Experimental Hydroponic Gardening with Municipal Waste-Water

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INTRODUCTION

A general practice, contributory to the degradation of the overall environment, is the single use of water for the transport and disposition of wastes. Therefore, processes which can employ waste-water, and concomitantly, help to improve its quality, are matters of interest. Hydroponic gardening requires large amounts of manurial compounds dissolved in water and municipal waste-water is a logical source of such materials. A useful product, food, can be obtained and concurrently, the pollution potential of the waste-water should be reduced. To these ends, experiments were designed to evaluate the use of hydroponics as part of a waste-water re-use process.

Chlorinated waste-water is known to be unsuitable for plant fertilization and irrigation when usual truck-gardening methods are employed (FAIR, et al, 1968), however, its usefulness in hydroponic gardening has not been described. Methods for irradiating waste-water have been described, (GULF GENERAL ATOMICS, 1970; BALLANTINE, et al, 1969; WOODBRIDGE, et al, 1972) and the means for carrying out this process were available, therefore, both methods of treatment were applied to aliquots of waste-water, and plants grown in them were compared.

METHODS AND MATERIALS

The hydroponics system consisted of five separate units. The units were forty-two inch diameter plastic pools, each with its own fill and drain apparatus. Each unit contained a carrier, a six inch deep bed of 1/4 inch river gravel in the preliminary experiments, which was replaced with horticultural perlite (W. R. GRACE & COMPANY, Cambridge, Massachusetts 02140) (3/16 to 1/4 inch) in the remaining experiments. Perlite (BOLLEN, 1969) was used because of its relative chemical inertness, porosity, and the resultant high volume of air space after drainage. In order to prevent excessive salts build-up, the beds were flushed with tap water every tenth day, and then refilled with test irrigant. A screen and plastic enclosure shielded the units from excessive sunlight and adverse weather conditions as well as serving as a barrier to insects and other herbivores.

Treated waste-water was obtained from Grant Street Sewer Treatment Plant, Melbourne, Florida. This plant services approximately 30,000 persons and handles between 1.5 and 2 million gallons of waste-water (ANNUAL REPORT, City of Melbourne, Florida, 1969) per day. Water treatment included primary settling, clarification, high rate filtration (trickling filter), secondary clarification, and chlorination. Samples were pumped from the secondary clarifier, before chlorination, into a 15 gallon plastic carboy storage container. Fifteen gallons were usually

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sufficient for three days use in the experimental gardens. In addition, two nutrient solutions were employed. The first was prepared according to a formula described by WITHROW AND WITHROW (1948), and the second was a commercial preparation; (NUTRI-SOL CHEMICAL CO., Tampa, Florida).

The Florida Institute of Technology Cobalt 60 radiation facility consists of a 27,000 curie source maintained in a 20 foot cylindrical pit filled with water. Aliquots of waste-water containerized in 5 gallon gasoline cans sealed with rubber gaskets were lowered into the pit by means of a cable and pulley system. The can was positioned at a predetermined point at which a calculated average dose of 50,000 rads was received at its center in 7.5 minutes. When employed, the nutrient solutions were subjected to the same process.

Aliquots of waste-water or nutrient solution were chlorinated with prestandardized commercial sodium hypochlorite solution (Clorox) during a contact period of fifteen minutes, then the residual chlorine was determined colorimetrically, by means of the orthotolodine method (BOLLEN, 1969). A chlorine-demand test (APHA, 13 ed. 1971) indicated that 2.3 ml of standardized sodium hypochlorite solution should be added to 8 liters of waste-water, and 1.35 ml to 8 liters of each of the nutrient solutions in order to ensure a residue of two parts per million, as required for the ordinary discharge of waste-water (FAIR, et al, 1968).

Nitrate nitrogen (APHA, 13 ed. 1971) was measured colorimetrically using brucine under acid conditions; ammonia nitrogen (APHA, 13 ed. 1971) was determined by nesslerization after alkaline distillation. Phosphate was determined by a modification of the Fiske-Subarrow method (APHA, 13 ed. 1971) in which the molybdophosphoric acid, was reacted with stannous chloride to form molybdenum blue.

