

## INTRODUCING HIGH INPUT RESISTANCE/LOW DIRECT CURRENT ANALOGUE SYSTEMS FOR MORE PRECISE MEASUREMENT ON THE PROPERTIES OF WATER

### Abstract

*The ubiquitous dielectric properties of water creates many problems in determining exactly what those properties are. Already there is discontent and division on what the actual resistance of water is Ohmic resistance. Depending on who you ask that question, it can range from 10 to 25 million to even 100 million Ohm ( $10^7$  to  $10^8$ ) for pure water. However in order to obtain accurate measurements, analogue instrumentation will be required that are able to present input resistances of at least 100 times higher than that of water. With a conservative estimate of 100 million Ohms resistance for water, a minimum input resistance would be 10,000 million Ohm (10 Giga Ohm,  $10^{10}$  Ohm). This will ensure that no significant errors are introduced by the so-called parallel resistance factor and associated electrical measurements. It is a technical fact that presently digital multimeters do not have the required input resistance or impedance (in the case of alternating current) to do so. It is the purpose of this essay to clear up some of the technical anomalies associated with flawed and inaccurate water purity testing.*

**Key words:** Ohm's Law, Conductivity meters, high input resistance and nano/pico ampere, equilibrium voltage.

### INTRODUCTION

Note! Water is a dielectric and thus an insulator. The flow of direct or alternating current is opposed under these circumstances. Water cannot possibly allow current to flow except for any hydrated/solvated electrons (anions) created in the water due to breaking and making of hydrogen bonds. There are bound to be a mixture of other anions and cations in the water as well from foreign matter under the rule "for every ion, there is a counter ion" as a natural form of balance. In the context of the subject matter of electro-chemistry and when producing so-called colloidal silver, also the practice of electro-photochemistry, simultaneous oxidation and reduction of silver atoms, *Direct Current* is used. Nevertheless, chemists have seen fit to avoid accurate testing using DC, but have instead opted to use Alternating Current.

The use of alternating current is by virtue of an ever changing voltage potential from a zero potential to a positive excursion and back to zero and then into a negative excursion before winding up at zero again not a suitable method. This up and down voltage potential completes the cycle (Hertz) per second of a sine wave and resistance makes way for Impedance, (AC resistance). Coupled to all this is the equilibrium voltage of water at 1.23 volt DC. Any applied voltage in excess of 1.23 volts DC decomposes water into its constituent components of hydrogen and Oxygen gas. This fact alone would make any current or resistance measurement impossible and highly inaccurate. The use of DC, provided the voltage on the probe would be limited at 1 Volt DC and feeding into electronic circuitry at 10kMOhm input resistance, would make very high resistances and very low current measurements a very precise task. Following on from these revelations, it can be deduced that measurements other than by DC are bound to be flawed and unreliable. This

would especially be the case if in addition to using AC, the wavelengths applied in different makes of conductivity meters would vary, i.e. from 50 Hz to 3,000 Hz, as different wavelengths would also create different impedances, such as 10,000 Ohm at low frequencies to just 50 Ohm at Radio frequencies. Consistent and comparable readings between different makes would be out of the question!

### **Water cannot conduct electric current.**

As a dielectric and insulator, ultra-pure water opposes the flow of electrical current. Water has a natural tendency to attract and dissolve any matter immersed in the water. Having established this other in water, it will now be necessary to qualify what different types of matter can be held by water. These are listed as follows:

\* Ionic matter, either cations (positive charges and missing one or more electrons) or anions (negative charges and an excess of one or more electrons). Ionic Silver (a cation) is a totally dissolved incomplete atom as compared to the hydrophobic nature of neutral silver, which is not. Current flow of ionic silver can be measured between cathode and anode. It would be best to describe that as Total dissolved ions (TDI) and not TDS for total dissolved solids as something cannot possibly be a solid and dissolved at the same time.

