Current Review of Sewage Effluent for Irrigation Use

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IN ATTEMPTING TO review the vast amount of literature dealing with the characteristics and use of sewage sludge and effluent, along with all of their ramifications and impacts on agriculture and the environment, I thought that perhaps a better title would be "Don't Waste the Waste!" However, I came across a title suggested by Whetstone[9] which I think you will agree is perhaps more appropriate: "The 21st Century — an Effluent Society." It is Whetstone's contention, supported by many authorities in this field, that recycled water will be routine in 50 years. One need only to look at the Colorado River system to realize that, in fact, we are doing this today.

Two major forces will be responsible for this development:

(1) improvement in sewage treatment, and
(2) water economics.

Modern developments in the area of improved sewage treatment have been hastened by the Federal Water Pollution Control Act Amendments of 1972. This Act set a goal to eliminate discharge of pollutants into navigable waters by 1985.

In addition to this Federal mandate, water economics are such that growing demands on an essentially constant supply of water can only be relieved by recycling. Whetstone[9] says, "The luxury of discharging once-used water will become a bitter memory of ancestral squandering." McGauhey[7] presents an even stronger case for recycling water: "If sewage were discharged without any treatment whatsoever, we should be sending a 2,000-ton train of water, on which we lately spent a great deal of money in purifying, to transport a single ton of organic solids. Worse yet, in the more common case of well-treated sewage, one good burro could carry all that is required of this half million gallons of water. Furthermore, we throw away the train at the end of a single trip. It is in line with our heritage of waste, but it is without parallel in the history of transportation."

It stands to reason that increased population demands on this water lead to increased waste problems. Each resident of a community usually contributes 70 to 100 gallons of wastewater per day, resulting in the production of one-quarter pound of sludge per day.[5] In the past, the nation's rivers, streams, lakes, and oceans have been used to dilute these wastewaters, but now the steadily increasing volume of waste is exceeding the dilution ability of our waters. Thus, increased nutrient levels of the water result in excessive algae and aquatic weed problems which upset the ecology of the system, not to mention obvious health hazards.

At present, most sewage waste is disposed of in landfills, lagoons, and the ocean, by incineration, and by application to the land. Because of environmental and economic considerations, application of sewage waste to the land appears to be by far the most feasible method of disposal. Benefits in using the land as a living filter are as follows:

1. The nutrient concentration in wastewater would be reduced by the biological, chemical, and physical processes in the soil.
2. The nutrients would be available for plant utilization and growth.
3. Renovated water would recharge the groundwater.

How then is this wastewater being applied to the land? Several approaches are currently being used:

1. Irrigation.
2. Overland flow.
3. Infiltration — Percolation.
4. Deep well injection.

IRRIGATION

Irrigation may be defined as a controlled discharge of effluent by spraying onto the land to support plant growth. Wastewater is thereby utilized by (1) plant uptake, (2) evapotranspiration into the air, and (3) percolation into the groundwater. The benefits from wastewater irrigation are many:

1. Inexpensive source of water,
2. Economic savings of potable water which could be used for purposes other than irrigation,
3. The utilization of green belt areas for recreation purposes in urban and suburban areas,
4. Economic return on the sale of crops, and
5. It is a positive alternative to advanced waste treatment and/or surface water discharge.

OVERLAND FLOW

Overland flow is a controlled discharge onto the land with a large portion of the wastewater appearing as runoff. It can then be recycled for other uses. As of 1973 this approach has not been used in the United States although it is used in Australia.[8]

INFILTRATION — PERCOLATION

Basically a flooding technique where heavy loading rates infiltrate and percolate into the soil with relatively small losses to evaporation. This process has been developed primarily for groundwater recharge.

DEEP WELL INJECTION

This approach is considered to be a disposal method rather than a wastewater treatment. It is one alternative along the coast to holding ponds on the surface during periods of rainy weather. This approach is currently being used in California, New Jersey, and Florida.

CHARACTERISTICS OF WASTEWATER

Wastewater may be quite variable as its composition depends on the following:

1. The domestic water system itself, including
   (a) water supply source,
   (b) treatment, and
   (c) conveyance system;
2. Inorganic and organic compounds in both industrial and domestic wastewaters;
3. Inflow and infiltration into the wastewater collection systems.

The greater the industrial base the wider the variation in its wastewater effluent. Table 1 illustrates a comparison between a residential vs. an industrial sewage sludge.

TABLE 1

Characteristics of Two Municipal Sewage Sludges

	Municipality	
Characteristics	Residential	Industrial
solids %	23.2	20.5
pH	5.4	5.6
N%	2.5	2.3
P%	1.3	0.8
K%	0.07	0.12
Ca%	1.6	1.1
Mg%	0.1	0.1
Cd ppm	18	165
Cr ppm	358	1754
Cu ppm	352	636
Mn ppm	372	890
Pb ppm	447	2748
Zn ppm	7915	11,812

After Burns & Boswell. 1975.

