile compounds present in water in infinitesimal doses among many other compounds, all require complex tools and highly sensitive analytical techniques. The use of a TwisterTM, a small trap for sampling, and a gas chromatograh links to a mass spectrometer and an olfactometer allows us to make progress today. However, the palate and nose are still irreplaceable to-

What are the complaints about?

The main complaints that Veolia's research must resolve, relate to chlorine and moldy tastes.

A chlorine taste, *however, reveals healthy water: chlorination, a bactericide system, is the most economical way to prevent water-related diseases today. Ozonation and nanofiltration can be used to reduce or avoid unpleasant tastes. The former was developed in 1905 by the Générale des Eaux. The latter, which is much more recent, uses membranes to filter microscopic particles and avoids the need for chemicals, but is still energy-demanding and costly to maintain. Both are justified when there is a particularly degraded water supply. In France, their use does not prevent chlorine from being added to water networks. There is a simple household solution to help reduce the chlorine taste: put pipe water in the refrigerator (chlorine dissolves in the cold and its taste goes away.*

A moldy taste *can have various sources. If it affects the resource itself, it comes from a microalga which produces geosmin and 2-methylisoborneol (MIB). It can also stem from organic molecules in the resource, which the treatment transforms into odor compound precursors. The latter, which are often fed on by bacteria living in the distribution network, are then transformed into odor compounds (trichloroanisole and tribromoanisole).*

ols in the process! Although it is subjective, tasting is the starting point for our research work. It provides the primary clues to guide us in an area of research. »

What does your work involve?

« Improving the taste of water and making sure that consumers like it». To get rid of bad tastes, we have a three-step approach which is largely similar to that used by Forensic Scientists!
Firstly, we identify and collar the compounds responsible. Then, we attempt to understand their biochemical evolution- which involves investigation, analysis and reflection, to find out how they come about and are transformed. Lastly, we work alongside operators of treatment facilities and managers of distribution networks to find solutions to neutralize them: implementing new processes or improving existing processes, or operating conditions. Our approach is pragmatic. We are gathering experience in order to create a data bank on water smells and tastes, which will eventually allow us to better detect and diagnose their source and get rid of them faster. »

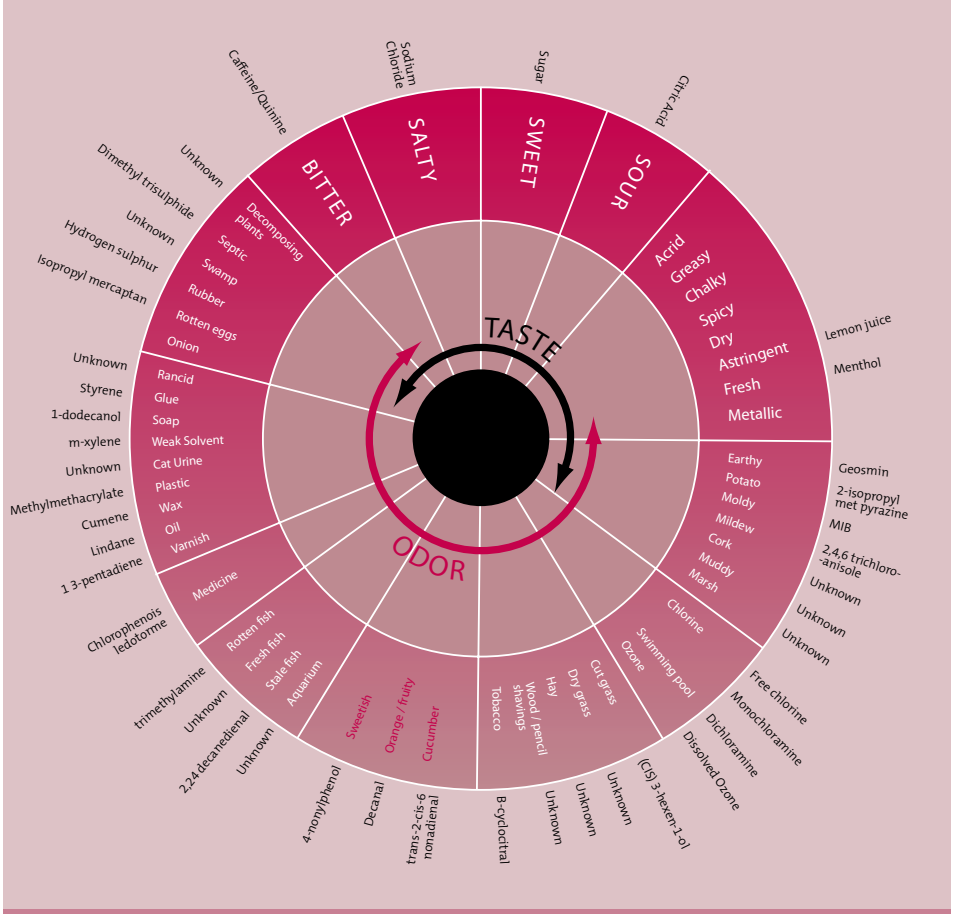
Where does the bad taste come from?