\* Uncharged immersed solids (UIS) such as organic and inorganic foreign matter, ranging from pathogens and hormones to bits of metal or silicon based materials. Current is unlikely to flow, but using optical observation of obscuring factors and light scattering, such levels of immersed solids can be detected with great accuracy. There was a time that MHO resistance measuring instrumentation was used as well as instrumentation for optical observation by way of sedimentometers, turbidity meters and nephelometers were in vogue. Unfortunately all of this has been replaced by AC based Conductivity meters, that I am still trying to figure out what exactly these are measuring. For one, the alleged reciprocals of conductivity/cm to resistivity/cm at values of 1 micro Siemens equalling 1 million Ohm respectively does not appear to have ever been verified. In fact, by using both digital and analogue instrumentation, these values can be out by as much as 90%, i.e. 1 micro Siemens equals only 100,000 Ohm resistivity instead of 1 million Ohm resistivity. Even lower values have been established. What a shame to consider that many scientists cannot be bothered with such detail and just rely on flawed conductivity principles.

**Note! There are many shortcomings contributed to the use of alternating current based conductivity metering to both DC resistance, resistivity/cm and its reciprocal conductivity/cm. Reading technical literature on the subject, highly confusing and impractical statements are presented. This is particularly true about what type of instruments to use. For that reason our research is concentrating on practicalities instead of theories, hypothesis and other impossible measurement techniques. One of these flawed measurement techniques, is the use of conductivity meters. These claim able to measure total dissolved solids, which in reality consist of ionic matter with charge and are not a solid at all, being 'totally dissolved'. A more accurate approach would be the use of Ohm's Law. A common denominator has been adapted by using Ohm's Law. This law is in reach of everyone interested in accurately determining Ohmic resistance, current flow in ampere/h of water Ohm's Law and a known voltage potential. Ohm's Law is a well-established constant. This paper will demonstrate the ease of how this can be accomplished.**

Measuring the electrical properties of water are marred by inconsistencies and illogical rigid adherence to false scientific principles. One of these questionable inconsistencies, is the continued

adherence to the concept of a maximum resistance to current flow of approximately 18 million Ohm (18.18 and 18.24 MOhm). This belief system claims that this occurs when water's pH value is neutral at pH7 exactly, as if there is a direct relationship between pH (parts Hydrogen) and the structure of water that changes with whatever that water is in contact with. Also what needs to be considered is the actual instrument used to measure such a relatively low resistance of 18 MOhm. This could be in fact a digital multimeter with a maximum resistance measuring capability not much higher than the resistance measured and invoking the 'parallel resistance factor' as part of the earlier mentioned OHM's Law. So far, no existing literature on this '18MOhm resistance factor' has emerged as if such technical information on this subject has been considered as totally 'irrelevant'. **Ref. Bevilaqua.** As if this were not enough, other ways of indirectly measuring the resistance of water, or its associate concept of 'Resistivity' over its alleged standard of distance over centimeter (cm) as an equally alleged reciprocal of conductance/conductivity (current flow over that same distance. It is claimed that a conductivity meter measures conductivity as if it were a current (I) under Ohm's Law on the assumed reality that whatever it measures in milli or micro Siemen relates directly to resistance/resistivity/cm under Ohm's Law. However nothing could be further from the scientific/technical truth. The most likely reason for this inconsistency is the fact that THE VOLTAGE POTENTIAL ELEMENT has been deliberately kept out of the equation of the presupposed resistivity/conductivity concept. To this fallacy must be added, that when it all boils down, only resistance/cm and current flow in fractions of an ampere hour are involved.

### **The subject of Ohm's Law**

Ohms Law imposes an intricate relationship with between voltage potential (V) or E, current in ampere (I) and resistance in Ohms (R), as shown in this triangular representation below.

## TRIANGLE

$$I = V/R$$

$$R = V/I$$

$$V = I \times R$$

- 1. Current = voltage divided by Resistance (Ohms)**
- 2. Resistance = voltage divided by Current (Ampere/h)**
- 3. Voltage = Current X Resistance.**

**Note! The designation for Volts (V) can also be expressed as E**

Knowledge of two parameters will provide knowledge of the third parameter.