Dissolved oxygen was determined with a YSA* Model 51A oxygen meter, and pH with a Corning ** Model 5 pH meter.

Coliforms were enumerated following the procedure set forth in Standard Methods: (a) the five tube presumptive test; (b) the confirmed test on EMB agar; (c) the presence of fecal <u>E. coli</u> in E.C. medium at 45.

Seeds of two varieties of truck garden plants were germinated hydroponically in untreated waste-water, then 50 seedlings of each variety were transplanted into each experimental bed. Ten of each variety were harvested weekly. A Mettler Balance was used to determine the wet weight of each plant within two hours of harvest.

EXPERIMENTAL RESULTS

Preliminary experiments were conducted in which a five-fold greater wet weight of radishes was obtained when they were irrigated with irradiated waste-water, as compared to those irrigated with chlorinated waste-water. Subsequently, the five beds were irrigated as follows: irradiated waste-water; KNO_3 added to waste-water before irradiation; KNO_3 added to waste-water after irradiation, and untreated waste-water as a control. The test plants were tomato and radish. The final mean wet weights of the plants in this experiment are compared in Figure 1.

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* Yellow Springs Instrument Company, Inc., Yellow Springs, Ohio
** Corning Scientific Instruments, Medfield, Massachusetts

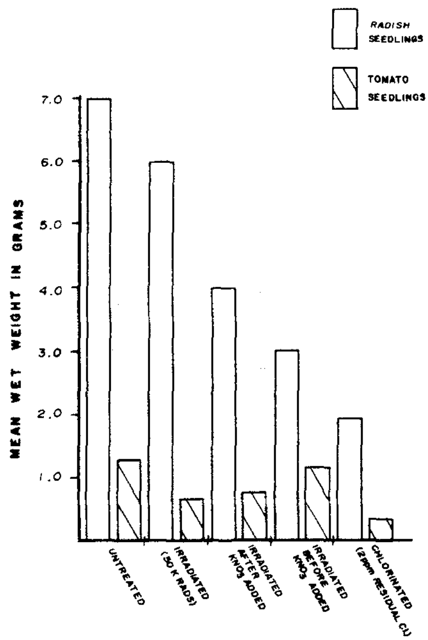

Figure 1. Mean wet weights of 28 day seedlings grown hydroponically using differently treated aliquots of waste-water.

Growth in the chlorinated effluent was one-fourth of that in the control and was also repressed when KNO_3 was added to irradiated effluent. Radishes grown in irradiated waste-water were appreciably heavier than any crops other than that grown as the control. Tomatoes, also grew best in irradiated waste-water, but seemed to do better too when there was a higher concentration of N as NO_3^-. They grew poorly in chlorinated waste-water, achieving only one-third the weight of the controls. Potassium as a required nutrilite was not investigated.

In a further comparison of the effects of chlorination, and irradiation on plant growth, aliquots of a nutrient solution designed for hydroponic farming at Purdue University (WITHROW AND WITHROW, 1948) were chlorinated or irradiated. These aliquots as well as aliquots of the untreated nutrient solution, untreated waste-water and irradiated waste-water were used as irrigants for the five beds. The test plants were radish and bush bean.

As is evident in Figure 2, radishes grown in nutrient solution (WITHROW AND WITHROW, 1948) were smaller when the solution had been either chlorinated or irradiated. In chlorinated solution, they averaged 2.0 grams; in irradiated, 3.0 grams and in untreated solution, 5.0 grams. Conversely, bean growth in either irradiated or chlorinated nutrient solution was better than that in the control. There is an apparent anomoly in either the bean plants or the nutrient solution in that in chlorinated nutrient solution, a 133% greater final weight, and in irradiated nutrient solution, a 75% greater weight of plants occurred as compared to those grown in the untreated control.

