¡De acuerdo!

Science made to your measure

Issue No. 1

Water

Water: starting point

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Preface

Dear reader,

In November 2012, a group of enthusiasts gathered in San José, Costa Rica, and decided to create a Latin American scientific magazine, particularly aimed at young people and presenting Metrology issues in a modern and visually appealing format.

Metro…what? Metrology? Right, Metrology, not meteorology. This is neither a mistake nor a pun. Metrology is the name of a not very well-known science, the applications of which can be found in almost all our daily activities.

Informing and arousing curiosity on the importance of Metrology in our lives, and the fundamental role it plays in innovation and the development of countries, is part of what we set out to accomplish when we created this magazine.

Accuracy and the definition of measurement units have always been a concern for leaders, producers, traders, sportspeople, scientists and consumers. For the purpose of measuring, several units have been established over the centuries, some of them as arbitrary as, e.g., a king's foot length or the weight of a carob seed. In 1875, seventeen countries signed the Metre Convention to establish the world authority on Metrology, as well as to define the units and standards that would be used to ensure the reliability of measurements in different parts of the world. Today, 93 countries formally use the International System of Units, facilitating international trade, scientific development, innovation and productivity, as well as the protection of consumers and the environment.

The idea of creating this magazine came up several years ago. We developed this project together with Alberto Parra del Riego, a social communicator and graphic designer, by using the quality of *Maßstäbe* magazine, published by the National Metrology Institute of Germany (PTB), as a model. Jens Simon, its creator, allowed us to replicate the concept in other countries. We found allies and partners for this project in various National Metrology Institutes throughout Latin America and, during the General Assembly of the Inter-American Metrology System, held late last year in Costa Rica, we took the opportunity to agree on the main points, establish the Editorial Board and set the idea in motion.

Given that agreements are the basis of this particular science and since we are convinced that seeking understanding is an essential principle for any activities undertaken collectively, we decided to name the magazine ***¡De acuerdo! - La ciencia a tu medida*** (*¡De acuerdo! - Science made to your measure*)[1].

The United Nations proclaimed the 2005 – 2015 period as the International Decade for Action "*Water for Life.*" To contribute to this action, we decided to give water a central place in the first issue. This issue includes articles about the importance of water for health, the environment, energy and sports, as well as the latest theories on how it came to Earth, among others.

Finally, I would like to make a deal with you: if you enjoy this magazine, please spread the word and share it among your friends. If you wish to leave a comment, please visit our website at *www.revistadeacuerdo.org,* and we will take your views into account when editing our next issues. I would appreciate hearing from you.

Wishing you an interesting and entertaining read, please accept my kind regards.

Alexis Valqui

[1] *¡De acuerdo!* = Agreed!

Alexis Valqui, Executive Director
¡De acuerdo! – Science made to your measure
Photo: Lisa Justine Neumann (PTB)

¡De acuerdo! Science made to your measure

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Water: starting point

"That very day, the second of October, Phileas Fogg had dismissed James Foster, because the fellow had committed the offence of bringing him shaving water at 84° Fahrenheit instead of 86°..." The cause of the unforgivable mistake of Fogg's valet is not clear in the pages of the novel *Around the World in Eighty Days*, by Jules Verne; however, we can almost be certain that it was all due to a "ladders" and "steps" problem.

Determining the temperature of an object is quite difficult. We can know if something is hot or cold, or even very hot or very cold, but this perception varies from one person to another and is extremely vague. To avoid any errors, and be as accurate as the valet Phileas Fogg has always dreamed of, we need to be able to express temperature as a number and to classify those numbers in an ascending order, that is, we need a scale.

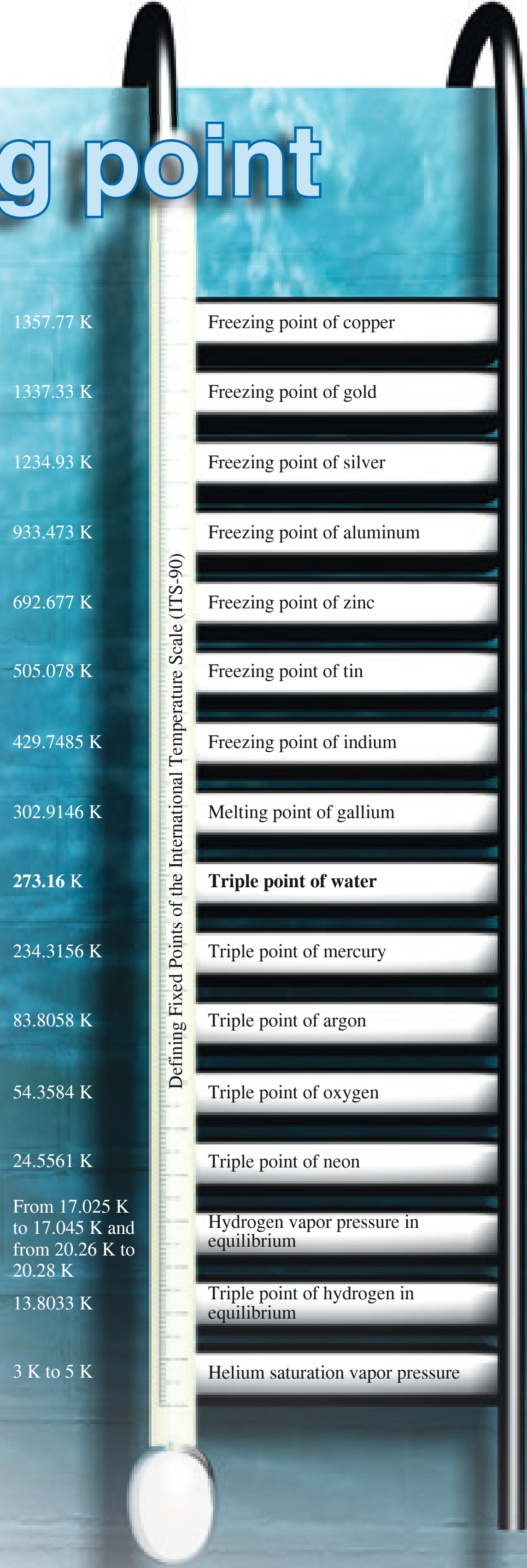
Water for measuring

Creating a scale is very similar to building a ladder: you only need to put a series of steps in the correct order and with the required separation. In fact, that is how the scales we use today to measure the temperature of objects were devised. That is why we use the word degree, which in Latin means step.

In order to measure temperature reliably, it is necessary to have the reference of a change that can be measured. Galileo Galilei was the first one to use the expansion of materials with heat, and their contraction with cold, to build a device that somehow made changes in temperature visible. One day in 1603, Galileo heated the air inside a tube and put it upside down in a dish of water. When the temperature inside the tube decreased, the volume of air in the tube decreased as well, causing the water to rise, and that was a change that could be measured!

He also discovered that if the temperature of the room where the tube was changed, so did the level of water within the tube, and that is how the Italian scientist managed to build a thermoscope (from the Greek *thermes* = heat and *scopio* = to look at). Years later, the German scientist Daniel Gabriel Fahrenheit added a graded scale to the tube (the Fahrenheit scale), allowing us to express temperature in a numerical value, and the world got to know the first thermometer.

To put steps on a ladder, it is necessary to "nail them down," so they do not move. The same happens with a measurement scale: values are "nailed down," establishing a direct relation with a natural phenomenon that can be repeated later in the same way. For the 0 of his scale, Fahrenheit chose the temperature of the coldest substance he managed to get in his laboratory (ice with salt).



Illustrations: Alberto Parra del Riego

However, in the middle of the 18th century, the Swedish physicist and astronomer Anders Celsius thought of "nailing down" the steps of his scale using the most evident and common thermal phenomena in nature: changes in the state of water. He assigned the value 0 to the boiling temperature and 100 to the freezing point, defining them as fixed points of reference, and then he divided the space in between into 100 steps. Three years later, his fellow countryman Carl von Linné would invert the scale proposed by Celsius, so it took the form we know today, that is, 0 °C for the freezing point and 100 °C for the boiling point of water. Because of its convenience, the Celsius scale turned out to be one of the most widespread and used scales for the observation of temperature and the analysis of thermal phenomena, and still is today.

Nailing down steps

Over time, it turned out that the "steps" of the Celsius scale were not as fixed as we thought. Factors such as atmospheric pressure and salts dissolved in water can significantly change the temperature at which water freezes or boils. Looking for a better scale, at the end of the 19th century, physicist William Thomson (Lord Kelvin) proposed a new temperature scale. The amazing thing about this proposal is that, with mathematical calculations and gas experiments, Lord Kelvin deduced the existence of a point at which the molecules and atoms of a system have the minimum thermal energy possible. He found out that this temperature was −273.15 °C, setting there the absolute zero to what he called the absolute temperature scale. Besides zero, in order to create his new scale, Lord Kelvin needed another point of reference and once again, he found it in water. This was the triple point of water, a phenomenon in which, under a single combination of pressure and temperature, the three states or phases of water (ice, water and vapor) can coexist.

Thanks to its accuracy and ease of execution, the scale proposed by Lord Kelvin gave rise to the so-called thermodynamic temperature scale. In addition, the unit of this scale (K) is one of the base units of the International System of Units.

In Mexico, those in charge of keeping the steps of the temperature scale "nailed down" are the members of the thermometry group of the National Metrology Institute of Mexico – CENAM (from Spanish *Centro Nacional de Metrología*), led by Doctor Edgar Méndez Lango. In his laboratory, there are no nails or hammers, but an extensive collection of bottles filled with water, which are called water triple point cells. "A cell is a sealed container where we keep a quantity of extremely pure water, that is, H_2O and nothing else," Méndez Lango explains.

To get our point of reference, we need the three phases of water (solid, liquid and vapor) to be formed in the cell. Impossible? "Not really," the expert points out. "We know that, to get ice, we have to put a container with water in the freezer and… there! we already have ice! If the freezer is too cold, all the water will turn to ice. With a little bit of practice, I can adjust the freezer control until I find a temperature at which the liquid and solid can coexist in equilibrium."

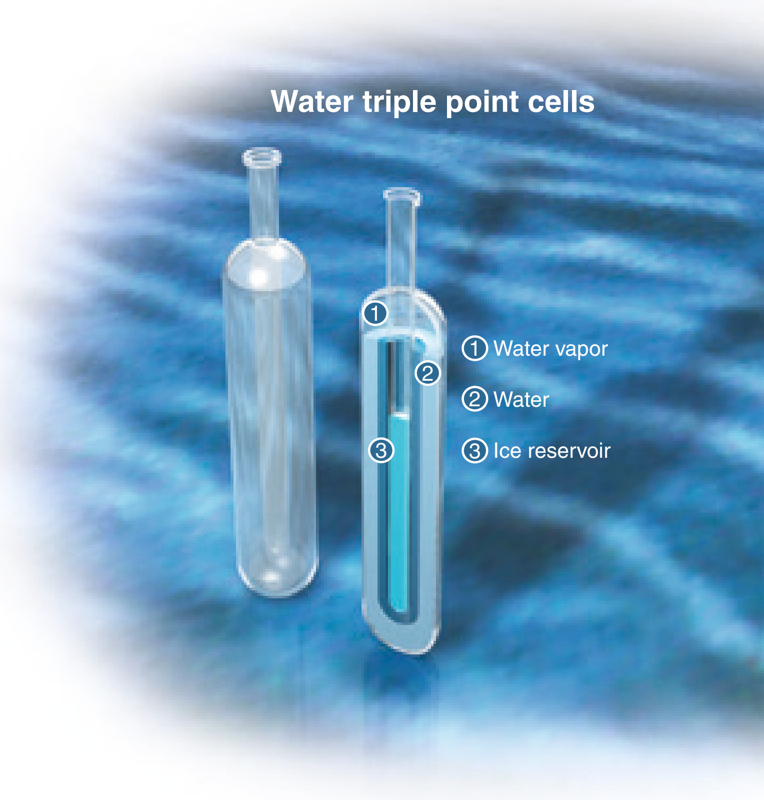
To get vapor, the expert explains that the lower the pressure, the lower the boiling temperature. So we start lowering the pressure of our water and ice. After a while, we will see that the water gradually starts to bubble, but also that the quantity of ice in the bottle increases. To obtain the triple point, the quantities of water, ice and vapor should remain unchanged, so we keep trying until we find a pressure and temperature at which water boils, without increasing the quantity of ice. In this way, by controlling pressure and temperature, we can have the three phases in equilibrium.

The triple point of water only occurs in the cell at 273.16 K (0.01 °C). So, if we put a thermometer in the cell, it should only read that value. If the thermometer shows another value, then we know it has an error and we can make adjustments to correct future measurements.

At present, in addition to the triple point of water reference, the temperature scale has 15 more fixed points. So, 16 "steps" are "nailed down" in total. When those temperatures are linked to the triple points of gases such as oxygen, hydrogen and the freezing points of metals such as silver, gold or copper, the measurements of a thermometer can be ensured for different temperature ranges.

If Phileas Fogg were traveling around Latin America today, he would not have to worry about the temperature of his shaving water. His valet could calibrate a thermometer in any of the several National Metrology Institutes in this part of the world. Their job is, precisely, to ensure that measurements performed in each country are correct and reliable. Therefore, throughout his journey, each morning Fogg would have in his bathroom a bucket of steamy water at exactly 30 °C (86 degrees Fahrenheit[1]).

Daniel de la Torre (Mexico)



[1]The degree Fahrenheit unit is not part of the International System of Units

Not only is 60 % of our body made up of water, but also the fruits we eat are composed of a large quantity of water. Water quality control in medicine is of vital importance, since the proper functioning of our vital organs may depend on it and several lives can therefore be saved.

Photo: © Glamy - Fotolia.com

Food and health

Fruits: natural sources of water

They come in all sizes, colors, textures and flavors, but they all have something in common: a high content of water, a healthy and safe liquid that can complement in a wholesome way the daily needs of our body.

In the middle of a nightmare, Sandra saw herself walking thirsty through a vast area of sand. The sun burned her skin, her clothes were soaked with sweat and dryness tormented her mouth. When she woke up, distressed, she found herself craving a piece of that water-melon she had bought on her way home and confirmed that a part of reality had leaked into her dreams since, indeed, her lips were dry. Without thinking twice, she went to the kitchen to get that slice that quenched her thirst and allowed her to resume her rest.

She had gone to bed without first recovering the liquid she had lost through sweat during her walk home and, therefore, her body woke her up, demanding what considered necessary to keep functioning healthily.

"About 60 % of our weight is water and we feel thirsty when our body has lost 2 % or more of that amount of liquid," explains Luisa Amelia De la Zota, Nutritionist at the National Food and Nutrition Center of Peru (*Centro Nacional de Alimentación y Nutrición del Perú*), who also specifies that this percentage is higher in children, reaching up to 75 %. In addition, she notes that thirst, that natural alarm for the lack of water, usually stops working effectively in seniors, so older people need to pay closer attention to their hydration.

Water helps regulate body temperature and is the means by which nutrients reach cells, as well as the vehicle through which waste is eliminated from our body. "It's in our blood, muscles, lymphatic fluid, bone tissue and skin; water is always present in the overall body composition, even in our bones, which seem dry," the expert says.

Moreover, she claims that, depending on the physical activity undertaken, a person eliminates an average of two litres of liquid per day, so it is advisable to drink at least that same amount, equivalent to eight glasses, over 24 hours. Otherwise, if your body loses and does not recover the amount of water lost, the process of dehydration starts, which fully affects the body and can cause cramps, blurred vision, skin and tongue dryness, dizziness, among other ailments.

Fruits are great providers of the liquids the human body needs. They all have water as their main component. However, some of them stand out precisely for having an extremely high content of this element. Among these, we can mention the cocona, orange, strawberry, pineapple, grapefruit, mandarin, rose apple, papaya, sweet cucumber, lime, banana passionfruit (*tumbo costeño*), melon, watermelon and camu-camu, the water percentage of which ranges from 88.5 % to 93.3 %.

"It is very important to eat fruits daily," De la Zota recommends, although she does not advise to replace water intake with fruits. "I would say it is advisable to supplement our body's demand for liquids with their consumption," she specifies, once again referring to two litres as the minimum amount to drink each day. In this regard, she estimates that the edible part of an orange –generally weighing between 100 and 120 grams– amounts to 80 millilitres or just over one-third of a glass of liquid. Likewise, she estimates that a piece of watermelon, weighing 100 grams, yields approximately 93 grams. Based on these examples, she claims that an adult can add the water input of various foods until completing the amount he or she wishes to take. To facilitate this task, she explains that the quantity of liquids can be expressed as grams, if referring to mass, or as millilitres, if referring to volume.

