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**A VALID ARGUMENT AGAINST THE USE OF AC BASED DIGITAL CONDUCTIVITY MEASUREMENTS IN FAVOUR OF ANALOGUE DIRECT CURRENT/RESISTANCE TECHNOLOGY.**

**Abstract:**

***Experimental research shows that there is too much reliance placed on the measurements provided by conductance meters. In fact, conductance measurements in micro Siemens or Mho fall short of testing the purity of water in all of its complexity. Conductance measurements only determine the charge carriers of the total dissolved (ionic) solids (TDS), but any other solids, immersed, dissolved or otherwise not carrying an electrical charge or Zeta potential (interfacial charge) remain undetected. This would be neutral metallic particles, organic and inorganic chemical compounds and/or colloids.***

***Water is a dielectric and thus an insulator. This condition allows electric current to flow when ionic material is present. The more ionic matter in the water the higher the conductivity or conversely the less ionic matter, the lower the conductivity will be. Both electrolysis and electrochemistry are involved. Electrolysis is a process using direct current. This is to enable the creation of a chemical reaction that otherwise would not happen. It utilises a voltage potential to acquire a decomposition voltage. The decomposition voltage is the required potential where water molecules break up into oxygen gas and hydrogen gas. The borderline where this happens is called the equilibrium voltage of water which is 1.23 volts DC. The decomposition of water will occur with any voltage potential higher than that. The decomposition of water causes electrical polarization by the creation of hydrogen ions (cations) which are attracted to anything negative, in particularly free solvated or hydrated electrons. Measuring the properties of stable water, below or above the 1.23 volt DC equilibrium voltage of water, is fraught with uncertainties. Probes and instrumentation to measure pH and Conductance values will contribute to flawed testing with incorrect impedances and/or low input resistances of the measuring instrument itself and in some cases, even cause electrical reactions. Digital instrumentation in particular does not measure, but samples the properties of water, using low value resistances as a load. The highest input resistance of a digital multimeter used so far provided an impedance of 200 million Ohm (200M Ohm or Meg Ohm). Most other digital instrumentation however operate at much lower impedances and for that reason are considered inadequate for the high resistance measurement of pure and ultra-pure water. This presentation will seek to address these issues with the re-introduction of analogue electronic instrumentation and equipment.***

**INTRODUCTION**

Much of our water is contaminated in a natural way as precipitated water, Glazier run-off and even juvenile water from volcanic eruptions and winding up as ground, surface and underground waters, by way of lakes and rivers, wells and bores respectively. Being the great absorber, water may contain just about anything in the way of elemental metallic particles and other organic and inorganic matter along the way. It even accommodates gases such as carbon dioxide in varying quantities. It would be safe to say that exposed to the environment, the diversity of natural contamination is limitless. Of concern however is the absorption of dangerous substances in excess, such as caused by

illegal dumping and run-off from chemical fertilisers as well as and the disposal of pharmaceuticals into waterways.

For many industrial, commercial, and experimental processes as well as using water for personal use, the expectation exists that such water be relatively pure and free from unwanted contaminants, hence the purpose of this paper.

**Note! The basis of our research is the science of so-called colloidal silver particles in dispersion, when colloidal silver is in reality not a colloid and particles are but atomic clusters in a state of repelling electrical suspension. With the production of concentrations rarely exceeding 20mg/l (20ppm), the aqueous medium it is produced in forms the bulk of the solution. Nonetheless this paper is equally essential for uses of water other than colloidal silver, such as in medicine and water for injections in particular, but without losing sight of other equally important uses where a certifiable high purity water is needed.**

Electrochemistry is a branch of physical chemistry between direct current and physical change in order to produce ionic silver. When simultaneously irradiated with light at a specific short wavelength, neutral silver is produced from ionic silver resulting in nanometre sized atomic silver clusters. Both electrolysis and electrochemistry are considered 'wet' chemistry, albeit, mostly in the realm of physics. Somewhere along the way, chemists introduced the concept of 'wet' conductivity measurement for water and also introduced the 'Siemens' including nominations such as milli Siemen and micro Siemens to depict variations of the Siemens for low conductivity water. Soon however, direct current measurement techniques using the concept of MHO (the backward spelling of OHM) was abandoned and a version having alternating current as its basis was introduced and adopted. Ever since that day, the measurement of ionic charge carriers has been compromised and flawed.