« The causes are numerous, variable and versatile! In order to find them, we have to solve equations with several unknown factors: finding the compounds responsible, the agents that produce them and the environments in which they are formed. When water has a bad taste, this could come from the resource, the treatment facility and/or the pipes. Our experience in Sweden shows that although a resource which is particularly rich in organic molecules can be at the root of a moldy taste, it cannot be the only factor: there is responsibility somewhere along the chain. A chlorine taste can be derived from treatment, and to a lesser extent, from chlorination before distribution or in networks. »

Why do pipes affect water's taste?

« It is essential to differentiate between the public and private distribution networks. In most cases, odor compounds nest in buildings, where water remains more static. All it takes to get rid of the moldy taste is to let water run a bit before drinking it. The dilapidation, composition and even the interior coating of pipes are also to be blamed. In some cases, old pipes discharge metallic compounds. They are also more exposed to development of biofilm, which nests in their rough surfaces, resulting sometimes

... Continuation of interview on page 5



Taste and smell hand in hand

Taste and smell are so connected that the term flavour refers to the taste and smell sensations experienced when tasting. The four fundamental tastes- sweet, salty, sour and bitter- are recognized by taste buds, while others such as chlorine, earthy, muddy and moldy tastes are more perceived by the nose, notably because of the communication between the back of the mouth and the nasal cavity. Some smells enter directly through the nose and are perceived when we breathe. Others, i.e. aromas, reach the nose through the back of the mouth, when we eat or drink (retronasal olfaction). 80% of taste is perceived retronasally, 10% nasally and another 10% by taste buds. This goes to show how important the sense of smell is in tasting. Savouring water can be a true nasal experience!

At the source of water's flavour

Compound	Smell	Detection threshold	Emission source
GEOSMIN actinomycetes	earthy	4 ng/l	cyanobacteria and actinomycetes
2-METHYLISOBORNEOL (MIB	moldy	15 ng/l	cyanobacteria and actinomycetes
2-ISOPROPYL-3-METHOXYPYRAZINE	fermentation	0.2 ng/l	actinomycetes
CYCLOCITRAL	fruity	2,000 ng/l	cyanobacteria
TRANS, CIS-2,6-NONADIENAL	cucumber	60 ng/l	algae
CIS-3-HEXEN-1-OL	grass	70,000 ng/l	algae
1-PENTEN-3-ONE	fishy, rancid	1,250 ng/l	algae, cyanobacteria
IONONE	violet	7 ng/l	algae, cyanobacteria
2,4,6-TRICHLOROANISOLE networks	moldy	0.02 ng/l	transformation into chlorophenol in
2,6,4-TRIBROMOANISOLE networks	earthy, moldy	0.03 ng/l	transformation into chlorophenol in
2,6-DI-TERT-BUTYL-4-METHYLPHENOL(BHT)	plastic	nd	polyethylene pipes

RESEARCH PROGRAM

Unknown odorous moleculs identified in Sweden

Water has smelled moldy in Nortalje for the past ten years. After managing the drinking water plant in this town of approximately 35,000 inhabitants since 2003, Veolia has now found the solution to this problem and has started altering processes accordingly.

