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IMECE2016-65930 (Status: Final paper submitted , Copyright received) **Schedule:** November 14, 2016 01:30PM - 03:15PM *Technical Paper Publicat*
Solute Ion Linear Alignment As The Energy Source To Address Aquifer Depletion Fresh Water Scarcity And Sea Level Rise Draft Paper 10

Authors

Name	Company	Author Order	Role	Copyright Received
Mr. Anthony Fresco	Carter, DeLuca, Farrell, Schmidt LLP	1	Contact Presentation and Lead Author	02 Jul 2016

Track 8 Energy

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Topic: 8-1 Energy-Related Multidisciplinary

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Session: 8-1-1 Energy-Related Multidisciplinary - 1

Name	Company	Phone & Fax	Role
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Abstract
There are reports in the literature that the lives of 4 billion people are at risk either now or in the foreseeable future, and includ even 130 million US citizens, mostly in the western states of California and surroundings and in Texas and Florida as being subject water scarcity primarily due to depletion of aquifers and ground water and losses due to evaporation. 1, 2 At the same tir according to the National Oceanic and Atmospheric Administration (NOAA), there is strong evidence that global sea level is now ris at an increased rate and will continue to rise during this century.3 Climate scientists at the Potsdam Institute of Climate Imp Research published a new study in the journal Natural Hazards and Earth System Sciences4 that found that the economic costs of s level rise increase more quickly than sea levels themselves. Although fresh water is scarce, obviously the oceans are virtually infinite source of water. Rather than trying to implement difficult fresh water usage restrictions, the best solution to the sea level r and fresh water scarcity would be to cheaply and efficiently convert sea water to fresh water and pump the rising sea water le inland to compensate for the underground aquifer depletion. The main problem with desalination has always been, and continues be, the high energy consumption and operating cost. Solute ion linear alignment propulsion was presented in ASME ES2010-9039 Solute ion linear alignment is a process in which potential energy of the electrostatic fields of like charged solute ions is converted kinetic energy. The current paper presents factors showing that solute ion linear alignment as a power generation method by fl distillation6 and which releases no carbon emissions could in fact be the only way feasible to cheaply and efficiently convert sea wa to fresh water and pump the rising sea water level inland to compensate for the underground aquifer depletion. Since solute ion lin alignment is based on the principle of capacitive deionization (CDI), anomalies concerning CDI are discussed. For example, opposite electrodes separated by 1 mm and subject to a differential voltage of 1.5 volts, the resulting charge densities on oppos electrodes of over 10 Farads/gram and material densities, e.g., carbon nanofoam, of 0.5 grams/cm2, the resulting force between positively charged ions on one electrode and the negatively charged ions on the other electrode is calculated to be in the range 10E+15 Newtons based on Coulomb's Law. The stability of charge densities in the range of 10 Coulombs/cm3 is also discussed view of the potential energy and resulting forces of such charge densities with consideration of possible differences in dielec properties in solids versus liquids for like-charged conditions. An analysis of the power requirements for the CDI charge absorpt and regeneration cycle is compared to the potential energy available from linear alignment to show that the linear alignment proc is expected to be a net energy gain process in the same category as combustion, which involves electron transfer, nuclear fissi which is the electrostatic repulsion of the protons in the nucleus, and nuclear fusion, which is caused by attraction of the nucl force. References 1Richey, A. S., B. F. Thomas, M.-H. Lo, J. T. Reager, J. S. Famiglietti, K. Voss, S. Swenson, and M. Rodell (201 Quantifying renewable groundwater stress with GRACE, Water Resour. Res., 51, 5217–5238, doi:10.1002/2015WR0173 http://onlinelibrary.wiley.com/doi/10.1002/2015WR017349/full 2Richey, A. S., B. F. Thomas, M.-H. Lo, J. S. Famiglietti, S. Swens and M. Rodell (2015), Uncertainty in global groundwater storage estimates in a Total Groundwater Stress framework, Water Reso Res., 51, 5198–5216, doi:10.1002/2015WR017351. http://onlinelibrary.wiley.com/doi/10.1002/2015WR017351/ 3http://oceanservice.noaa.gov/facts/sealevel.html 4Boettle, M., Rybski, D., and Kropp, J. P.: Quantifying the effect of sea level r and flood defence – a point process perspective on coastal flood damage, Nat. Hazards Earth Syst. Sci., 16, 559-5 doi:10.5194/nhess-16-559-2016, 2016. 5Fresco, A. N., (2010), Solute Ion coulomb force monopole motor and solute ion lin alignment propulsion, Paper No. ES2010-90396, pp. 585-594; 10 pages doi:10.1115/ES2010-90396, ASME 2010 4th Internatio Conference on Energy Sustainability, Volume 1, Phoenix, Arizona, USA, May 17–22, 2010 Conference Sponsors: Advanced Ene Systems Division and Solar Energy Division ISBN: 978-0-7918-4394-9 | eISBN: 978-0-7918-3871-6, © 2010 by AS http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1607290
6Contest.techbriefs.com/2014/entries/sustainable-technologies/4465/

Presentation Author Biography
He graduated from City College of New York (CCNY) in 1970 with a B.E. (Mechanical) (five year program). From 1970 to 1974, started out as an assistant engineer with Con Edison (New York City) in their gas engineering department. In 1974 he received M.S.M.E. from then Polytechnic Institute of New York, now the NYU Tandon School of Engineering. From 1974 to 1979, he had seve different engineering positions at Ebasco Services involved with the design of both fossil and nuclear power plants. From 1979 2000, he was at Brookhaven National Laboratory (Upton, New York) where from 1979 to 1981, he was involved with the design a procurement of a very large helium compressor installation for the superconducting magnets of the then ISABELLE Project (pro accelerator), now the Relativistic Heavy Ion Collider (RHIC). From 1981 to 2000, in what is now the Department of Nuclear Scie and Technology, he was involved in various projects and tasks related to primarily regulatory safety issues for nuclear power plar mostly for the US Nuclear Regulatory Commission (USNRC) but also for some U.S. Department of Energy (DOE) facilities. Since 20 he has been working as a patent agent registered to practice before the US Patent and Trademark Office. He is currently at Carter, Luca, Farrell and Schmidt, LLP, 445 Broad Hollow Road, Suite 420, Melville, New York 11747. He is a Life Member of the Ameri Society of Mechanical Engineers. He was the 1986-1987 and 2012-2014 Chair of the ASME Long Island Group and is a member of Group Leadership Team serving as Honors and Awards and Secretary.

Reviewer Comments
Reviewer 1:

check English text

Reviewer 2:
Well written paper about a novel water purification technique that sounds similar to CDI. Not being an expert in the field, I cannot really comment on the electrochemistry of the work, however the electrostatic calculations make sense. The paper is oddly written that it reads as more of a long winded discussion, however the topic is very interesting and relevant and I believe the contribution I warranted for publication as a conference paper.