Ohm is a measurement of direct current resistance and forming part of Ohm's Law together with voltage potential and current in amperage. See the triangle of this relationship below. Resistance in practical terms ranges from fractions of an OHM to millions of OHMs. The thought that one could equate a reciprocal in conductance using different alternating current in a medium such as water, not being a solid conductor by way of resistivity i.e. higher resistance lower conductance and lower resistance a higher conductance, was a technical error of the highest order. It was also proof by the designers of such equipment of a lack of understanding the properties of water, that to this day are still not completely understood by science.

Initially, Ohm's Law was somewhat adhered to by using direct current and resistance measurements with the descriptions of low values of amperage and resistivity (MHO) respectively. The term 'Resistivity' was introduced to indicate the flow of current on the outside of solid conductors and illustrated by imagining a solid metallic block, such as a cube and the current flow on the outside of one surface of the cube to that of another opposing surface with the distance of travel along three surfaces being a measurable concept. That concept could be in millimetres, centimetres, decimetres or even metres, depending how large the cube's dimensions were. That was mistake number one. How can anyone relating current flow on the outsides of a solid conductor cube with a formless quantity of water and arrive at the same result. The second mistake sadly was to see that the spelling of Ohm backwards as Mho, when it really would have more 'questionable' sense to have written Ohm upside down as being the reciprocal. If that was not enough in the way of errors, it would appear that either impedance, parallel resistive loading and the need of high input resistance

loading and even more so the equilibrium voltage of water seemingly being ignored. No wonder that all of these artefacts caused incorrect readings and the subsequent polarization of the water respectively.

It is most likely why at some stage Mho measurements were abandoned and Conductance meters measuring in milli and micro Siemens were introduced with all the technical and unscientific nonsense that came with it. Only a vague reference was made to Resistivity as its reciprocal, without that aspect ever verified that 1 micro Siemens was indeed the reciprocal of 1 million Ohm resistivity measured with a probe over 10mm (1cm). No consideration was ever given to the principles of Ohm's Law, direct current measurements in micro, nano and even pico ampere, high resistance measurements in millions and thousands of millions of Ohm necessary for the proper measuring of these values. In addition alternating current ranging from 50Hz to 3 KHz were used, with each of these frequencies having their own impedance (AC resistance) and still ignoring that fact that water is (a) not a solid conductor, (b) the prospect of electrical decomposition of water, (c) that current is unlikely to flow 'linea recta' in water and not following the shortest path between electrodes and (d) obstacles in the water such as impurities, neutral metals and organic matter and finally (e) the electrical obstructions water had to flow around. However there are superior ways of testing the properties of water that can be standardized against. There is one final anomaly with the concept of conductance/resistivity measurement and that is the absence of voltage, common with the relationship between voltage, current and resistance according to Ohm's Law. Even with the use of direct current, that three identities of voltage potential, resistance in Ohms and current in amperage, any changes in one will change to value of the other two. A recent experiment proved this to be very true. For some time a regular and consistent voltage potential of 300 Volts provided sufficient pressure to allow 500 micro ampere to flow in commercial deionised water of around 10 to 100 million Ohm resistance. However by doubling the voltage potential to 600 Volts gave a three-fold increase of 1,500 micro ampere (1.5mA/h). That would also mean that it is not only the impedance of conductance measurements, but also the voltage potential used on the probe that can influence the accuracy of the conductance measurement. Obviously we have to look at a more precise way of measuring the ionic properties of water, but also of anything else in the water that carries no charge.

#### **A COMPLETE STRATEGY FOR DETERMINING THE MOST NEEDED ANALYSIS OF WATER**

Water has many uses but some commercial and industrial uses demand an improved and standardised purity of water. A relatively comprehensive analysis of water dictated for its intended use will require more than just a simple conductivity test of its ionic state or not. The total of the ionic dissolved solids are not the only contents that can influence water's inherent properties, the total of undissolved and immersed solids can do so as well and often to the detriment of the purity of water. The total of undissolved and immersed solids represented by organic and inorganic material, undetected by conductivity measurements, is even able to prevent required and programmed current flow to a mere trickle. One of these is the almost instantaneous contamination of the electrodes by an unwanted coating of some unknown chemistry in water, particularly such found in some forms of distilled water. All manner of things can happen in and with water, due to water's response to just about everything it is in contact with, even the type of material the vessel it is contained in. This phenomenon has been collectively named the Enigma of Structured Water. In the publication "Handbook of Industrial Water Conditioning" by BETZ, Eight Edition 1980 under section 53 page 366/368, it refers to the corrosive effect of high levels of carbon dioxide, causing the

ionization of water molecules by producing carbonic acid as follows:  $\text{H}_2\text{O} + \text{CO}_2 = \text{H}^+\text{CO}_2^-$ . Any Hydrogen ions  $\text{H}^+$  formed during decomposition will translate into  $\text{HCO}_3^-$  a bicarbonate ion. Any Sodium in the water can then produce Sodium hydroxide (caustic soda). And this is only one example of what can happen with any undissolved (ionic) solids. It is also claimed that compared to surface waters with a relatively low carbon dioxide content of between 1 and 10ppm, well and bore water can have carbon dioxide levels as high as 100ppm. Conclusion: tests and analysis conducted on water will need to assess any extreme contamination levels, to prevent any of these detrimental chemical side effects as illustrated can occur with just Carbon dioxide alone.