Water in Nortalje is drawn from a forest lake into which the surrounding trees drop their residue. Rich in extremely soluble organic matter from the source, it was unclear as to why the water reaches people's homes tasting moldy.

Odorous molecules

For the first time ever, Veolia set up a Twister™ to find the answer. As a result of testing, 4 odorous molecules and their precursors were identified, 4 of which had never been listed. This also meant 4 new compounds, which did not appear on the shelves of the olfactory library. Researchers racked their brains and established the connection between their structural 'fingerprint', as detailed by a mass spectrometer, and the existing molecules.

The network in the spotlight

They then tested water samples for a year at various locations along the network. They concluded that the moldy taste was present everywhere and varied little from season to season. It could, however, suddenly appear within the space of an hour. All of these elements helped to conclude that the network itself was the cause of various odor compounds.

A history of developments

Researchers have explained the appearance of the moldy taste by a combination of factors linked to the resource, treatment and network. The chlorine used to purify the water transforms the organic molecules present in the resource into odor compound precursors, which are in turn transformed into odor compounds by the micro-organisms lining the walls of the pipes (biofilm) – indeed the Swedish are rather against chlorinating their networks. After three years of investigating, researchers have handed over the remedial phase to operators. Process adjustments are currently being carried out within the drinking water plant, in particular in order to hone the chlorination process – milder techniques, which should avoid generating odor compound precursors.

> *"A noisy environment can, for example, change the taste."*

Malodorous water and emotional recollections

Perceptions of taste and smell are subjective and often associated to personal recollections and feelings. They vary according to the individual, their age, sex and circumstances – a noisy environment can, for example, change the taste. Linked to social imagination, perceptions can also differ depending on the country and era. In addition to the four fundamental tastes – salty, sweet, bitter and sour – Asians lay claim to a fifth taste sensation, umami, pertaining to half-sweet and half-savoury foods. A third of the French population complains about the chlorine taste of tap water (1); Americans on the other hand, refuse to drink it when it does not smell of chlorine, out of fear for their health.

Miasmas and collective memory

Before Pasteur ever discovered microbes, scientists were adamant about the dangers of smells. Commissioned by his fellow members of the French Royal society of medicine, Jean-Noël Hallé carried out in 1790 an olfactory survey along the banks of the river Seine in order to detect deadly stenches(2) – he was to be the first incumbent of the public hygiene chair created in Paris in 1794. The foul smells of the city, the putrid odors given off by stagnant water, cesspools and refuse, and even cemeteries and hospital rooms, were then considered to carry illnesses responsible for large deadly epidemics such as cholera. Linking together dirtiness, stench and pathological risks, the miasmas theory was born and was premise to the hygienist movement developed in the 19th century.(3) Does malodorous water, which spontaneously arouses a threatening feeling, revive forgotten collective fears? Yet "everything that smells bad is not dangerous and everything that is dangerous does not smell bad".(4)

(1) Data 2001 – Report from the Office parlementaire d'évaluation des choix scientifiques et techniques sur la qualité de l'eau et de l'assainissement [French Parliamentary office for assessing scientific choices regarding the quality of water and wastewater treatment] (2002-2003).
(2) Alain Corbin – "Le miasme et la jonquille" [Miasmas and the daffodil] – Flammarion, 1986.
(3) Georges Vigarello – "Le propre et le sale" [Clean and dirty] – Seuil, 1985.
(4) Professor Brouardel, quoted by Catherine de Silguy in "Histoire des hommes et de leurs ordures" [The story of mankind and its refuse] – le cherche midi éditeur, 1996.