As if their significant liquid supply were not enough, usually water-rich fruits also have a substantial amount of vitamin C. These are substances the human body needs, but does not produce by itself. There are several, and each of them is essential for some function of the body, so they need to be administered through food. Specifically, the vitamin C that water-rich fruits have, also known as ascorbic acid, is essential for our teeth, gums and blood vessels. In addition, the edible part of fruits (and, in the case of oranges, also the peel) has a significant amount of fiber as well. While fiber is not a nutrient, it consistently contributes to the proper functioning of the intestine and is good for digestion.

Fruits with an intense orange color, such as the papaya or mandarin, also have a high amount of beta-carotene, which the liver and the intestines turn into vitamin A, to ensure the eyes and the mucous membranes work properly and to give skin a healthy look.

"It is important to mix the colors of fruits, since each color has different nutrients and, therefore, a diverse richness; just like white food, derived from milk, provides calcium, and red meat provides iron. If at the end of the day we find that we have eaten food of all colors, we most likely have had a balanced diet," De la Zota says.

However, the expert notes that in the case of fruits rich in water and vitamin C, the latter may be lost if fruits are cut and the pulp is kept in contact with oxygen in the air for a long time, since the oxidation process starts immediately. For this very reason, she is not a big fan of extracts since, while the water and other nutrients the fruit may have remain intact, in addition to the abovementioned vitamin C loss, there is also a loss of fiber, which is often discarded and therefore, wasted.

Something similar happens with sauces, desserts, marmalades and main courses, since the liquid from fruits dries out and vitamin C is canceled out during the cooking process. Although juices and ice creams are made with fresh products, they also suffer that loss when they are cut or in contact with air. "Ideally, fruits should be eaten raw, whole and well-washed," the nutritionist notes, and she also recommends eating the skin.

Regarding this outer cover, she explains that its role is precisely to protect the inside of fruits, and points out that those with a high liquid content are the ones that usually have a thick skin, such as the melon, watermelon, pineapple and coconut. The juices of these fruits would be easily lost if the tissue surrounding them were not impermeable and strong.

Source: Food composition tables of Peru. National Health Institute (*Instituto Nacional de Salud*)/National Food and Nutrition Center. Prepared by María Reyes García, Iván Gómez Sánchez Prieto, Cecilia Espinoza Barrientos, 8th Ed., Lima, Ministry of Health (*Ministerio de Salud*), National Health Institute, 2009.
Graph: Alberto Parra del Riego

And where do the liquids that fruits so generously give us come from? Well, from soils that are also rich in water, such as jungles, where rainfall is frequent, or from the subsoil, since plants like the coconut palm, for example, have very long roots that, showing nature's wisdom, supply the plant with the liquid taken from very deep sources.

The most generous:

Camu-camu (*Myrciaria dubia*)
This delicious fruit that grows in the Peruvian rainforest stands out for its extremely high content of vitamin C, having the highest quantity. For this reason, it strengthens the immune system and protects the body against free radicals that cause cells to age. It is used in the preparation of soft drinks, ice creams, creams and desserts.

Watermelon (*Citrullus lanatus*)
It is not without reason that its English and German name is watermelon and *Wassermelone*, since every 100 grams of watermelon, 93 grams are liquid. In addition to its freshness and sweetness, it greatly helps the human body eliminate toxins, being a natural diuretic.

Banana passionfruit (*Passiflora tripartita*)
It also has 93 % of water and a high content of vitamin C, as almost all fruits do. It is eaten raw and is used to make soft drinks and desserts.

Orange (*Citrus sinensis*)
Its water percentage reaches 88 % and, in addition to its high vitamin C content (92.3 mg), it provides beta-carotene, which then turns into vitamin A, highly beneficial for good eyesight and healthy skin.

Mandarin (*Citrus reticulate*)
Apart from its 90 % of water, this really tasty and juicy fruit is rich in vitamin A and C. It also has vitamin E, potassium, magnesium and phosphorus.

Pineapple (*Ananas comosus*)
Its main component is water, reaching 89.3 % of its weight. The smaller ones are tastier and healthier, since they better concentrate their flavor and benefits.

Rose apple (*Syzygium jambos*)
This fruit is low in calories and water amounts to 90.7 % of its weight. It grows in the Peruvian rainforest, where it is eaten raw. It is a great help against constipation and to clean the skin.

Strawberry (*Fragaria vesca*)
With a high potassium content, strawberries help eliminate water through urine. This fruit contains 89.1 % of water.

MARIELLA CHECA (PERU)

Curious fact:

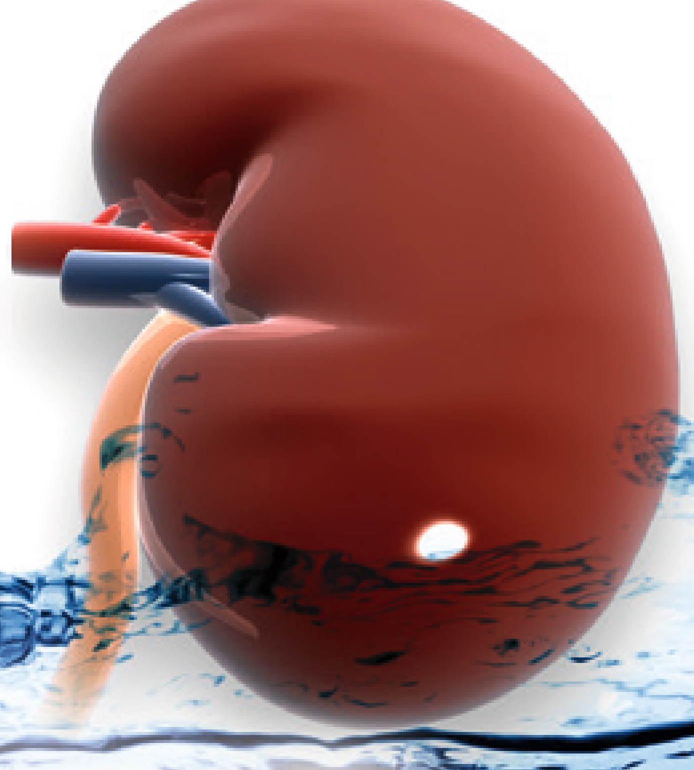
While we have seen that fruits are a natural source of water, there are also dehydrated fruits.

Raisins or dried figs, for example, have a longer shelf life than in their original state, since after losing their liquids, the sugars they contain are concentrated and act as natural preservatives.

Moreover, the main causes of fruit decay, i.e. micro-organisms, bacteria and fungi, need air and water to survive, so eliminating or reducing the presence of these elements as much as possible will extend the shelf life of food.

Photos (pp. 8-9): Fruits, Walter Hupiu

When water quality is vital for life



In the next 24 hours, two small organs the size of your palm –your kidneys– will filter around 190 litres of blood. What is the importance of this task and how does an artificial kidney work? Find out the difference between tap water and the liquid used to purify the blood when the kidney function needs to be replaced.

Every day, the human body carries out the difficult task of regulating, on its own, the composition of its fluids, which is continually altered by the intake of water, salts and nutritional substances.

Around one-fifth of the total blood pumped by the heart in each contraction goes through the kidneys, where it arrives via the renal artery. This means that approximately 1500 litres of blood go through these organs every 24 hours. Of this total, these sophisticated machines process around 190 litres of blood every day and remove around 2 litres of waste and extra water, in the form of urine.

The 190 litres of fluids filtered daily in the kidneys represent three or four times the total amount of water present in the body of an adult person. Though the percentage varies with age, 60 % of the weight of an adult's body is water.

With the shape of a bean and a size of approximately 10 cm long and 6.5 cm wide, these organs, which you could hold in one hand, are located near the middle portion of the back, just under the lower ribs, one on each side of the spine.

Its main functions include eliminating substances that our body does not need, producing hormones for the formation of red blood cells and bones, regulating blood pressure and controlling water and salts in our body.

Waste removal occurs in tiny units located within the kidneys, which are called the nephrons. Each kidney has around one million nephrons, each having very small blood vessels, the glomeruli, that act as strainers or filtering units, keeping normal cells and proteins within the blood flow and letting waste and extra water pass through. In addition to conserving water, the kidneys must also retain sodium and glucose. At the same time, they must eliminate nitrogenous products that are toxic (in particular, an organic substance called urea), and that are produced as a result of protein breakdown.

And what if they do not work?

One of the functions of the kidneys is to filter sodium, removing it from the body through urine. When for some reason these organs are damaged, they may not filter as well as when they are healthy, leaving sodium within the body and causing an increase in blood pressure and an edema due to water retention.

Most kidney diseases attack these tiny functional units –the nephrons–, causing them to lose their filtering capacity. Though this may have a sudden onset (e.g., as a result of an accident causing an injury, surgeries or intoxications with medicines, among other causes), in most cases injuries develop slowly and silently, so the damage to the kidney may be noticed years –and even decades– after the process has begun.

The two most common causes of kidney failure are diabetes and high blood pressure. But there are also hereditary factors and other diverse causes (such as infections, kidney stones, obstructions, cysts and the effects of certain medicines).

High blood pressure progressively damages the kidney, and this damage can be divided into five different stages. In the first three stages, the function of one or both kidneys is relatively preserved and, as a result, physicians usually prescribe a conservative treatment. In the fourth and fifth stages, however, there is evidence of major failure with such a reduction in the filtering capacity that dialysis is needed. Though kidney disease can be asymptomatic, which is usually the case in the early stages of the disease, today it can be detected with simple exams, such as urine and blood tests. Therefore, the disease can be detected during routine exams or by chance, when tests are requested for the treatment of other conditions or symptoms.

The gradual loss of kidney function is known as chronic kidney disease (CKD) or chronic kidney failure. Some people are born with just one kidney and, nevertheless, they can live a normal and healthy life (with a healthy diet). Since a person can live with just one kidney, thousands of people around the world donate a kidney to be transplanted into a relative or friend.

What is the limit of kidney function? Specialists say that when kidney function is reduced to less than 25 % of its capacity, severe health problems develop; if it is reduced to less than 10 % or 15 %, the person needs some sort of renal replacement therapy, i.e., treatments to clean the blood (dialysis) or a kidney transplant.

In the case of CKD, the kidney function is not restored, that is why it is necessary to replace it through dialysis. Acute kidney failure (when the kidney is suddenly damaged) is totally different.

Two forms of dialysis are used to replace kidney functions until they are restored or a transplant is performed: hemodialysis and peritoneal dialysis.

Hemodialysis, which is the most common treatment, uses a filter called a dialyzer, which works as an artificial kidney to purify the blood. During the hemodialysis treatment, the blood leaves the body through a puncture with a fixed needle and gets to the dialyzer through some tubes; the dialyzer then filters both the waste and the extra salt and water. Then, the clean blood flows through another set of tubes and, through another needle, enters the body of the person receiving treatment, without any waste. The hemodialysis machine monitors blood flow and removes waste from the dialyzer.

This process, which is generally carried out at specialized centers, usually takes three to four hours, and must be performed three times a week. But, who invented it? And how was the first machine made?

With just a sausage casing and the motor of a windshield wiper

In 1941, Willem Kolff, a Dutch physician, noted for the first time that it was possible to remove urea and water from blood through a cellophane membrane. To do so, he immersed a cellophane bag full of blood in a solution of sugar and salt dissolved in water, just like when we dip a tea bag in water. Waste, such as urea particles, passed through the cellophane, in a physical diffusion process called dialysis (in this case, hemodialysis or blood dialysis). The passage of water through the membrane is a consequence of osmotic pressure, but it can also be complemented by an ultrafiltration process, where water is actively pushed out of the blood medium. (Artificial kidneys combine all three processes mentioned.)

With this knowledge and the assistance of Hendrick Berk, an engineer, Kolff built the first successful dialyzer in the world. In 1943, in the Kampen Hospital, during the Nazi occupation of the Netherlands, Kolff used his invention –an artificial kidney– for the first time in a human being. The hemodialysis equipment he used had a cellophane tube (of the same kind used as a sausage casing), which, when folded around a metallic cylinder, would fill with the blood of the patient propelled by a peristaltic pump. The whole equipment, activated by the motor of the windshield wiper of an old dismantled Ford, would turn while immersed in a container holding a bath with the composition of the plasmatic fluid. The patient died, as did the next 14 patients. Finally, two years later, patient number 16, a 67-year-old woman, was the first one to survive acute kidney failure and hemodialysis. Her name was María Schafstad, and was in prison when she went into a uremic coma. Kolff successfully carried out a long dialysis session; the patient lived for another seven years and died of causes unrelated to her kidney problems.

The first country that openly accepted and implemented this method for its immediate use was Canada, in Montreal.

Kidneys seen on a magnetic resonance image (MRI).
Photo: © Andrey Burmakin - Fotolia.com

Water quality: which one can be used in hemodialysis?

One can easily imagine that the quality of the water used in hemodialysis is a key factor in the efficiency of the treatment. It must comply with quality requirements that are higher than those established for drinking water, since water for dialysis comes into contact with the patients' blood, despite being separated by the membrane of the dialyzer, being one of the main elements of dialysis therapy. In general terms, it can be said that water used for hemodialysis should not exceed 10 % of the toxic concentration established for drinking water.

A review of the treatment of water for hemodialysis published in the magazine *Nefrología* (Nephrology), indicates that, since the fluid used for dialysis is generally made from water from the public network, most of the complications registered, regarding the quality of the water used, have been the result of contaminants present in the water and, therefore, of the methods employed for its purification. That is why substances such as chlorine (added to treat drinking water), can be found in the fluids used for dialysis, and doctors may see the following complications in patients: reactions to pyrogens (rests of bacteria, that can cause fever), hard-water syndrome (water with a high content of dissolved calcium and magnesium), or aluminum intoxication (while this element is a natural component of water, aluminum sulfate is usually added during the treatment of drinking water, acting as a filtering agent).

Therefore, just like drinking water, water for hemodialysis can contain contaminants of both chemical and microbiological origin. Besides aluminum, among the first group of elements, we can find: chlorine, calcium and magnesium, fluoride, nitrates, copper, zinc, sodium and potassium. Among the second group of elements, we can find: bacteria (such as Pseudomonas), viruses, fungi, algae and protozoa.

In every country, different institutions –both public and private– carry out analyses of the water used for hemodialysis upon the request of hospitals and treatment centers for kidney diseases, in order to guarantee its quality control.

National legislation specifies the physicochemical and microbiological parameters this water has to comply with. Therefore, based on the sampling of the water used for hemodialysis, laboratories that carry out quality control analyze its contents to see whether it complies –or not– with the parameters set forth in terms of maximum levels allowed. This procedure requires using special lab equipment, such as ion exchange chromatographs and atomic absorption spectrophotometers.

Approximately every 30 days (this frequency varies according to each country's legislation), a sample of the water coming out of the dialysis water filters (which filter chlorine and other elements described, apart from bacteria, in the machine room) and going into the machines, is taken and analyzed. However, if a patient develops a pyrogenic reaction (fever, chills) during a dialysis session, a sample is immediately taken to conduct a bacteriological analysis.

Numbers in Argentina

In Argentina, the National Institute of Industrial Technology – INTI (from Spanish *Instituto Nacional de Tecnología Industrial*) is a reference institution regarding the quality control of water used for hemodialysis, and there are different regulations that establish the physicochemical and microbiological parameters this water has to comply with.

According to official data (INCUCAI, February 2013), there are approximately 28 000 patients in the country who are undergoing hemodialysis, in 536 treatment centers.

The INTI specialists believe that, regarding the analysis of water used for hemodialysis, the establishment of criteria to guarantee the quality of measurements in the laboratories involved in these analyses is long overdue. In order to achieve this, it would be necessary to implement different measures, such as intercomparison tests and the preparation and provision of reference materials to these laboratories.

Intercomparison or interlaboratory tests are tools to guarantee the quality of a laboratory's measurement results, by comparing its analytical results in a specific test with the ones from other laboratories in a similar field.

Reference materials provide the required traceability in measurements and are used, for example, to calibrate equipment, to control the quality of measurement results and to validate methods.