Note that there are no appreciable differences in the first seven characteristics, most of which are essential plant nutrients, but that the primary differences are in the heavy metal content. Note further that these high concentrations of heavy metals are found in sewage sludge — not sewage effluent. There is a difference between the two. Sewage sludge contains most of the organic solids which are separated out during processing and contain little water, whereas sewage effluent is the liquid outflow from the sewage treatment processes and contains 99.9985% water.[6] Table 2 illustrates two effluent sources which likewise vary due to industrial inputs, but note the relatively low concentrations of metals in the effluent fraction compared to the sludge.

Note that a number of metals in both states but especially in Michigan exceed the recommended drinking water standards, while conversely those in the low range are well below the water quality limits. It should be apparent, therefore, that plant growth problems are more apt to be associated with the sludge fraction rather than the effluent fraction. There is concern, nevertheless, that continued use of effluent over a long period of time may cause metal build-up to the point of plant toxicity. Burns and Boswell[2] found that the high metal content of the industrial sludge seriously affected rooting in bermudagrass and centipedegrass. Centipedegrass was more seriously affected by the industrial metals than was bermudagrass.

TABLE 3

Performance of Bermudagrass and Centipedegrass Cuttings in Sewage Sludge from Two Sources

	Bermudagrass		Centipedegrass	
Characteristics	**Res.**	**Ind.**	**Res.**	**Ind.**
Total root length mm/cutting	55	12	40	3.5
% cuttings with roots	100	93	100	25

After Burns & Boswell. 1975.

In addition to the heavy metals, the salt content and the biological composition affect the quality of wastewater.

Recently we sampled one treatment plant located close to the shore in Florida and were surprised to find the effluent analyzed 2,000 parts per million of total salts. Apparently the influent lines were allowing saltwater to leak into the system, causing a problem with high soluble salts.

The biological agents associated with wastewater are of great concern to the public health officials as well as to the general public. In general, three groups of organisms are involved: (1) bacteria, (2) parasites, and (3) virus. It is generally assumed that disinfection of secondary treated effluent eliminates the potential hazards associated with the bacteria as well as the parasites, but the control of viral organisms is a moot question, primarily because of the difficulty associated with studying virus. Recently, however, with the completion of St. Petersburg's Southwest Plant, we now have a sewage treatment plant which produces an effluent in which the virus is non-detectable.

The Southwest wastewater treatment project, in St. Petersburg, was selected by the National Society of Professional Engineers as one of its "Ten Outstanding Engineering Achievements of 1976." All the wastewater from this plant is recycled for turf irrigation. Approximately 8,000 acres are expected to be irrigated by 1980. During periods of heavy rainfall, the effluent is injected into deep wells. Thus zero discharge to surface waters ensures complete elimination of pollution problems. This is the first major regional wastewater treatment system in the nation to achieve zero discharge.

In Table 4, Baldwin presents some interesting economic considerations relative to effluent treatment, disposal, and utilization. He presents a number of probably acceptable disposal alternatives if wastewater is treated to minimum levels. Note that all treatment levels are adequate for utilization of this wastewater on turf facilities if health considerations are followed. Treatment B is the current treatment level of the new St. Petersburg plant. Relative costs for these different levels of treatment are presented by Baldwin[1] in Table 5. It can be seen that treatment costs may more than double our current expenditures to meet new Federal standards of zero discharge by 1985. The St. Petersburg plant (treatment B) by using turf for its disposal has been able to reduce the costs involved.

TABLE 2

Range of Concentration of Metals in Wastewater

	Conc. Range mg/L		Rcm'd. Drinking Water Std's. mg/L
Metal	**Cal[1]**	**Mich[2]**	
Cadmium	< 0.005-0.22	< 0.008-0.142	0.01
Chromium	——	< 0.02-0.70	0.05
Copper	< 0.006-0.053	< 0.02-3.36	1.00
Mercury	0.0002-0.001	< 0.0002-0.044	0.002
Nickel	0.003-0.60	< 0.002-880	no std.
Lead	0.003-0.35	< 0.050-1.27	0.05
Zinc	0.004-0.35	< 0.03-8.31	5.0

[1] After Chang and Page. 1977.
[2] After Cohen. 1977.

TABLE 5

Relative Sewage Treatment Costs

	Level	¢/1000 Gal (5-10MGD Plant)
	Raw Sewage	—
A.	Secondary & chlorination	20
B.	"A" + filtration + flash chlorination	30
C.	"A" + N removal to < 10 ppm N	30
D.	"A" + filtration + P removal to < 1 ppm	40
E.	"D" + N removal to Grizzle-Wilson Std.	47

After Baldwin. 1975.

