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Assessment of Julian Woods Community's Living Machine and Greenhouse Malfunctions

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October 3, 2006

1. Context

Back in the early 1990s the Julian Woods Community (JWC) wanted to expand to accommodate additional households with their associated homes. County regulations left the JWC with undesirable options for treating sewage: a chemical treatment plant, or connecting up to a municipal sewage plant at a considerable distance. Due to a high water table and underlying rock strata, sand mounds were ruled out. The main candidate alternative was a living machine,[1] built along the ideas of John Todd.[2] After preliminary studies, the JWC retained a consultant who designed and built it. There was no off-site effluent. Wastewater was either cleaned, and returned as greywater in the first of two greenhouses, or sent through a second greenhouse, in which growing beds for vegetables and flowers took up the remaining water, and transpired it to the open air.

By 2006 many of the plants in the living machine were either dying or stressed. Since healthy plants are required for the living machine to function, the community was faced with a crisis. Soil tests revealed high levels of nutrient overload, in particular boron. Nutrients from the treated sewage were being parked in the soil. The JWC compounded the problem by using compost, a nutrient-rich medium, as the initial bed material.

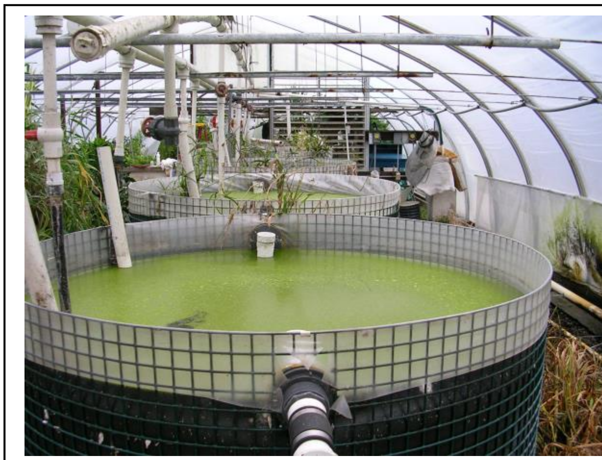
Tania was called in to assess what was going on, and to come up with possible solutions. She had already been involved in the design and construction of the living machine at the Center for Sustainability at Penn State.

What the JWC ended up doing, gradually, was exchanging the nutrient-rich soil in the greenhouses for poor soil from the surrounding site. On reflection, the Community would have been better off using poor soil to begin with.

2. Description of Existing Conditions

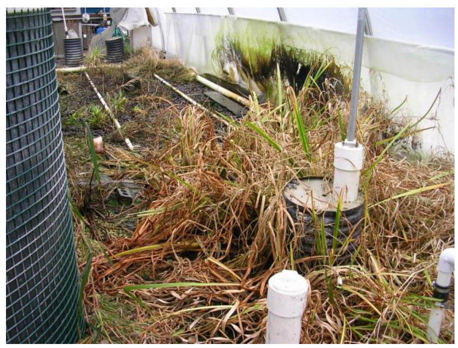

Above: all Canna lilies, elephant ears, and pennywort have died in both marshes. Some tough bamboo-like reed plants and a large philodendron are sole survivors in the second marsh (above left). A small amount of carbon (dried dead leaves) is visible on the sand filter (left); and tiny duck weed covers otherwise empty open aerobic tanks. A few papyrus hang on in the earlier tanks (below).

Below: L-R: Rotting plants in second marsh; chlorosis on remaining plants; dead plants atop the first open aerobic tank…





Above: There are a few grasses surviving in the second marsh – some seem to be thriving as they are going to seed. It would be good to identify these grasses to determine whether to allow them to propagate; at present, it is best to leave them since other plants are failing to thrive and the living machine requires living root systems upon which to build healthy bacterial populations. Given that we're approaching winter, it will be difficult to establish other vegetation.