Claudia Mazzeo (Argentina)

Flour, eggs, sugar... and moisture!

The air around you and a delicious chocolate cake have something in common: they both contain small water molecules in the form of vapor, that we call moisture. Did you know that moisture plays a major role when cooking food?

"Luis, can you pass the butter and eggs from the fridge, please?"
"Do you know what you're doing?" Luis asks, a little doubtful.

"Yes…well, almost. My mother is a pastry chef, and I have seen her do this a million times."
"To be honest, I'm worried Adrián," Gabriela says laughing. "You haven't even read the recipe!"

Adrián, Luis and Gabriela want to throw a surprise party for their friend Carolina, who is about to turn 17. They have borrowed the bakery of *Doña* Elena, Adrián's mother, to bake the birthday cake, apart from cookies, muffins and treats for the party.

Although the three of them have visited *Doña* Elena's bakery on several occasions, they are not quite sure how to proceed.

"Adrián, remember that the cake should be spongy and moist, and the cookies crunchy, not the other way round!" Luis quips.

"Very funny, Luis. Relax guys, we just need to follow the recipes, that's all. Look, this one is for the cake and that one for the cookies."

"How odd, both recipes start with the same ingredients: butter, eggs, sugar and flour," Gabriela says surprised. "How do cookies and a cake come from two recipes that are so similar? We'd better ask your mom for help, Adrián."

Doña Elena, with years of experience, willingly agrees to help the kids, so they can have the best pastries at the party.

"Before we start, wash your hands and preheat the oven."

When they start cooking, Gabriela takes the opportunity to clear her doubt. Why do both recipes have similar ingredients but produce such different results?

Doña Elena might not be a scientist, but she is an expert confectioner and she knows a lot about food science.

And as she explains, it has much to do with water and moisture.

Water in the air?

Have you noticed that, on hot days and when filled with a cold drink, a glass usually has drops of water on its surface? These drops are the result of moisture in the air, condensing around the glass.

Moisture is water vapor present in the air. A part of the air surrounding us is formed by water molecules.

Air can contain a certain amount of water vapor, depending on the ambient temperature. The hotter the environment, the more moisture air can hold without vapor condensing. Just as air contains water, so do the food and ingredients used by the kids to cook. Almost all food contains a certain amount of water molecules. In baking, sugar, eggs, dairy products and fruits provide most of the moisture for the recipe, since these ingredients have a high water content. Due to high temperatures in the cooking process, the water content reaches its boiling point and is released as vapor.

"And is it possible to change the water content?" Luis asks.

"Sure! Look, do you see that strawberry cheesecake over there?" *Doña* Elena points out. "That one is baked in a bain-marie. Under the container with the mixture, I placed another one with hot water. Besides making baking more even, the heat slowly evaporates water, increasing the air moisture within the oven and keeping an even temperature around the cake. And these dried fruits over here were fresh fruits; I dehydrated them by using hot air."

The optimal mixture

As for flour, it is a hygroscopic ingredient, which means that it can absorb water. In the cake mixture the kids are preparing with *Doña* Elena, the flour granules absorb part of the vapor released by the other ingredients. The rest is retained by the air within the oven.

Flour also absorbs moisture from the environment. On a rainy or wet day, a cup of flour left in the open for several hours will weigh a little more than what it would on a dry day.

If you weigh a cup of flour at home and then leave it outdoors on a wet day, you will notice that the scales will read a few more grams than the previous measurement.

"However, flour can also lose moisture," *Doña* Elena explains to Gabriela. "Since cookies are baked at a higher temperature, flour loses more water as vapor."

"Besides," *Doña* Elena adds, "if you check the cookie recipe, it has a smaller amount of flour than the cake recipe."

"Of course! Less flour means less moisture absorbed. That is why cookies are drier than cakes," Adrián figures out.

For the best cake

When making pastries, ambient moisture may affect the final result. And sometimes, it may not be what we expected. For example, if it is a very dry day out, pastries will often turn out dry too. And this works the other way around as well: on wet days, baked foods may absorb too much moisture, making cakes too heavy and preventing them from rising, even if you used baking powder, sodium bicarbonate or yeast.

"And what can we do to prevent moisture from ruining pastries? I can't imagine the number of ingredients that could be lost if something goes wrong!" Adrián exclaims.

"Well, in my bakery I have a dehumidifier, which is basically a device to remove excess moisture from the environment."

"I've heard that in large factories, the whole production environment is controlled," Luis adds. "I suppose moisture is also measured."

"Yes, they use instruments called hygrometers. There are three types: absorption, hair or electrical hygrometers."

"But I don't have a hygrometer at home. What can I do to prevent moisture from ruining a cake?" Luis asks *Doña* Elena.

"Well Luis, we usually avoid opening the oven door during baking, to keep the temperature and moisture conditions relatively stable. And we can add more or less water to the mixture, depending on the recipe and on how dry or wet the day is."

"So, it seems our pastries turned out great. I'm sure Carolina will love them!" Gabriela says smiling, while taking the cake out of the oven.

"Yes! Look how good these cookies are! Crunchy and golden brown!" Luis exclaims.

"And the cake is spongy and well-formed," *Doña* Elena states complimenting them. "I might bring you to cook with me more often!"

Jasson Clarke (Costa Rica)

Did you know…?

Human and animal hair has been used for many years as a moisture sensor, due to its hygroscopic and elastic properties. Hair is under tension and it stretches or contracts, depending on the greater or smaller amount of water vapor in the environment.

Images (pp. 14-15): Cake, Alex Ado;
Condensation, Mike Fretto (http://www.sxc.hu)

What a surfboard has to do with Metrology is something scientists can explain. What we can all agree on is that sports are good for our health… and also for the environment. London 2012 and Rio 2016 are examples of what organizing sustainable Olympic Games means.

Photo: © christianalm - Fotolia.com

Let’s move!

Waves, wind and measures

"Eureka," said Archimedes once while taking a bath, back in the 3rd century BC, when discovering that a body immersed in a liquid experiences an upward thrust equal to the weight of the liquid it displaces. This is his famous principle, but also one of the reasons why thousands of people around the world can enjoy surfing and sailing.

On the world's coolest beaches, surfers look for the most challenging wave, the one that will allow them to be, for a brief moment, the king of the seas. Something similar happens with those who practice sailing, who aboard their ships —all alone or with a crew— sail across rivers, seas and oceans, chasing the freedom given by the apparent lack of borders.

Who would think, then, that such a carefree feeling depends on dozens of precise calculations and exact measurements? When floating in those waters, who would remember poor old Archimedes, who put a lot of effort into developing his famous principle? The truth is that while enjoying the sea breeze in our face, surfing or sailing is not just about our agility and coordination: first we have to float. The buoyant force discovered by Archimedes, which depends on the density of water and the volume of the submerged body, is involved in the buoyancy of the board. The gravitational force that acts by sinking the board due to the weight of the surfer and that of the board itself, which is related to the density of the material used in manufacturing, greatly factors in as well. So, who is to say that sailing is pure relaxation now?

Daniel and Alberto Demicheli have a clear idea. Following the family tradition, these brothers have always been involved in water sports. As boys, while Daniel chose surfing, Alberto turned to sailing and yachting, as these sports are internationally known. Over time, they both became professionals, competing internationally and participating in the development of these sports in their home country, Uruguay. The passion they feel for these activities leads them to practice them as naturally as any other athlete, but years of experience taught them to understand that measurements play a central role in these sports.

Surfing

Before even starting to ride a wave on a surfboard, calculations and measurements already have a prominent place in this sport, since the size of the board is not chosen randomly. First, it should fit the surfer's body type, so the board can float in the water. To achieve this, that thrust exerted on them, which Archimedes spoke about, would have to be greater than the combined weight of the board and surfer, otherwise they would both sink.

Therefore, the first step is to choose the surfboard size based on the surfer's body. The heavier the surfer, the thicker the board to increase buoyancy, since by increasing thickness (while maintaining its length and width), the volume increases.

In addition, the surfboard size will also depend on the surfer's skills —beginner or professional—, on how big or small the waves are and even on the seabed slope. "As you learn to surf, you also get to know the sea and your gear: surfboards," says Daniel, who has been a surfer for 34 years and a board manufacturer for 20. Worldwide, board sizes are expressed in feet[1] and their length may range from 6 to 9 feet. The speed a surfer achieves on a board will depend on the force of the waves, the shape of the board and the surfer's skill to place the board where the wave thrust can be maximized. With this in mind, smaller boards are faster, but also more difficult to maneuver and are not recommended for beginners. In beaches with large waves —over two metres high—, surfers will go faster, so longboards are more suitable. In fact, increasing the surfboard length implies increasing the sliding surface, providing more stability, which is one of the most desired factors when surfing on a beach with big waves. Apart from being dangerous, falling off a surfboard will certainly hurt.

Surfboards may also vary in shape. Made of light polyurethane foam, covered with fiberglass and resin to make it waterproof (since if water penetrated the material, the board density would increase and reduce buoyancy) and with a wooden strip reinforcing the structure, a surfboard has a point or nose, a central section and a tail that may vary in shape, where three removable fins are placed (acting as a rudder). As seen from the side, surfboards curve upwards in the nose and tail, making them hydrodynamic. This helps them fit the waves, reducing friction with the water and allowing a faster sliding.

[1] Unit of the English system that is not part of the International System of Units – SI (1 foot = 30.48 cm)

However, in order to glide over water, it is not enough just to get carried away. In this regard, other fellows were involved: by the end of the 15th century, Renaissance man Leonardo da Vinci was the first one to establish the laws of friction governing the motion of a rectangular block sliding over a flat surface; then came French engineer Guillaume Amontons, who in 1699 devoted most of his time to theorize about the friction between two bodies and the resistance generated in sliding, and finally it was the turn of Newton, with his laws governing the dynamics of bodies.

To prevent friction from slowing down surfers propelled by waves over water, designers provided surfboards with specific shapes —concave across their width, like a gutter, for example— to help sliding.

And while the elements that should be taken into account when designing or choosing a surfboard have been several so far, that is not all. The salinity of water should also be considered, since it affects its density and, therefore, the buoyancy of the surfer and surfboard. “For surfing in brackish water,” Daniel explains, “a thicker surfboard should be used, to offset low buoyancy. However, in the Caribbean, where the salt levels are higher, surfers can float with a thinner board.”

“Even water temperature has an influence,” Daniel pointed out. In cold weather, surfers should use a neoprene wetsuit, which preserves body heat but absorbs water, increasing the person’s weight. That is why boards in colder waters should be thicker, to offset weight and allow the surfer to float. “In warmer waters, however, surfers don’t need suits and the surfboard can be thinner.”

Sailing

While in surfing the importance of measurements is concealed by the natural movement in water —and, in addition, they are not significant when competing, since the different categories only take the surfer’s age into account—, among those who practice sailing, calculations and measurements are impossible to forget. The principles and forces that make a ship float are the same as in surfing, but contrary to the apparently relaxed spirit of that sport, those on a sailboat should inevitably be familiar with the metrological world. So much so, that yacht clubs usually have a measurement committee, of crucial importance for sporting competitions.

In sailing, the different racing systems may be divided into two main groups. On one hand, there is handicap racing: competitions where sailboats of different sizes are involved. Under this system, for the different

Photo: © EpicStockMedia - Fotolia.com

boats to compete against each other, a requirement is that similar characteristics must be defined, and their evaluation is based on measurements, which are then used to compare the performance of each ship according to its characteristics. The differences in measurements are compensated for by adding or subtracting minutes from the arrival time.

For example, a lighter boat would have a lower resistance of water to its movement, making it faster; or a ship with a larger sail surface would receive higher wind power, among other issues that may represent a comparative advantage over other ships.

Therefore, in order to cancel out the external factors so that what is at play is the person's skill, we turn to the measurement committee members, who are often sailing enthusiasts but, above all, they are experts in the metrological field. Their mission is, precisely, to take hundreds of measurements periodically; they can do it once a year, before an international competition or if the ship has been modified.

On the other hand, there is class racing, which includes categories where all ships have equal or similar characteristics. Worldwide, some of the most well-known classes are: Snipe (two sailors), J24 (three to five sailors), Optimist or Laser (one sailor each), among others.

Each of these classes has specific measures in terms of length, width, weight and sail surface and, in order to compete, the measurement committee of the club the sailor belongs to must ensure that the various requirements are met. The weight of the ship and even that of the crew, the size of the ship in different sections, the sail thickness, the pole angle. Everything counts and all is used to prepare what is known as a measurement certificate —specific to each ship—, this is why the measurement work could take up to three hours per boat, explains Bernie Knüppel, racing officer and member of the Measurement Committee of the Uruguayan Yacht Club.

While using measuring tapes, levels, set squares, densimeters and scales, among other tools, his work is so important that measurement experts are usually trained in international centers to handle these standards.

But once aboard the ship, the link with measurements is not broken. "There's a lot of physics and other sciences in sailing, and as you start learning more about physics, you realize there are more things you can use. For example, it is very important to know how pulleys, levers or vectors work, or even friction," said Alberto, who has been involved in sailing for decades.

It has also proven useful to make the actions of sailors faster and more effective, in order to maneuver and place the sails in a position to maximize the force of the wind, among other issues.

Today, after several years of practice, Alberto and Daniel agree on the fact that technological development has contributed substantially to their sports, improving people's performance, by developing better materials or equipment such as GPS (a system transmitting data from a satellite network that makes it possible to globally determine the position of an object or person anywhere in the world), facilitating the work aboard the ships.

But beyond technology, the essence remains the same: measurements are still very important when traversing the waters in search of excitement.

DANIELA HIRSCHFELD (URUGUAY)

For Daniel Demicheli, surfing is not only a hobby but also an occupation, since he works making surfboards in his workshop, which involves molding, measuring and preparing boards to practice surfing. Photo: Silvana Demicheli

Sports are also good for the environment

During the last Olympic Games, in London, the event organizers flew the green flag for environmental protection and decided to go big. With a series of far-sighted planning and development measures, London 2012 became the host of the first sustainable Olympic Games, and Rio 2016 is set to follow in its footsteps.

The celebration of the 2016 Olympic Games in Brazil may become the first one aimed at zero carbon emissions, if the ecological project specifically developed for this sporting event is completed. Rio 2016 organizers, less than four years before the Olympic flame is ignited again, have a clear goal that follows what was started in London 2012: the construction of stadiums in the Brazilian city is following a similar logic to the one applied by the previous organizers in terms of environmental care.

Brazil may become a real icon for green and sustainable trends worldwide, if it achieves what it set out to do. Rio de Janeiro will undergo a major urban and social transformation: building highways, tunnels and Bus Rapid Transit lines, which entail exclusive bus lanes and the revitalization of the port area, will be a priority.

In addition to the progress towards environmental protection, today Brazil has the chance to build, right in the middle of Rio de Janeiro, an ecological Olympic complex named Solar City Tower, a project by the Swiss architecture firm RAFAA. This structure would be built in Cotonduba Island and, apart from offering an ideal viewpoint of the city, it would allow solar energy to be harnessed in order to power the Olympic Village. It is a self-sustaining tower that would supply energy both to the Olympic Village and the city of Rio de Janeiro, by using natural renewable resources.

By implementing this project, it would be possible to harness solar energy by placing panels at ground level, while the surplus energy would be channeled to a seawater pump inside the tower, producing a waterfall effect into the pool. At the end of the day, the excess water would be released with the help of turbines, which in turn would generate the energy required for the night.

Building on successful models

The Organizing Committee of London 2012 Olympic Games was known for incorporating environmental sustainability to the event, an issue that is becoming increasingly relevant worldwide. A social environmental sustainability plan was developed based on five strategic points: climate change, waste, biodiversity, inclusion and healthy living. Its main goal was to use the major impact of this sporting event to inspire a long-lasting change. The idea was clear: the sustainability concept should be understood as a whole, that is, globally considering all the aspects required to hold an event (planning, building, working, playing, socializing and traveling).

When the sports complex that would accommodate thousands of athletes and spectators from all over the world was designed, environmentally friendly values were taken into account to avoid making the same mistakes as in previous games.

Due to its high water demand, London is considered to be an area of high water stress, so during periods of drought it shows a significant water shortage. For the construction of the Olympic Park and the various sports centers, the ODA (Olympic Delivery Authority) developed a strategic plan to reduce drinking water consumption by 40 % over the standards of previous years. The initiative was based on two strategies: to reduce consumption and to use alternative water supplies for non-potable uses.

