BIOROCK AT THE SAHARA FOREST PROJECT, QATAR

INITIAL REPORT

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Three pilot Biorock® experimental projects were started at the Sahara Forest Project site at Qafco, Messaieed Industrial City, Qatar during the January 12-19 visit by Tom Goreau. These include production of building materials from saline brines, removal of limestone scale from industrial cooling systems, and stimulation of halophyte growth for greening the deserts. The basic design of the initial set up of each pilot project is described below along with suggestions for their maintenance.

1. BUILDING STRUCTURAL MATERIAL

Biorock® materials were originally invented by the innovative architect Wolf Hilbertz for production in the sea of prefabricated construction materials of any size or shape that are stronger than conventional concrete (Hilbertz, 1979). These materials can be used on land, and are ideal for marine applications because they are the only marine construction materials that are growing, get stronger with age, and are self-repairing (Goreau, 2012). Their development as “green” construction materials (Pawlyn, 2011) has been delayed because the focus of Biorock research for the last 25 years has focused on marine ecosystem restoration (Goreau & Trench, 2012). This pilot project represents a long overdue return to Hilbertz’s original motivation for developing these innovative materials.

Three steel structural elements (henceforth, “posts”), each composed of 6 curved steel bars meeting at both ends and braced at various points along their length had been previously designed and constructed by the Sahara Forest Project. These were placed in a lined salt pond whose salinity was measured by Bill Watts as being 5.5%, or about 157% of standard seawater of 3.5% (note that seawater in the Persian Gulf near Doha has salinity around 4% due to high evaporation). The winter temperature was low, around 15 degrees C.

Each of the posts was wired up, with it’s own anode, to a separate controllable power supply. The power supplies for posts 1, 2, and 3 were initially set in a controlled voltage mode at 3.0, 4.0, and 5.0 Volts DC respectively. Rust began to disappear, bubbling began, and white mineral deposits began to form within one day, with the rate highest at 5V, lower and 4V, and minimal at 3V. The amperage was recorded periodically over two days, after which the voltage was increased by one volt to 4.0, 5.0, and 6.0 Volts on the posts respectively, because there was little visible growth on the lowest voltage post, indicating it was not getting enough current. Following this change all posts began to have rust disappear, slowly bubble hydrogen, and turn white with mineral growth. Note that these set voltages are at the power supply, and are lower at the posts due to voltage drop in the cables and junction potentials. Amperages varied by a few hundredths of an amp with a diurnal cycle that showed a drop in amperage over the night and an increase in the daytime, certainly due to the temperature effect on brine conductivity. After 3 days the power supplies were reprogrammed to a constant current mode at 0.4, 0.8, 1.2, and 1.5 Amperes respectively, with voltage varying to meet a constant current output.

Current and voltage outputs with time are shown in the accompanying graphs. It is recommended that the voltage and amperage readings be periodically checked and noted. The posts should be left to slowly accrete minerals, whose growth can be determined every other month or so with calipers, and periodic readings of salinity and temperature are desirable. It will be of great interest to compare growth rate versus the current input.

The maximum growth rate for hard material (circa three times the compressive strength of concrete made from ordinary Portland cement) should not be over about 2 cm per year. It is estimated that it will take about a year or more for the material to close the spaces between the steel bars, depending on the rate of growth. Due to the design of the posts this will leave a hollow interior space. Alternate designs for greater strength might include a center axial bar, so that the post fills in from the inside out, instead of from the outside in, as in the present design, which should be stronger.

Seasonal changes in salinity and especially in temperature should affect the growth rate and quality of the mineral deposits. High salinity and high temperature promote deposition of aragonite limestone, while lower temperatures promote magnesium hydroxide deposition, which is much less strong. It is likely that under winter conditions weaker minerals will be deposited, but with aging these will convert to harder limestone. Harder material will form during summer.

As we have never had a chance to measure growth under such extreme seasonal variations, it will be of great interest at the end of the experiment to section the material and determine seasonal variations in growth rate, mineral types, chemical composition, and structural strength, which will provide important guidance to optimizing the quality of the materials produced. By recording the current output, we can determine the amount of materials produced per kilowatt-hour, and its cost, and compare that to concrete construction materials.