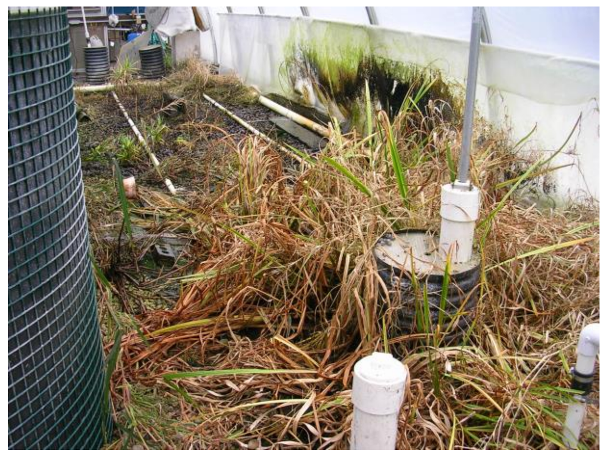


Above left: dead Canna lilies in the second marsh. Deb planted a small houseplant (wandering Jew) in foreground to see how it would fare.
Above middle: dying water iris (sweet flag) in first marsh

Above: Chlorosis on pennywort and a pokeweed in marsh 2, near philodendron.

At left: rotted root of an elephant ear plant from the second marsh.

Left: View of second marsh from rear of treatment section. **Above:** a grass plant at the base of the philodendron, already experiencing some chlorosis.



Above left: view of first marsh from rear of treatment section. **Above right:** view of first marsh from front of treatment section (to the right as you walk in the greenhouse door). Splash guards have fallen apart and water from the first marsh shoots out from the PVC recirculation pipe onto the greenhouse wall to the one side, and into the gravel bed below the tanks to the other side. Against the greenhouse plastic, algae has accumulated on the plastic. Unclear if the black stuff is accumulated dead algae or something less desirable. Black molds should definitely be avoided.

In the evapo-transpiration (ET) greenhouse, the dahlias are suffering. **At left** is a healthy dahlia from the middle of the second ET greenhouse, whereas in the **middle** and to the **right** are stunted blossoms from the first ET greenhouse, just after the treatment section.



Above: also strongly affected in both ET greenhouses are the zinnias. The plants appear to have a viral wilt, as evidenced by the right-most photo. The blossoms are small and mal-formed, if they bloom at all. Chlorosis is evident. Brown spots on the leaves may be from fungus.



Lemon verbena (**above left**) and purple salvia (?), (**above middle and right**), have thin, twisted new growth, and blossoms are stunted and poorly formed. Chlorosis is also evident.




Above: Detail of chlorosis on young tomato plant and peach tree in second ET greenhouse. Suggestive of nutrient deficiencies [manganese? Iron?]. Best bet would be to test the soil!!

More chlorosis in first ET greenhouse plants

Below: stunted and deformed lettuce plants (Jean Giddings' garden section). Mottled leaf surface suggests spider mite damage, but none were found. Ozone damage could look similar – but this makes no sense either. Galinsoga was similarly affected, but not adjacent purslane or wood sorrel.

Far left: Oak leaf lettuce. **Middle:** Galinsoga. **Above:** Romaine lettuce.

Left and below: Detail of Red Sails lettuce; Purslane at **right** is fine.

Arugula (**at left**) in Jean Giddings' garden section exhibits some signs of chlorosis, while nearby green and red swiss chard appear unaffected.

These bottom three photos are of a pesky weed ground cover in the ET greenhouse that exhibits similar thin and deformed new-growth leaves, plus mottling on the leaf surface akin to what was observed on the lettuce and galinsoga.

Some of the pepper plants in the second ET greenhouse had pronounced leaf curl – the soil was moist, so it was not a moisture issue. **Below left and center:** a Thai pepper plant has an odd white coating along the leaf edges. Some plants, like the ivy in the photo **below right**, seem immune.

To gain a more accurate understanding of what is occurring would require that some of the plants be taken to the PSU Plant Pathology Lab for proper identification of the problem, including possible viruses, fungi or bacterial problems. Also, the soil in the two ET greenhouses should be sampled and sent out for a complete soil test, including testing for trace minerals.