METHODOLOGIES

It all starts with tasting

Tasting is the very foundation of research on the taste of water. Pinpointing a smell or a taste and defining it with words helps to steer analytical studies in the right direction.

Weekly sessions

Taste and smell are personal assessment criteria and, as such, Veolia's Water Research Center organises "tasting sessions" which, similar to consumer panels, are held once or twice a week in order to smooth out subjective perceptions and highlight general trends. A dozen researchers volunteer to test the waters. They will have followed basic taster training (initiation to taste and smell physiology, identifying fundamental tastes). They taste the water as they would wine, looking to describe its flavour.

Clues on the generating factor

Water said to smell of mold, grass, waste oil, algae or medicine indicates the probable cause of the taste. The sharper the assessment – making out a taste of mushroom, humus, earth, or cork requires a certain amount of experience –, the more precise the given direction will be, and the easier it will be to find the source and act on it.

Threshold effects

Tasting also helps to define the perception threshold of smells and tastes. A calibrated system that identifies, out of the multiple odor compounds present in a sample of water, those which are responsible for a bad taste, in particular if they taste the same. Knowing the perception thresholds also makes it possible to observe whether, when compounds which give the same taste are mixed together, the taste is brought out or not. Furthermore, the nose has a key role in assessing efficiency of the "deodorising" measures implemented (see Rennes is drinking tap water again).

"They taste the water as they would wine, looking to describe its flavour."

Sessions
Three tasting sessions are currently underway at the Maisons-Laffitte centre. Researchers are testing: water artificially charged in odor compounds to determine perception thresholds; municipal water circulating in two pilot networks to study both the effects of biofilm and the pipe surfaces on the taste of water.

... Continuation of interview on page 3

in a moldy taste. PVC and cast iron pipes, are more sensitive to biofilm than others... When in contact with chlorine, plastic pipes can produce trichloroanisole, which, when highly concentrated, smells of medicine, and if transformed into trichlorophenol by bacteria, gives a moldy taste... Some resin pipes used in anti-corrosion treatment of networks, discharge more or less organic compounds depending on their composition...»

What solutions exist to get rid of unpleasant tastes and smells?

« A wide range of solutions for a multiplicity of causes. Action can be taken at each stage of water treatment- aeration, filtration, coagulation, disinfection, activated carbon adsorption, biological treatment...- and at the network maintenance level- cleaning, upgrading, replacement... However, developing treatments to rid water of ultra diluted compounds is a tricky task. We normally use more concentrated substances to decontaminate water. To make a comparison, trichloroanisole begins to smell as of 0.03 ng/l (1), while European potability standards for pesticides stand at 100 ng/l. Generally, the measures needed to eliminate unpleasant tastes are costly, while the latter are often fleeting. There should be a balance between the satisfaction requirement and expenses to be incurred, which in the end depends on what the consumer-citizen is willing to pay for the taste quality of water. » ■

(1) 1 nanogram = 10-9gram.

3 QUESTIONS FOR...

Geneviève Leboucher

Geneviève Leboucher,
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Why undertake research on the taste and smell of water ?

« Improving the taste of water is a priority for consumers and local authorities. Veolia is therefore obliged to come up to these expectations. Generally, the French trust tap water (84% of the population) and are satisfied with its quality (76%). However, based on our, they attach an increasing amount of importance to the taste of water, to the point of making it the first water service assessment criteria this year (for 53% of them), ahead of information on the quality of water (34%) and its price (32%). Despite the fact that only 1% of water distributed is actually used as drinking water, they still judge the overall service quality based on the taste of water. »

What were the causes for dissatisfaction ?

