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Abstract: - The use for scheduling irrigations and for determining water allotments for landscapes is being adopted by water purveyors, agencies, landscape architects, and maintenance personnel. The needs of the dry and hot areas of the Mediterranean, like Greece, in water and especially irrigation water are huge, while water reservoirs are less each year. Therefore the proper management of processed liquid urban and industrial waste, coming mainly from industries processing agricultural products, provides an additional water supply to the conventional ones, which can be used in urban green open spaces in Greece.

A problem occurring because of irrigation is also soil salinity. To address this problem we can use water from liquid waste processing, thus adding another water supply to our options for irrigating the urban green areas, and reducing the pollution that may occur from channelling this water to various natural receptors.

Key-Words: Liquid Waste, Urban green areas, Irrigation, Salinity, Management practices,

1 Introduction

One of the problems created by development in the modern world is the disposal of urban liquid waste and of liquid waste from industries producing and processing agricultural products. The disposal of liquid waste of this kind played, and still plays, an important role in the pollution of water receptors (rivers, lakes, seas, groundwater) resulting in the downgrading of ecosystems – receptors, the (temporary) contamination of supply and irrigation water, the dissemination of diseases and the creation of unpleasant situations for those living in the proximity or somehow connected to those water receptors.

In order to reduce the adverse impact from the disposal of this kind of waste, as well as to exploit an additional water supply that is very important, at least for the hot and dry areas of the Mediterranean like Greece, emphasis was put on the processing and potential re-use of liquid waste.

Processed liquid waste, when not disposed of in water receptors, can be used in various ways.

Such a way is to manage liquid waste to address salinity problems when irrigating urban green areas.

The first time liquid waste was used for irrigation dates back in ancient Greece and specifically the Minoan civilisation [1] , [2] .

Soil salinity in a urban green area is expressed by a suspension of plant growth along with visible or invisible symptoms on plants. (Figure 1)

Figure 1. *Visible symptoms of high salinity* in maple [3]

Such symptoms are decay of plants, a dark blue-green colour, and occasionally thicker leaves with ceraceous surfaces. Many times symptoms are similar to those caused by lack of water [4].

In most cases salinity levels of processed urban liquid waste ranges between 450 and 2000 mg/l (EC_w= 0,7 to 3,0 dS/m). To prevent the creation of saline soil appropriate waste management practices should be adopted, irrespective of the salt content of waste [5].

The objective of this paper is to highlight the use of various liquid waste management practices for addressing salinity problems. We also wish to highlight the importance of using an alternative water supply for irrigation in urban green areas in Greece.

2 Materials and methods

2.1 Leaching

When there is, or is expected to be, a high content of soluble salts in the soil, those are leached with water in addition to that required for the consumptive use for the current period. This additional quantity of water removes a quantity of salts towards deeper layers.

The additional quantity of water required for leaching salts is expressed by a leaching coefficient (LR) representing the minimum quantity of water, expressed as a fraction of the actual consumptive use, that must be infiltrated deep through the root layer zone in order to keep soil salinity to a prescribed level. The leaching coefficient is calculated with formula (a):

$$LR=EC_w/[5(EC_e)-EC_w]xEl \quad \text{(a)}$$

where EC_w is the electric conductivity of irrigation water in dS/m, EC_e is the desired electric conductivity of the soil saturation extract in dS/m (corresponding to a given cultivation and its desired performance level) and E1 is the leaching efficiency coefficient that ranges between 0,3 – 1 . [6], [7].

Formula (a) applies when irrigation is carried out with surface methods or spraying. In drip irrigation the rinsing coefficient is calculated with formula (b):

$$LR=EC_w/3EC_{50} \quad \text{(b)}$$

where EC_{50} is the electric conductivity of the soil saturation extract in dS/m, corresponding to a 50% performance of the cultivation.

Thus, by using liquid wasted that has been processed and has an appropriate electric conductivity we can use this additional water quantity provided by LR coefficient, in order for salt concentration in the area of the root layer to be within acceptable limits for the normal development of plants in urban green areas.

Also the irrigation manager must be familiar with root depths and soil characteristics such as infiltration rates, textural qualities, and drainage. The following figure 2 illustrate these relationships between plant tolerance, salinity, and irrigation leaching requirements.