Draft Recommendations/Comments
Comments
The paper is of good quality and acceptable for the conference.

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SOLUTE ION LINEAR ALIGNMENT AS THE ENERGY SOURCE TO ADDRESS AQUIFER DEPLETION FRESH WATER SCARCITY AND SEA LEVEL RISE

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ABSTRACT

There are reports in the literature that the lives of 4 billion people are at risk either now or in the foreseeable future, and including even 130 million US citizens, mostly in the western states of California and surroundings and in Texas and Florida as being subject to water scarcity primarily due to depletion of aquifers and ground water and losses due to evaporation. [1, 2, 3] At the same time, according to the National Oceanic and Atmospheric Administration (NOAA), there is strong evidence that global sea level is now rising at an increased rate and will continue to rise during this century.[4] Climate scientists at the Potsdam Institute of Climate Impact Research published a study in the journal *Natural Hazards and Earth System Sciences*[5] that found that the economic costs of sea level rise increase more quickly than sea levels themselves.

Although fresh water is scarce, obviously the oceans are virtually an infinite source of water. Rather than trying to implement difficult fresh water usage restrictions, the best solution to the sea level rise and fresh water scarcity would be to cheaply and efficiently convert sea water to fresh water and to pump the rising sea water level inland to compensate for the underground aquifer depletion. The main problem with desalination has always been, and continues to be, the high energy consumption and operating cost. Similarly, efforts in the past to transport fresh water from northern latitudes have faced the difficulty of high energy costs for pumping water over long distances.

Solute ion linear alignment propulsion was presented in ASME ES2010-90396[6]. Solute ion linear alignment is a process in which potential energy of the electrostatic fields of like charged solute ions is converted to kinetic energy. The current paper presents factors showing that solute ion linear alignment as a power generation method by flash distillation[7], and which normally releases no carbon emissions, could in fact be the only way feasible to cheaply and efficiently convert sea water to fresh water and pump the rising sea water level inland to compensate for the underground aquifer depletion. Since solute ion linear alignment is based on the principle of capacitive deionization (CDI), anomalies concerning CDI are discussed. For example, for opposite electrodes separated by 1 mm and subject to a differential voltage of 1.5 volts, the resulting charge densities on opposite electrodes of over 10 Farads/gram and material densities, e.g., carbon nanofoam, of 0.5 grams/cm^2, the resulting force between the positively charged ions on one electrode and the negatively charged ions on the other electrode is calculated to be in the range of 10^{15} Newtons based on Coulomb's Law. The stability of charge densities in the range of 10 Coulombs/cm^3 is also discussed in view of the potential energy and resulting forces of such charge densities with consideration of possible differences in dielectric properties in solids versus liquids for like-charged conditions. An analysis of the power requirements for the CDI charge absorption and regeneration cycle is compared to the potential energy available from linear alignment to show that the linear alignment process is expected to be a net energy gain process in the same category as combustion, which involves electron transfer, nuclear fission, which is the electrostatic repulsion of the protons in the nucleus, and nuclear fusion, which is caused by attraction of the nuclear force.

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INTRODUCTION

Freshwater scarcity is increasingly perceived as a global systemic risk. Previous global water scarcity assessments, measuring water scarcity annually, have underestimated experienced water scarcity by failing to capture the seasonal fluctuations in water consumption and availability. Blue water scarcity globally has been assessed at a high spatial resolution on a monthly basis. It has been found that two-thirds of the global population (4.0 billion people) live under conditions of severe water scarcity at least 1 month of the year. Nearly half of those people live in India and China. Half a billion people in the world face severe water scarcity all year round. Large water consumption relative to water availability results in decreased river flows, mostly during the dry period, and declining lake water and groundwater levels. Notable examples of rivers that are fully or nearly depleted before they reach the end of their course include the Colorado River in the western United States and the Yellow River in North China. The most prominent example of a disappearing lake as a result of reduced river inflow is the Aral Sea in Central Asia, but there are many other smaller lakes suffering from upstream water consumption, including, for example, Chad Lake in Africa. Groundwater depletion occurs in many countries, including India, Pakistan, the United States, Iran, China, Mexico, and Saudi Arabia.

Aquifer or groundwater depletion requiring deeper drilling to reach water is being experienced. The solutions that have been presented include putting caps to water consumption by river basin, increasing water-use efficiencies, and better sharing of the limited freshwater resources to reduce the threat posed by water scarcity on biodiversity and human welfare.[1, 2, 3]

At the same time, according to the National Oceanic and Atmospheric Administration (NOAA), there is strong evidence that global sea level is now rising at an increased rate and will continue to rise during this century.[4] Climate scientists at the Potsdam Institute of Climate Impact Research published a study in the journal *Natural Hazards and Earth System Sciences*[5] that found that the economic costs of sea level rise increase more quickly than sea levels themselves.

There has been a very interesting study that considers delaying future sea-level rise by storing water in Antarctica.[8] According to the study, sea level will continue to rise for centuries. The option of delaying sea-level rise by pumping ocean water onto Antarctica was investigated. Due to wave propagation ice is discharged much faster back into the ocean than expected from pure advection. A millennium-scale storage of >80% of the additional ice requires a distance of >700km from the coastline. The pumping energy required to elevate ocean water to mitigate a sea-level rise of 3mm/yr exceeds 7% of current global primary energy supply. According to the study, 1 mm sea level rise equals 360 billion tons of water. The pumping requires about 850,000 wind turbines 1.5 MW each to generate electricity or 7% of the world's capacity. It is stated that at the same time, the approach offers a comprehensive protection for entire coastlines particularly including regions that cannot be protected by dikes.

According to the study, solely in terms of throughput, mitigating sea-level rise of 3mmyr−1 would require 90 of the largest pump stations currently under construction in New Orleans, each assumed to pump ~360m3 s−1, which corresponds to ~11×109 m3 yr−1 (Alyeska Pipeline Service Company, 2013). The height of the ice sheet of about 4000m means that it would require a constant power of 1275GW to elevate the potential energy of the associated ocean water. This is equivalent to~7% of the global primary energy supply of the year 2012 (International Energy Agency, 2014). The power required for the actual pumping may even be higher and reach 2300GW under optimistic assumptions. It will have to be generated by renewable resources to avoid the additional climate change and sea-level rise associated with fossil fuels. The Antarctic continent is windy enough to support such pumping using wind energy, with around 16.7TW available in a 200km wide band along the coast of East Antarctica (Archer and Jacobson, 2005). Around 8% of that energy would need to be extracted to compensate for the potential energy increase of the pumped water alone, which is equivalent to 850000 wind-energy plants of 1.5MW, running on full capacity The scope of such a project is unprecedented and would require major technical innovations, if possible at all. Therefore, costs cannot be reliably estimated. Based on simple upscaling of the costs of the Trans-Alaska Pipeline with height, length, and throughput, the costs will be orders of magnitude higher than the costs associated with local adaptation measures (Hinkel et al., 2014). However, it is important to note that in this study on sea-level adaptation, protection is only installed if considered economically favorable. In contrast, storing water on the Antarctic ice sheet would offer general protection for entire coastlines and poor regions that would otherwise be left unprotected. The associated investment could change the mitigation costs by significantly increasing the demand (thereby technical progress) for renewable energies. By generating an additional demand for renewable energies of the order of 10% of the global energy supply, this approach offers a link between the mitigation and adaptation problem of climate change.

