Applying Magneto-Hydrodynamic Physics to Water Purification in Potable and Industrial Applications

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IBM *Innovation to Be Greener* Competition
The National Society of High School Scholars
April 30th, 2008

Introduction

One of the hottest topics receiving attention in the media, scientific, political, and economic sectors of the world today is water purification. Today, both traditional water softening methods and plastic, disposable water bottles, that Americans traditionally take for granted, disturbs both local land and water ecosystems alike. Indeed, scientists agree that our current methods of water purification, no matter how ingeniously designed, have unavoidable environmental consequences. However, if newer methods are not developed to reduce the effects of such methods, it is certain that both local communities and global ecosystems will suffer without further intervention in the years to come.

The benefits of water purification are manifest, both in residential and industrial markets. Water purification can provide additional benefits, such as removing impurities that can gather over time in either our bodies or externally in pipes and other conduits. It is easy to decipher that water impurities can deteriorate the condition of human body. However, impurities that can gather in pipes and other conduits often cause damage to infrastructure that requires costly repairs. For example, the recent trend in the computer industry has been to abandon the air cooling methods in favor of water cooling. Purified water is in high demand by computer data centers for use in server cooling. Currently, the cost of repairing damage caused by water impurities is a heavy burden on the industry.

The semiconductor fabrication industry can benefit greatly from systems that enable water to be reused. An estimated 2000 gallons of highly purified water is required to process each 8 inch semiconductor wafer—more is required to process 12 inch wafers. Proposed systems for treating water used in semiconductor fabrication are expensive in order to reach required purity. Such systems require several different chemical and physical technologies to work perfectly in order to achieve the required purity. On the other hand, purification systems must be compatible with dozens of chemicals used at various stages in the fabrication process.

Abstract

Using research on both current and developing water purification methods, a solution is presented to the water purification crisis that is both environmentally and economically friendly. Operating on the principles of magneto-hydrodynamic physics, the purification system removes contaminants, including hardness, various volatile organic compounds, dissolved chemicals and fertilizers, and dissolved gases such as chlorine, from the water through a series of electromagnets without the need for traditional filtration. The purifier will provide water quality comparable to bottle water, enabling plastic waste and transportation costs to be eliminated. Since it creates no environmentally-damaging waste, the system outperforms current water treatment facilities and is more eco-friendly.

The purifier could be easily deployed in residential homes, and even whole communities to provide marked benefits on both the economy and the environment. In my local school and community, purchasing disposable water bottles is often the alternative to drinking tap water, often because of high levels of hardness and chlorine that are unpleasant to taste. Such a purification system could rapidly replace disposable water bottles while providing the same quality and taste that local community members expect from purified water.

Cost-effectiveness was addressed as a key concern of the design implementation. In terms of electricity, the system will draw up to 125 watts when the purifier is operating

at 1000 GPM at peak efficiency. Comparably, some of today's most advanced continuous deionization systems aimed at reducing electrical costs to water purification consumes about 2000 watts per 1000 gallons of product – a 1600% increase in energy consumption – and an equal amount of salty waste water.

The Problem

Pure, clean drinking water is a critical necessity of every community. Today, however, it is becoming more difficult to provide this to growing multitudes in our communities. Water purification, in some areas, is the only available solution. However, we must also make sure that whichever method that we use to purify our drinking water be as environmentally friendly as possible, so that we continue to preserve our children's future homeland. Therefore, today's leading scientists have a number of goals when innovating on current water purification methods:

- Water purification and/or desalination for drinking at low cost and energy
- High-efficiency water purification for the technology industry at low cost
- Water purification and stabilization of hydroculture systems
- Water stabilization of aquaculture (i.e. aquariums, fish farms)

Today's water purification systems have various pros and cons in their design and environmental impact. Below is a list of various water purification methods, including their benefits and their shortcomings.