### ***Some notes about alternating current as used in conductance meters***

***Alternating current (AC) is actually a sine wave consisting of a pure single frequency tone. Examples are the 50 or 60 Hz sinewaves for our electrical power and musical tones that cover the entire audible spectrum from 20Hz to 20,000Hz. The amplitude of sinewaves are of an averaging nature and defined as Root Mean Square (RMS), meaning equal to a value compared to a direct current and amplitude or voltage level over time that would produce a comparable averaging value of power dissipation in a resistive or inductive load. If the use of an RMS value is intended for an AC wave to mimic a Direct Current, it would be another reason for not using AC for measuring the dielectric properties of water that way.***

***Anything can and will happen to sine waves. Reverberation can bounce off the inner walls the container holding the water and cause mixing of the original signal and the echo which will arrive late and cause a phase difference. Before long the mixing sounds, the original sine wave being subject to sub-harmonics and harmonics will start to square itself and distort the sine wave. Sinewaves are more difficult to produce and to maintain than pulsed DC. Sinewaves are produced by oscillators (amplifiers that are being powered by positive feedback) that are difficult to control. It is unlikely that when conductance probes are submerged in water, any sinewaves are likely to be absorbed, particularly the higher frequencies, that actually heat up water with their energies. A microwave oven is a perfect example of this. Sinewaves incidentally rise from zero to a positive amplitude, return to zero, go to a negative amplitude and subsequently rise to zero again, completing a 360 degree cycle (Hertz or Hz). See illustration below.***

### **HOW TO OBTAIN A MORE COMPREHENSIVE VIEW OF ANY CONTAMINATION**

It must now be clear that alternating current based conductivity measuring instruments, not taking any notice of impedances and polarization properties of water and a blindness to contamination made visible by light scattering and light blocking principles, must be an unacceptable practice. Instead there is no alternative but to revisit the likes of Sedimentometers, turbidity meters and nephelometers that are able to see turbidity, albeit redesigned with modern electronic/optical techniques and components. One problem with such reintroduction of optically based equipment are the absence of rectangular and square thin walled glass cells, clear all around and ideal for 90 degree light scattering analysis, used during the 1900's

A recent event caused by contaminated water is illustrative of what can go wrong! Having established an accurate production of quantum nanometre sized neutral atomic silver clusters by electro-photochemical means, I was surprised when confronted by a different type of commercial water that would not work as expected. For years, using deionised water and subjected to a combined voltage potential of 300 volts at a controlled and limited current of 500 uA/h, suddenly only allowed a trickle of 9uA/h to flow between two pure silver electrodes. Even an unexplained voltage drop of some 110 volts was measured. Seriously considering an inadequate Dc power supply and generation equipment, the entire system was re-built with more current-robust components, in

particular the stepdown transformers. It proved a wasted effort, as it proved no remedy for the earlier loss of power. Something else was influencing the parameters! However in an attempt to question and identify this 'something else', let us look at the physics of Ohm's Law. There are three related factors involved as the triangle below indicates. They are resistance (Ohm), voltage (potential) and current (amperes) respectively.

#### ILLUSTRATION OF OHM'S LAW TRIANGLE

Voltage = Current times Resistance

Current = Voltage divided by Resistance

Resistance = Voltage divided by Current

Within the realm of electrochemistry, we are primarily concerned with the relationship between the current levels that are able to flow against the resistance that water imposes on it. It follows the principle of reciprocal values, i.e. the higher the current flow, the lower the opposing resistance of the water will be, as well as when resistance increases, the less will be the current flow. Both scientifically and technically, CONDUCTANCE has nothing whatsoever to do with it being just an artefact. It all started when the need arose to determine specific electrical properties of water, i.e. resistance and current. That proved difficult as the resistance of relatively pure and ultra-pure water, being an insulator and a dielectric opposes current flow. To measure either resistance or its reciprocal current, the use of very high input resistance meters are required. With input resistances thousands of times higher than those of a particular water being tested a reasonable accuracy of the water's dielectric properties can be attained. That means an input resistance in the Giga Ohms range ( $10^{12}$ ) and some assurance for accuracy (parallel resistance loading errors). Simultaneously, the reciprocal (inversion) in current would be  $10^{-12}$  Ampere. The graph below indicates this relationship between resistance on the one hand and current on the other.