Research by way of experiment has indicated so far, that measuring conductivity/cm in Siemen units does not immediately equate to resistance/resistivity/cm. In fact it was shown to be out by a large error factor of 90%, i.e. measuring only 10% of what it was expected to be, i.e. 1 micro Siemen = 1 MOhm was only 100,000 Ohm. Not that the conductivity may have been wrong, but the structure of the water and what was in it by way of uncharged contamination, caused the failure of the reciprocity principle. The second contributing factor would have been the failure to take the voltage potential into account, especially an alternating voltage that changes every fraction of a second that direct current could not and would not do. To ensure the accuracy of the instrumentation used, comparative tests are made with 1% standard high resistance resistors. Because of the very high resistances involved with water, up to 1 Giga Ohm (1,000 million Ohm) only 1% resistors are used

ranging from 100 MOhm to 10,000MOhm. Every time a resistance measurement is made, it is immediately confirmed by checking the result with one of these standard 1% precision high Ohm resistors or combinations to arrive at the resistance measured.

### **A specific experiment measuring the resistance of water over 1 metre.**

A few years ago, a long acrylic tank measuring 1200mm long and holding approximately 40 litres of deionised water from a reliable source (approximately 0.1 Micro Siemen) measured 1,000 million Ohm over a distance of 1,000mm between two silver electrodes. Reducing the distance between the two silver electrodes to just 400mm, a reduced resistance of 300 million Ohm was obtained. That must have been the actual resistance of the water. This suggested that the measurement is non-linear. A further test not long after, using a DIY acrylic probe outfitted with two pieces of pure silver foil (99.998%) measuring 10x10mm and 10mm apart, also came up with an identical answer, i.e. 300 million Ohm as proof of that.

### **More anomalies with conductivity measurements.**

A recent event is illustrative of some of these anomalies and other shortcomings. This occurred when trying to explain a reading of 1 micro Siemen/cm with its reciprocal in resistivity as being the equivalent of 1 million Ohm (1 Meg Ohm). Test after test, a reading of only 100,000 Ohm was obtained, coupled with earlier readings of another batch of water measuring only 65,000 Ohm. This is a very high error factor that should not be ignored. Obviously something is very wrong! Unknown factors must be influencing these readings. It is also possible that reciprocals of micro Siemens/cm and resistivity in Ohm do not really correlate with each other as expected. As a matter of technical interest, a number of different makes of digital and analogue multimeters were used, including a very high input resistance instrument called a Vacuum Tube Volt Meter. At these low resistance measurements of 100,000 Ohms, all instruments read about the same. However for readings higher than about 50 MOhm, the average digital multimeter is unable to cope and different makes can no longer agree what is being measured. It is for such inconsistencies that suggests that something more consistent than the average digital multimeter or conductance meter has to be introduced. Our technical and scientific argument and other factors for this change in attitude are shown in the following section:

1. Water not only takes the shape of the container it is in but also adjusts its molecular structure to match the material the container it is made of but also any material immersed or dissolved in it. The container may not be bigger than a standard 10x10mm cuvette or a hundred litre tank. Such a difference in volume cannot be ignored. We have measured 1,000 Meg Ohm over a 40 litre volume of water over a distance of 1,000mm. Even over a reduced distance of 10mm, the water still measured 300 Meg Ohm.
2. Water forms structured water, depending on what material it is in contact with or more complex, when foreign matter is in the water that may either be hydrophilic or hydrophobic.
3. Current in water, if very pure, must be at a very small value and in the order of  $10^{-6}$  to  $10^{-10}$  (micro to pico ampere/h range). Its reciprocal in Ohmic resistance would equate as below:

1 million Ohm ( $10^6$ )	= 1 micro ampere/h ( $10^{-6}$ )
10 million Ohm ( $10^7$ )	= 100 nano ampere/h ( $10^{-7}$ )
100 million ohm ( $10^8$ )	= 10 nano ampere/h ( $10^{-8}$ )

1,000 million Ohm ( $10^9$ ) or 1 Giga Ohm = 1 nano ampere ( $10^{-9}$ )

For even higher precision, a custom designed 10,000 million Ohm input resistance ( $10^{10}$ ) prototype instrument is used. This equates to 100 pico ampere/h ( $10^{-10}$ ).

4. A number of experiments have indicated that current flow in water does not follow a straight line or the shortest distance between two electrodes. It seems similar to electric current flow in resistivity measure over a specific distance, following a path along the surface of a solid conductor between two opposing surfaces. It has been suggested that electric current in a tank filled with water may follow a similar electrical trajectory, a substantially longer trajectory than the distance between two immersed electrodes.