Thus, the authors freely admit the scope of the project is unprecedented and would require major technical innovations, if possible at all. The technical innovations required include technical innovations in renewable energies. It can be concluded that an alternative to fossil fuels and current renewable energy sources such as solar and wind that actually has a higher energy density or an energy density comparable to nuclear fission and is significantly less expensive than any of the current energy technologies is desperately required not only to significantly reduce the cost of desalination of sea water but also of desalination of inland aquifers and to pump water inland over long distances from the world's coast lines to replenish the ground water consumption. It is reasonable to expect that, in so doing, a truly sustainable and long-lasting economic boom

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throughout most of the world would be generated, and one which should enable a reasonable standard of living not only for the current world population of 7 billion but also for the future billions of additional persons expected due to population increase.

To that end, solute ion linear alignment propulsion was presented in ASME ES2010-90396[5]. Solute ion linear alignment is a process in which potential energy of the electrostatic fields of like charged solute ions is converted to kinetic energy. This paper intends to demonstrate that solute ion linear alignment as a power generation method by flash distillation[6], and which normally releases no carbon emissions, could in fact be the only way feasible to cheaply and efficiently convert sea water to fresh water and pump the rising sea water level inland to compensate for the underground aquifer depletion. Since solute ion linear alignment is based on the principle of capacitive deionization (CDI), anomalies concerning CDI are discussed. For example, for opposite electrodes separated by 1 mm and subject to a differential voltage of 1.5 volts, the resulting charge densities on opposite electrodes of over 10 Farads/gram and material densities, e.g., carbon nanofoam, of 0.5 grams/cm^2, the resulting force between the positively charged ions on one electrode and the negatively charged ions on the other electrode is calculated to be in the range of 10^{15} Newtons based on Coulomb's Law. The stability of charge densities in the range of 10 Coulombs/cm^3 is also discussed in view of the potential energy and resulting forces of such charge densities with consideration of possible differences in dielectric properties in solids versus liquids for like-charged conditions. An analysis of the power requirements for the CDI charge absorption and regeneration cycle is compared to the potential energy available from linear alignment to show that the linear alignment process is expected to be a net energy gain process in the same category as combustion, which involves electron transfer, nuclear fission, which is the electrostatic repulsion of the protons in the nucleus, and nuclear fusion, which is caused by attraction of the nuclear force.

It is necessary state that this paper mainly is intended to further expand upon the preliminary analysis of solute ion linear alignment propulsion that was provided by the author in ASME ES2010-90936 and now extending into the coincidental power generation, flash distillation and particle acceleration that occurs during the process. By no means does this paper provide an all conclusive analysis and in fact this paper will in all likelihood add to the list of important unresolved issues in physics which are often ignored when judging new technologies which arise. Since CDI is related to the field of supercapacitors, it is hoped this paper will contribute to increased understanding in that field as well.

Some important examples of such unresolved issues are provided by the great Nobel Prize winning physicist Richard Feynman in his Feynman Lectures.[9] In Vol. I, 4-1 "What is energy?" he states "...It is important to realize that in physics today, we have no knowledge of what energy *is*. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way..."

In Vol. II, 8-6 "Energy of a point charge", he states that it is also known that the electric fields emitted by the positively charged protons and the negatively charged electrons represent one form of energy. The energy of a single point charge q is

$$E = q/4\pi\varepsilon_0 r^2 \qquad (2)$$

and the energy density at the distance r from the charge is

$$\varepsilon_0 E^2/2 = q^2/32\pi^2\varepsilon_0 r^4 \qquad (3)$$

Feynman states that there is nothing impossible, in principle, about extracting energy from an electric field and there are fields where it is possible. While the result for $r = \infty$ is zero, a problem occurs when $r = 0$. Feynman states that locating energy in the field contradicts the assumption of the existence of point charges. If it is assumed that elementary charges such as an electron are actually small distributions of charge, there arises a difficulty with this point of view. Similarly, if it is assumed that something is wrong with the theory of electricity at very small distances, or with the idea of local conservation of energy, difficulties arise also with such assumptions. These difficulties still exist to the current day.

A related paper by the author "Dielectric analysis for torque of a solute ion Coulomb force monopole motor"[10] cites an article entitled "Is the Universe Leaking Energy?" by Tamara Davis[11] who discusses the redshifting of light, or the expansion of the wavelength and loss of energy with the expansion of the universe. The idea of drawing an imaginary membrane around a region of the universe and adding up the energy inside is discussed, and Davis states that "The situation would be even more complicated if the accountants were to count dark energy, which is causing the universe to accelerate. The nature and properties of dark energy are still a complete mystery, but it appears that dark energy does not dilute as the universe expands. Thus as the volume of the membrane increases, the amount of energy in that volume increases as well, with the additional energy seemingly coming out of nowhere! One might think that the increase in dark energy could balance out the losses in all other forms of energy, but that is not the case. Even if we take dark energy into account, the total energy within the membrane is not conserved." Although it is concluded that there is no loss of energy of the light, when considering the universe as a whole, there is no unique value to the energy of the universe. The universe does not violate conservation of energy, rather it lies outside that law's jurisdiction.

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In another example, let us assume a mechanical force is used to compress a spring (which as a normal matter is electrically neutral) and let it expand and then compress it again and expand indefinitely in repetitive cycles. Eventually the spring constant will decrease, less force will be needed to perform the compression because the spring will become weaker and eventually the spring will snap due to fatigue.

If analogous actions were performed essentially by mechanically pushing together two like charges and letting them expand and then pushing together and expanding again indefinitely, would the repulsion force between the two like charges decrease?

With this in mind, with respect to CDI and the proposed solute ion linear alignment process, the following should also be considered:

1. Circa 1884, Arrhenius introduced the theory of solvation. It was not well received at the time. Why not? As discussed in the ASME ES2010-90396 paper mentioned below, it is a well known fact that salts such as sodium chloride, NaCl, readily dissolve in water with very little energy input, i.e., about 6.5 kJ/mole . This is attributed to the high dielectric constant for water of 75-81. The structure of the water molecule as a polar molecule enables the water molecules to easily penetrate between the sodium Na+ and chlorine Cl- ions in the NaCl crystal. This penetration of the polar water molecules between the Na+ and Cl- ions shields the Coulomb potential between the Na+ and Cl- by a factor of about 75 so that the NaCl crystals readily dissolve in water. In contrast, the enthalpy of formation of NaCl is about -410.9 kJ/mol.