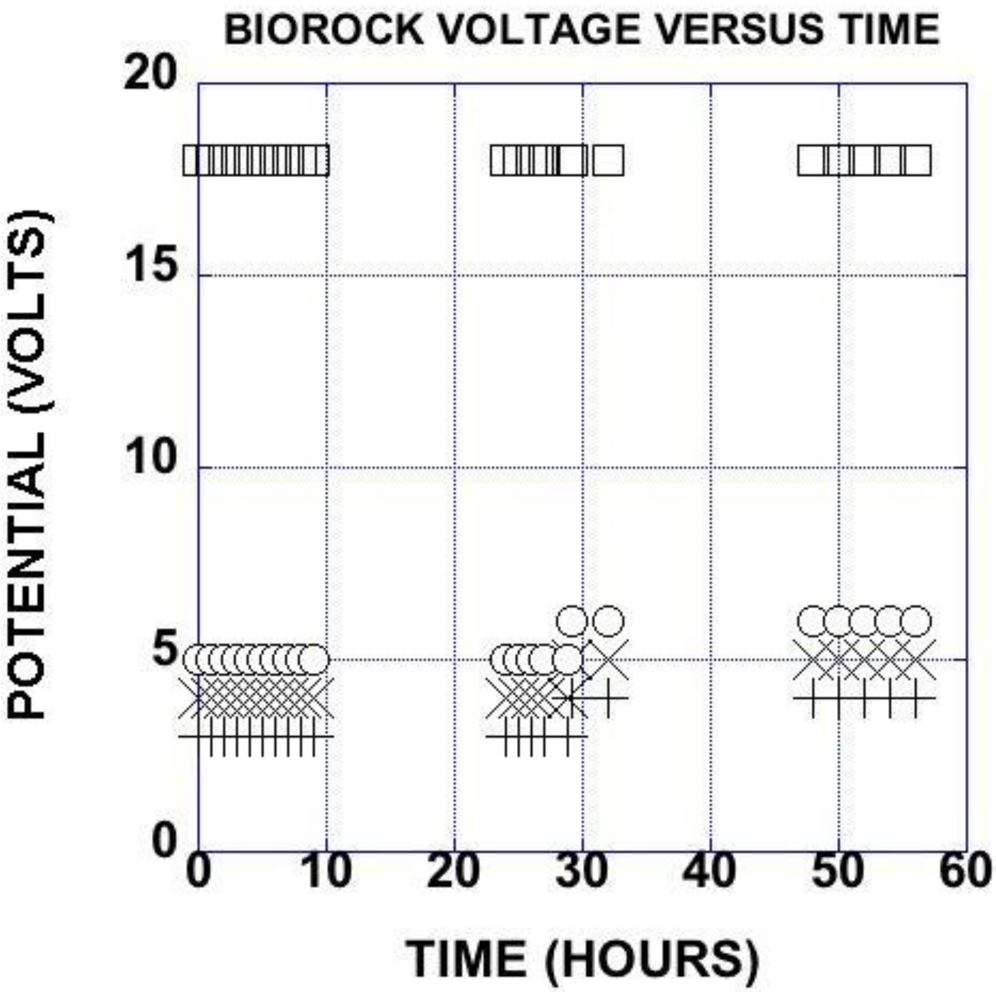

FIGURE 1. VOLTAGE OF BIOROCK PROJECTS VERSUS TIME, JANUARY 16-18, 2013. VOLTAGE WAS SET IN A CONSTANT VOLTAGE MODE, AND REMAINED STABLE. AFTER 29 HOURS THE VOLTAGES ON THE POSTS WERE INCREASED BY 1.0 VOLTS. AFTER 56 HOURS THE CHARGERS WERE CHANGED TO CONSTANT CURRENT MODE. THE + SYMBOL IS POST 1, THE X SYMBOL IS POST 2, THE O SYMBOL IS POST 3, AND THE SQUARE SYMBOL IS THE HALOPHYTE TANK.