5. There is the equilibrium voltage of water at 1.23 volt DC and the subsequent decomposition of water molecules into hydrogen and Oxygen gas. With water molecules being dipolar in nature, splitting up water molecules will polarise the water into positive charges (Hydrogen) and negative charges (Oxygen). Conductivity meters with their probes carrying excessive voltage, may have prompted Manufacturers to use AC as a pseudo strategy to overcome that problem. Simply reducing this volts potential to just one volt DC or lower, may have prevented such anomalies. Another anomaly is the fact that with using DC, Ohms Law displays a direct relationship between Current (I) in ampere/h, Resistance (R) in Ohms and voltage potential (V) as shown previously. That this makes a difference, was indicated when a voltage level of 300 volts DC at a limited 500 micro ampere was doubled to 600 volts DC. It provided a means of increasing the limited current flow of 500 micro ampere to a three-fold increase of 1,500 micro ampere/h.

6. The answer is in the utilisation of *'high input resistances and low currents'* analogue based instrumentation for measuring all aspects of water's electrical properties, something most digital instrumentation is unable to cope with. A simple analogue circuit, using a single common 8 pin DIL operational amplifier will be provide these 'analogue based' DC conductivity meters with input resistances as high as 1 Tera Ohm (National Semiconductors) or 1.5 Tera Ohm ( $1.5 \times 10^{12}$ ) Radio Corporation of America (RCA), provided that feedback resistors of 10KMOhm are able to be obtained. Unfortunately, conductance meters of any kind are only able to measure charge carriers as part of the total dissolved ions, and perhaps hydrated electron flow in the water. Anything else, such as electrically neutral materials, organic or inorganic, as immersed solids will require optically orientated instrumentation in order to make full assessment of fouling contamination. Suitable instrumentation for non-charged contamination was presented in the 1900s by way of turbidity, density and 90 degree light scattering by the Turbidity meter, the Densitometer and for light scattering analysis by the Nephelometer respectively. However to gain access to both types, turbidity and light scattering simultaneously, these instruments have to be combined in the one unit for ease of analysis and determination.

### **Undissolved and immersed solids.**

Undissolved and immersed solids and even floating debris floating on top of the water could be anything at all. If a silver anode is not covered by a sleeve of plastic or nylon at the point where immersion with water surface occurs, a film of free silver metal forms and floats on the water's surface. This phenomenon gives the appearance of crystalline flowers, for lack of a better description. Whatever is in the water other than charge carriers or even free hydrated or solvated electrons, is bound to be there and perhaps in a significant quantity for the water to be considered polluted. Water originates from melting glazier run-off, precipitation and rain from above, and

collected in surface waters like rivers and lakes as well as juvenile waters from geysers and volcanic eruptions. Water will, due to its nature as a natural dissolver and adhesive qualities collect anything it comes into contact with. Filtration, distilling, deionising and demineralising all play a part in a purifying strategy to provide clean water, whatever that description means. No matter how pure water is, simple exposure to our atmosphere, it will soon become polluted again. How polluted, only visible observation by optical means is able to quantify pollution levels. This can be accomplished by measuring obscuration (densitometry) or 90 degree light scattering (nephelometry), to determine pollution/contamination levels, a task well beyond even the most sophisticated conductivity meter.

### **Instrumentation for water purity testing and observation**

***Note! In addition to normal organic and inorganic contamination of water, today's society also brings with it contamination of our waterways with artificially created hormones, pharmaceuticals, antibiotics and even dangerous recombinations of these contaminants. Often too small to filtrate, requiring very-specialised instrumentation to do so. In order to detect these minute contaminants the shorter wavelengths of light and special linear and circular polarizing implementation, including rotational light functionality, will need to be utilised.***

### ***Light scattering analysis***

Much can be detected with light scattering techniques at different wavelengths of light. Such techniques can be used to detect and observe objects in the water at specific sizes. A red diode laser at around 600-700nm will most likely cause the scattering of light from particles (for lack of a precise description) down to 600 to 700nm in size, as wavelengths longer than the size of particles cannot be wholly absorbed. For particle sizes below these values, a green diode laser will be more appropriate because its wavelength range covers from 560-490nm. When however approaching particles smaller than those wavelengths, a violet diode laser at 405nm will be more suitable, but there are problems here. In particular with nanometre sized atomic silver clusters. Normally visible light down to green has a vibrational (thermal heating) effect by jostling the atoms about. In an around 420nm and at a level of 2.6eV, the violet light is an ionising radiation instead. In order to illustrate a relationship that exists between the frequency of light and particle/cluster size, I presented three samples of colloidal silver to a visiting scientist. The first sample was irradiated with red light and showed scattering. A green diode laser was shone on the second sample and like the first one presented sufficient scattering. However when I held up the third bottle, he looked at it and pointed his green diode laser at the sample and seeing no light scattering, remarked, "That is just plain water". I shook my head, took a 405nm violet diode laser and showed him there was plenty of scattering. Argument closed or not?