Note! To be absolutely certain that high input resistance meters are showing the correct value, standard 1% precision resistors are used to compare readings. These standard 1% resistors range from 10MOhm to 10,000MOhm.

For convenience sake it starts somewhere in the middle at 1 million Ohm.

#### Standard relationship between current and resistance in solid conductors and not ignoring the voltage factor.

0.01 micro ampere	= 100 million Ohm
0.1 micro ampere	= 10 million Ohm
1 micro (1/millionth) ampere	= 1 million Ohm (1MOhm)
10 micro ampere	= 100.000 Ohm (100KOhm)
100 micro ampere	= 10,000Ohm (10KOhm)

Unfortunately, the lowest value of current and the highest value of resistance are only of a modest value, but already beyond the capacity of most digital multimeters. Only Field effect transistor or integrated circuit operated multimeters as well as Vacuum Tube Voltmeters (VTVM) are capable of

handling extreme resistance ranges as high as 1,000 million Ohm. To also measure current at Nano ampere  $10^{-9}$  and Pico ampere  $10^{-12}$  is beyond standard and conventional test equipment. These limitations in test equipment may have prompted manufacturers of test equipment to seek an alternative way of measuring the current and resistance values of water by introducing the concept of Resistivity in vogue in the 20<sup>th</sup> Century to measure electric current flow between two opposing surfaces of a solid metallic conductor, e.g. copper and silver. In order to adapt this to a liquid like water, the word Ohm was spelled backward to Mho as a resistivity factor and the micro Siemen for the measure of Conductivity as being inversely proportional. Spelling the word Mho backward did not make sense but writing it upside down would have. The graph for that is somewhat similar and an unofficial representation of the reciprocal values is shown hereunder, but seems to have left out the applied voltage factor:

100 MOhm resistivity	= 0.01 micro Siemen
10 million Ohm resistivity	= 0.1 micro Siemen
1 million Ohm resistivity	= 1 micro Siemen
100,000 Ohm resistivity	= 10 micro Siemen
10,000 Ohm resistivity	= 100 micro Siemen

All would be well but for a few inconsistencies. The most blatant one would be measuring the values of resistivity and conductance over a distance of 1 cm (=10mm) when it is most unlikely that current and/or resistivity travelled in a straight line and the shortest distance between two electrodes. It is more than likely that the movement of charge carriers (and possibly hydrated electrons) would cause cations to flow one way and anions the other. Couple that with the constant making and breaking of Hydrogen bonds as well as polymerisation matrixes of water molecules and contaminants, there is every reason to think of current in water within the confines of a tank, behaving more like lightning through the atmosphere in a type of Zig Zag trajectory and perhaps even more so. This and the jostling by Brownian movement would add to this inconsistency.

A second inconsistency, interfering with current movement arises out of the decomposition of water by introduced voltages over and above the equilibrium voltage of water at 1.23 volt DC. Water's dipolar character would polarise into positive and negative charges of Hydrogen and Oxygen respectively. This is evidenced by the fact that conductance meters are based on various frequencies between different makes of alternating current (AC) rather direct current (DC). As a direct result of using different impedance in different makes, comparisons between such meters are inconsistent.

### **Facts and fallacies in relation to the testing of water**

1. The Term Siemens was first used in the late 1800s, when a German engineer and inventor named Werner von Siemens created an Ohmic standard for a length of copper telegraph cable. This took the shape of a column of Mercury one metre high that measured 0.95 Ohm, a very low DC resistance for a solid.
2. The term Mho was introduced soon after in order to establish the reciprocal of Ohm in measuring a DC electric current flow over a specific distance, i.e. a metre, decimetre or centimetre as well as a function over time, i.e. Ampere/hour.
3. Dissatisfied with the concept of MHO, that term was replaced by Conductance over 1 cm (10mm) for measuring the electrical current flow in water and its reciprocal of Resistivity/cm in line with Ohms law.

4. Due to the perceived polarisation effect of water, Direct Current 'MHO' measurements were replaced by Alternating Current measurements in Siemens, irrespective of its frequency dependence. This reciprocal range is supposed to be something like the chart shown before, starting from a low resistivity (1 Ohm) for a very high conductance to a very high Resistivity (100 M Ohm) and a very low Conductance.