Other observations in the greenhouses:

- The compost pile was not a "proper" pile, but simply a mish-mash of straw, a few plants (probably diseased), and residual purchased potting mixes (complete with perlite).
- The eggplant were all attacked severely by flea beetles – the worst infestation ever, according to Deb.
- Debris from dead plants littered the stone surfaces of the first and second marshes.
- The treatment system did not smell badly, suggesting that there is sufficient aeration taking place. Air bubbles were evident in the first three aerobic tanks, indicating that the air stones are doing their job.
- No one had re-inoculated the treatment system for quite some time.
- With fewer plants in the treatment section, more treatment water flows into the ET beds.

3. Tentative Conclusions and Recommendations:

1. **Compounding of problems**: Since so much of the vegetation has died in the treatment section, there is great reduction in the level of evapotranspiration from that section, which means that most of the treated water is moving on into the ET greenhouses. This is a common condition during the winter months, when the vegetation in the living machine dies back, but this year it has occurred during the summer months. Robert Forsberg reports that the system is automated to ensure that the water level in the gravel below the ET greenhouse soil beds is maintained between 21" and 27", never reaching the 36" needed to reach and saturate the soils in the ET greenhouse beds. Approximately 600 to 900 gallons per day comes from the treatment section and the balance of the water needed comes from well water. Consequently, excess moisture should not have been a problem. Excess moisture can do several things: leach minerals, lock up certain mineral nutrients (due to higher pH), reduce available soil oxygen (if the soil gets saturated at some level and begins to stagnate) and facilitate the growth of fungi, viruses and diseases. Since we do see signs of these things occurring, and we know that the living machine itself has suffered significant die-off, three things come to mind:

    a. **pH imbalances** – if the treatment water is too alkaline and more of this water is entering the ET greenhouses, then the soil pH and plant health will be affected.

    b. **Fungal spores can pass through the UV sterilizer unharmed** – and fungal diseases from the treatment section could therefore spread into the ET greenhouse sections

    c. **Nutrient imbalances from paints or other items washed down the drain** – While organic compounds, including turpentine, is readily broken down by microorganisms in living systems, certain nutrient loads, like zinc from zinc oxides that might be in paints, could create nutrient imbalances and whack out the system. An excess of zinc, for example, interferes with magnesium and iron uptake in plants. Zinc would propagate through the system and enter the ET beds where it would then interfere with plant metabolism. Weakened plants would then be more susceptible to diseases. Micronutrient levels play a critical role in soil and plant health.

2. **Seasonal inoculation**: To function properly, especially with the stress of seasonal changes, Dr. John Todd recommends that living machines be inoculated with local pond water with each change of the season – that is, four times a year – to ensure a proper "healthy" mix of bacteria and microorganisms. When the water hyacinths first died off, this should have been the first clue of an ecosystem out of balance, and the system should have been re-inoculated with healthy biota.

3. **Jump-starting the treatment section**: Since the system was not inoculated with new, healthy bacteria, the less healthy bacteria flourished and made it more difficult for the healthier ones to get re-established. Since we see die-off in all of the system components, one is led back to the source, which is the external septic tanks. One might take off the cap and investigate what is occurring there. I have heard of some folks putting yeast into their septic systems to help break down the biosolids – this might

be one thing to try. Another might be to introduce some pond water here – say, a 5-gallon bucket of pond water into which one adds a quarter cup of (live culture) cider vinegar. The idea is to jump start the biology just before it enters the greenhouse.