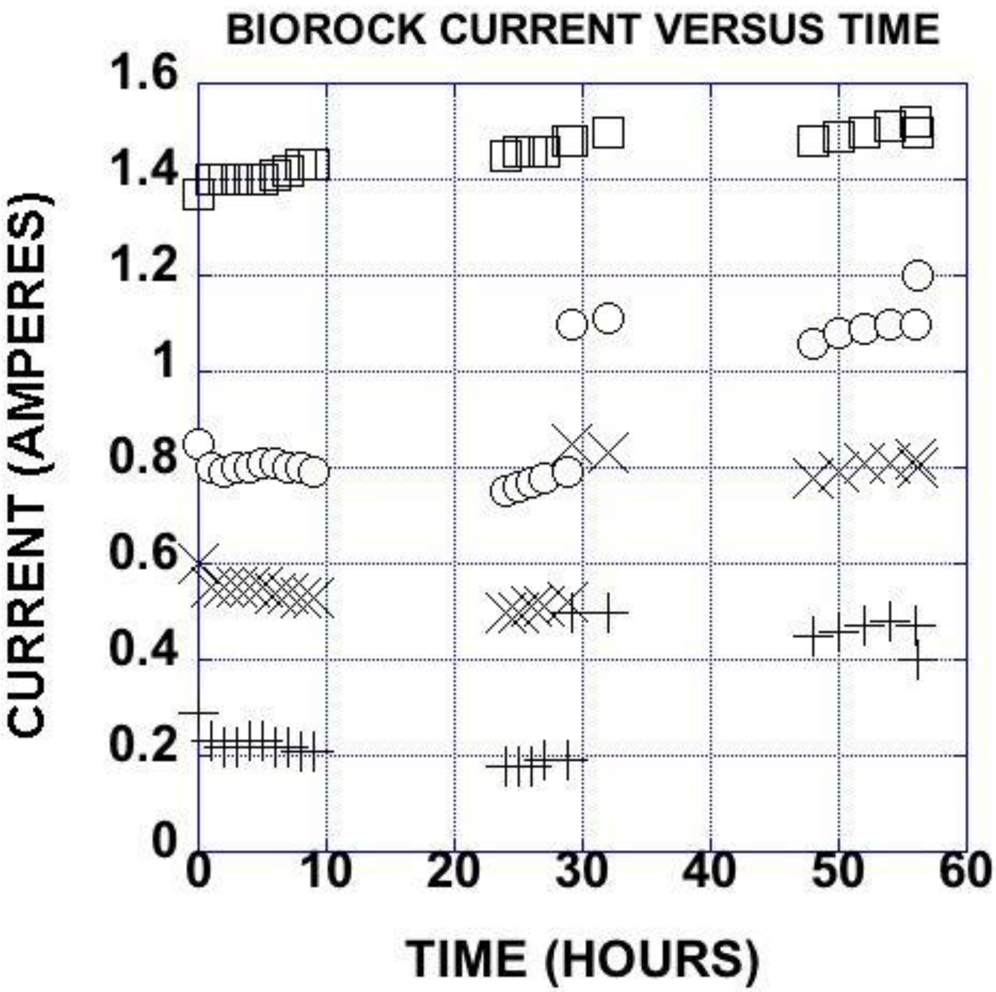

FIGURE 2. CURRENT OF BIOROCK PROJECTS AT CONSTANT VOLTAGE VERSUS TIME, JANUARY 16-18, 2013. CURRENT FLUCTUATED BY A FEW HUNDREDTHS OF AN AMPERE AS CONDUCTIVITY OF THE WATER CHANGED DURING DAILY TEMPERATURE CYCLES. AT 56 HOURS THE CURRENT WAS SET TO FIXED VALUES. SYMBOLS ARE AS IN FIGURE 1.