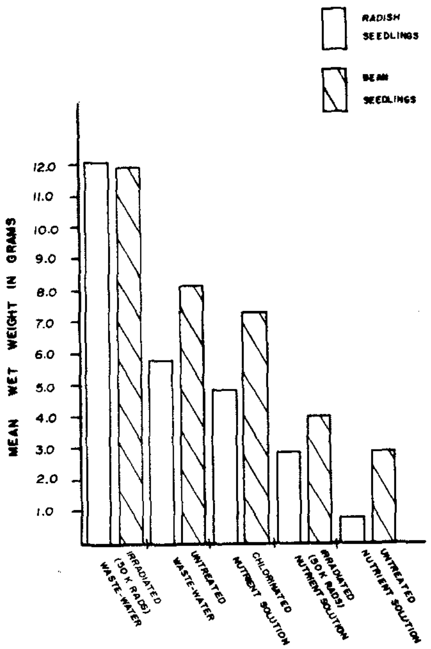

Figure 2. Mean wet weights of 28 day seedlings grown hydroponically in irradiated and untreated aliquots of waste-water and in irradiated, chlorinated and untreated aliquots of a nutrient solution (WITHROW AND WITHROW, 1948)

Nitrate, ammonia and phosphate levels were determined in each of two beds, one planted with beans and radishes and the other without plants. Irradiated waste-water was the irrigant for both beds. Tests before and after application to each bed indicate that the number of plants used was not large enough to remove significant amounts of these nutrients from the waste-water.

Bacterial numbers as coliforms, were estimated in each of the irrigants and in each hydroponic bed before irrigation. Samples were obtained by washing the beds with two liters of coliform-free tap water and collecting a 200 ml portion at the drain outlet. These data are summarized in Table 1.

The coliform population in the nutrient solution (WITHROW AND WITHROW, 1948) was low (20 per 100 ml), as was that in the irradiated nutrient solution (110 per 100 ml); chlorination had little or no effect. The numbers in waste-water and irradiated waste-water could reasonably be expected in these type waters. The addition of chlorine to the nutrient solution before irrigation reduced the bacterial population in the receiving bed by more than an order of magnitude. The initial value of 2200 was reduced to 1400 within one week, to 200 by the second week, and to 20 by the final week. The irradiated waste-water bed had a population about half that of the untreated waste-water bed, reflecting the bactericidal action of gamma irradiation. There was however a build-up of the bacterial population in the irradiated waste-water bed, from an initial population of 70 per 100 ml to 800 per 100 ml within one week, 9400 per 100 ml in two weeks, and back down to 2000 per 100 ml by the third week. This is probably due to the absence of residual antibacterial activity and the resultant resumption of reproduction, as well as the normal replacement of species.

TABLE 1

Coliform Populations (Presumptive MPN) per 100 ml
of the Various Irrigants used in Hydroponic Experiments

Irrigant	MPN ($X10^3$)				
	Baseline Irrigant	Bed Washings	No. days after addition of irrigant to bed 7	14	21
Nutrient Sol. (7)	0.02	24.00	3.50	1.70	1.70
Irradiated Nut. Sol. (7)	0.10	16.00	4.90	2.60	1.70
Chlorinated Nut. Sol. (7)	0.02	2.20	0.14	0.20	0.02
Waste-water*	7000.00	5.40	11.00	14.00	7.00
Irradiated waste-water	240.00	0.07	0.80	9.40	2.00