« Perceptions in water taste vary from one country to another and depend in part on consumption habits. 24% of the unsatisfied French bring up chlorine, limestone and bad taste as the main cause for discontentment. The Italians also complain of chlorine and limestone but 60% of the population of this country is dissatisfied with tap water. Nearly 80% of them drink bottled water, making them the biggest consumers of bottled water in Europe. Is that the reason why they don't like tap water or is it the other way round? 53% of Germans are very satisfied with tap water and only 28% actually drink it! In Germany, water is generally chlorine-free. This may be the reason for their high satisfaction. We therefore need to have a local approach to water tasting. »

"Perceptions in water taste vary from one country to another and depend in part on consumption habits."

Will we eventually work on the taste of water as we do with wine in order to obtain different products corresponding to each consumer's taste ?

« We are already "working" on water obtained by reverse osmosis desalination: enriching it in mineral salts in order to make it digestible by the human body. Some countries ask us to add fluorine to prevent tooth decay. Even if this may seem a little far-fetched, adding a particular taste is therefore technically conceivable! From a more commonplace outlook, as oenologists strive to make certain aromas stand out in their wine, we are currently working to make water taste as neutral as possible and are studying the entire water chain in order to do so. Research can help to improve taste quality of water through better knowledge of resources, adapting water treatment lines, understanding the evolution in the taste of water in distribution pipes, and even designing network treatments. »

Twister™, the odor stealer

Invented in 1999 by the Belgian chemist, Pat Sandra to concentrate volatile compounds in a liquid solution in order to identify them, Twister™ is a small magnetic bar, 1 to 2 cm long and 1 mm in diameter, inserted inside a thin layer of glass covered in silicone. The magnet makes the device spin when it is plunged in the liquid – hence the name Twister – in order to speed up the transfer of compounds. The silicone then stores them. Veolia came up with the idea of using this piece of equipment as an odor trap, indeed as a hook, fixing device and detector in one. By simply plunging it for 2 hours in a water sample, it picks up on and takes a print of the smells; after steeping it in a 250° environment, it will release them. This user-friendly device (it can even be used by the general public) has the main advantage of being able to store volatile compounds as opposed to transferring, which encourages loss. In order to "steal a picture" of particularly fleeting odors, it can even be used a few days running as a "camera", preserving the memory of water's journey in the networks.

TECHNOLOGIES

Seizing the elusive

By studying the smell and taste of water, researchers have tackled the complex world of subtlety and volatility. In order to find the cause of bad taste, they have to use their intuition and turn to extremely sensitive and sophisticated investigative and analytical technologies: with a dilution rate in picograms (10^{-12} g/L).

Game of hide and seek

Even when a bad taste chronically affects tap water, it often appears only on occasion. Odor compounds are fleeting, unstable, and present in homeopathic doses. They quickly disperse and their chemical composition is not yet fully understood. Tasting remains the most reliable way to detect them when they do indeed appear but capturing them still remained a real problem until fairly recently. How do you fix evanescent molecules? The use of Twister™, an ultra-sensitive captor/recorder (absorption trap) has, since 1999, resolved the issue (see above).

Sorting and transferring vapors

Once fixed on the Twister™ (small magnetic bar), the odor compounds have to go through a different process to be analysed individually. The Twister™ is placed in a desorber/condenser, allowing the compounds desorbed from the Twister™ to be sent on a chromatographic column in order to locate them. Desorption/condensation operations can be compared to a sauna session interrupted by an ice-cold bath: a rapid heating session at 250 °C (12°C/second) extracts the molecules from the Twister™, followed by a sudden plunge into – 100 °C liquid nitrogen making them enter as a bloc into the chromatograph where they will be very gradually heated up again to 300 °C (2°C/minute). They will then arrange themselves along the column according to their boiling point.