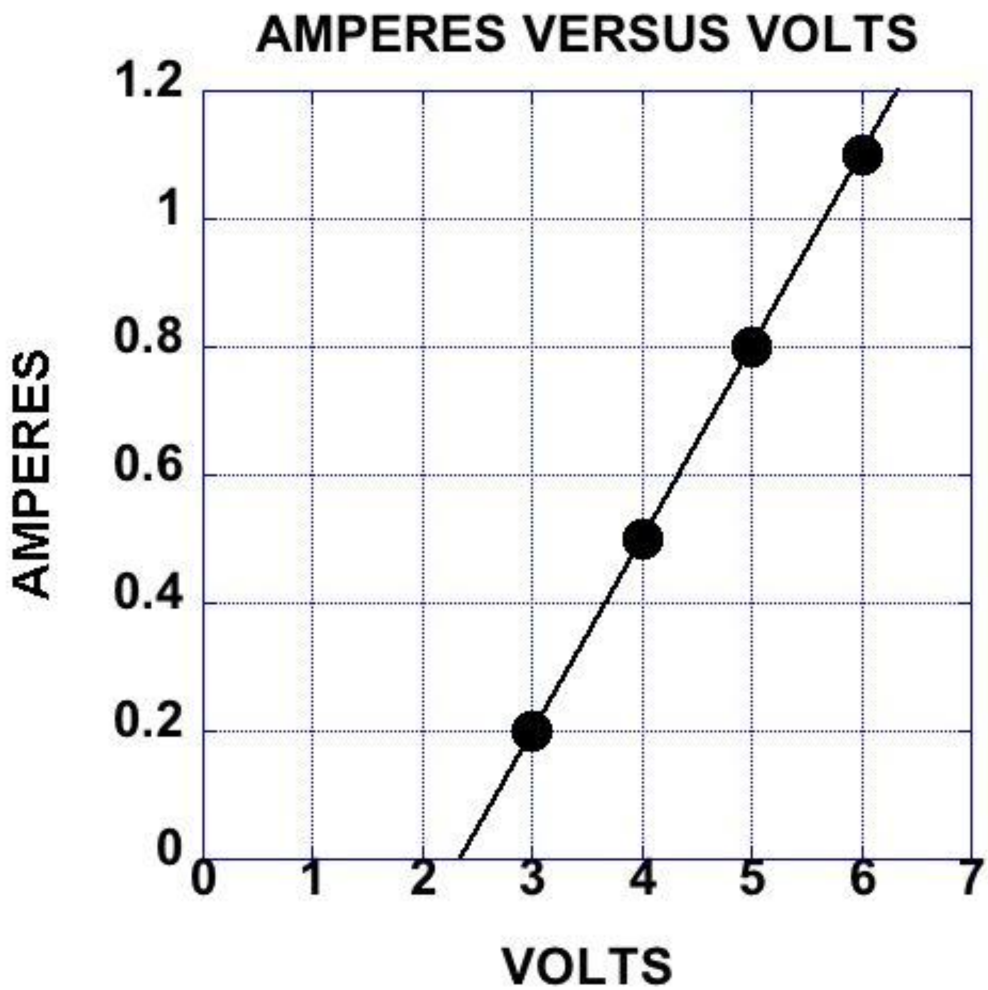

FIGURE 3. AMPERES VERSUS VOLTS FOR THE POSTS SHOWS A LINEAR RELATIONSHIP WITH A SLOPE OF 0.3 AMPERES PER VOLT, OR A RESISTIVITY OF 3.3 OHMS. THE ZERO INTERCEPT OF 2.3 VOLTS INDICATES THAT THE JUNCTION POTENTIALS PLUS VOLTAGE DROP IN THE CABLES AMOUNT TO 1 VOLT OVER THE VOLTAGE REQUIRED FOR ELECTROLYSIS OF WATER.

2. SCALE REMOVAL FROM COOLING SYSTEMS

Seawater and hard groundwater used for industrial cooling will precipitate out limestone scale in boilers, pipes, and heat exchangers, clogging them up and requiring costly replacement. An adaptation of Biorock® technology is being tested to precipitate out limestone at the intake, and create chemical conditions that prevent scale formation downstream. This adapts designs that were originally prepared by Wolf Hilbertz to prevent bio-fouling of ocean thermal energy conversion water intake pipes.

A four pipe PVC manifold was designed and constructed by the Sahara Forest Project. These needed some redesigning to optimize their function, adding ports for electrical connections and to sample the inflow and outflow for chemical analysis. The purpose of this redesign was aimed at 1) placing the cathode at the inflow end to generate alkalinity at the intake in order to precipitate out limestone at the start of the pipe, and allow its periodic removal; 2) placing the anode at the outflow end so that acidity is flushed out of the system so that it does not inhibit the limestone precipitation efficiency at the cathode, and so that the subsequent cooling water, being acidic, will prevent scale formation downstream when it is warmed up in the heat exchangers, greatly increasing their lifetime. A further advantage of this arrangement is that chlorine generated at the anode will sterilize the system and prevent biofouling of the tubes or microbial reactions that could clog heat exchangers.