Therefore, dielectric material provides a first way of "violating" conservation of energy. It is only a violation of our understanding of how conservation of energy should be applied when dealing with electric forces and fields.

2. Capacitive deionization, upon which solute ion linear alignment is based, was first proposed in 1961 by Arnold and his colleagues[12]. Their capacitive deionization (CDI) process was suggested for desalination of brackish water. Referring to FIGS. 1, 7 and 8, it involves utilizing as electrodes a material with very large surface area so that when a voltage under the barrier voltage, i.e., about 1.5 volts to prevent electrolysis, is applied across the electrodes, the positive ions in a solution move towards and accumulate on the negative electrode and the negative ions move towards and accumulate on the positive electrode until saturation occurs.[13]

In the early 1990s, James Farmer et al. at LLNL developed carbon aerogel which has a surface area of 400 m2/g or greater. Due to the huge surface area, the capacitance of the carbon aerogel can vary from 15-30 Farads/g. Since 1 Farad = 1 Coulomb/Volt, if 1.5 volts is applied across the electrodes in the capacitive deionization process, which are generally separated by about 1 mm, then you can accumulate between 22-45 coulombs/g on each electrode surface. So essentially there are 22-45 coulombs of positive charge separated from 22-45 coulombs of negative charge by a distance of about 1 mm apart. **Calculating the attraction force based on Coulomb's Law, $F = k\ q1q2/er^2 = 9E+9\ (45 \times 45)/81(1E-3)(1E-3) = 225\ x10E+15$ Newtons. How can this be done using only 1.5 volts?**

The conventional explanation is that there is never any significant deviation from electrical neutrality during processes such as CDI and electrolysis. Therefore, seemingly without recognizing the apparently enormous magnitude of the resulting forces following the charge accumulation mode of CDI, the conventional explanation is that the presence of the electrodes and the surface charge created by the voltage creates a "balancing" of the electric fields to avoid deviations from electrical neutrality so that the positive ions can slowly migrate to the negative electrode despite the attraction forces of the negative ions in the solution and the negative ions can slowly migrate to the positive electrode despite the attraction forces of the positive ions in the solution .

The alternative is to perform the separation of the ions mechanically by nanorobots in nanorowboats. **It would be necessary for the nanorobots to effectively perform Work approximately equal to F(r) x r or 225 x 10E+12 Joules.**

It is proposed by the author that the proper reference point for the efficiency of capacitive deionization and electrolysis is the amount of MECHANICAL work required to move the ions towards the electrode surfaces. Therefore, electrodes provide a second way of "violating" conservation of energy.

3. In capacitive deionization, the electrodes are maintained at the 1.5 V potential difference during the ion adsorption phase. It can be assumed the repulsion forces between the like-charged solute ions are very weak because the ion fields are engaged in attraction to the oppositely charged electrode surfaces. Otherwise, it would not be possible to adsorb the huge amounts of charge that are possible. For example, since the capacitance of carbon aerogel is in the range of 30 farads/gram and 1 gram of carbon aerogel = 2 cm^3 and 1 farad=1 coulomb/volt, this is about 22 coulombs/ cm^3. Since for singly charged ions such as sodium and chlorine there are 1.6×10^{-19} coulombs/e-, then there are approximately $6 \times 10^{+18}$ ions/coulomb. Then 22 coulombs/ $cm^3 \times 6 \times 10^{+18}$ ions/coulomb = $1.32\ z\ 10^{20}$ ions/ cm^3. Even if the interionic force is in the range of about 10^{-14} N, considering the forces acting in 3 dimensions, the overall interionic forces within the cube are again very large. Assuming each 1 cm side of the cube contains 10^6 ions, the force on each corner of the cube may be calculated as 10^{-14} N x 10^6 or 10^{-8} x the "cross-force coefficients" from the other two dimensions, which can be approximated as the number of ions in each side of the cube, i.e., 10^6. Therefore, the force is approximately $10^{-8} \times 10^6 \times 10^6$ or 10^4 N. (There are 4.45 N/lbf).

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An alternative explanation, or perhaps an additional explanation, may perhaps be derived from the paper "Dielectric analysis for torque of a solute ion Coulomb force monopole motor". It is shown that for like charged ions on opposite sides of a sheet of dielectric material, instead of inducing a consistent distribution of like charged ions within the dielectric material along the surface of the sheet, as is the case for the conventional scenario of a dielectric material being placed between oppositely charged electrode plates, rather a distribution of alternately charged ions, i.e., positive and negative, positive and negative, positive and negative, etc. is induced along the surface of each sheet. This may in fact result in neutralizing any electric fields from the free sodium and chlorine ions that would otherwise pass through the dielectric material. Therefore, the dielectric constant of the material may in fact significantly increase as compared to the conventional scenario. This effect could perhaps be induced in the CDI electrodes significantly increasing the dielectric constant of the electrodes and thereby enabling accumulation of amounts of charge significantly greater than would otherwise be possible.

As will be understood later, these effects could be of great benefit for application to the linear alignment process by significantly reducing the longitudinal forces within the electrode material during the charge acceleration process. Once the Na+ and Cl- ions are repelled from the solid electrode material, linear alignment of the Na+ and Cl- ions by transverse longitudinal electric fields of the main electrodes and the partition electrodes results in repulsion forces between like-charged solute ions that predominate because of isolation of excess charge in a liquid such as water where the ions have more freedom to rearrange themselves. In fact, due to the forced rearrangement in the liquid H_2O, the repulsion forces may be greater between the H+ and H+ ions rather than between the Na+ and Na+ ions and greater between the O—and O—ions rather than between the Cl- and Cl- ions. See FIGS. 9A and 9B. Therefore, the dielectric constant of the water may be effectively reduced by the presence of the like charged ions.

The charge adsorption phase is carried out until the electrode surfaces become saturated with ions. At this point, in conventional CDI, there are two options. The first is just to remove the voltage and let the ions move away from the respective electrode surfaces until equilibrium of the solution is achieved. This option can include energy recovery of about 20% of the capacitive deionization electrical work that was applied to accumulate the charges on the surface, since there can be a current generated in a wire placed across the electrodes. However, this is a slow process, taking about 1 hour usually. The second option is to apply a reverse voltage of 1.5 volts across the electrodes so that the electrode surfaces can then repel the ions back into the solution by the force of the electric fields on the surface. The work required to perform this repulsion is approximately equal to the work required to perform the accumulation of the charges on the electrode surfaces.