To achieve this, social education, more efficient irrigation systems and the use of technologies allowing a 30 % saving over previous standards, were identified as the main focus.

Reduction was achieved by using non-potable water, which led to a 26 % saving over the desired 40 %. It was used for toilet and urinal flushing, water cooling in the Olympic Park Energy Centre and to feed irrigation systems.

The use of alternative water sources made it possible to reduce drinking water consumption by 10 % by using non-potable water. The roof of the Velodrome was fitted to capture rainwater, which was used to reduce water consumption across the network by 75 %. This building is the most efficient infrastructure in the Olympic Village. Another source of water recovery was the roof of the Copper Box building, where basketball was played, which allowed rainwater harvesting, saving 40 % of annual consumption.

For reusing waste water, a treatment plant funded and operated by Thames Water, called Old Ford Water Recycling Treatment Works, was built to treat and recycle black, grey and runoff water from North London. The plant, which has a filtration unit, a membrane bioreactor (MBR), an active carbon absorption unit and a chlorination unit, has been designed for an optimum capacity (from an energy point of view) of 500 000 litres per day, being the first large-scale water recycling plant in England.

For the distribution of reclaimed water, a piping network of 3.6 km was built.

Water sports demands

The Aquatics Centre is one of the largest water consumers in the London park. Each pool has a series of filters used to treat pool water, and each of them has to be washed with over 19 000 litres of water, over a 10-day cycle.

Due to its quality, the water used to clean the filters could not be used in the swimming pool, since it would not meet the requirements for bathing water, so it is usually discarded. However, in the swimming center, a filtration system has been installed in order to reuse the filter cleaning water in toilets, so an estimated 2.7 million litres a year could be saved.

Conscientious building

The International Olympic Committee decided to follow through with this idea and with the project to implement sustainable ideas in all stages. The velodrome used in London will be taken to Rio 2016; there, stadiums are being built with reused materials that were taken from unused and abandoned buildings. Within the Committee, they say they are confident that they are making good decisions. Raising awareness among organizers, athletes, sponsors and the general public is a way of contributing. The eyes of the world are on these events and this is the best way to set an example.

Much of the design and construction of the London buildings was made with recycled or reused material. The rubble from demolished buildings was used as bridge backfill. More than 60 % of the elements used were taken to the site by rail or by sea, thus avoiding the use of more polluting forms of transport, such as trucks or planes. The goal was to minimize toxic gas emissions and guarantee that the buildings that will be left as legacy can face the effects of climate change. With the demolition of buildings, 97 % of the material was recovered, which was reused to build the Olympic Park.

Sustainability awareness

During the celebration of the games in London, people all over the country were encouraged to take part in sporting activities and lead an active, healthy and sustainable life. For this reason, in order to emphasize a healthy lifestyle, people were not allowed to arrive at the Olympic venue by car, and consequently, there were no public parking lots either. Everybody had to get there by public transport, cycling or walking.

And, as the icing on the cake, it was decided to develop a strategic plan to recycle all the plastic bottles used during the games. ECO Plastics and Coca-Cola funded this project together. This year, the soda company inaugurated the largest plastic recycling plant in the world, located in Lincolnshire, Northern England. An interesting and encouraging fact is that each recycled bottle may save enough energy to make a 60 W light bulb work for six hours and a ton of recycled plastic saves 5774 kWh[1] of energy.

Experiencing it first-hand

Martina González del Solar and Pedro Ibarra went to London. She went as a spectator. He went as a member of the men's field hockey team. They both witnessed the great work of the organizers to develop distinctive Olympic Games. A sporting event that, apart from encouraging amateur physical activity and the values of sports, for the first time promoted environmental care by implementing actions from the pre-production to the closing stages of the competition. Just like everyone else who attended, they were able to contribute to the efforts made for this to happen. Raising awareness of the fact that we need to take care of our world and stop hurting it was the starting point from which the organizers began to fly the green flag, the people of London took the lead and athletes and spectators complied, no questions asked.

- Did you know that London 2012 was going to promote environmental awareness?

Pedro: No, the truth is nobody had told us about it. But it was amazing. Everything was well organized. For example, there were five waste bins: one for plastic, one for cardboard, one for cutlery, one for liquids and one for food.
Martina: It was the same for spectators; in fact, there were volunteers checking that this was observed.

- All those demands, were they any trouble?

Pedro: Not for us the athletes; on the contrary, we were pleasantly surprised. Everything was clean; it was a pleasure to be there. Besides, we knew we were contributing to the protection of the environment, which was very fulfilling for us.
Martina: Not at all! It made everything easier, allowing us to behave naturally. And I'll tell you what…it has caught on, now we are implementing it at home.

- Stadiums were built with a high percentage of recycled materials, did it cause any problems when playing the sport?

Pedro: No, none. In fact, if you didn't know, you couldn't tell. Everything was perfect. There were green spaces to enjoy, stadiums were big and functional, the locker rooms were amazing and the Village where we lived was super comfortable.
Martina: I didn't play, I just watched, but I'll tell you one thing: if you had your ticket to see some sporting event, public transport was free and it worked perfectly.

Luckily for the future of our planet, the organizers have done their part with great success. Now we can only hope that the accomplished goals become an example for future games, and that all these efforts do not turn out to be just an anecdote, but that the plans for Rio 2016 be effectively implemented.

Jazmín Beccar (Argentina)

Martina González del Solar and Pedro Ibarra had an unforgettable experience in London 2012, both on and off the field.
Photo courtesy of Martina González del Solar

[1]kWh is not part of the International System of Units.
1 kWh = 3.6×10^6 J

Photos (p. 21): Leaf, © Stauke - Fotolia.com. Athlete, © berc - Fotolia.com
Composition (p. 21): Alberto Parra del Riego
Image (p. 22): © Stephen Finn - Fotolia.com

Analyzing the behavior of the various elements that make up the world in multiple scenarios is one of the tasks of scientists and metrologists. To achieve accurate measurements, certain factors such as height or water salinity, among others, should be taken into account. If you want to drink some *mate* 3000 metres above sea level or have a swim in the Dead Sea, you are probably in for an interesting surprise.

Photo: © lily - Fotolia.com

The environment

Backpacking experiences

Lessons learned traveling

Just a while ago, the two brothers had arrived with their backpacks in Potosí, a Bolivian city located 4000 metres above sea level. After traveling almost 3000 kilometres since they left Montevideo, Andrés and Joaquín checked in at a downtown hostel and went out to look for a cheap place to eat; they had not eaten in hours and were very hungry. But shortly after they left, they started noticing that they were short of breath and had trouble breathing. Besides, Joaquín was getting a headache as well, and Andrés was a little dizzy. They were suffering the first symptoms of what is known as altitude sickness.

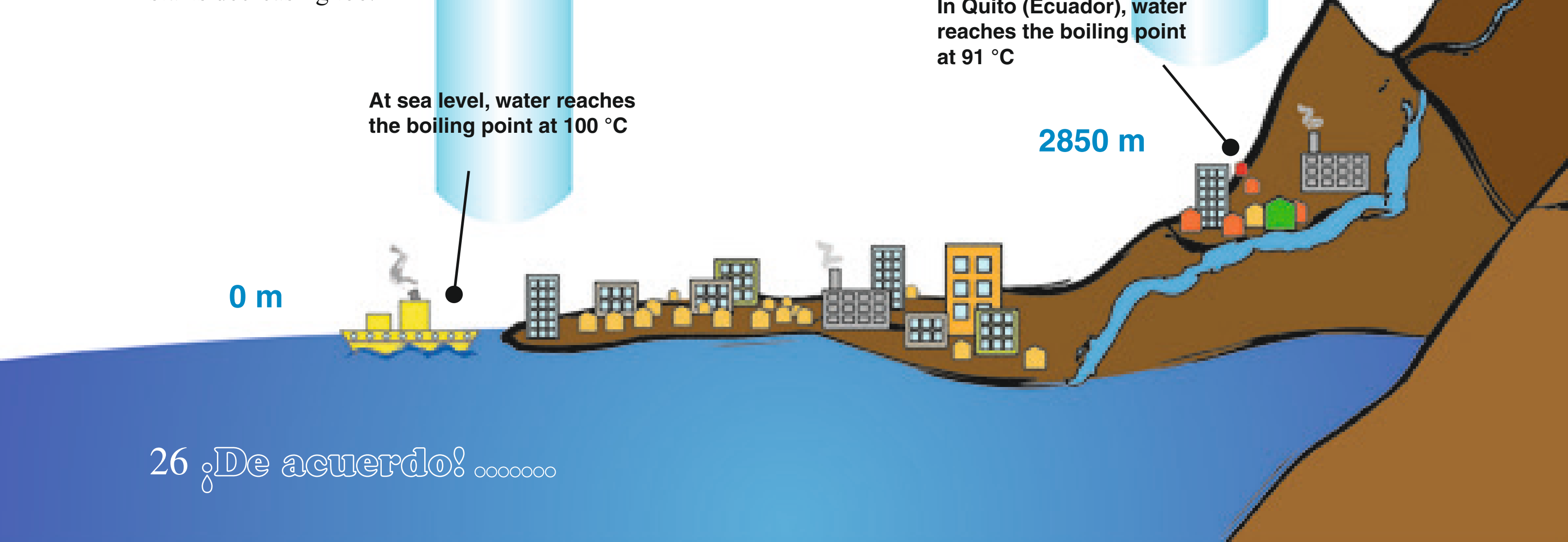
This is the name given to the physiological reactions the human body experiences when arriving at high altitude locations. As you start to go up, there is a gradual decrease in atmospheric pressure and, while at sea level the oxygen concentration in air is constant (21 %), at a higher altitude the partial pressure of oxygen starts to decrease. This makes the number of oxygen molecules per cubic metre of air to decrease, and oxygen saturation in blood starts decreasing too.

The brothers realized that, apart from those first symptoms, they were not hungry anymore and, quite the opposite, Andrés was feeling nauseous. Then, they remembered they had read about altitude sickness when getting ready for the trip. Generally, this sickness starts to show at an altitude above 2400 metres. Therefore, the two young men abandoned the idea of getting something to eat and returned to their hostel.

When they got to the hostel, Joaquín thought he could do with some *mate*. Like many other Uruguayans, he always travels with his *mate*, the container that has the same name as the infusion itself. In his home country, it is usually a special type of calabash gourd, similar in size to a cup, which undergoes a drying process so that the traditional beverage can be prepared in it.

Joaquín went to the kitchen to boil some water. He still had Uruguayan *yerba*[1] in his backpack. While heating the water, he started to talk with a Spanish guy who told him that he had just come from the eastern area of Bolivia. When Joaquín saw that the water was bubbling, he removed it from the fire and put it in his thermos right away. He went back to his room and, following the traditional method, put some *yerba* in the *mate*, poured some water and put his silver straw in. But when he took a sip, he felt something was wrong or, at least, not what was expected.

[1](TN) *Yerba* is the name given to the dried and thinly chopped leaves of a tree (called *yerba mate*), which are used to prepare the infusion.



The *mate* was much colder than it was supposed to be. How could that be if he had just boiled the water? This was another effect of altitude, one which Joaquín had never heard of or read about.

If we put water to boil at sea level, we can check with a thermometer that the boiling temperature is at 100 °C. Instead, in Potosí, La Paz or any other location at a higher altitude, the temperature at which water reaches the boiling point is lower. This occurs because atmospheric pressure decreases when elevation increases, since the column of atmospheric air above is shorter and, therefore, weighs less; it exerts less pressure (atmospheric pressure is equal to the weight of this air column per unit area). Water boiling involves the formation of vapor because some molecules have enough energy to escape the force of attraction between them and the resistance exerted by air on the liquid surface. This air resistance is the result of atmospheric pressure and, for this reason, if the external pressure is reduced, less energy is required for a liquid to start boiling.

The boiling temperature is the temperature at which the vapor pressure of the liquid is equal to the external pressure. At this point, vapor does not only form on the surface, but also within the liquid, creating the typical bubbles and turbulence of boiling. The boiling point measured when the external pressure is 1 atmosphere[1] (1013.25 hPa), is called normal boiling temperature.

Considering all this, at an altitude of 1500 metres above sea level –where atmospheric pressure will be 851.13 hPa– water boils at 95 °C. And therefore, the water for Joaquín's *mate* reached its boiling point at 86 °C, approximately 14 °C less than in Montevideo.

[1]The atmosphere (atm) is a unit for measuring pressure that is not part of the International System of Units (SI). The unit of pressure of the International System of Units is the pascal (1 Pa = 1 N/m²).

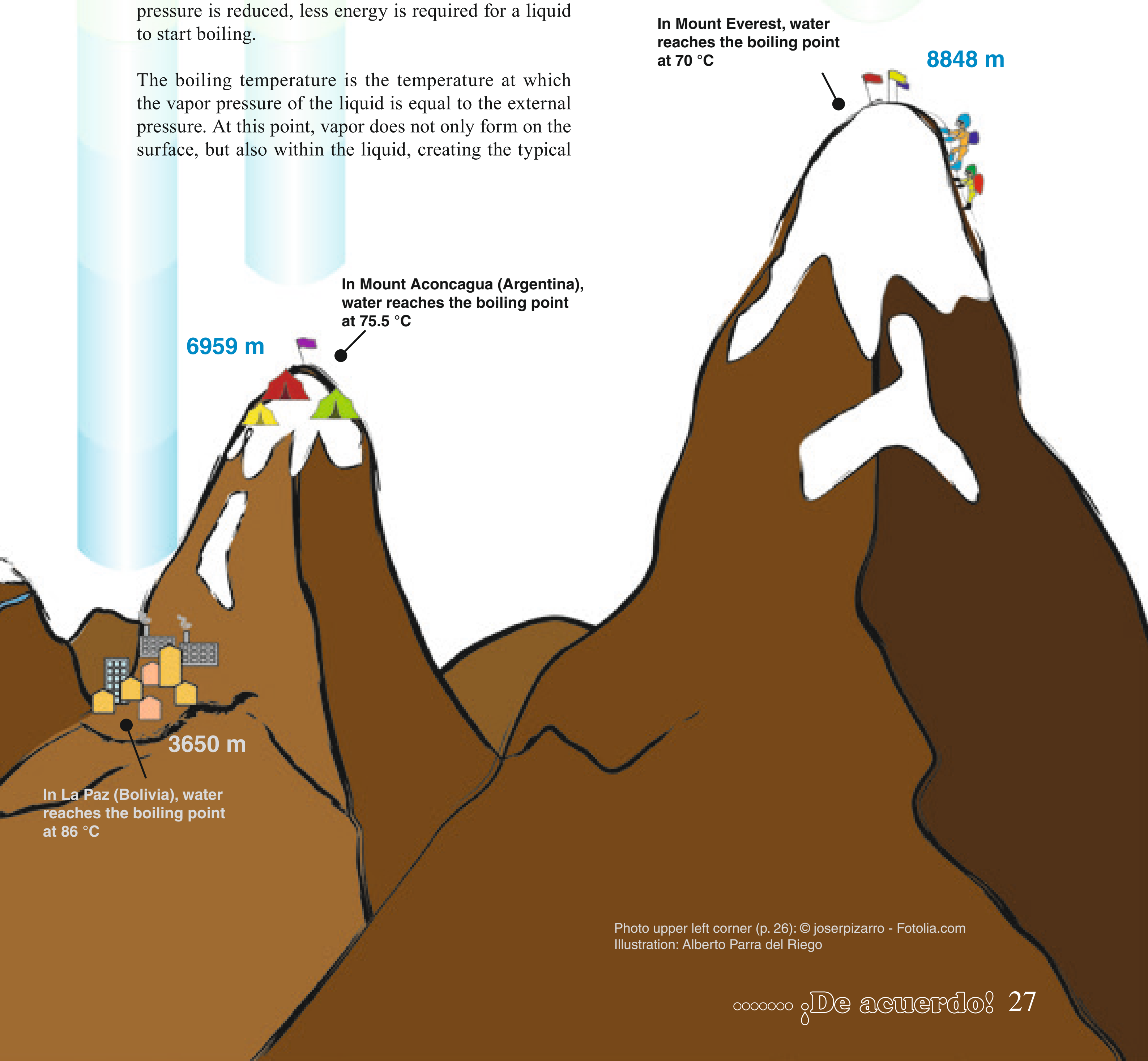


Photo upper left corner (p. 26): © joserpizarro - Fotolia.com
Illustration: Alberto Parra del Riego

The next day, both brothers were feeling a little better; they got up and went to the kitchen to have some coffee. There, the Spanish guy Joaquín had met the night before was already having breakfast with two Chilean girls that had arrived in Potosí that very morning. The five of them started to share their experiences. Joaquín told them what had happened while making his *mate* and how that morning he had found an explanation for it, thanks to the hostel receptionist. The young man who worked there had already heard similar stories from tourists, who noticed the water was colder than they expected when it boiled. Being a native of Potosí, he knew that the required temperature for water to boil at that altitude was quite lower than 100 degrees Celsius and had thus explained to the Uruguayan brothers.

