Wastewater Reuse for Irrigation : an Acceptable Soil Conditioner?

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Abstract:

Drought climatic conditions occurring around the Mediterranean region and the Balkans, suggest serious consideration as to the reuse of treated effluents resulting from treatment of domestic effluents. Taking into account that about 70% of the total water resources are used for agricultural purposes and mainly irrigation, then a tremendous conservation of hydrological resources can occur. Using however non-conventional quality water for irrigation, presents a number of ecological and health risks and poses problems connected with soil and ground water contamination. This paper concentrates in the general evaluation of the effects of these effluents on soils, and investigates and evaluates their effects in terms of organic matter enrichment and soil conditioning

Keywords: *treated sewage; wastewater; salinity, soil fertility, humus*

Introduction:

Fresh water is our most precious natural resource. With many countries facing severe water shortages, reusing water for irrigation and industrial purposes is becoming more favourable. Te amount of water needed to irrigate farm crops, golf courses, and other landscape usually exceed 70 percent of the drinking water we use.
When recycled water is used for irrigation, more of our natural supply of drinking water will be available for domestic use.
In planning and implementation of water reclamation and reuse, the intended water reuse application dictate the level of wastewater treatment required, the quality of the finished water and the method of distribution and application.

Cyprus with a total surface area of 9250 Km^2 due to its semiarid climate faces a problem of inadequacy of water for both its domestic and irrigation needs.

The mean annual rainfall over the island is 500 mm which corresponds to 4600 million cubic meters of water over its total area.

Due to the aridity of the region a proportion of about 80% of the rainfall returns to the atmosphere as loss by evaporation and evapotranspiration.

If a balance is carried out of the water resources of Cyprus then in the incoming, one may include the mean annual crop of 900 million cubic meters which can be analysed into 67% surface runoff and 33% groundwater whilst in the outgoing, one may include 37% of losses in the sea, 30% pump age and flow from springs, 21% mean annual yield of the dams and 17% as diversions for spade irrigation from the streams[3].

In Cyprus there are no permanent surface water streams or lakes but until some years ago, underground water resources were adequate to meet the local water demand.
However overexploitation of the underground water leads to a gradual decrease of groundwater resources.

The reuse of sewage effluents however should be seriously considered as an important strategy in conserving water resources.

Experimenting with reusing wastewater:

Soil samples were taken from an area which was irrigated with treated effluent for about eleven years. Other plots in this area were also irrigated with fresh groundwater obtained from nearby wells.

Samples were taken from both irrigation plots at intervals of 10cm to a depth of 1.20 m.

The location selected was in Aglandja area, the farm of the Agricultural Research Institute.

The soil in this area is characterised as Saltic Fluvisols, and its content was homogeneous throughout all profile.

The clay content varied from 20.2 to 22.4 % with high sand content.

We can therefore define it as sandy-clay loam. They are poor in organic matter content 1% but rich in general Carbonate (CO_3), 16-19%.

Therefore their pH is high 8.92-9.87 which shows alkalinity characteristics.

In these soils only crops with high pH tolerance can grow.

As previously mentioned two types of water were used for irrigation.

1. Fresh ground water from a nearby well
2. Treated wastewater

The sewage had domestic origin with no industrial wastes. A secondary type of treatment is carried and treated water is collected at a pond near the investigation site.

Characteristics of ground farm water

The following were the major characteristics of the ground water used:

- high content of soluble elements toxic to agriculture
- electric conductivity = 3.0 mmho/cm
- from the cations predominant is Na^+ = 21.7 mg/l
- from the anions predominant is Cl = 15.5 mg/l

It should be noted that Na_2CO_3 is one of most toxic to crops

Characteristics of treated effluents used

Content similar to fresh ground-water but contains additional elements and salts toxic to crop.

- Electric conductivity = 2.8 mmho/cm
- High in Na^+, Cl, CO_3 and high pH averaging 8.3

Table 1 below shows analysis of Treated Sewage (TS) in terms of cations - anions

Water Type	EC	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	CO_3	SAR
Treated Sewage	2.8	8.3	2.2	5.3	21.2	0.3	14.8	7.3	5.2	0.9	11.0

Table 1. Electrical Conductivity in mmho/cm, and soluble cations-anions of water in meq/l. Average values of treated sewage samples over a ten year period.

General water quality characteristics

It is anticipated that water having been used once for some purpose, can be reused in agriculture. Such effluent may possess undesirable constituents such as salts, trace elements, organic compounds, pathogens and other constituents that may affect soil, crop, public health, and generally the environment [4].