For the proposed solute ion linear alignment, during this charge reversal process, instead of the electric field being orthogonal to the first and second electrodes, additional partition electrodes are inserted around the first and second electrodes. There are additional surfaces involved. In fact in the example illustrated in FIGS. 2-5, there are a total of 12 electrode surfaces, three coplanar pairs associated with the positive terminal and three coplanar pairs associated with the negative terminal. The partition electrodes cause the positive ions to become a local excess of like charged positive ions and the negative ions to become a local excess of like charged negative ions.

Instead of orthogonal electric fields applied for the discharging of the electrode surfaces, transverse longitudinal electric fields are applied. The electrode surfaces in the immediate vicinity of the particular ions become repulsive to those ions so that the ions are forced away from the electrode surface which performed the accumulation but cannot move towards the partition electrodes. It is proposed herein that they are forced into approximately a linear alignment and the only way for them to move is to take the path of least resistance which is the open end of the electrode assembly. This is where the hypothetical planes of like charged ions are formed to convert potential energy to kinetic energy.

ASME ES2010-90396 PAPER – "CROSS-FORCE COEFFICIENT" NOT CONSIDERED

The potential energy of the single layer of 10^{16} ions may be approximated as follows.

Assume that the ions are distributed as $(10^9 \times 10^7)$ = 10^9 Long (z-direction) x 10^7 Wide (x-direction), i.e., (1 meter long x 1 cm wide)

$$Fz = nz\ F(r) = nz\ [kq1q2/\varepsilon r^2] \qquad (9)$$

$$Wp = nx \iint nz\ [kq1q2/\varepsilon r^2]dnz\ dr = nx\ [nz]^2/2\ *\ [kq1q2/\varepsilon r] \qquad (10)$$

for $nz = 1$ to 10^9, the number of ions in the z-direction, and $r = 10^{-9}$ meter to ∞, the distance between each pair of solute ions, and $nx = 10^7$, the number of ions in the x-direction.

The terms q1 and q2 are the charge of each ion, in coulombs,

k is a constant 9×10^9 N-m^2/coul^2.

The potential energy was calculated to be

$$Wp = \tfrac{1}{2}\ 10^7\ [10^9]^2\ *\ [\{(9x10^9)(1.6x10^{-19})\ (1.6x10^{-19})\}/$$

$$[(81)(10^{-9})]] = 1.4x10^4\ \text{N-m} = 1.4x10^4\ \text{Joules} = 14\text{KJ} \qquad (11)$$

"CROSS-FORCE COEFFICIENT" CONSIDERED

As compared to ASME ES2010-90396 paper, instead of the electrode length L = 1 meter, assume L = 10 cm = 0.1 meter

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Assume Fz = 10E-3 Newtons with cross force considered, i.e., C = Nx (number of rows of ions in X-direction = W/r

where W=width of electrode = 1 cm = 0.01 m and r is the distance between each ion, which is an unknown.

Since Nx = W/r and Nz = L/r, set Fz = Nx Nz (k/ε)(Q1)(Q2)/r^2=

(W/r) (L/r) (k/ε)(Q1)(Q2)/r^2 = WLkQ1Q2/εr^4 =

Stokes Law Eqn. = $6\pi\eta Rv$= 10E-03 Newtons

(for v = 10 E+08 m/sec, R= 5 x 10E-10 m, $\eta = 10^{-3}$ N-sec/m^2)

Solving for r^4 = WLKQ1Q2/(ε x 10E-03 Newtons)=

(10E-2 m)(10E-1 m)(9x10E+9)(1.6 x 10E-19) (1.6 x 10E-19)/[81 (10E-03)] = 2.84 x 10E-30

r = 4.1 X 10 E-08 m

For the distance between each ion with cross-force coefficient considered to have a total force FZ on one row of ions.

C = W/r = 10 E-2m/ 4.1 x 10 E-08 m = 2.4 X 10 E +05

(Cross-Force Coefficient in Z direction)

POTENTIAL ENERGY CONSIDERATION

From equation (10) of ASME ES2010-90396 (without considering the cross-force coefficient):

Wp = nx $\iint$nz [kq1q2/εr^2]dnz dr = nx [nz]^2/2 * [kq1q2/εr]

Wp = (W/r) (L/r)^2/2 * [kq1q2/εr] =

[(10E-2 m)/4.1 x 10 E-08 m] [(10E-1 m)/ 4.1 x 10 E-08 m] ^{2}/

2 * [(9x10E+9)(1.6 x 10E-19) (1.6 x 10E-19)/

(81 * 4.1 x 10 E-08 m)] = 5.5 x 10E-05 Joules

Assume this value is then multiplied by the Cross-Force Coefficient

W/r = [(10E-2 M)/4.1 x 10 E-08 M] = 2.4 X 10 E +05

Wp = 2.4 x 10 E +05 x 5.5 x 10E-05 joules = 13.2 joules for a total ion accumulation of

W/r x L/r = 2.4 x 10 E +05 x 2.4 x 10 E +06 = 5.76 x 10 E +11 ions.

M = 5.76 x 10 E +11 ions x [35.5 g CL/6 x 10E + 23 ion] = 3.4 x 10E -11 g

Specific Energy = Wp /m = 13.2 Joules/3.4 x 10E -11 g =

3.9 x 10E +11 Joules/g CL

Specific Energy for Na+ ions would be slightly higher since 23 G Na/6 X 10E + 23 ion.

We can conclude that the Potential Energy Wp is extremely sensitive to interionic distance r since with the Cross-Force Coefficient considered,

$$Wp \sim 1/r^5$$

If we decrease r1 from 4.1 E-08 m by a factor of 10 to r2 = 4.1 E-09 m , then Wp2 =

Wp1 [r1/r2]^5 = 13.2 Joules x[10]^5 = 1.32 Megajoules!

This would represent the amount of energy from 5.76 x 10E +13 ions rather than 5.76 x 10E +11 ions. This clearly shows the sensitivity to r.

However, there are unknowns or unaccounted for effects in the calculations which include:

1) The validity of Stokes Law for the initial conditions, particularly assuming the force F = 10 E-3 N, as per the ASME ES2010-90396 paper and V = 10E+8 m/s which is nearly the speed of light.

2) In the decrease of r1 from 4.1 e-08 m by a factor of 10 to r2 = 4.1 E-09 m, The force F and velocity v will increase significantly such that the relativistic effects would clearly need to be considered.

3) Structural considerations for the electrode assemblies to maintain integrity under the potential forces – although the forces on the structure would decrease very rapidly. In addition, the forces within the electrode material itself may be actually negligible as explained above.

Since there are two electrodes (one for Na+ ions and one for Cl- ions) and assuming a single layer at each electrode, the total energy produced could be as much as 2.64 MJ for a single operational cycle.