Joaquín's story led the Chilean girls to tell another experience they had recently had, also involving water. It was on their way to Bolivia from Santiago de Chile, when they stopped for a few days in San Pedro de Atacama, a Chilean town located more than 1600 km north of the capital. Near that town, about 50 km north, lies the *Salar de Atacama*, the largest salt flat in Chile and the fifth largest in the world.

The girls told them that they did not want to miss the opportunity of visiting that vast expanse of land, where salts from the soil accumulate and are carried by the dissolution caused by rainfall, being finally deposited there once water evaporates.

But above all, they wanted to visit Lake Cejar, in the northern section of the *Salar de Atacama*. This lake has become a popular tourist attraction, where you can bathe and feel the so-called floating effect, caused by a high concentration of mineral salts in the water.

Salts solidified by evaporation accumulate around the lake and that is why the water where tourists swim is saturated with mineral salts, such as lithium and sulfur.

For this reason, swimming in Lake Cejar is a unique experience. Your body floats with such ease that it is possible to be completely relaxed in the water, without sinking. One may say it is almost impossible to drown, since the density of this water is greater than the density of the human body, and according to the principle of buoyancy, a person cannot sink under these conditions. The density of salt-saturated water is greater than 1.1 g/cm^3, while the density of the human body is approximately 1.05 g/cm^3.

Buoyancy is explained by the Archimedes' principle, which states that any body completely or partially submerged in a fluid at rest is acted upon by an upward force the magnitude of which is equal to the weight of the fluid displaced by the body. This force is called upthrust or buoyant force and is measured in newtons, according to the International System of Units.

The high salt concentration makes people float and those who swim in Lake Cejar have a very relaxing experience. The Chilean travelers really enjoyed swimming there and were delighted to have made that trip in summer.

While they were there, other tourists told them that, on the way to Potosí, there is an even larger salt flat than the one in San Pedro de Atacama. The *Salar de Uyuni*, located 3650 metres above sea level in southwest Bolivia, is one of the largest lithium reservoirs in the world, apart from accumulating significant quantities of potassium, boron and magnesium. This salt flat looks like a great white desert and, if visited in winter, temperatures may reach 10 degrees Celsius below zero (–10 °C).

About 40 000 years ago, the area now occupied by this desert was covered by Lake Minchin and subsequently, about 11 000 years ago, by Lake Tauca. But apart from the *Salar de Uyuni*, the Poopó and Uru Uru lakes, a little further north, are also vestiges of these great prehistoric lakes.

Lake Poopó is the second largest one in Bolivia and is a salt water lake. If the temperature dropped to 0 °C, we could observe the so-called cryoscopic depression of water (or freezing point depression, as metrologists call it), where water does not freeze at zero degree Celsius.

This occurs due to a property of solutions that, in certain conditions, experience a decrease in the temperature of their freezing point.

That is, if we wanted to freeze a water sample from Lake Poopó, we would have to bring it to a lower temperature due to the high concentration of salts dissolved in the lake. The freezing temperature would therefore be lower than 0 °C, which is the freezing temperature of pure water.

Potosí. A city located in southern Bolivia, with an altitude of 3900 metres.
Photo: Miguel Angel Montesdeoca

Salar de Uyuni. Located in the department of Potosí, Bolivia, it is one of the largest lithium reservoirs in the world and has a surface area of 10 582 km^2. Photo: Miguel Angel Montesdeoca

The cryoscopic depression will be greater, the more substance is dissolved, but it also depends on the nature of the solvent and the solute (the substance dissolved). Raoult's law states that the cryoscopic depression is directly proportional to the solvent's molality and cryoscopic constant.

Molality (m) is the number of moles of solute a kilogram of solvent –in this case, water– contains. The mole is the unit to measure the amount of substance and one of the seven base units of the International System of Units. Its symbol is mol.

For water, the cryoscopic constant value is 1.86 °C/mol/kg. This means that molal solutions (m=1) of any solute, in water, freeze at –1.86 °C.

The travel stories told during that morning encounter in the Potosí hostel were not over. Breakfast lasted for a while, because after Joaquín's and Andrés' tales about their first impression of the city, when suffering the typical symptoms of altitude sickness, the anecdote of the *mate* water that boiled at 86 °C and what the Chilean girls told about the peculiarities of water in the salt flats, the Spanish tourist told them that he also had something to tell regarding water. On his travels through various countries, he had made the mistake of swimming in a polluted river and had accidentally swallowed some water, which made him catch a stomach bug.

The contamination of water courses may be the result of natural sources or human activities. Industrialization, among other things, causes an increasingly greater production of waste, some of which is dumped in the water. A large part of this waste has a high metal content, such as lead or mercury, which pollute the water.

According to the World Health Organization, water is considered to be polluted when a change in its physical, chemical and biological properties occurs, making it lose its potability or preventing its use in activities where it would be used under normal conditions. The provisions in force in various countries also state that water used for the preservation of fish and water flora and fauna should also be free of pollution. In Uruguay, for example, a series of regulations were established to prevent pollution, based on an extensive classification of water courses, according to specific parameters that measure to what extent several pollutants are present in water.

The most common method to measure the level of water pollution is to conduct a water sample analysis in a laboratory, but there are certain parameters that, due to their characteristics, should be measured in the sampling site. For this purpose, some field instruments such as an oximeter or colorimeter may be used.

But beyond the possible tools available to measure certain types of pollution, the Spanish traveler will never know what exactly caused the infection. However, what he does know for sure is that when traveling the world and our continent, knowledge is acquired day by day. And there is no doubt that Joaquín, Andrés, the two Chilean girls and their new Spanish friend still have much to explore and also much to learn.

GRISELDA DÍAZ (URUGUAY)

Why is seawater salty?

Legend has it that a man once received a magic mill as a gift. The device had the power to give its owner anything he asked for. A greedy neighbor stole the mill and, while escaping on a boat, the crook asked for salt. Huge amounts of salt began spilling from the mill. Soon, the ship was loaded with salt and ended up sinking. It is said that the sea is salty because, in its depths, the magic mill is still producing salt without stopping.

With or without the mill, oceans around the world have an impressive amount of salt. Just to give you an idea, it can be said that the water of any beach is 220 times saltier than that of a lake or a river. If we took all the salt from the oceans and sprinkled it over the Earth's surface, it would form a layer of over 166 metres thick, about the height of a 40-floor building. That is why our beach vacations taste like salt.

Sitting on the beach, drying in the sun after taking a dip, we can feel the strong taste of salt in our mouth. For those with sensitive skin, a slight itching will reveal the presence of a salt layer on their body. But if the sea is fed by rivers and streams, why is the sea salty but rivers are not?

A liquid mill

While the salt mill is part of a legend, it is not wrong to say that sea salt comes from the slow milling of the Earth's rocks. Sea salt started out as rocks on the ground. Rain and water, flowing over the continents in the world, eroded and pulverized the rocks and, through the rivers, carried those minerals to the sea. "Seawater is salty due to the presence of sodium chloride. And the bitter taste comes from the magnesium sulfate, a second component of seawater in order of concentration," explains Dr. EvgueniChoumiline, fromthe Interdisciplinary Center of Marine Sciences (*Centro Interdisciplinario de Ciencias Marinas*) of the National Polytechnic Institute of Mexico (*Instituto Politécnico Nacional de México*).

"It all started when the Earth was still very young and with major volcanic activity," Choumiline elaborates. "Large quantities of gases and water vapor formed a primitive atmosphere. In the clouds, when water vapor interacted with gases such as hydrogen chloride and hydrogen sulfide, acid solutions of high concentrations were produced. Sodium, magnesium, calcium and other elements were extracted from the rocks due to the reaction of their materials with the acid aqueous solution."

It is estimated that, each year, rivers and streams around the world carry about 4 million tons of salt to the sea. Seawater is salty not only because it contains salt, but also due to its extremely high concentration; this means that there is a lot of salt in a small amount of water. When the sun heats up the sea surface and water evaporates, the sea loses water but not the salts. Over the years, this process has caused the salt of the sea to concentrate.

This same process has also created amazing salty lakes such as Lake Cejar in Chile or the Dead Sea in Jordan. Unlike other lakes where there is an inflow and outflow of water and materials, in salty lakes water is evaporated by the sun and wind, causing astounding saline concentrations, even higher than in the sea.

Rivers are not the only source of saline material for the ocean. Salts also come from organisms that live there, such as mollusks, crustaceans or corals, which form their skeletons and shells from salts taken from the sea. When they die, these organisms dissolve, giving their material back to the sea. In addition, the material that the water cannot dissolve ends up accumulating in sediments at the bottom.

Drinking until dying of thirst

Our planet should be called Water instead of Earth, since almost 70 % of its surface area is covered by water. However, this large quantity of water is not fit for human consumption, since it is salty and harmful to our health. Trying to drink it would cause a strange paradox: the more salt water we drink, the thirstier we would become, and we would finally die of thirst. The problem lies in what is called osmosis, a physical phenomenon our body cells use to pass liquid through their membranes.

Osmosis is a phenomenon that allows liquids in the human body to pass from one cell to the other, moving through tissues without any pump driving their movement. "To explain it, let's recall the high school experiment where, in a container divided by a cellophane sheet (semipermeable membrane), salt-saturated water is placed on one side and tap water on the other," explains Manuel Fuentes Díaz, from the Mexican Institute of Water Technology (*Instituto Mexicano de Tecnología del Agua*). The osmosis phenomenon occurs when tap water starts to filter through the cellophane into the salt water side. The reason for this is that the system tries to equalize the salt concentrations and, since salt cannot pass through the membrane (being semipermeable, it only allows water to pass, not salts), the only way to reduce the concentration is that more water passes to the side with more salts.

If we drink salt water, cells (with a lower saline concentration) give away water in order to balance the concentration, so we begin to dehydrate. In addition, the kidneys that filter toxins from the blood accumulate salt until they become damaged. Our body also tries to eliminate excess salt through perspiration, urine and feces, but uses more water in order to do so. Finally, a dehydration process takes place, which may result in death.

Water for all

In our society, there is an ever-growing demand for water: water for industry, water for agriculture and, of course, water for people. As this thirst increases, our planet's fresh water reserves (water without excess salts), are increasingly at risk. Since 97 % of all the water in the world is salt water, desalination has been identified as a solution to the drinking water shortage. The benefits of water desalination, with regard to the uses of desalinated water, are great. One of the most significant benefits is to achieve the development of cities or towns where there is a very small amount of fresh water, such as in the Caribbean islands, the Spanish islands, Japan, Singapore and the Arab countries, or in areas with low water availability, such as Florida and California in the United States, northwest Mexico, including the Baja California Peninsula, and the north of Chile and Venezuela.

Desalination is a process whereby fresh water is obtained from salt water. There are different methods but, today, only reverse osmosis (membrane technology) and distillation (which involves boiling water) offer a competitive cost.

In the reverse osmosis process, pressure is applied on a saline solution to pass through a semipermeable membrane. Only water passes through this membrane to the side of lower saline concentration, in contrast to normal osmosis, and salts are mostly retained.

The other method, mostly used in Arab countries, is the thermal process, which basically involves applying heat to water in order to evaporate and condense it. The collected water is low in salts. These methods can also use vacuum, facilitating the process by reducing the liquid's boiling temperature.

However, these methods are not ideal. Currently available technologies still require a significant expenditure of energy (pumps to push the water in reverse osmosis or fuels to heat the water in the thermal method), so the cost of desalinated water increases. "Start-up costs are high, and operation and maintenance costs are not competitive compared to those of well extraction and surface water treatment. That is why desalination is only recommended when no other cheaper alternative is available to obtain drinking water," Fuentes Díaz explains.

If we are to believe the legend, somewhere, at the bottom of the sea, there is a mill still working constantly today, making seawater salty. Likewise, throughout Latin America, there are teams of researchers "milling and grinding" their creativity, seeking solutions to desalinate the sea and provide more drinking water for those dying of thirst in a beach full of water.

Daniel de la Torre (Mexico)

The Dead Sea. Thus called for its scarcity of aquatic life, it is located between Israel, the West Bank and Jordan. Its high salinity prevents the human body from sinking naturally.
Photo: © toshket - Fotolia.com

Water has been used for many years to produce energy, which not only illuminates our dark nights, but is also capable of moving a whole national industry forward. In the future, we will probably not need to drill the earth or pollute the environment to make our cars or motorcycles move. Scientists in Chile have already taken the first steps to research the potential wonders of water.

Energy

A long journey

Emilia and the drop of water

Emilia dozed off, almost without noticing. That day, she had gotten up really early to meet her parents at the airport, who had returned from a trip. That is why, after lunch, with a glass of water in her hand, she went to the back yard and let herself fall on a deckchair. After a while, she was sound asleep, and the sun's rays soon reached the table where she had left the glass of water. It was summer and there was little moisture in the air.

Shortly afterwards, she began to dream and to fly over some of those places her parents had visited, which they had been describing to her over lunch. And as this happened, another journey began: a drop of water, coming off Emilia's glass, was starting to change from the liquid to the gaseous state due to the sun's heat. This was the beginning of the drop's journey through evaporation but, of course, it did not start the journey alone. There were many other drops in the atmosphere.

But apart from the sun's energy, certain atmospheric conditions were necessary for the drop to evaporate. The air should not be saturated, that is, with a high content of water vapor, since if that were the case, the drop would not have the capacity to evaporate. That is why, on very humid days, if we hang out the laundry, it takes longer to dry. Once evaporated, in order to continue its journey, our drop would need ascending currents in the atmosphere. And on this journey upwards, it would start to cool down until it would be liquid again and become part of a cloud.

A new stage of the journey now begins. The cloud is moved due to various meteorological phenomena and it rarely rains in the same place where it was formed.

Experts can estimate how much water will fall using a numerical model called hydro-estimator, based on information from satellites and radars. This estimated forecast is useful for activities that depend on rainfall, such as agriculture and hydroelectric power generation. But more accurate data is obtained afterwards, on the ground. Rain gauges or telepluviometers are used to measure the amount of water that fell.

The journey our drop began took it to a cloud, which ended up giving it back in the form of rainfall, together with many other drops. In this case, the drop went back to water. It fell in the course of a river that flowed into a lake, formed by a dam. Even without knowing it, the drop still had a long way to go. A dam had been built in that area to produce electric power using a process that entails transforming one form of energy into another. How would the drop participate in this process that involves passing from potential, to kinetic and finally to electric energy?

Water courses are used for the generation of hydroelectric or hydraulic power. Once the course of a river is stopped by building a dam, a reservoir is formed, which provides water reserves for several months, even with low rainfall. For this reason, weather forecasts are very important for those who work in dams. To make weather forecasts, there are several instruments that, apart from measuring the amount of rainfall in all the areas of influence of the water course, also measure other conditions that will facilitate –or not– the process. Air, water and soil temperature, atmospheric pressure, moisture, wind speed and direction, height of the cloud base, quantity of evaporation and solar radiation can all be measured.

One day, the mechanism that causes energy to be transformed made our drop and all the others feel they were being pulled. Somebody had opened the distribution gates of the dam and the drops crashed into the turbine blades, where they would leave some of their energy. There were millions of drops that managed to move the turbine, converting potential energy to kinetic energy, which was possible due to the fall, i.e. the difference between the reservoir's water level and that of the river that follows its course. The turbine would then transfer the kinetic energy to a generator that would finally convert it to electric energy.

This procedure brings us to the subject of renewable energy, because water is not consumed and, once it is used to generate a new form of energy, it keeps flowing downstream. Other renewable energy sources are, for example, the wind that generates wind power when air molecules in motion hit the turbine blades and the sun that generates solar thermal energy by heating water in thermal tanks with radiation.