The physical, chemical and biological constituents of wastewaters are important parameters in the design, collection and reuse of treated effluent [3].

In recent guidelines [5], four categories namely salinity, infiltration, toxicity and "miscellaneous problems" are used for evaluating conventional sources of irrigation water. The physical and chemical constituents in treated effluents need careful consideration in order to evaluate or detect possible short or long-term effects on soils and crops from salts, nutrients and trace elements [3].

Constituents of concern in treated sewage are:

a. Suspended Solids, which can develop sludge deposits and consequently anaerobic conditions
b. Biodegradable organics, whose decomposition can lead to the depletion of dissolved oxygen in the receiving waters,
c. Pathogens, bacteria, viruses and parasites which can transmit diseases,
d. Nutrients which include, nitrogen, phosphorous and potassium .They are essential in plant growth, but when discharged in waters, can lead to undesirable growth.
e. Stable (refractory) organics, like phenols, pesticides and chlorinated hydrocarbons. These organics tend to resist conventional methods of wastewater treatment and are toxic to the environment.
f. Hydrogen ion activity or pH affecting solubility and alkalinity of soils.
g. Heavy metals which are basically of no concern to Cyprus as there are no heavy industries, and
h. Dissolve inorganics, like sodium, magnesium calcium and others, which can be damage crop and pose soil permeability problems.

Risk assessment and analyses on organic matter

The criteria listed in Table 2 were applied in the investigation of the risk of the treated sewage intended for irrigation. The results show that at most times the quality of this effluent does not meet the appropriate levels and poses some kind of risk [6].This is interpreted as great care should be taken when using such effluents in order to minimize or eliminated ground or groundwater contamination.

Organic matter or humus in wastewater is formed by decomposing action of soil microorganisms, which break down animal and vegetative matter into elements that can be used by growing plants.

Because of its low specific weight and high surface area, humus has a profound effect upon the physical properties of mineral soils with regard to improved soil structure, water intake and reservoir capacity, ability to resist erosion, and the ability to hold chemical elements in a form readily accessible to plants.

Figure 1 shows the organic matter content at 10cm intervals, up to a depth of 120cm for both samples, one irrigated with farm water and the other irrigated with treated sewage. In both profiles it is evident that organic matter content decreases with depth.

In the profile of soil irrigated with farm water, the average profile content is 0.35 (0.71-0.19) g/cm3 and that of the soil profile irrigated with sewage is 0.44 (0.87-0.14) g/cm3.

By looking at the same figure, and after comparing profiles, it is also evident that the soil sample irrigated with treated sewage at depths up to 60 cm shows a higher organic matter content ranging from 24-40%.

At depths over 60cm, the organic matter content is very similar in both profiles.

If average organic matter values are compared, we can conclude that soil irrigated with treated sewage demonstrates

a profile total organic matter content higher by 21%.. It is however recommended that the amount of organic matter added be compatible with the amount of organic matter estimated to be absorbed by the plants [7].

The aim is to improve soils and at the same time to take care so that no undesirable materials enter the groundwater.

As mentioned before, the decreasing of values of humus after the 60cm depth in both profiles minimizes the risk of groundwater contamination. On the other hand it should be noted that groundwater table in Cyprus is usually at high depths, so its contamination is quite unlikely.

In experiments with wastewater sludge which contains high amounts of organic matter sludge, a 20% of sludge addition to the receiving soil when used as a soil conditioner, showed optimal performance [8]. Soils in Cyprus generally demonstrate high pH values, usually above 10, and present various agricultural problems which are however manageable if proper care is given [9].
Proper care should then be exercised when using treated effluents which when used in combination with high pH soils pose a higher risk factor in the sodic soils of Cyprus.

N	Criteria	Treated Sewage value	Criteria range	Risk Estimation
1	$\frac{Ca+Mg}{Na+0{,}23Ca}$	0.35	>1	Natrium risk YES
2.	$\frac{100(Ca+Mg)}{Na}$	36	>60%	Natrium risk YES
3.	$\frac{100Mg}{Ca+Mg}$	50	<50%	Magnesium risk YES
4.	$\frac{288}{5.Cl}$	4.9	>18	Chloridisation YES
5.	$\frac{288}{Na+4Cl}$	3.9	6-18	Chloridisation YES
6.	$\frac{288}{10Na-5Cl-9SO_4}$	4.35	1.2-6	Chloridisation YES
7.	$\frac{6620}{Na+2.6Cl}$	138	<1.2	Chloridisation YES
8.	$\frac{(Na+K)\,100}{Ca+Mg+Na+K}$	74.33	<66%	Alkalinisation possible
9.	$\frac{Na}{Ca+Mg+Na}$	0.73	<0.6	Alkalinisation possible
10.	$\frac{Na}{Ca+Mg}$	2.74	<0.7	Alkalinisation possible
11.	$\frac{Na+K}{Ca+Mg}$	2.90	<1-No 1-4 - Possible >4 - Sure	Alkalinisation possible
12.	$SAR=\frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$	9.65	<10	Dangerous level
13.	$ESP=\frac{100(0.01475SAR-0.0126)}{1+(0.01475\,SAR-0.0126)}$	13	<5-10%	Irrigation Dangerous