At sizes of 10nm and less, pico and nanometre sized atomic silver clusters, phenomena of relativistic events (Photo electric, quantum confined electrons and local plasmon resonances become part of the equation. There are many surprise aspects with silver and in particular when sized at dimensions approaching the very low nanometre and high picometre levels and the same may be true of the aqueous media of water it is contained in. It is no longer under control of Classical Physics we are familiar with, such as gravity. Now the laws governing Quantum Physics apply. This is what is assumed at this stage:

When a long wavelength of light measuring 600nm strikes a quantum confined electrons on the surface of a pico or nano sized silver atoms, these 600nm light photons should technically speaking be absorbed as thermal energy and heat up these atoms. Whilst the incoming photons, not



assuming there is only one, strikes the various atoms, a local oscillation of some outer-skin electrons, temporarily endowed with photonic energy (local Plasmon Resonance), will release that photonic energy again as soon as the local oscillation subsides. Because the wavelength of the incoming photons is much larger than the dimensions of the pico and nanometre atoms/clusters, the oscillation itself is also scaled down. It may be in fact measure only ten nm. As the release of such photons as secondary radiation, this radiation may be matched to just 10 nm and be blue-shifted as a result. That means that a long wavelength of 600nm carrying only vibrational thermal energy has been converted to a much shorter wavelength of 10nm with ionising energy. There are claims that in some such events blue-shifts as short as 200nm have been recorded.

**Conclusion:** Light scattering has much to offer irrespective of what is in the water, including any contaminations. These type of analysis can be considerably enhanced by incorporating linear cross polarising filter systems in order to distinguishing between content with and content without a refractive index at visible wavelengths. An ideal tool for a nephelometer outfitted with cross linear polarising filters.

### **Measuring obscurity.**

There is a clear difference between clear water and water full of muck. It definitely will block some of the light if the water is contaminated with organic and inorganic matter. To what extend light will be blocked after it has passed through a contaminated solution of water and picked up by a sensitive photo-detector or diode will indicate the level of obscurity and thus the contamination by foreign matter.

**Conclusion:** Both light scattering techniques and obscurity (turbidity) testing can be done simultaneously done on the one instrument. It has been tried.

### **Other ways of measuring impurities in water such as by refractive index variations.**

Most materials differ by their refractive index and that is measurable at differing frequencies/wavelengths. Silver has no visible refractive index other than a scientific statement that 97% of all visible light is reflected, but so far I have found no record where the remaining 3% is located. Perhaps it is partially in the red or infrared as well as at 420nm, an area known to absorb these wavelengths as heat at one end and violet at the other. Water on the other hand absorbs just about every wavelength and only becoming super transparent at, and you would not believe this, at around the same wavelength where silver absorbs light at between 417-420nm, depending on purity of both substances. It is thus obvious from the aforementioned facts that a combination of spectrophotometry, linear cross polarization and other optical techniques can be used to quantify impurities in the water by way of change of refractive index at varying wavelengths. It is a well-known among 'pre digital camera era' photographers, that highly reflective metals such as silver and aluminium do not visibly polarise light, but highly refractive materials such as glass and water do. Note! Circular polarisers only partially come into this equation as they are exclusively used on digital video and camera equipment.

### **CONCLUSION**

**From the foregoing it will be obvious that the complete assessment of the purity of water and whatever is in it, either purposeful or accidentally, requires a scientific and technical multi-disciplinary approach. Use a conductance meter for measuring ion content level, but augment this absolutely with optical instrumentation to determine concentrations of anything else in that may**



**be in the water that conductivity instrumentation cannot detect. Only then can an informed decision can be made on the 'state of purity' of water.**