Photo: Oriana Larrea, Uruguay

Non-renewable energy sources are those that are gradually depleted, such as carbon and oil.

For a better use of resources, that is, to achieve a sustainable energy policy, it is necessary to encourage the use of alternative energies, such as wind, solar or hydroelectric power. But it is also important to improve energy efficiency, by optimizing the use of energy.

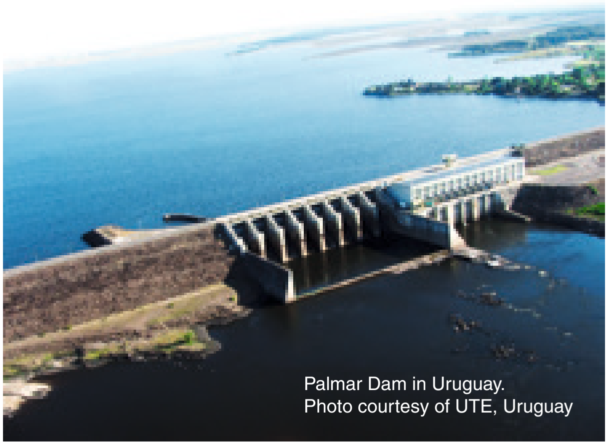
Once the electric energy is obtained, it will be transported from the power station where it was generated to consumption centers through transmission lines, which are high voltage electricity conducting cables capable of carrying large amounts of energy to places far away. Transmission lines carry a voltage of hundreds of thousands of AC volts and are placed on high-voltage towers between 15 and 30 metres high. Electrical power can also be transported through underground high-voltage cables. In this way, it arrives to the distribution substation, where the voltage of the lines is reduced, with transformers, to medium voltage and, finally, to the voltage used in each country (e.g., 220 V in Uruguay).

The energy provided by the drop, whose journey we have witnessed, then went back to Emilia's house, transformed in low voltage electric power of 220 V, to illuminate her room. About 400 million drops of water allowed Emilia to study at night for 3 hours, using a 75 W light bulb.

One day, Emilia's mother decided to change the old 75 W incandescent lamp to a brand new energy-efficient lamp, which only requires 18 W. Therefore, every night Emilia can light up her room with the energy of 100 million drops of water, thus saving the other 300 million drops, which are used by Fabián, her neighbor, to charge his laptop. If Emilia or her father checked the electricity meter of their house, they would see that it is moving more slowly than before and, probably, when they get the next bill from the electric company, they will realize that their monthly consumption is lower.

That is how Emilia, her family and her neighbors can have light and engage in various activities that depend on electric power, thanks to the contribution of that drop of water and many others that once embarked on a long journey.

GRISELDA DÍAZ (URUGUAY)


Palmar Dam in Uruguay.
Photo courtesy of UTE, Uruguay

Power consumption in numbers

If Emilia uses a 75 W incandescent lamp for 3 hours a day (10 800 s), the daily power consumption is 810 000 joules (1 J = 1 Ws)

To calculate the volume of water necessary to generate that amount of energy in the turbine, we use the following equation, by matching the potential energy of water before the fall with the electric power generated in the turbine:

$$E = 0.9 \times \rho \times g \times h \times V$$

E: Energy to be generated in the turbine (810 000 J)
0.9: turbine efficiency (90 %) (10 % of the energy is assumed to be lost as thermal energy)
ρ: density of water (approximately 1000 kg/m^3)
g: acceleration due to gravity (approximately 9.8 m/s^2)
h: height from which the drop begins to fall up to the turbine (e.g., 23 m)
V: volume of water in m^3 that needs to pass through the turbine to generate the required energy

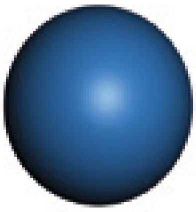
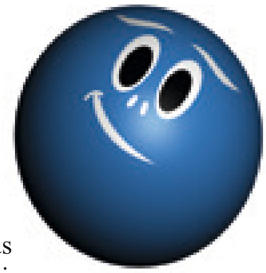
Therefore: $V = E / (0.9 \times \rho \times g \times h)$

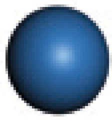
$$V = 810\,000\ J / (0.9 \times 1000\ kg/m^3 \times 9.800\ m/s^2 \times 23\ m) = 4.0\ m^3$$

100 drops of water have a volume of 1 ml (one millilitre)
100 million drops amount to 1 m^3 (one cubic metre)
Therefore, Emilia used 400 million drops of water to illuminate her room for 3 hours with an incandescent lamp.

Energy by nuclear fusion

A challenge for science



Today's world is constantly changing. We live in a technologically connected world, with industrial productions and an extensive use of energy. In fact, the demand for energy has increased to the point where today there is a worldwide energy shortage, and Chile, affected by this crisis, is trying to find new ways to generate energy, apart from the use of fossil resources, such as oil.

In order to find a solution to this problem, scientists have started to closely examine plasma and controlled fusion, as a way to generate energy by nuclear fusion.

What is plasma?

"Plasma is the fourth state of matter. In school we learned the solid, liquid and gaseous states. If we apply heat to a solid, after a while it will turn to liquid, and if we keep applying heat to a liquid, it will vaporize and turn to gas. If we keep applying energy to a gas, it will turn to plasma. Electrons separate from the atom, leaving a gas of charged particles: ions, electrons and also neutral particles," explains Leopoldo Soto, a Plasma Physics and Pulsed Power researcher, who conducts his research in the Chilean Commission of Nuclear Energy (*Comisión Chilena de Energía Nuclear*) and in the University of Talca (*Universidad de Talca*) in Chile.

In the universe we can find plasma in the sun, for example, as well as in any other star. In our planet, this state of matter is used in various everyday applications, such as fluorescent tubes and even the well-known plasma screen televisions (hence, their name).

Generating energy by nuclear fusion processes

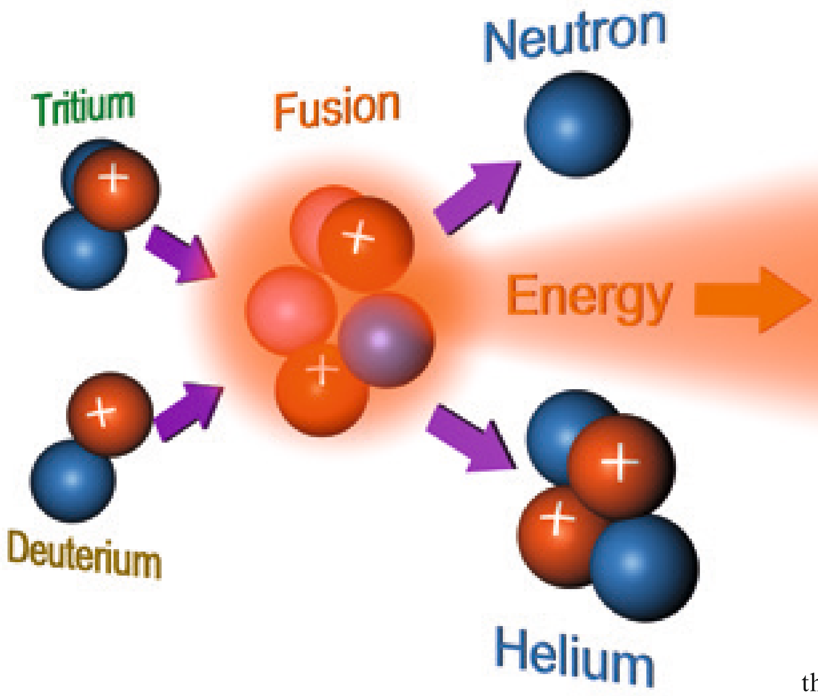
"Nuclear fusion involves forming plasma from light atoms and, to accomplish this, the easiest and most efficient fusion is the fusion of hydrogen isotopes. The most common hydrogen isotope (protium) contains one proton in its nucleus (a subatomic particle with a positive charge), around which one electron rotates (a subatomic particle with a negative charge). The next isotope required is called deuterium, which contains one proton and also one neutron (subatomic particle with no charge) in its nucleus. Finally, an isotope called tritium is also required, which contains two neutrons, one proton and one electron revolving around. If we manage to fuse the deuterium and tritium nuclei, these would form a helium nucleus and leave a free neutron. This neutron would be freed releasing a large amount of energy, and that is the energy generated by fusion," Soto explains.

Now, the neutron energy should be captured so it can be harnessed. This is accomplished when the neutron hits the wall of a heat exchanger in contact with a boiler full of water; heat will turn water into vapor and it will move the turbines generating electricity. This process should occur for a large number of neutrons.

Naturally occurring hydrogen (protium) and deuterium are easily found on Earth. Hydrogen is found in water and, logically, it is found most abundantly in the sea. "We have the whole sea to take hydrogen, but the most important elements for a fusion are its deuterium and tritium isotopes. Deuterium is found in a ratio of 0.015 % in seawater and is produced in other parts of the planet; tritium has an abundance of 0.00001 %, which means that naturally occurring tritium is extremely rare. Tritium can be produced artificially by bombarding lithium with neutrons, which generates helium thus creating tritium," the expert notes.

However, nuclear fusion as a method for generating energy has not been accomplished yet anywhere in the world. "Today, while the experiment of fusing nuclei of hydrogen atoms can be performed –the fusion of some of those nuclei occurs–, the energy released in the process is lower than the energy required for the process to occur, so it does not work as an energy source yet," Soto said.

"To accomplish nuclear fusion, the compromise of three parameters is required: temperature, density of plasma and duration, that is, the plasma needs to be at a temperature around 100 million degrees Celsius. Moreover, at that temperature, the density of plasma multiplied by the duration of the plasma should surpass a certain number."



Research on nuclear fusion in Chile

In Chile, apart from the Department of Thermonuclear Plasma (*Departamento de Plasma Termonuclear*) of the Commission of Nuclear Energy, there is a research group within the Chilean Commission of Nuclear Energy that studies these issues. Soto himself, in 1999, developed an idea which was submitted to a science contest: to conduct research with more limited resources, specializing in smaller experiments. “I thought: we will never be able to build the biggest machine in the world, but we could build the smallest one, and be the leaders there. We managed to lower the limit of required energy (which was thousands of joules) to 0.1 joule, that is, four magnitudes. We are the world leaders in the development, building and conducting of experiments on nuclear fusion in small devices. Today, our research is developed in other parts of the world and our work is referenced by groups in places such as India, Japan, Mexico, Argentina, etc.,” the researcher explains.

Their research has allowed them to conclude that plasma is more stable in experiments with small devices than in big machines; however, many challenges still lie ahead to accomplish a controlled nuclear fusion. Once it becomes possible, energy could be generated using seawater and, in this regard, Chile has considerable natural resources to implement it. “Our country has significant advantages; it has an extensive coast and lithium salt flats in the north, some of the largest ones in the world. If fusion could be used to generate electric power, many problems could be solved, since with enough electric power, we won’t have any problems with, for instance, charging battery-electric cars. In the case of these cars, once again lithium has a significant role, because those batteries are lighter and, precisely, in Chile we have a lot of lithium.” Therefore, we could assume that seawater could become an almost unlimited source of natural resources, which may help us meet our future energy needs.

Camila Ibarlucea (Chile)

Illustrations: Alberto Parra del Riego
Photo: Sea, Francisco García

So close, yet so far away. In recent years, a lot has been said about water scarcity, but it still sounds too abstract for us. Understanding what some people have to go through every day to obtain this transparent and apparently common element, makes us reconsider our expectations regarding the blue planet.

Photo: © Comugnero Silvana - Fotolia.com

Water economy

How many litres of water does your hamburger have?

Virtual water

Have you ever considered how many litres of water you consume with your breakfast? Venture a guess: a quarter of a litre? Half? A whole litre? Two litres? This article will show you how, even if you do not have the habit of drinking water during meals, a light snack may conceal a consumption of the vital liquid of almost 1000 litres.

When in March 2008, British Professor and researcher John Anthony Allan was notified he was going to receive the Stockholm Water Prize (an international award that recognizes outstanding achievements in water related activities), he probably took his finest glass, filled it with water and drank a toast, trying not to spill a single drop.

Apart from crowning his long career, this recognition was given for having coined the term "virtual water" in 1993, a concept aimed at making the water embedded in products and processes visible, thus promoting savings in water.

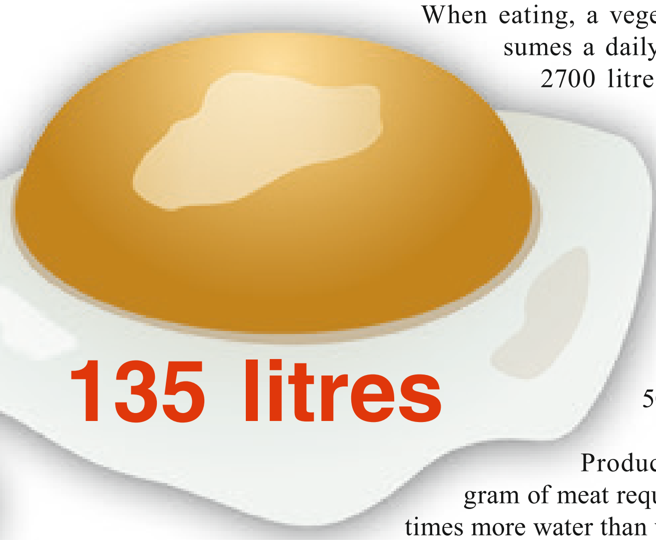
The idea is that we consume water not only when we drink tap water or take a bath, but also with every piece of food we eat and when buying clothes, shoes or even a piece of paper. In other words, water is required both for making a tomato grow and for extracting a ton of oil, or for producing a bag of chips. Virtual water is a qualitative metaphor that, according to Allan himself, defines the volume of water required to produce a good or to offer a service.

Behind a simple cup of coffee, there are 140 litres of water used for growing, producing, packaging and shipping the beans. Depending on preferences and culture, the amount of virtual water hidden behind an American or European breakfast may be around 1100 litres (about three filled bathtubs).

How did we arrive at this last figure? To the 140 litres of coffee we should add 80 litres more if we have a piece of toast, 240 litres more if we drink a glass of milk, another 70 litres if we add an apple, 120 if we eat an egg and 480 if we round it off with a slice of bacon.

In his book *Virtual water: tackling the threat to our planet's most precious resource*, Allan refers to the concept of virtual water that he introduced to the scientific community in these terms: "It has been fun to spot a number of ideas that thousands of other scientists and millions of engineers in the water sector have not," showing us not only that he made a valuable contribution by increasing worldwide visibility of the problem of excessive water consumption, but also that challenges and good humor are the fuel that drives creation. The calculations that lead to assert that, e.g., a potato hides 25 litres of virtual water and a glass of beer (250 ml) actually hides 75 litres, or that a hamburger (150 g) hides the disturbing volume of 2400 litres, are estimates. Just as it is not the same to produce a 200-gram potato than a 50-gram potato, when estimating virtual water it is also necessary to identify the production place and time –which have a bearing on the crop's water needs–, as well as the technology used (since if it is less efficient, it will probably consume a greater volume of water).

Therefore, depending on the agricultural practices and the type of crop, between 1000 and 1700 litres of water are needed to produce one kilogram of cereals. This amount includes the water absorbed by plants, the water that evaporates and the water degraded due to agricultural production.

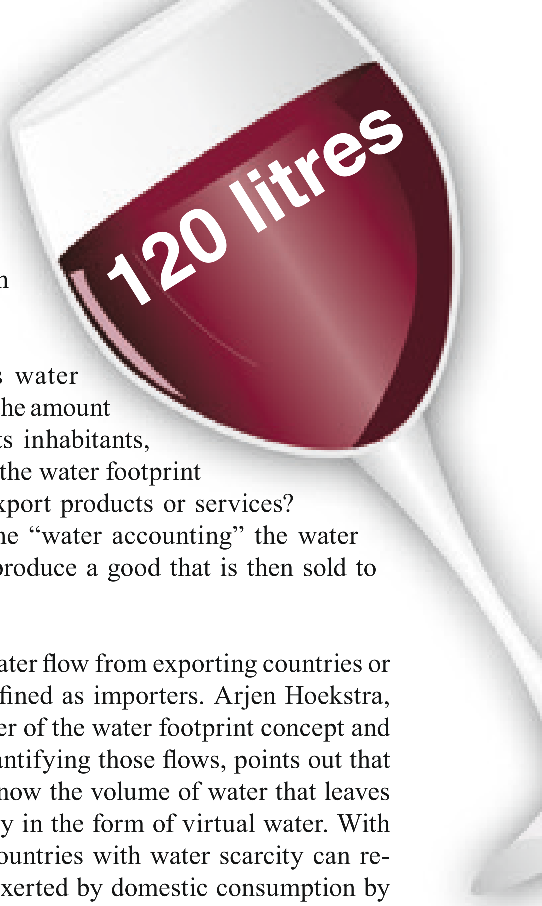


When eating, a vegetarian consumes a daily average of 2700 litres of virtual water. For someone who is not a vegetarian and eats meat, this figure can easily amount to 5000 litres.