Assuming 6 X 10 E+13 ions x 1 coulomb/6 X 10 E+18 ions = 10E-5 coulombs = 10 microcoulombs

Specific heat of water c = 1.0 cal/gram °C or 4.2 J/gram °C

From Wikipedia "Enthalpy of Vaporization":

c_p = 75.3 J K^{-1} mol^{-1} x (80 K) x (1 mol/ 18 grams) x (1000 grams/Liter) = 334666 J = 0.34 MJ

Enthalpy of vaporization, 40.65 kJ/mol X (1 mol/ 18 grams) x (1000 grams/Liter) = 2258 KJ

2260 KJ = 2.26 MJ required to boil 1 l (1 kg) of water

0.34 MJ to raise 1 liter water to the boiling point from 20 °C to 100 °C.

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Total Q = 2.60 MJ/liter at 1 atm

Therefore, if the calculation of 2.64 MJ/cycle for the electrode assembly is anywhere near accurate, then about 1 liter or 1 kg of water could be boiled per electrode cycle of operation.

Since CDI operates at about 1.2 volts, capacitor work
W = ½ VQ = 0.5 (1.2 volts) (10 x 10 E-6 coulombs) =
6 x 10 E-6 joules.

There is additional work for pressure drop in the solution and charge acceleration based on electrode repulsion and linear alignment. Even if this is 100 times the charge accumulation and conventional discharge power of 6 microjoules, the total work appears to be less than 10 millijoule to produce approximately 13.2 J to about 1.32 MJ.

The power from the linear alignment is comparable to nuclear fission where a 1 ev neutron impacts a U-235 nucleus to yield 200 million eV or 200 MeV.

Thus the linear alignment appears to totally reverse the problem of desalination of excessive energy consumption by instead producing energy during the linear alignment process. Additionally, it appears to provide a clean, powerful and inexpensive method of power generation.

EXISTING CDI PLANTS – ENERGY CONSUMPTION FROM WIKIPEDIA Large-scale CDI facilities
In 2007, a 10,000 tons per day full-scale CDI plant was built in China for improving the reclaimed water quality by ESTPURE.[14]

This project enables the reduction of total dissolved solids from 1,000 mg/L to 250 mg/L and turbidity from 10 NTU to 1 NTU, a unit indicating the cloudiness of a fluid. The water recovery can reach 75%.

Electrical energy consumption level is 1 kWh/m^3, and the cost for water treatment is 0.22 US dollars/m^3.

ENERGY CONSUMPTION COMPARISON
Conventional CDI – I KWH/M^3= 3600 KJ/1000 liters = 3.6 KJ/liter energy consumption for brackish water of 1000 ppm reducing to 250 ppm.

By comparison, proposed linear alignment process appears to produce about 2.6 MJ/10 microcoulombs of adsorbed charge.

Therefore, for 1 liter/ cycle x 4 cycles per minute x 60 minutes/hour, the capacity is 240 liters/hour x 24 hours/day = 5760 liters/day or 5.76 m^3/day or 5.76 metric tons/day so approximately 1740 electrode assemblies (42 x 42) of about 20 cm x 5 cm x 5 cm each would produce 10,000 metric tons/day by flash distillation for comparison to the CDI plant in China. The area required is at least about 43500 cm^2 or less than 5 m^2.

At the same time, power would be produced rather than consumed:

Assume 2.6 MJ/cycle x 1 cycle/ 15 sec or average of 0.17 MJoules/sec or 0.17 MW per electrode assembly.

For 1740 electrode assemblies, this results in about 296 MW of power generation.

In contrast, the most energy efficient conventional method of seawater desalination is reverse osmosis, which requires about 3 KWH/m^3 energy consumption, and does not produce power generation.

POTENTIAL ENERGY CONSIDERATION FOR LINEAR ALIGNMENT PROCESS
Additionally, since the potential energy equation for Wp is proportional to $1/r^5$ for the energy potential in the z direction (longitudinally along the length), then since r1 = 4.1 E-09 meters initially,

90% of the energy is released when the ions move to a distance of r' =1.6 x 4.1 x 10 E-09 meters = 6.5 x 10 E-09 meters

This results from $[1/r1]^5 - [1/r']^5 = 0.9\,[1/r1]^5$ or $0.1\,[1/r1]^5 = [1/r']^5$ or $r'^5 = 10\,r1^5 = r' = 1.6\,r1$

Thus the release of energy should be extremely rapid.

CONCLUSION
It has been shown that there is a very serious crisis of water supply occurring and developing that will eventually affect 4 billion people on the planet, including up to 130 million US citizens. It is a well known fact that fossil fuels are the least expensive energy source in most cases, ignoring environmental effects, but are too expensive to permit more than limited applications of desalination such as municipal drinking water. It is crucial that a truly inexpensive and virtually inexhaustible energy source be found for large scale desalination for agricultural purposes and for pumping water inland over long distances to compensate for depletion of ground water. Solute ion linear alignment should be considered a likely candidate energy source to meet these objectives in a world whose population is expected to increase to over 9 billion by 2050. A truly sustainable global economic boom would occur if any such energy source is realized and the chances of serious global conflicts may be reduced.

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ANNEX A

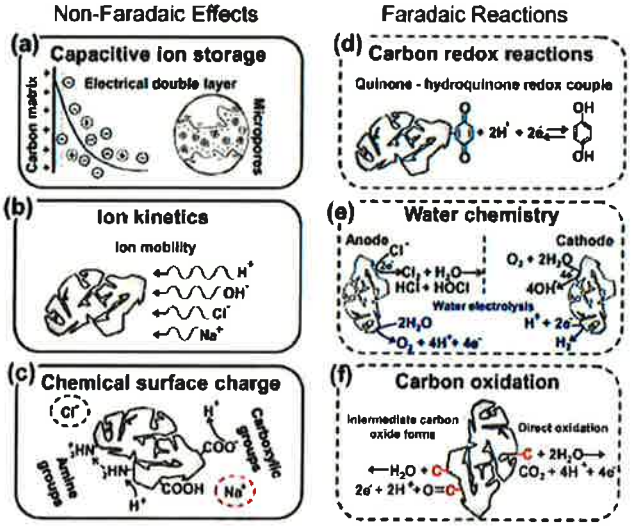


FIG. 1- Overview of important electrochemical reactions and processes in CDI electrodes. Effects (a–c) can be classified as non-Faradaic, and (d–f) as Faradaic processes.