A drop in an Olympic size swimming pool

Thus, the compounds can be identified by the mass spectrometer and sorted by the olfactometer. The mass spectrometry detector sees each of the compounds go through one by one, breaking them up and identifying them as the olfactometer simultaneously characterizing their flavour. Odor compounds can only be located by smell – a tiny minority representing approximately a millionth of the organic compounds present in drinking water, themselves only in minute concentration (3mg/l). Researchers then isolate them during "sniffing" sessions, which require intense concentration for thirty minutes or so – beyond which perceptions become blurred. By combining intuition and structural analysis, odor compounds can be defined: the taste and smell of water finally deliver the secret of their identity.

"Researchers then isolate them during sniffing sessions"

Taste and Smell Research Laboratory in Maisons-Laffitte
A gas chromatograph is used to decompose water and isolate molecules according to their degree of volatility. It is combined with a mass spectrometer, which gives their structural fingerprint, as well as an olfactometer, which helps to locate those that have a smell.

"Sniffing" session with the olfactometer.

RESEARCH PROGRAM

Rennes continues to recapture the taste of water

According to a CECOP 2005 survey, 58% of Rennes' inhabitants are satisfied with the taste of tap water compared to 38 % in 2003. Out of the third of the population declaring themselves regular drinkers of tap water, 84% of them are satisfied with it. When water was no longer attractive because of its chlorine taste, jugs of water started to reappear on restaurant tables and in school canteens. A look into Veolia Eau's project to recapture the taste of water in Brittany's capital city over the past 4 years.

"A weaker chlorine smell has been clearly observed."

Tackling the taste of water is an difficult task in Rennes: drinking water is produced by three plants and from a blend of 5 different sources, with the city divided into 2 distribution zones. A chlorine taste, which varies depending on the time and the place, is frequently reported.

Tasting markers

The taste hunt started in 2002 when a panel of tasters was set up. The objective was first to map the city into taste zones, then to assess the efficiency of the actions undertaken and finally, to guarantee regular monitoring of the taste of water. Tasting sessions first took place every week and are now scheduled every 3 months for 30 days. Out of the thirty tasters, half of these individuals work for Veolia and the other half for the city's technical services. They have all received training.

Chemical analysis research

The Twister™ is used to identify molecules responsible for taste in resources and treatment plants and to analyse the impact of technical changes implemented. Taste being particularly fleeting with the general public, Veolia researchers have perfected a system in which Twister™ captures the water compounds found in networks for 3 days running. Testing them provides a scientific complement to taster observations.

Expanding the network's re-chlorination

The first results have come following the installation of 5 chlorination stations on the network. Rather than injecting chlorine in high doses on the way out of the water plant, irrigating 550 kilometres of pipes in Rennes, it is distributed in gradual, more restricted doses, never higher than 0.3 mg/l (a threshold at which consumers notice the substance). A weaker chlorine smell has been clearly observed by the panel of tasters.

Carbon's leaps and bounds

Modernizing one of the drinking water plants has meant passing a major taste quality milestone. The installation of a granulated activated carbon filtration system and coagulation-flocculation optimisation have resulted in a decrease in the organic matter rate, beneficial as the earthy taste has disappeared (not as strong as chlorine but bothersome all the same), and a near 40% cut in the quantity of chlorine needed to purify water.

The contribution of network modelling

Moreover, developing a hydraulic modelling tool to observe the way water circulates and chlorine is distributed in the network represents a precious decision-making tool. A surplus of pipes has been removed in order to reduce water's journey time. This prevents the risk of moldy tastes developing. Chlorination has also been adjusted as a result. « Controlling water's chlorination and journey time across the network is a battle that we fight everyday», underlines Sébastien Neaud, the Agency's Network Manager. « In addition to corrective measures carried out in the plant, good network management is an essential condition in guaranteeing pleasant drinking water.»

This scientific chronicles supplement comes with a video on «The taste and smell of water »

IThe 4-minute video was produced with the help of Marie-Odile Monchicourt (journalist for France Info).

Discover the video and the supplement on the Veolia Environnement's intranet and internet sites (R&D section).

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