Sometimes questionable anomalies are included in Conductance graphs, such as the one claiming that resistivity of water cannot exceed 18.24 M Ohm, a reciprocal conductivity of 0.0548 uS/cm. This is alleged to occur at a pH of 7, where water is neutral, neither acidic nor alkaline. Others again place the resistivity at around 25 MOhm. If no proper high DC input resistance instruments of at least 10,000 MOhm (10 Giga Ohm) was used but for a low input resistance multimeter, serious questions must be raised. Not that there is any excuse for not using high input resistance meters, when both RCA (Radio Corporation of America and National Semiconductor have had affordable integrated circuit (IC) operational amplifiers available with input resistances of 1.5 Tera Ohm and 1 Tera Ohm respectively. 1 Tera Ohm equals 1 million-million Ohm. The original RCA series CA3130, 3140, 3160 are some of the ICs with these specifications and have been available for decades. More recent ICs from other makes have similar specifications. Also more readily available are the required 10KMOhm feedback resistors, but only in surface mount construction.

**Note! There appears to be no verification that all of the values of Conductance are in fact the reciprocal of the corresponding resistivity values. Well, how could anyone? Conductance is measured by using Alternating Current which is not compatible with the Direct Current by which resistivity is measured. Read the next section for further explanations.**

5. So-called AC resistance should actually be properly referred to as an Impedance. The word 'impedance' means an opposition to the flow of current. It is also frequency dependent. An impedance at 100 Hz is different to an Impedance at 1,000Hz and an impedance at radio frequencies is different again. Alternating current can range from just thousands of Ohm for audio to just 50 Ohm at radio frequencies. The use of direct current resistance however has nothing whatsoever to do with any frequencies and as such is not frequency dependent. It is just DC or Direct Current, similar to what is charged into a battery. It does not have an impedance but instead is referred to as a high or low resistance input or output.

AC impedances are what it says. There is an impediment or opposition to the flow of electrical current caused by the introduction of electro-magnetic field force lines that are subjected to the electro-magnetic entity of Reluctance. During each half cycle, current is both reluctant to flow and not flow. This create magnetic lines of flux.

6. Polarisation of the electrical properties of water occur when voltages introduced exceed the equilibrium voltage of water. Polarities may also be created by other electrical disturbances in the water such as changes in the dipolar character of the water molecules. With the equilibrium voltage of water 1.23 volt DC, exceeding that voltage is going to interfere with the electrical stability of water, causing decomposition.

7. Water has dielectric properties and is thus an insulator, measuring very high resistance values for pure water and low resistance values for impure water. To measure such high resistance and low current values, i.e. Tera Ohm and Pico ampere values are beyond the range of conventional test equipment as stated earlier and in particular hybrid instruments like a conductance meter operating

on AC. To also expect such Conductance meters to measure non-conduction materials such as neutral metals, gasses, organic matter as well as in the water *is **wishful speculation!***

8. There is always the problem in describing the concept of dissolved solids. Some scientists just relate this to ionic matter, but the truth is that total dissolved solids can mean matter in the water that is either dissolved or immersed. Such total dissolved and/or immersed solids can have an adverse effect on the purity and quality of the water. Processes such as deionising and reverse osmosis of water in order to remove ionic matter and metallic salts may still contain harmful materials such as pharmaceuticals (as well as their more dangerous recombinations), drugs, hormones and pathogens. For that type of contamination, knowing the Conductance factor in micro Siemens is useless on its own. Perhaps we may have to revisit the old analogue test equipment used in the 1900s such as the Turbidity, Nephelometer, Densitometer and other such equipment for physical observation of some of these dissolved and immersed organic matter contaminants. An instrument just being completed may answer some of these questions. It uses cross polarised light scattering principles that coupled with short wavelengths of (violet) light can make very small particles visible and quantifiable. This analogue instrument combines both the properties of a nephelometer (analysing light scattering at 90 degrees) and the turbidity meter, measuring light obstruction levels.

Such an instrument that can combine the elements available in the nephelometer (light scattering at 90 degree) and also can measure the amount of light that is being blocked (turbidity) is being constructed with new feature and components not available decades ago. One of those features is the cross linear polarisation that will enable to recognise and measure metallic content as separate from organic matter.

## **CONCLUSION**

There is a need for better and more precise instrumentation for all tests on water, irrespective if used for drinking, producing colloidal silver, used as a base for medications and supplements and in particular for injections. Perhaps this is best offered in the area of analogue electronics where indeed instrumentation can go much lower and higher in measuring parameters of pure and unpure water by factors of millions in some instances. When testing water we simply cannot rely on just conductance measurements alone. Instead, optical and electronic strategies need to be included for determining levels of contamination that cannot be measured or observed by conductance meters due to an absence of ionic charge.

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