1. **Granular Activated Carbon filtering**: GAC, a form of activated carbon with a high surface area, absorbs many compounds including those that are toxic. Water passing through activated carbon is commonly used in municipal regions with organic contamination, taste or odors. However, the impact of buying new filters and disposal on the environment often outweigh the benefits of using the system.
2. **Distillation**: involves boiling the water to produce water vapor. The vapor contacts a cool surface where it condenses as a liquid. Because the solutes are not normally vaporized, they remain in the boiling solution. Even distillation does not completely purify water, because of contaminants with similar boiling points. In fact, the distillation apparatus is ideal for the growth of Legionnaires' disease.
3. **Reverse osmosis:** Mechanical pressure is applied to an impure solution to force pure water through a semi-permeable membrane. Unless membranes are well-maintained, algae and other life forms can colonize the membranes.
4. **Ion exchange:** Most common ion exchange systems use a zeolite resin bed to replace unwanted Ca^{2+} and Mg^{2+} ions with benign Na^{+} or K^{+} ions. Unfortunately, this system produces gallons of salty waste water during the cleaning process.
5. **Electrodeionization**: Water is passed between a positive electrode and a negative electrode. Ion selective membranes allow the positive ions to separate from the water toward the negative electrode and the negative ions toward the positive electrode. Current deionization systems, however, cannot treat hard water sources, as the device can only handle minute amounts of dissolved calcium carbonate ($\leq$0.5 ppm). Also, such systems are expensive to operate and highly energy dependent.

Those Most Affected in the Local Community

In Kinnelon, NJ, water purification is a growing concern for everyone. Over the past decades, our local ground water has been put in jeopardy numerous times by droughts during the summer months, flooding during the fall and spring, waste chemicals from local refineries, gas stations, farms, and contamination from buried minerals in underground wells. In 2004, the New Jersey state legislature, with the approval of community members, passed the Highlands Act to prevent land development in selected areas where the community water source is in jeopardy of runoff contamination.

Each and every year, more land area is put under the Highlands Act as locally collected data shows that the conditions are not improving. Recent data shows that not only the hardness and sodium content of the water far exceeds consumer standards (305 ppm for hardness, 91 ppm sodium, above maximum levels) but also contains almost every other possible water contaminant ranging from dissolved radioactive compounds, heavy metals, nitrides, cyanide, arsenic, volatile organic compounds such as 1,1,1-tricloroethylene, and high levels of chlorine. Unfortunately, the pace at which New Jersey is being transformed from a suburban to urban area limits the effects of most water protection methods. Even restrictions on development posed by the Highlands Act are under continuous threat by land developers and community members.

Due to these concerns, there is much distrust in the water supply, and therefore an increase in the purchase of bottled drinking water. Now, alongside the threat to our water is the increasing threat of disposable water bottles to our local environment. In fact, so many bottles are either disposed of in community landfills or by roadsides that the local wildlife is suffering. Parents of children at my school have come together to raise awareness through a non-profit organization called “Kinnelon Conserves.” Through a month-long research project, the group has found that over 270 plastic bottles – enough to represent 40% of our school community – are disposed of in the trash each day during lunch. Over the course of a year, this would be equivalent to 295,000 plastic bottles. Because of this, the group designed a reusable polycarbonate plastic bottle for sale at the school, but is failing to attract buyers because of the quality of the community drinking water. Clearly, a better solution to the problem must exist.

Definition of Parameters and Scope

The proposed advanced ionic purification system could be used to dramatically improve the quality of our community water source and other community water sources around New Jersey, where it would be most useful in purifying the drinking water for human use. Since the purifier is relatively inexpensive and compact, it could be used both in individual homes and at water treatment facilities. The system would be able to make new water sources by bringing in those that were unfit to drink into the community drinking water supply. Once in place, the system would purify the water to a level comparable to a traditional industrial water purification system, where it is critical that the water must be free of any contaminants.

Description of the Proposed Solution Design

Today’s complex deionization systems use a DC electric field to remove various dissolved ions from the source water. The system consists of two charged plates, both a cation (+) and an anion (-), to create a high electric potential across the source water. As the water passes through the filter, the various dissolved ions in the source water begin to move towards the oppositely charged plate; for example, Ca^{2+}, a positive ion of $CaCO_3$ and also the main element of hard water, moves towards the negatively charged plate, and the CO_3^{2-} ion moves towards the positively charged plate. As this occurs, the dissolved ions pass through a semi-permeable resin that allows ions to travel one-way into an ion dump area (marked concentrate), leaving purer water behind (marked dilute), sometimes leaving only 0.01% of contaminant in the final product. Having passed through the resin, the dissolved ions are discharged, into the environment, as concentrated brine that also wastes the source water. This causes local environmental damage to both agriculture and the local environment and often leads to the eutrophication of various local streams and lakes.