Table 2. Various criteria for the estimation of wastewater risk factors [2]

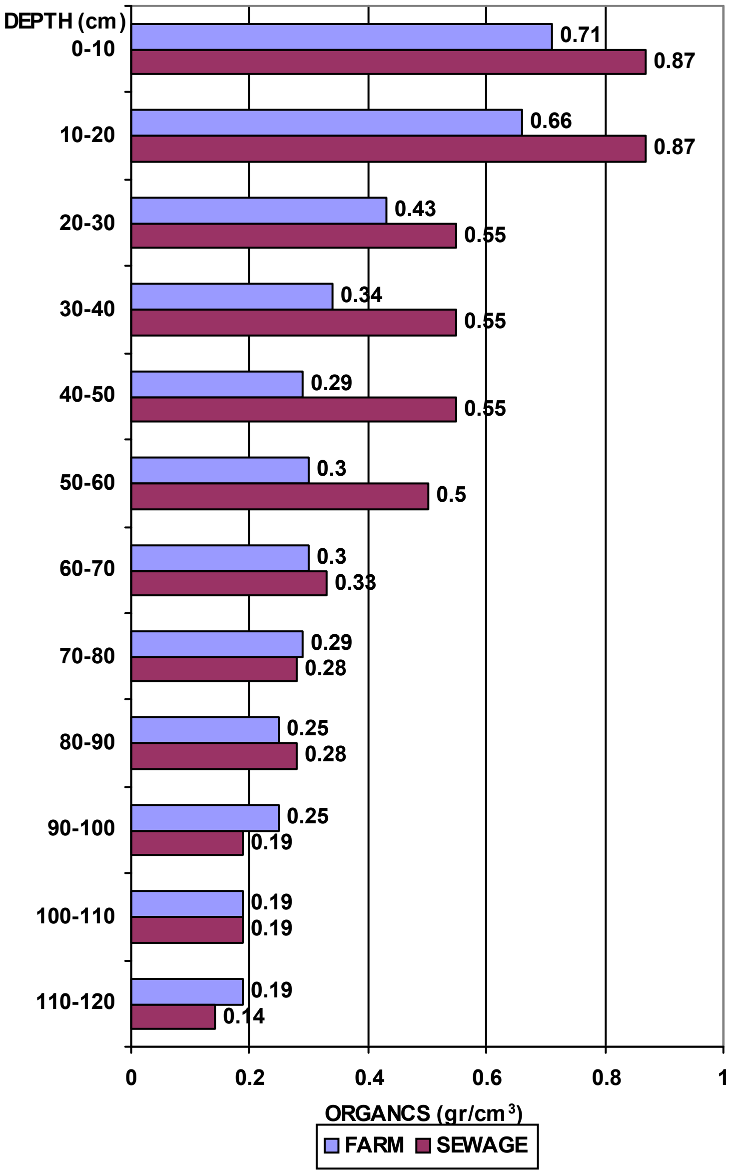

Figure 1 Organic matter content for both soil profiles

Conclusions

It is clear that ingredients contained in treated wastewater may create undesirable effects on soils and groundwater. However, careful management may overcome these effects. Soils in Cyprus are generally of low organic content. It is evident that by using treated wastewater for irrigation, besides the great savings in hydrological resources, the organic content of soils increases by about an average value of 21% of the soil profile. Due to this increase of organic matter; soils demonstrate structural improvement and consequently improvement of soil fertility. Structural improvement improves soils mechanically, and as a result the resistance to erosion is increased. This may be of greater interest in the restoration of disturbed land. Most of the humus that originates from treated sewage irrigation is gathered at the first 60cm of the profile and consequently around the plant root zone, which is highly beneficial to plants.
It is however suggested that all factors should be well considered before planning a wastewater reuse network.

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