Producing a kilogram of meat requires 5 to 20 times more water than what is used to obtain a kilogram of cereals. This is due to the fact that the rearing of animals takes several years and, over this time, animals consume cereals (wheat, oat, barley, corn, dried peas, soybean flour and other cereals) and fodder (such as grass or dried hay). In addition, they drink water, which is also needed to supply the premises.

The concept of virtual water is associated with that of water footprint. The water footprint of a country is the total volume of water used to produce the goods and services consumed by its inhabitants. It includes not only the water used for growing crops or other organic resources, but also that used in the industrial process and the transport of goods.

The water footprint measures the demand for water resources based on three types of water: the so-called green, blue and grey water. Green water refers to rainwater and is used in agricultural production (activity that creates the highest water demand in the planet), and in the production of inputs and goods. Blue water represents fresh water consumed from the planet's water resources (surface and ground water) by people, or for artificial irrigation and livestock consumption. Lastly, grey water is the volume of water polluted both by household use or the industry, including waste from agriculture.



But if a country's water footprint measures the amount of water used by its inhabitants, what happens with the water footprint of countries that export products or services? Who includes in the "water accounting" the water a country uses to produce a good that is then sold to another country?

There is a virtual water flow from exporting countries or regions to those defined as importers. Arjen Hoekstra, considered the father of the water footprint concept and well-known for quantifying those flows, points out that it is important to know the volume of water that leaves and enters a country in the form of virtual water. With this information, countries with water scarcity can reduce the pressure exerted by domestic consumption by importing water-intensive products and exporting goods that consume less water instead.

The United States, Argentina and Brazil export billions of litres of virtual water each year through crops and trade, while other countries such as Japan, Egypt and Italy import billions of litres of virtual water.

An expert in green economy, Agricultural Engineer Walter Pengue, states in his book *La apropiación y el saqueo de la naturaleza* (The appropriation and plundering of nature) that Argentine soybean exports, for the 2004/2005 season, represented 20 times the volume of water available in countries such as Israel.

On the other hand, when China imports 18 million tons of soy, it "virtually" receives the 20 billion cubic metres of water that were required to produce it, Pengue says, and he notes: "The environmental agendas of Argentina should include information about the virtual water trade in their national accounts." In fact, this is not a minor detail, but a vital piece of information that every inhabitant should know on a daily basis.

CLAUDIA MAZZEO (ARGENTINA)

What is your water footprint?

Different organizations offer virtual tours aimed at proving that each drop of water counts. National Geographic, for example, invites its website visitors to change the course of events, by taking a water tour around their home, diet, power consumption and consumer behavior. All with one purpose: to give back to lakes, rivers and aquifers the volume withdrawn due to water misuse.

http://environment.nationalgeographic.com/environment/freshwater/change-the-course/water-footprint-calculator/

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Keep in mind:

- According to the 4th United Nations World Water Development Report (2012), humans are over-consuming natural resources at an unsustainable rate. Approximately 3.5 planet Earths would be needed to sustain a global population achieving the current lifestyle of the average European or North American.
- A child born in the developed world consumes 30 to 50 times as much water as one in the developing world, according to the 1st United Nations World Water Development Report (2003).
- Of all water on Earth, 97 % is salt water, and of the remaining 3 % fresh water, some 70 % is frozen in the polar icecaps. The other 30 % is mostly present as soil moisture or lies in underground aquifers. Therefore, less than 1 % of the world's fresh water is readily accessible for direct human uses (U.S. Geological Survey, 2009).
- The global volume of stored groundwater is poorly known; estimates range from 15.3 to 60 million km^3 (4th United Nations World Water Development Report, 2012).
- The world's water crisis is not related to the physical availability of water, but to unbalanced power relations, poverty and related inequalities (UNDP: Human Development Report, 2006).
- In 2030, 47 % of the world population will be living in areas of high water stress, where the annual water supply is less than 1700 m^3 per person (OECD: Environmental Outlook to 2030, 2008).
- Over 80 % of wastewater worldwide is not collected or treated, and urban settlements are the main source of pollution (4th United Nations World Water Development Report, 2012).
- Eighteen percent of the world population, or 1.2 billion people (1 out of 3 in rural areas), lack access to a toilet and practice open defecation (WHO/UNICEF Joint Monitoring Programme (JMP): Progress on Drinking Water and Sanitation: Special Focus on Sanitation, 2008).

Vegetarians, at the vanguard of water conservation

Human beings consume a daily average of 2 to 3 litres of water for drinking, between 30 and 400 litres for household needs and from 1500 to 4000 litres for producing food.

What would happen if every person on the planet adopted a diet comparable to that of the European or North American population, primarily based on meat consumption? Global water needs would increase over 75 %.

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Shopping habits that help

To reduce virtual water consumption, paying attention when shopping is a good option.

- Avoid consuming products whose production involves the use of large volumes of water.
- Pay attention to the containers and packaging of the products you choose. Excessive volumes of paper or cardboard usually exceed the value of virtual water embedded on the products or food they contain.
- Familiarize yourself with the virtual water content of each item of food, committing to a responsible consumption.
- Avoid products from places that are experiencing a high domestic pressure on their limited water resources.
- Think before you buy: 30 % of all the food produced ends up in the trash.
- Reduce the amount of meat you eat and replace it with other protein sources as often as possible.
- When choosing clothes, compare the volume of virtual water used in the production of the different types of materials (cotton, wool, leather, jean).

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Illustrations (pp. 40 - 41): Alberto Parra del Riego

Water passing through my house... and my water meter

Connected to the piping of your house, there is a small device that constantly measures how much water your family uses, from the showers you take in the morning to when you brush your teeth before going to bed. What other information does a water meter provide?

It is ten thirty in the morning. Sebastián gets out of bed, ready to enjoy his first day of vacation. It's not every day one can get up late and with no worries, Sebastián thinks.

He grabs his towel and goes to take a long shower. A whole hour under the hot water, relieving the stress of his final exams and projects.

After getting ready and having breakfast, Sebastián grabs a book and goes out to the balcony to get some fresh air, while reading the crime novel he bought last month.

"Hi, Sebastián! Enjoying your vacation, right?" The voice sounds familiar. He looks up and sees *Don* Miguel, who comes every month to take the water meter reading from the Herrero's home.

"Good morning, *Don* Miguel, you should take some holidays too!"
"But who would come to measure the water that passes through your house?" *Don* Miguel says smiling: the same joke they tell each other every summer.

This time, Sebastián thinks for a moment. *Don* Miguel comes on the second Tuesday of each month, lifts a lid outside the Herrero's house, takes some notes and leaves. Few people are as curious as Sebastián so, to clear his doubt, he asks:

"How do you know how much water we use at home?"
"Well, it's not actually me who measures it; I only transcribe the data the water meter displays."
"That little thing? That gizmo knows how much water we use over an entire month? Impossible."
"Well, if you want to know, I can explain it; I happen to have in my truck a water meter just like the one installed in your house."

As *Don* Miguel explains to Sebastián, when the Romans invented the aqueduct system over 2000 years ago, nobody paid for water; its consumption was totally free.

Some time later, of course, rulers noticed that a lot of water was wasted this way and the first solution they found was to equally charge all inhabitants for its usage.

"It's not a bad idea, actually; we all use water and we should always pay the same."
"Yes, it may seem so, but look at it this way: how many people live in your house?"
"Three: mom, dad and me."
"Well the Guzmán family, next door, includes six people and they have three dogs. Monthly, they use more water than in your house. Besides, look at the house across the street. Suppose the Rivera family left town yesterday and will not be using any water for three weeks. Would it be fair to charge the three houses the same for the water they use?"
"Well, if you put it that way, it would be good to know exactly how much water is used in each house."
"Right. It would be difficult and unfair to estimate how much water each family uses if we only considered the number of people as a factor. That is why we need to know exactly the volume of water they use."

The water consumption registered by a water meter is usually the amount of liquid that has passed through it since its installation. In every house, the amount of water that passes through the meter is measured each month, recording the difference between the current reading and that of the previous month.

For example, in Sebastián's house, they consume about 20 cubic metres of water each month.

Every time a water faucet is turned on, water flows from the water main to the house piping and to the faucet, passing through the water meter first.

How do we know it?

There are several makes and models of water meters, but basically, according to their operating principle, they are divided into four types: volumetric, velocity, ultrasonic and electromagnetic meters. Among these, the first two are most often used in homes and business premises. And, probably, the one installed in your home is either one of those two.

The meter *Don* Miguel brings, just like the one at Sebastián's house, is a volumetric meter and, as its name suggests, it measures the displaced volume of liquid.

"This is how volumetric meters work: within the body of the meter there are some compartments with a specific volume and a mobile system that moves due to volume changes between those compartments. This system includes an oscillating piston or a disk. When water passes through the meter, the chambers are successively filled and emptied, making the piston or disk move again and again. This movement activates a magnet, which drives the meter's recording system."

A velocity-type meter is also known as an inferential meter, since the volume that passes through the meter is deduced or inferred from the velocity of the water jet that passes through it.

"No, that sounds too complicated!"
"Ok, I'll explain it in a different way."

Don Miguel shows Sebastián another meter with four vanes inside, forming a rotor or turbine.

"Well, this is a velocity-type meter. When water passes through the turbine, the meter records the number of turns it makes. Each turn corresponds to a specific volume. If water enters at a higher speed, it will turn the turbine faster, meaning that a greater volume has entered."

The other two types, ultrasonic and electromagnetic meters, are much more advanced and are used by large industries.

The exact measurement

Since the water measurement systems seem so accurate, Sebastián asks him if there is any way his meter can register more or less volume than what really enters his home.

"Well Sebastián, actually, errors are present in almost everything we do. When we take a measurement, there are several factors that may make it more or less close to reality. Some of these errors can be controlled, because we know where they come from."

"And what may cause them?"
"Since we need to know precisely how much water was consumed in each home, meters need to be sensitive enough to register up to the last litre of water. So, two of the most important factors that may affect the operation of a meter are: water temperature and pressure."

As *Don* Miguel explains to Sebastián, meters operate within a specific water temperature range. Luckily, this range is quite broad, around 0 °C to 40 °C, and the water that reaches the Herrero's home, and every home in general, is within those limits.

Water pressure, on the other hand, is also an important factor to take into account. Water pressure is the force the water has when flowing through pipes and through the meter. Water meters have a maximum level of pressure they can withstand on a permanent basis, under which they operate without wearing out and providing accurate measurements. In addition, the water that passes through the meter should be potable and free of impurities, since they may affect its operation and measurement.

To guarantee their proper functioning, meters are checked to ensure they meet the requirements set out in the regulations of each country. Therefore, both the water company and your family can be certain that the correct amount is paid for the water consumed.

Outside your house, there is probably a water meter similar to this one connected to the water piping, to register the amount of water used in your home.
Photo: Water meter, Caroline Koolschijn (http://www.sxc.hu)
Illustration (p. 43): Alberto Parra del Riego

Measuring water consumption in each home helps promote water saving and avoid waste, since everyone pays for the amount they use.
Photo: Dave Millet (http://www.sxc.hu)

Every drop counts

"Well, I should be going now, Sebastián, but there's one last thing I want to tell you. It would be good if you and your family could be careful of how much water you are consuming, and that is another function of the water meter. As you know, drinking water is a limited resource and we must preserve it."
"Of course, *Don* Miguel. Sometimes I'm shocked when I see broken pipes wasting litres and litres of water in the street!"
"So am I. We must avoid these water leaks at all costs and call the water company as soon as we see one. But in your home's piping system there may also be a leak, without you noticing it."

"And I guess the meter also registers the water lost due to that type of leaks, right?"
"You're right. A meter can register from a small jet of water to a major consumption when several faucets are turned on. That's why it is important that your family takes note if the water bill is too high. If the consumption that month has been unusual, it is possibly due to a leak in the piping of the house."
"Great, I'll keep that in mind. Go now, *Don* Miguel! And thank you for taking the time to clear my doubts!"
"My pleasure! And always remember to preserve water to avoid wasting it!"

Once *Don* Miguel was gone, Sebastián was left wondering about that one-hour shower he had taken when he got up, and even felt guilty about it. How much water and money could he have saved if he had known that every drop counts!

Jasson Clarke (Costa Rica)

Activity: Registration of water use at your home, school or college

We invite you to run a water saving campaign at home or in your school.

1. Take the latest water bill from your home and register how many cubic metres of water were consumed that month. If you are running the campaign at school, ask a school authority for the bill, notifying him/her of your water saving initiative.
2. Then, if the campaign is at your home, ask your family to try to avoid wasting water.
   - Turn the faucet off while brushing your teeth, or better yet, use a small glass of water to rinse your mouth, or turn the faucet off while shaving.
   - Wash the car with buckets of water instead of a hose.
   - Try to take shorter showers in the morning.
   - Check for leaks or dripping in faucets or toilets.
   - Use the short cycle on the washing machine or dishwasher.
3. If the campaign is in your school:
   - Arrange things so that you can save the maximum amount of water.
   - Avoid leaving the faucets on in the bathroom.
   - Try to take shorter showers in the morning.
   - With the principal's permission, put bottles with sand or water tightly closed in the toilet tanks, to minimize the amount of water per flush.
4. Lastly, when the next bill comes, check if your consumption decreased, both in terms of cubic metres and the money you will have to pay this time.

These simple actions will represent significant savings for your family and school, and will also give our planet a well-deserved break!

If you won't drink the water...

Apparently available to everyone, clean and healthy water is still a luxury for millions of people. Therefore, governments have pending tasks and users should take precautions.

Doña Maura wakes up at five in the morning to accomplish her first task of the day: waiting for the tanker truck that provides water for the slum where she lives in Ventanilla, on the outskirts of Lima. With a great deal of effort, her children help her walk up the hill with the buckets, once full. They must walk carefully. Every spilled drop means losing an asset that is scarce in their home and represents a high cost, since the cubic metre distributors buy for about 0.20 dollars is then sold for 4, 6 or 8 dollars.

Maura's is not an isolated case: 800 thousand people suffer a similar situation in Peru's capital city and, throughout the country, 2 million city inhabitants do not have access to a safe water network. If rural areas are included, this figure increases to 4 million. In Latin America and the Caribbean, more than 34 million people need to drink water from natural sources or use alternative methods to domestic pipes. And in the whole world, statistics show that more than 768 million people do not have access to safe water. Therefore, increasing adequate supply and sanitation services is one of the targets of the seventh United Nations Millennium Development Goal: *Ensure environmental sustainability.*

"Water is a determinant of health and an essential condition to achieve the economic development of peoples," the regional coordinator of the technical team for water and sanitation of the Pan American Health Organization (PAHO), Eng. Ana Treasure points out. She explains that the time required for collecting and transporting water to homes reduces hours of family productivity. In addition, the consumption of contaminated water leads to waterborne diseases preventing children's attendance to schools as well as mother's attendance to their jobs, who must stay at home taking care of the small ones, thus impacting their income.

"The illnesses that are detected quicker are those that cause diarrhea," the expert mentions, "but we're concerned about the existence of chemical substances and metals in water and their probable long-term consequences: different types of cancer, kidney failure and even cognitive impairment due to, for example, lead in water."

Besides the biological components, such as larvae or algae, water might be contaminated with organic and inorganic substances. "Water coming down the Andes brings metals. We have mines, tailings and lots of processes that end up excessively contaminating rivers," says Eng. Eduardo Ismodes, Chairman of the Board of Sedapal, the company providing safe water to the city of Lima. The Chairman also explained that water that flows from mountains, through springs, is not always as pure as people think, as it can naturally contain metals. As contaminants vary depending on the location, the engineer notes that the metals that get to *La Atarjea*, the treatment plant he leads, are usually iron, aluminum and arsenic.