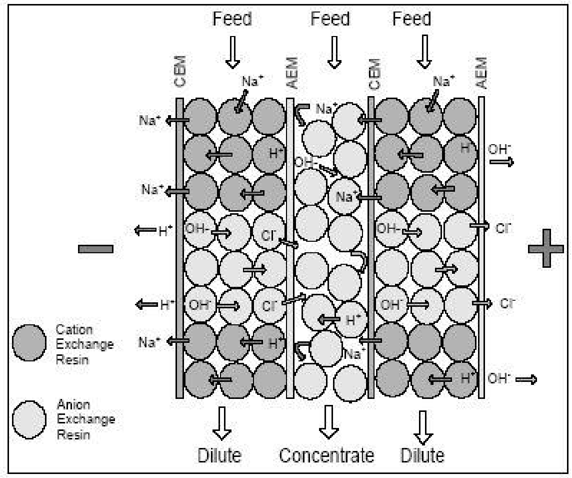


Figure 1: A Traditional Complex Electrodeionizer

In the proposed purification system (Figure 2, page 6), instead of using a DC electric field, an AC electromagnetic field is used to achieve the same effect without the environmental impacts of a traditional deionization system. I conceived my purification system while researching water conditioning systems in use today. One of those systems, which uses electromagnetic waves to increase the solubility of dissolved compounds in the water to reduce hard water deposits. The system typically uses a voltage of 18V AC and draws about 0.37 W of power when fully operational for each gallon of water that flows through the system per minute. Water passes though a first coil that charges the water with a first series of magnetic field waves, and then bombards the water with magnetic field waves traveling in the opposite direction through a second coil at various frequencies to create a mixture of water molecules that are either more negatively or more positively charged in solution. This, in turn, makes the ions less likely to come out of solution as they now have both positive and negative water molecules “partners” to bind with.

To achieve the inverse effect, that is, to lower the solubility of dissolved compounds in solution, the coils may be placed in parallel. Because the magnetic field created by each coil is working against the other, the water begins to lose its dipole-dipole charges with the ions in solution. As a result, the solubility of dissolved compounds in solution declines, and the ions begin to come out of solution. Both terminals act as collectors of both negatively and positively charged dissolved ions. As water passes through the system, each terminal will begin to collect precipitate as the positively charged ions in solution bind to the negatively charged ions, and lower solubility is achieved. Along with solid precipitates, the system also removes dissolved diatomic gases, such as fluorine and chlorine. Furthermore, by varying the frequencies of the magnetic waves or bombarding the water with multiple frequencies of magnetic field waves, different dissolved compounds may be removed at once while keeping certain dissolved compounds in solution (i.e. where some amount of dissolved fluorine is desirable). This can all be done by controlling how much charge is left on the hydrogen and oxygen dipole.

Costs of Production and Implementation

Cost of operation is always a great concern when designing and developing systems for long-term use. Unlike other water purification systems, this one does not use an ion exchange resin that can get worn out, does not consume costly chemicals while in use, and uses significantly less energy than a traditional deionization system.

Typical deionization systems are less energy efficient because of the large DC voltages they operate at, sometimes as high as 600 volts (V), and the amount of current they draw and as much as 3 amperes (A) when operating at peak efficiency. The large voltages are required by the deionization industry because they must impart an electromotive force on weakly charged ions. Therefore, without considering the efficiency of the system, a traditional deionization system uses about 2000 watt-hours (2kWh) for every 1000 gallons of water that it treats.

However, my purification system, rather than moving ionized particles using electricity, simply deals with temporarily removing the dipole-dipole forces from the water molecules that keep contaminants dissolved in solution. Therefore, my system will consume far less energy to achieve the same effect. The water conditioning system that I based my design from, for instance, draws 10 watts when in operation at a voltage of 18V AC. Based on these numbers, my purification system may draw up to 125 watt-hours for every 1000 gallons of product created and lose less energy to the environment, as the AC current is typically known for better transmission rates. More power is needed to