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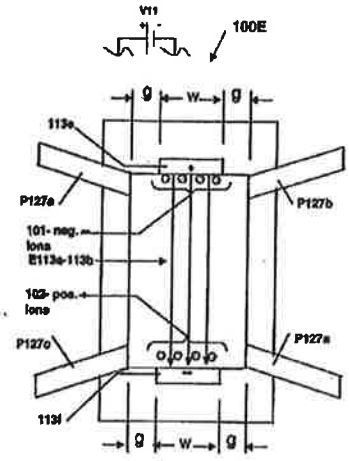


FIG. 2 – Charge accumulation mode – Work W1

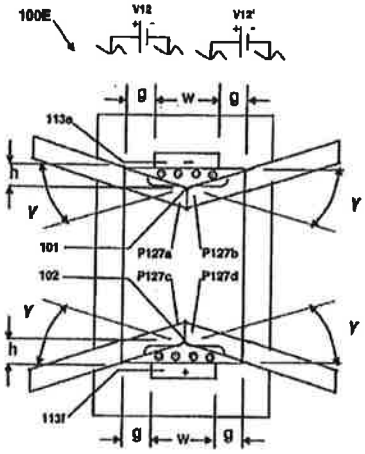


FIG. 3 – Charge acceleration mode – Work W2

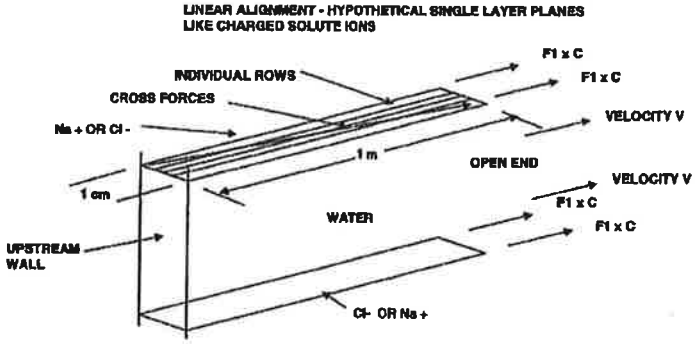


FIG. 4 – Hypothetical planes of solute ions in linear alignment

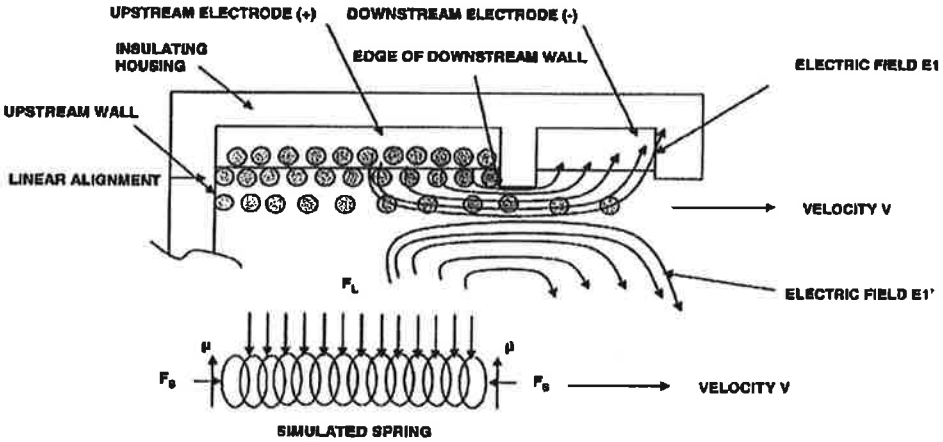


FIG. 5 – Linear alignment of solute ions for charge acceleration

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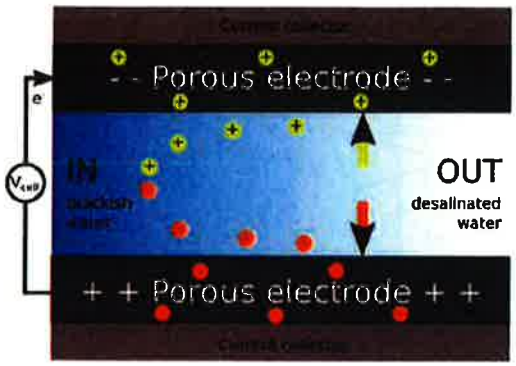


FIG. 6

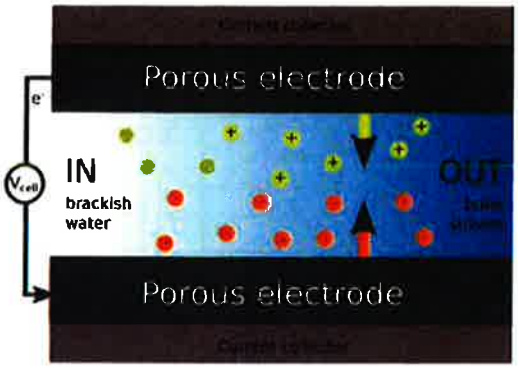
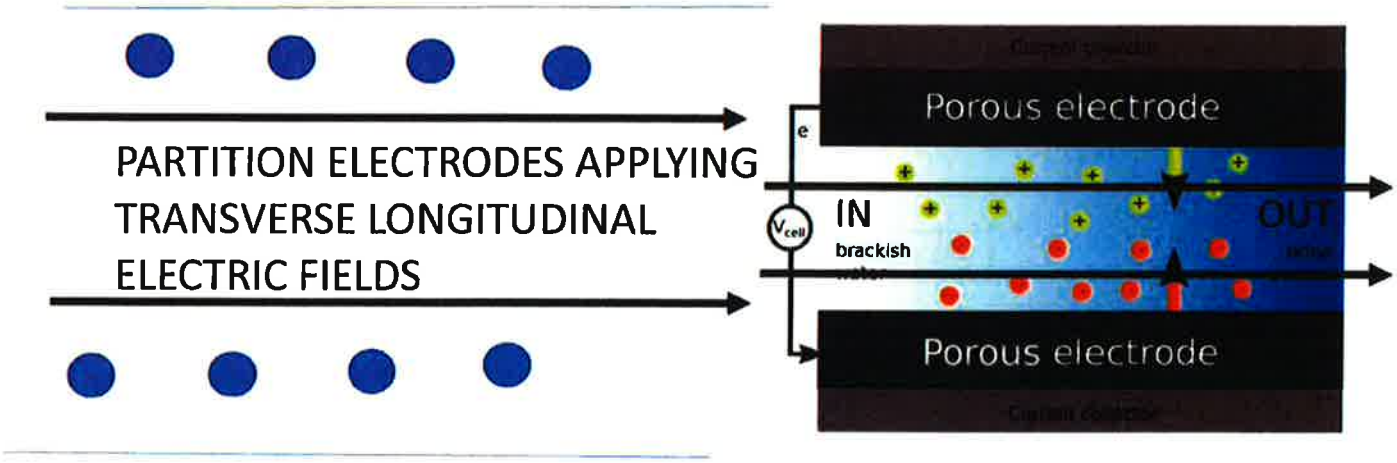