It took a few days of searching electrical and plumbing supply houses in Qatar to find all the needed parts. Due to the time needed for the glue to set and seal the cable glands, the final assembly could not be completed during my visit, or I would have had to change the ticket and stay back one more day at added expense for ticket change and time. But all the needed steps were arranged and Paddy was instructed in the straightforward final assembly the following day.

It is intended to run all four tubes at different amperages, in order to determine the most efficient conditions, which will depend on electrical charging rates and on water flow rates. Two more chargers are needed so that they can all be used, and a request was made to obtain two more, plus a spare. Once they are set up I will work with Paddy to suggest initial operating conditions, and then we will use photographs of the cathodes (which consist of four 3 millimeter threaded rods clamped together to maximize surface area) to determine the rate of growth of materials and, if needed, change the operating ranges of the power supplies in order to maximize information.

Due to the axial cathode arrangement, some of the water under high flow conditions might bypass the cathode, and based on results possible redesigns to maximize precipitation efficiency will be proposed. It is suggested that a cathode mesh that more nearly fills the entry, wider and shorter than that used, might be more efficient, although mineral growth will need to be monitored so that the mineralized cathodes can be removed before they plug up the flow and exchanged for new ones to avoid impeding water flow. The rate at which that happens will depend on the efficiency of the design, the current, the flow rate, the temperature, and the salinity, so some experimentation may be needed to get the best results. The payoff could be to save a great deal of money in thermal cooling systems used in many industrial processes.

3. HALOPHYTE GROWTH ENHANCEMENT

The Biorock® process has been shown to greatly increase intertidal salt marsh grass and submerged seagrass growth, survival, and ability to resist environmental stress (see papers in Goreau & Trench, 2012). Plants show greater root growth, greater increase in height, greener leaves, and more stems per clump. The Biorock process is thought likely to equally increase growth and survival of plants in saline soils, but there has not been a previous opportunity to test this. The first such experiment is being made at the Sahara Forest Project. It is anticipated that this will provide a simple, cheap, and completely new way to increase growth of plants in saline soils and allow the expansion of agriculture to desert areas where it was not previously possible, a truly revolutionary development.

An anode and a cathode were placed at opposite corners of one of two identical halophyte enclosures. These had been planted only a few weeks before with a variety of salt tolerant desert plants, and most looked to be in poor condition. The tank has an underflow of salty brine, the same as in the pond with the posts. A trickle charge of 18 volts was applied to the entire field, a voltage similar to that of a nominal 12 volt solar panel, and so easily replicated in the field. The current was found to be very stable. After three days the power supply was reprogrammed to a constant current mode of 1.5 amps.

Because the plants have been stressed by transplantation, and because the roots do not likely reach through the sand to the salty groundwater below, visible results will take a little while to become apparent. Based on previous work with salt marsh grasses, we anticipate visible differences between the charged plot and the control plot in a few weeks. Paddy will keep an eye on the plots and periodically photograph them, paying special attention to differential changes in plant height, budding, branching, and number and color of leaves. This should continue for an entire year.

Based on the results it will be desirable to greatly expand these experiments to wider range of conditions in order to find out the optimal charging rates per unit area, and the effects of ground water salinity on the electrical conductivity and biological benefits. We expect that simple and cost-effective new methods will be developed that could transform desert agriculture.

4. FOLLOW THROUGH

These are exciting projects that could result in many breakthroughs and commercially valuable processes that should be developed by Biorock International Corp. and the Sahara Forest Project. I thank Paddy, Bard, Bill, Jelle, Steve, the electricians, and plumbers for their hands-on help, and all the staff at the Sahara Forest Project for advice and discussions. Please email me if there are any questions. I have previously submitted my ticket invoice for the Boston-Qatar round trip ($884). This should be reimbursed along with my time to The Global Coral Reef Alliance. Please note that since GCRA is an IRS 501 (c) 3 non-profit tax-exempt organization, this counts as a donation that is US tax deductible if the donor has US tax liabilities.