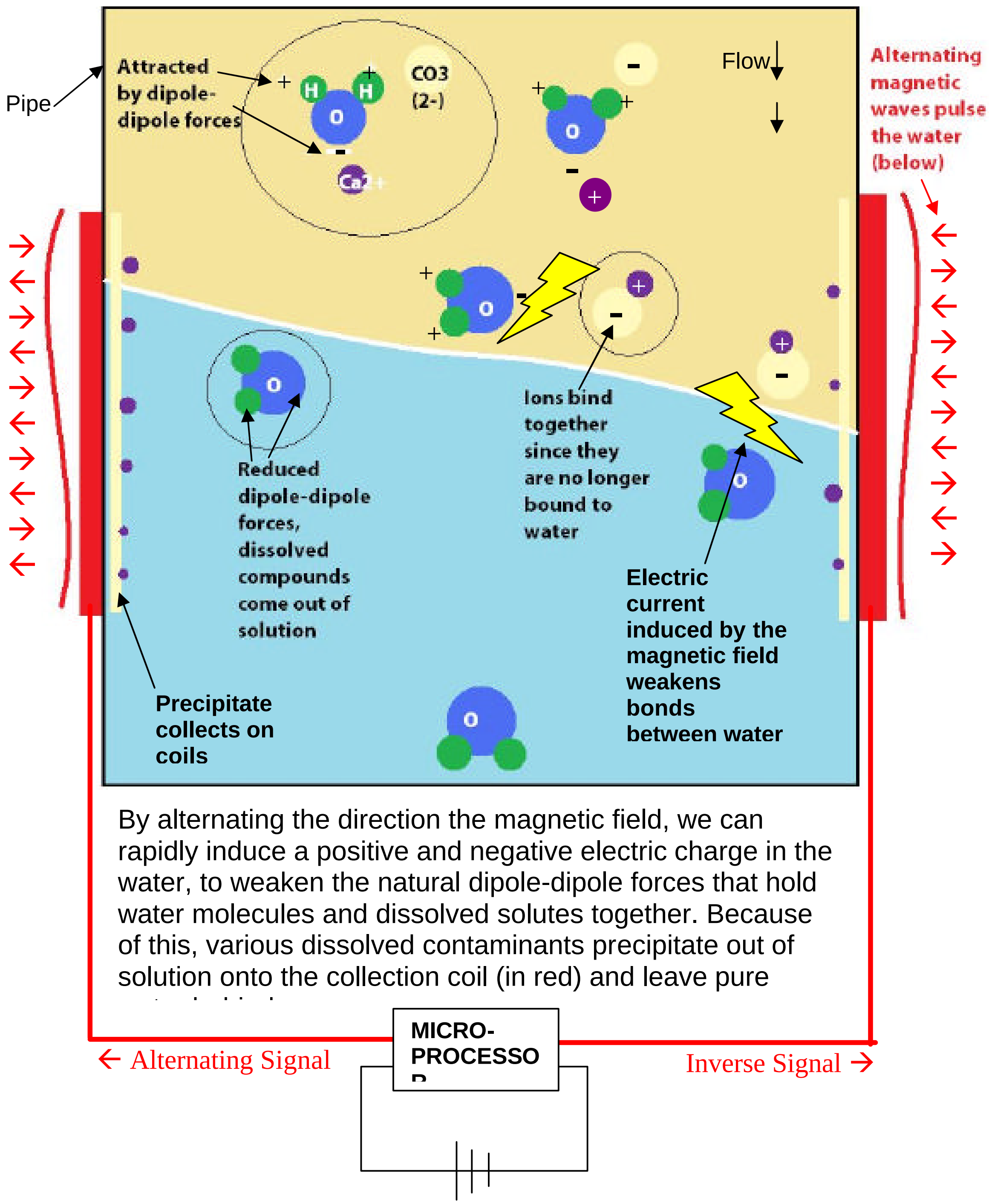
Another cost of operation of the machine would be in cleaning the apparatus. Every so often, the precipitate will need to be removed from the inside of the device. One method of solving this problem is to use interchangeable parts that can be swapped out whenever necessary for cleaning. Also, a protective thin film layer may be placed inside the device for the precipitate to collect on. Since the waste collected is in solid form rather than liquid, it poses little to no harm to the environment when disposed and reduce the cost of removal in comparison to liquid hazardous waste disposal.

Production costs will also be greatly minimized in comparison to similar systems. The microprocessor device, along with sufficient coiled wire, and safety controls should limit the cost of production to $200 for a residential system, $1200 for a commercial system and $2000 for an industrial system.

Proposed Timeline

I would consider breaking the research, development, and marketing into three different stages. First, a series of research tests could be performed within three to six months to determine the various limitations of the device and develop a prototype model. Various intellectual property documents would be filed at this point. From there, it would be safe to move to a 1-month, double-blind study that would assess market validity by performing a comparison of both at-home and industry user satisfaction with the performance of the device. From there, the development process could proceed to manufacturing, which given the simplicity of the design can proceed with great pace. The product may be to market to residential and commercial consumers within a year’s time.

FIGURE 2: Proposed Design



By alternating the direction the magnetic field, we can rapidly induce a positive and negative electric charge in the water, to weaken the natural dipole-dipole forces that hold water molecules and dissolved solutes together. Because of this, various dissolved contaminants precipitate out of solution onto the collection coil (in red) and leave pure

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