The expert says the purification process must be constantly adapted to the changing water conditions, as the pollution levels and characteristics vary every day. Therefore, treatments are defined based on quality laboratory analysis results. After the chemical, physical and biological processes, 92 % of homes in Lima receive water with cleanliness levels beyond the minimum requirements established in the *Regulation of Water Quality for Human Consumption*. However, Ismodes points out that water can be easily recontaminated while arriving to the houses through dirty or dilapidated pipes, if stored in a tank or if it sits in a cistern with no proper maintenance. Even then, the expert does not recommend boiling the water and the subsequent storage of treated water, as the procedure eliminates the chlorine residue that protects it, rendering it defenseless against potential bacteria that could make contact with it; boiling the water is a solution only if the liquid is consumed immediately after it is boiled.

Ana Treasure adds: "Boiling water is expensive because it requires fuel, and is also dangerous, because a child can experience an accident and suffer burns." The World Health Organization (WHO) recommends, as an alternative to boiling water and in case of an emergency, to add bleach or chlorine to water before its use. According to the expert, two or three drops of the disinfectant should be added for each litre of water.

As the engineer states, ecosystems are very stressed due to the pollution generated by different industries, pesticides used in agriculture, mining and the lack of sanitation in certain communities, especially in rural areas. In this regard, Treasure shares the figures of the last report on this topic from the World Health Organization and the United Nations Children's Fund (UNICEF), according to which, until 2011 more than 1 billion people in the world practiced open defecation due to the lack of adequate facilities: "For the water to be clean, it needs good sanitation conditions. When it rains, if people and animals practice open defecation, feces pollute the river. Moreover, water creates the need for sanitation, because 80 % of used water is dirty when dumped again, risking the health of the population when no facilities for eliminating feces exist."

Ismodes states also that more attention and education is necessary in this regard. As he puts it, many use the sewage system as a trash can and throw waste there that should be taken by the garbage collector. Feathers from nearby markets and fat from restaurants challenge the maintenance of infrastructures that, while planned as a 50-year solution, after 15 years are already deteriorated.

Treasure underlines the fundamental role of education, not only to ensure people's commitment to properly use the available facilities, but also for them to become aware of the fact that access to drinking water is a human right which is fair and necessary to demand and defend.

Mariella Checa (Peru)

Water cannot be drunk from a mirage and it cannot be manufactured. We should preserve it. Photos: Walter Hupiu

Measuring with a cabbage?

When the National Metrology Institutes worldwide were defining the base measurement units, such as the metre, the kilogram and the second, they never thought of including a cabbage in their sophisticated laboratories. However, a group of fun and enthusiastic young people used it to experimentally measure the acidity of certain foods and beverages.

"When we arrived in San José, we noticed the friendliness of its people. Luckily, we had already booked a place to stay from Germany, thanks to contacts we had from the ASA[1] interns of the previous year, so we could start with our project straight away," says Mara Büter, one of the two young Germans who took their experience to the National Metrology Institute of Costa Rica – LACOMET (from Spanish *Laboratorio Costarricense de Metrología*).

By organizing workshops and experiments related to Metrology, LACOMET is interested in showing the importance of accurate measurements in daily life and arousing the curiosity of children and young people in this field of science.

On its website (http://www.lacomet.go.cr/niños), LACOMET publishes a series of experiments ranging from manufacturing a simple thermometer to using a cabbage to measure the pH concentration and therefore determine the acidity of foods and beverages. These parameters are also measured in the food industry –with slightly more sophisticated devices, obviously– to guarantee food quality, to ensure no harmful elements are present and to protect people's health.

"During the period of adaptation, we started researching other projects on Metrology for children. We found out what the Spanish-speaking population lacked in that regard. Furthermore, we increased our knowledge about the International System of Units (SI). The first stage ended with a study about the implementation of the SI among Costa Ricans and we made a diagnosis about the country's situation. During the second stage, we started developing different types of information material. Our three target groups were children, young people and adults. While preparing the materials we increased our knowledge on Metrology in general and became aware of its importance in our daily life. As a means of dissemination for each group involved, three different types of brochures were prepared."

"After that, we started preparing teaching materials: the central task of our project. Our vision of that material was that it needed to be useful to spread knowledge about the International System of Units (SI), demonstrate the importance of measurements in daily life and spark interest in Metrology among students. Besides, we wanted material that could be used by teachers and children throughout the country. Therefore, we thought about a minimum cost for required materials, the free use of the materials and a self-learning approach, so that children could use the material on their own as well as teachers in their classes, even with no prior Metrology knowledge," adds Carlos Stickel, the other member of this young group of international cooperation (ASA) that provided support to LACOMET.

Today, thanks to the international agreements of the different National Metrology Institutes, young people from all over the world not only have the chance of learning

[1] German international cooperation program that awards internships to European students and young people between 21 and 30 years old with technical vocational education.

Image (p. 48): Cabbage, © Angel Simon - Fotolia.com other languages and getting to know other cultures, but they can also share and receive scientific knowledge and experiences without the need for dressing in white. However, for certain experiments, it is desirable to wear something you will not miss in the future, as cabbage might leave some difficult-to-remove stains.

LACOMET's workshop modules have three parts:

- A general introduction to Metrology, its history and its importance
- The experiment
- Assessment and explanation of results

Both the introduction and the assessment and explanation of results sections are guided by the teacher. The experiments follow an interactive and self-learning approach. Students carry out the experiments while they follow the instructions included in the teaching material, either individually or in small groups.

With these activities, students discover the importance of sciences and math in everyday life, through the applications detailed in each experiment.

"Some difficulties arose during the implementation of the activities. Contacting public and private schools in San José was very difficult. We sent e-mails to different schools to present our project. Many did not quite understand what our goal was. First, we wanted to observe classes in several schools to learn about the methodology used in Costa Rica. Many schools did not reply, so we went and spoke to the principals in person. This proved to be very helpful for the progress of our project. We established contact with three schools that accepted their classes being observed and then we agreed with the teachers on the dates and content of our workshops. Unfortunately, the exam period began, and it was not possible to complete our workshops in all the schools."

The group of ASA interns sharing some Metrology experiments with children from a Costa Rica school.
Photo: Marcela Prendas

"But at a school in Tres Ríos we were able to implement all the developed experiments. It was a huge success: students were very happy and interested. And the feedback from teachers was also very good. We realized there are great differences between public and private education. In Costa Rica, one-fifth of the population lives in poverty, but in downtown San José and in the neighborhoods we visited, it is almost unnoticeable. When we went to the state schools, teachers told us about the problems they face every day," says one of the young travelers who had the opportunity of visiting Costa Rica as part of the cooperation agreement.

"Thanks to a contact made with one teacher, we got to present our entire project at the University of Costa Rica, where we gave an informative talk to chemistry teachers."

"To end our project, we developed a website from where our teaching materials can be downloaded (www.lacomet.go.cr/niños)," Mara Büter mentions.

The explanations of the experiments are very illustrative, so previous knowledge in Metrology is not necessary.

The materials required to make the experiments are things we use daily and most of them can be found at home. Therefore, the cost of materials is reduced to a minimum.

If you wish to know more about the exciting and novel world of Metrology, just turn on your computer, connect to the Internet and look for *Proyectos* (Projects) in LACOMET's website. There you will find a link to *Metrología para niños y jóvenes* (Metrology for children and young people) There is also a download area, where you can find explanations and applications of the experiments developed so far.

"Due to the valuable experiences we had in LACOMET, and in Costa Rica in general, it was difficult to say goodbye. We will always remember the kind people and the good experiences we enjoyed," concluded the young Germans who formed the working group of this great project for children, young people and teachers.

Alberto Parra del Riego (Germany)

How did water come to Earth?

Water is a vital element for our survival. It is present in the form of oceans, rivers and glaciers in 71 % of our planet's surface area. About 55 % to 78 % of our body is made up of water, and it is the same for plants, that need this element to survive. Since all living beings depend on water, we have often wondered: what is the origin of this element?

A theory suggests that oceans were formed when hydrogen and oxygen were chemically combined under the planet's crust and emerged as volcanic vapor, which later condensed, turned into rain and reached the surface.

But nowadays, the most prominent theory among scientists is that water came by way of comets that hit the Earth. "Comets bring the original material of the solar system and some of them are located in the Kuiper Belt, a region in the outer solar system. The important thing about these comets is that their components, including water, have not been altered by the sun's radiation, so we can know the primordial chemical composition of our solar system," says Hugo Zeballos, MSc in Astronomy from Leiden University and Professor of the Department of Basic Sciences (*Departamento de Enseñanza de Ciencias Básicas*) of the Catholic University of the North, in Coquimbo – UCN (from Spanish *Universidad Católica del Norte*).

In fact, in recent times, this theory has gained more support due to the extraction of material from comets orbiting near the Earth. In 2011, a group of scientists discovered water in the comet Hartley 2, using the space telescope *Herschel*.

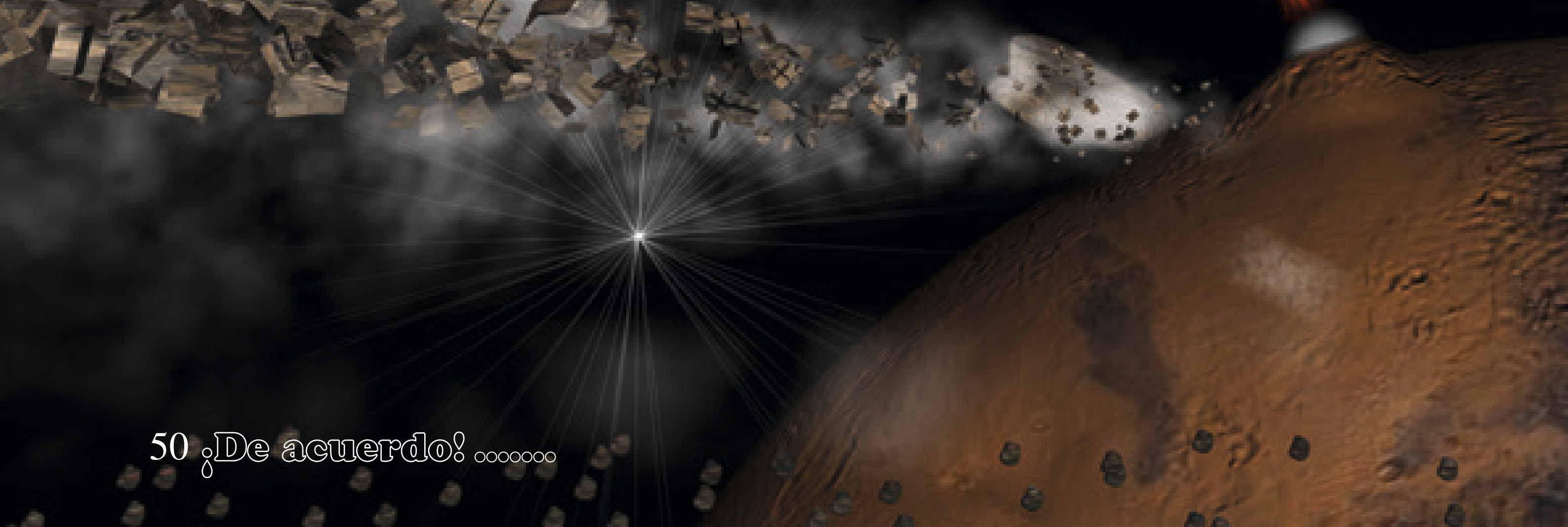
"Orbiting space telescopes have some kind of panel where they capture comet particles with a special gel, which are later analyzed in laboratories," Zeballos explains. This method allowed the analysis of the chemical components of comets and it was possible to prove that the water composition found was the same as the one on Earth.

A portion of the water on Earth that is present in oceans is called heavy water, which contains oxygen and deuterium, a hydrogen isotope with an extra neutron in its nucleus. For a comet to be the original source of the water in our planet, it must contain the exact proportion of regular and heavy water as the one found here. Until comet Hartley 2, no comet had ever been found to meet this criterion, since generally the other comets studied had twice the amount of heavy water compared to Earth. This was due to the fact that they came from other regions of the solar system, altering their composition due to their trajectory in space.

Other theories

However, these are not the only theories. In fact, this issue has been the subject of debate among scientists for many years and a definite theory to answer this question has not yet been established. Another theory states that water came to Earth when it was being formed, through the impact of asteroids and meteorites rich in water, distributing this element all over our planet by sheer force. "As they are generally exposed to the sun, meteorites have lost some of their primordial material or identity, which is why this theory has been more difficult to prove," Zeballos explains.

And finally, a more recent theory states that our planet received water molecules from interstellar dust with water inside. "Molecules can be found in dust grains created



in the atmosphere of colder stars that are growing (red giants), when the temperature decreases and silicates, the main component of dust grains, condense," the expert notes.

Scientific advances in the study of comets and the origins of the universe

Due to all these theories, scientists have been focusing mainly on the study of comets and asteroids. In this regard, one of the leading countries on astronomy in Latin America is Chile, the home of important astronomical centers, located in the northern region of its wide strip of territory. Thanks to these large telescopes, it is possible to conduct further research on these subjects, also trying to discover the origin of the universe, or to study dark energy and matter[1]. In the region of Coquimbo, the Association of Universities for Research in Astronomy (AURA) manages the Southern Astrophysical Research Telescope (SOAR), the *Gemini* Observatory and the Cerro Tololo Inter-American Observatory (CTIO). The latter has recently installed the dark energy camera[1] or *DeCam*, a 570-megapixel camera that will allow us to follow comets and asteroids, and to study dark energy and matter. "A machine like the *DeCam* is perfect for discovering comets, asteroids and objects that are moving in our solar system, since it can cover much of the sky in a short time, repeat the operations and see whenever a star, or an asteroid or comet, is moving, and start studying families of asteroids or comets particularly in this field," states Dr. Christopher Smith, Director of the AURA Observatory in Chile.

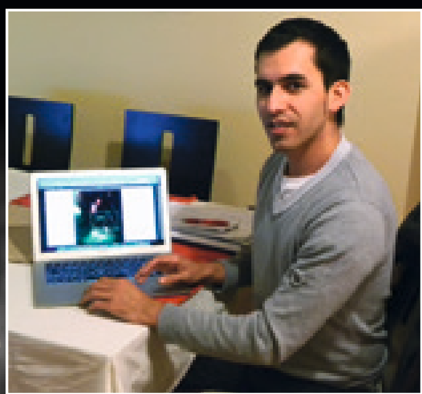
Even from the first days of operation of the *DeCam*, scientists were already suggesting to map out the sky and look for asteroids, comets and objects in the Kuiper Belt. "With the *DeCam*, you can start studying their chemical composition through various filters and, once you have the compositionof the family, you can choose some comets and start studying them with spectrography[2], which enables a more accurate study of their composition. To this end, you can use the spectrographs of the *Gemini* telescope or the SOAR," Smith notes.

Another of AURA's future projects that will contribute to this survey is the Large Synoptic Survey Telescope (LSST), which will be also located in the Coquimbo region. It is an 8.4-metre telescope with a 3200-megapixel camera with the ability to map out the sky in only 3 nights. "With the LSST, we will have a huge database of asteroids, comets and objects; their tracking will be amazing, since we will find from 80 % to 90 % of objects moving in the solar system," he explains.

Finally, at an altitude of 5000 metres in the Chajnantor Plateau, we have the ALMA radio telescope, composed of 66 high-precision antennas that will enable us to study the origins of the universe. "With ALMA, it will be possible to study the formation of planets, far away galaxies, the formation of stars and molecules like that of water, through millimetre and submillimetre wavelength, from infrared to radio waves," the expert states.

With these telescopes and the new astronomical projects that will be implemented, scientists are expected to be able to find new evidence to support once and for all any of the theories that explain the origin of water on Earth. Astronomers have been further studying these theories and hope they will be able to find an answer in the near future.

Camila Ibarlucea (Chile)



Hugo Zeballos, MSc in Astronomy and Professor of Basic Sciences in the Catholic University of the North
Photo: Camila Ibarlucea
Illustration: Alberto Parra del Riego

[1] Dark energy is a mysterious form of energy that would explain why the expansion of the universe has been accelerating and dark matter is matter that does not emit electromagnetic radiation.

[2] A technique to measure the distribution of the radiation intensity detected by each wavelength value.

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