* Fecal E. coli found only in untreated waste-water

DISCUSSION

In the usual treatment of waste-water, the addition of certain chemicals, chlorine, for example, in quantities sufficient to kill large percentages of bacteria may also stunt plant growth, kill bivalves and other shellfish, and may themselves become pollutants. The application of Gamma irradiation is a relatively new approach to such treatment; it has probable utility in the destructive oxidation of organic chemicals, the selective removal of specific refractory molecules (BALLANTINE, et al) disinfection, including virucidal activity, (SULLIVAN, et al 1971) may have some effect on sludge beneficiation, and leaves no radio active residue (GULF GENERAL ATOMIC Inc. 1970). Mean wet weights of various seedlings were used to compare the effects of chlorination and irradiation on waste-water for use in hydroponics. Figure 1 demonstrates a distinct inhibition of the growth of radishes and tomatoes in chlorinated waste-water. Several possible explanations for this action include the potential toxicity to the plants of the chlorine itself. Useful (commensal) bacteria may also have been decimated as were the coliforms as shown in Table 1 when chlorination of the irrigant preceded application. Equally probable is the combination of chlorine with other compounds, such as certain amines presumed to be present in the waste-water, to form chloramines.

When a chlorinated standard nutrient solution (WITHROW AND WITHROW, 1948) was employed there was marked improvement in the growth of radishes and beans as compared to those in the unchlorinated nutrient solution (Figure 2). The facts that chlorination of waste-water has deleterious effects on the growth of radishes and tomatoes, and chlorination of a nutrient solution has little effect on the growth of radishes and beans, strongly supports the hypothesis that chlorine may have combined with some undefined compound in waste-water to produce an inhibitory substance.

Irradiation and chlorination result in fairly strong oxidations, (BALLANTINE, et al, 1969; FAIR, et al, 1968), therefore, an easily oxidizable inhibitory substance present in the nutrient solution may have been altered by either process. This further supports the suggestion that the combination of chlorine with undefined compounds in waste-water might inactivate an inhibitory substance in the waste-water as suggested by the apparently anomalous data in Figure 2. Figure 3 confirms that the effects noted are properties of the treated substrata, since the growth of radishes in Nutrisol, is not affected at any time during the experimental period by either chlorination or irradiation of the third substrate.

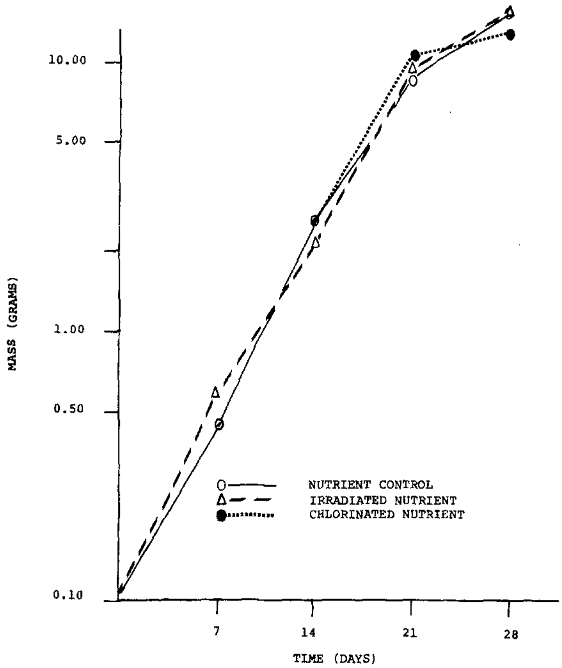

Figure 3. The growth of radishes with time in untreated, irradiated, or chlorinated Nutrisol (NUTRISOL CHEMICAL CO., Tampa, Fla.)

Hydroponics, in its present state of development, is readily adaptable to the use of waste-water treatment plant effluents, probably removing plant nutrients which might otherwise become pollutants,as well as producing foodstuffs economically. Further a second-time use of otherwise lost water can be accomplished. Concurrently, the value of irradiated waste-water as a nutrient solution in hydroponic gardening is demonstrated by the plant growth, herein described. A comparison of growth in waste-water and in a standard nutrient solution (Figure 2) also suggests the high manurial value of waste-water. While there is disagreement (GULF GENERAL ATOMICS, 1970; BALLANTINE, et al, 1969; WOODBRIDGE, et al, 1972) concerning the economic value of irradiation in water treatment, it is suggested that its employment may enable the development of useful processes which may compensate for any costs greater than those of conventional treatment.

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