4. The cider vinegar is recommended because Deb reported that the system pH is around 7.8, which is not excessively high, but these living systems work better in a slightly more acidic environment. Consequently, I would recommend trying the following to jump-start the “good” microorganisms in the system again:

    a. First, inoculate the first marsh, each open aerobic tank, the sand filter and the second marsh with pond water: 5 gallons each in the marshes, and 2.5 gallons each in the tanks and sand filter [Deb Fisher and I did this today]

    b. Next, prepare a 5-gallon bucket of properly aerated compost tea, as per Dr. Elaine Ingham’s procedure. Note: this requires proper compost, which is presently lacking, so we will work with what is available, but it may not be very good. The compost tea includes molasses to feed the good bacteria. The resulting strained “tea” should be diluted – say 1 Quart of compost tea to 5 gallons of pond water. Add to that a quarter cup of cider vinegar and about as much yogurt whey. Stir vigorously and pour into watering cans. Water the first marsh and the first three aerobic tanks with this mixture. DO NOT use this mixture further into the system because we want to avoid nutrient loading. Although dilute, the compost tea will contain a lot of nutrients. We don’t want the nutrients. We want the microorganisms!

    c. With the rest of the compost tea, dilute it about 50/50 with pond water and use it to water the plants in the ET greenhouses, spreading it around as best as possible to reintroduce good microorganisms back into the soil. Aim to **feed the soil**. Compost tea, properly made and filtered, can be an excellent foliar spray too, but I’d be wary of it given the quality of the compost that was used to make it. <u>Add about a tablespoon of cider vinegar</u> to each gallon of the 50/50 compost tea and pond water. The aim here is to **acidify the soil** a bit more.

    d. Observe how the system responds. Repeat steps a and b in another month. Then aim to do it four times a year.

5. **Clean up the greenhouse BIG TIME**. Rake off and remove all dead plant debris from all of the marsh areas, and pull out any remaining dead plants from the open aerobic tanks and take them out of the greenhouse to some other location to compost separately. Do similarly with ANY and ALL diseased plants from the ET greenhouses.

6. **Replant the marshes** with grasses, reeds – anything that will take. Re-seed the open aerobic tanks with a variety of aquatic plants to see if you can find anything else that will survive. Bob Cameron can probably provide a few token “seed” plants to try from the PSU system. Remember, John Todd usually seeds the system with a huge variety of plants and allows the system to sort out itself. [Bob Cameron can be reached at 876-0129]

7. **Keep the ET greenhouses planted –** with cover crops such as oats, rye, Madison hairy vetch, fava beans (or bell beans), and garlic. You want something that will germinate and grow quickly to keep the beds covered into the winter months to build soil fertility, healthy organic matter, and to retard viral and fungal activity. Winter rye might be better because it will survive the cold, however, it grows more slowly than oats. Vetch and bell beans will fix nitrogen in the soil; bell beans also exude natural chemical substances that retard certain fungal growths like verticillium wilt. Both are cool-weather-loving plants. Garlic planted generously throughout the greenhouse beds has anti-bacterial and anti-fungal action that will help to reduce the presence of unwanted micro-organisms in the soil. The aim is to stimulate healthy biological activity. Greens from these plants can then be harvested and composted in the spring to jump-start your compost pile (see next instruction).

8. **Establish a proper compost pile** with proper instructions about how to add to it and maintain it. Autumn is the perfect time to do this because one can gather fresh leaves to stockpile to provide carbon to which fresh green matter (NON-diseased, NON-seed-laden) or nitrogen rich manure (as from the chickens) can be added. A proper biodynamic compost pile involves layering
   a. 6 inches of carbon-rich matter (dry brown leaves or straw),
   b. 6 inches of nitrogen-rich matter (chopped up green plants, green grass, vegetable food scraps or fresh manure), and
   c. about an inch of soil (which seeds the system with microorganisms to start the composting process).
   d. Repeat the layering until the pile is at least 5 feet x 5 feet x 4 feet high or so.

   Yogurt whey and/or sugar-water (super-saturated, 1 lb sugar per gallon water) can be added to enhance the decomposition process. The pile should be turned at least twice in a year [e.g. early June and mid-July] and aerated sufficiently at each turning. Moisture content is critical. If too wet, unhealthy anaerobic organisms will be breeding. If it is too wet or if there is too much nitrogen, the pile will start to smell bad. It is VERY important to turn it and work more carbon-rich matter into it – another reason to keep dry, brown leaves or straw on hand. If it is too dry or lacks sufficient nitrogen-rich material, it will remain cool and you will not observe the composting process taking place. Wet the pile with sugar-water (molasses is even better) to jump-start the biological process, and fork in more nitrogen-rich matter if it is available. There is no substitute for properly-made and cured compost that can be used in the greenhouse.