Turf is a natural for sewage effluent disposal for the following reasons:

1. Use of nutrient constituents, primarily nitrogen and phosphorus, on an annual per unit area basis is high and should minimize groundwater contamination by these elements. This is especially true in Florida where we have a year-round growing season — thus we have year-round utilization;
2. Turf is perennial. Use continuity is year-round and not interrupted by cultivation, seeding, or harvesting operations that are common to other forms of agriculture;
3. Turf has a high water requirement throughout the growing season;
4. The use is in close proximity to the source thereby minimizing transmission expenses.

The economic savings on the fertilizer value alone from sewage effluent are presented in Table 6.

Certainly sewage effluent is not going to solve all of our nutrient and water requirements — in fact it undoubtedly will cause other unknown problems, but it is a resource which at this state of the art bears serious consideration for utilization on turf facilities.

Currently our turf research program is involved in one aspect of sewage effluent utilization for turf purposes. This work is supported in part by the American Society of Golf Course Architects Foundation through the United States Golf Association Green Section Research and Education Fund, Inc. Our concern relates to the heavy metal content of effluent and, although found in relatively small amounts, what their ultimate effects might be on bermudagrass and St. Augustinegrass.

Our first effort was to contact those people who are currently using effluent for turf purposes in Florida. Apparently because of the psychological concerns of the public over the use of effluent, and because of the present as well as future legal restrictions, no one would admit he was using effluent. After many phone calls, letters, and personal visits, we were able to contact a few people who were willing to cooperate. We are currently working with them.

TABLE 4

Treated Sewage Effluent Disposal Alternatives
Yes — Probably Acceptable

	Level of Treatment	Inland Waters	Estuaries and Bays	Gulf of Mexico	Deep Wells Inland	Deep Wells Coastal	Deep Ocean	Percolation Ponds	Parks and Golf Courses	Hay and Other Forage Crops	Fruits and Vegetables
A.	Secondary Plus Chlorination	No	No	No	No	Yes	Yes	No	Yes[1]	Yes	No
B.	Secondary Plus Filtration Plus Flash Chlorination	No	No	No	No	Yes	Yes	No	Yes[2]	Yes	No[3]
C.	"A" Plus N Removal To <10 ppm	No	No	No	Yes	Yes	Yes	Yes	Yes[1]	Yes	No
D.	"A" Plus Filtration Plus P. Removal To < 1 ppm	No	No	No	No	Yes	Yes	No	Yes[2]	Yes	No[3]
E.	"D" Plus N Removal P < 1 ppm N < 3 ppm SS < 3 ppm	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes[2]	Yes	Yes[3]

1. Where access would be restricted following irrigation.
2. Assuming virus free effluent.
3. Presently unacceptable. Certain crops, such as citrus, may utilize virus free effluent under a strict monitoring program.

After Baldwin. Personal Communication. 1975.

Our field work involves gathering samples of the effluent currently being used. In those cases where it has been utilized for a long period, detailed soil samples have been gathered, along with plant tissue samples. The soil and plant analyses are incomplete at this time, but the effluent analyses are summarized in Table 7. In all cases, the concentration of the five metals we are studying was well below the recommended drinking water standards. Note especially in Table 7 most effluent samples were taken directly from the sewage treatment plant. We do not anticipate phytotoxicity problems from the continued utilization of these sewage effluents.

Miss Cindi Donoho is responsible for the conduct of this study. Cindi is currently attempting to establish phytotoxic levels of cadmium, lead, zinc, copper, and nickel on bermudagrass and St. Augustinegrass. We anxiously await her results so that sound judgments can be made on the future use of sewage effluent of varying quality for turf purposes. My current feelings are that sewage effluent is a tremendously valuable resource and should be utilized to its fullest.

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TABLE 6

Value of Nutrients Applied with Typical Secondary Sewage Effluent at 1 Million Gallons/Day for 1 Year

Nutrient	Amount in* Effluent ppm	Amount in 1 Million Gallons Pounds	Applied in 1 Year Pounds	Unit Value (Applied) $/#	Value Per Year $
N	30	250	91,250	19¢	17,338
P	10	83	30,295	7¢	2,120
K	6	50	18,250	75¢	1,369
Ca	32	267	97,455	2¢	1,949
					TOTAL 22,776

*These concentrations are variable from different treatment plants.

TABLE 7

Heavy Metal Content of Florida Effluent Direct from Treatment Plants and Currently Utilized for Turf Irrigation

		Parts Per Billion				
Source	Range	Cd	Cu	Ni	Pb	Zn
Treat. Plants	L	.05	1.5	.5	.5	10
(10)	H	40.00	6.0	25.0	2.0	70
Golf course (6)	L	.05	1.5	ND	ND	5
Not diluted	H	.15	18.5	1.0	6.0	350
Golf course (5)	L	.50	1.0	ND	1.5	3
Diluted	H	3.00	150.0	.5	8.0	61

ND = Not detectable