FIG. 7

POSITIVE ELECTRODE SURFACE DURING REPULSION PHASE – REPELLING POSITIVE IONS VIA TRANSVERSE LONGITUDINAL ELECTRIC FIELD

+ + ++ + + ++++



NEGATIVE ELECTRODE SURFACE-DURING REPULSION PHASE – REPELLING NEGATIVE IONS VIA TRANSVERSE LONGITUDINAL ELECTRIC FIELD

FIG. 8

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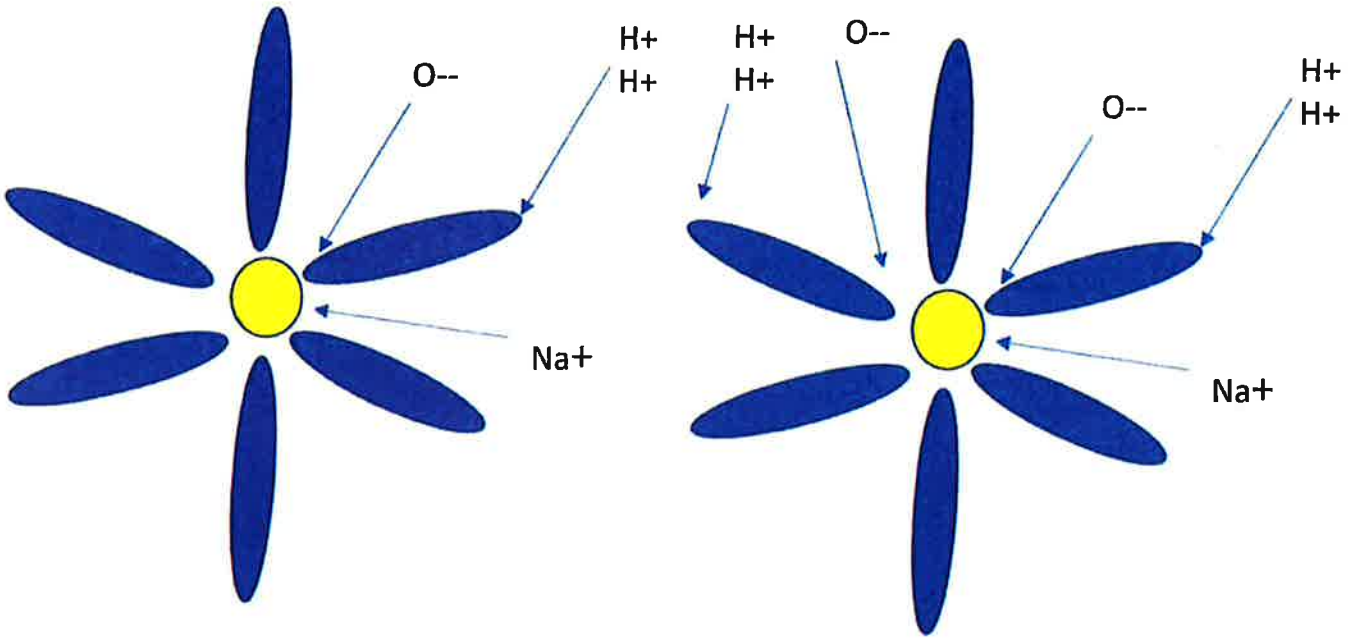


FIG. 9A--SODIUM VERSUS HYDROGEN REPULSION

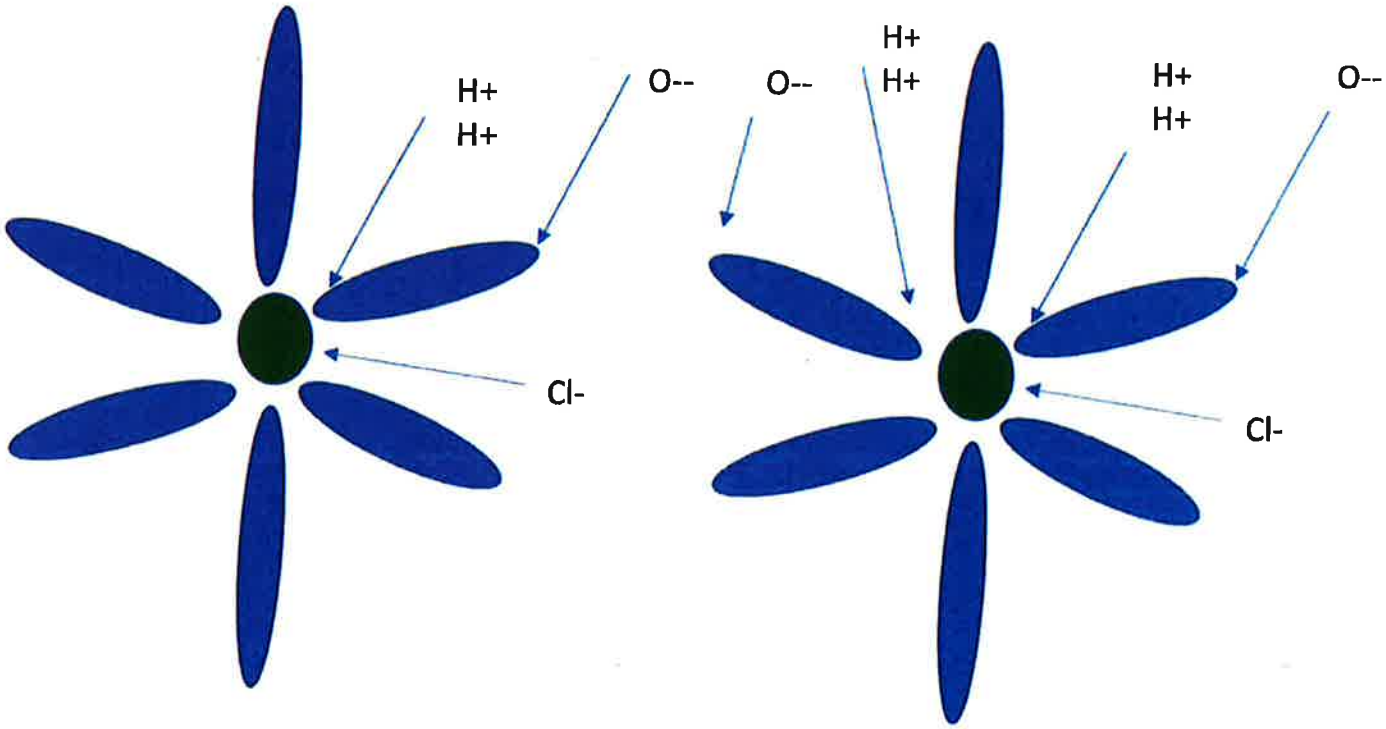


FIG. 9B --CHLORINE VERSUS OXYGEN REPULSION

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