9. **From soil testing**, determine what nutrients are lacking in the soil of the ET greenhouses and devise a plan for rebuilding soil health. It is likely that the poor health of plants in the ET greenhouses and the massive vegetative die-off in the treatment section are only linked by the three factors mention in item 1 – incoming water pH, propagation of fungal spores, and micronutrient imbalances. The living machine should absorb the full nutrient load of the incoming sewage, so that what waters the plants in the ET greenhouse is NOT "sewage", but could be thought of literally as something very close to potable water. This means it is not carrying nutrients (nitrogen, minerals) to the plants in the ET greenhouses – only water. After a dozen or more years of growing high-nutrient-demand plants in the greenhouse, the soils have likely begun to grow depleted of key minerals and elements. Chlorosis and increased pest and disease problems indicate poor nutrient management. Different plants require different nutrients

to thrive, so the soil test results are critical to understanding what is going on and taking proper corrective measures. Timberleaf Soil Testing is best. Using the Penn State soil testing services and requesting trace mineral and other analyses will work – but we will have to help you interpret the recommended soil amendments to convert them from chemical additives to healthier organic ones. Soil pH should be checked regularly too, since pH imbalances can lock up soil nutrients so that the plants cannot take them up.

10. <u>In the meantime</u>, proceed with using compost tea and seaweed foliar spray to "feed" the plants as needed in the ET greenhouse. Consider proper crop rotations, using cover crops to rebuild soil health, and – as a last resort – "solarizing" the soil. Once present, plant diseases are difficult to eradicate except through rebuilding soil health or finding some way to kill the disease.

11. <u>Keep in mind that chlorosis</u> is not necessarily a nitrogen deficiency, but can result from any of a number of nutrient deficiencies. In fact, nitrogen deficiency shows up first in older leaves on the plants, while most of the chlorosis I observed is on the new growth. Comparing what I observed today with my book references:
    a. The discoloration of the raspberry leaves (older plant leaves) suggests insufficient soil acidity - raspberries require a more acidic soil
    b. The discoloration of the peach tree leaves is suggestive of a nutrient deficiency, possibly iron or manganese…which would have been precipitated by the pH being too high.
    c. The mottled appearance of Jean Giddings' lettuce plant leaves looks like lettuce mosaic virus – infected plants will be stunted, yellowish and will fail to head properly
    d. The curled pepper leaves could be an initial symptoms of a virus – can't pinpoint it further without closer observations of the plant and its fruit.
    e. While I did not photo-document most of the tomato plants, I observed that most of the older plants were affected by septoria leaf spot, which is a common fungus that thrives under moist conditions. Potassium bicarbonate is a good remedy, and copper-based soaps. We can supply sources for both if you are interested. Diseased tomatoes should be composted IN A SEPARATE COMPOST PILE and spread around shrubs or trees elsewhere, not in the greenhouse or in outside gardens.
    f. Based on sketches and descriptions in the *Reader's Digest Illustrated Guide to Gardening*, under "Plant Disorders", it is likely that the deformities observed in the lemon verbena, dahlias, purple salvias, and the ground-cover weed are caused by a virus. It is generally advised that these affected plants be dug up and destroyed. Certain insects, like aphids, are known to spread the virus to other plants. John Peplinski at the Penn State Plant Pathology lab could more precisely identify the plant diseases. He is in room 220 Buckhout Lab (behind Osmond Lab on campus). Plant specimens can be dropped off at room 210 Buckhout Lab, the Plant Pathology office. One form must be filled out for each plant specimen submitted. Their number is 865-3761.

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[1] The trademark for Living Machines now belongs to Living Technologies, Inc.
[2] http://www.oceanarksint.org/