Salinity of Irrigation Water (High)	Plant salinity tolerance Based upon Soil Salinity (EC-mmho/cm)		
	<4 (Low)	<8 (Medium)	<10
Multiplication Factor for increase of irrigation over evapo-tranpiration			
<.7(no salinity)	1.0	1.0	1.0
1.0 (low salinity	1.35	1.15	1.1
2.0 (moderate salinity)	2.0	1.6	1.5
3.0 (high salinity	4.0	2.6	2.4

Figure 2. *Irrigation Leaching requirements* Based Upon Water Salinity and Plant Salinity Tolerance [3]

Also to the following figure 3 we can see the tolerance of some plants to the soil salinity. Salinity tolerance in plants is also expressed in mmhos/cm in direct comparison to soil salinity levels. Unfortunately, relatively few ornamental plants have been tested for specific salt tolerance.

High Tolerance (Soil Salinity to 10 mmhos/cm	**Species of plants**
	Bougainvillea sp.
Good Tolerance (Soil Salinity to 8 mmhos/cm	Pinus halepensis
	Euonymus japonica
	Gazzania spp
	Pittosporum crassifolium
Moderate Tolerance (Soil Salinity to 6 mmhos)	Juniperus chinensis
	Elaegnus angustifolia
	Ligustrum sp.
	Thuja orientalis
Poor Tolerance (Soil Salinity to 4 mmhos)	Arbutus unedo
	Viburnum tinus
	Hibiscus siriacus
	Pittosporum tobira
	Vinca minor
	Rhamnus alaternus

	Festuca ovina glauca
Very Poor Tolerance (Soil Salinity to 2 mmhos/cm)	Photinia fraseri
	Mahonia aquifolium
	Rhododendron spp.

Figure 3. *Plants salinity tolerance* in Urban areas [3]

2.2 Drainage

The water used in urban green areas may create problems of secondary salinity, in case of a high water table (Figure 3, 4). In such cases it is necessary to create a drainage network parallel to the irrigation network, especially in hot and dry areas like Greece. The role of the drainage network is to lower the high water table to a desirable level in order not to have salts transferred to the area of the root layer through capillary rise[1].

In case processed liquid wastes are used for irrigating the above areas, one should not fail to mention that constructing a drainage network is necessary, since the average rates of electric conductivity of liquid waste are rather high. Through drainage the risk of salt accumulation in the area of the root layer is avoided resulting in the creation of suitable conditions for plant growth.

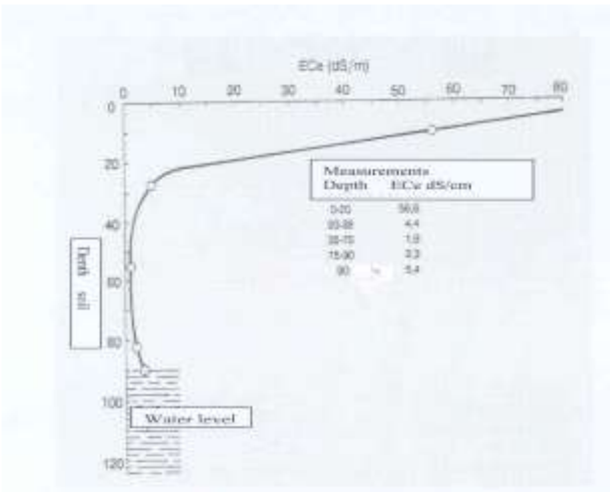

Figure 3. *Salinity profile in the soil profile* when there is a high water table [8]

Figure 4. *Salt crystals on the soil surface.* This soil has an ECe of 4.4 Ds/m.

2.3 Pre irrigation

Another practice that may be used is pre-irrigation, i.e. using water prior to seeding turf or planting urban green areas.

This irrigation type is used in many cases for two reasons: a) to wash away salts from the soil surface, accumulated from previous periods, in order to facilitate the installation of plants, and b) to secure the humidity necessary in order for plants to grow with no problem. Processed liquid waste is a good source of water for pre-irrigation, because salinity at this time is not a problem.

This practice consequently reduces the quantity of salt in the area of the root layer and creates favourable conditions for plants. At the same time we avoid the use of good quality water that could be used later, at the pick season for plant maintenance.

It is also recommended to irrigate before the period of rainfalls, if the total rainfall is usually insufficient for full leaching. Rain is the most effective leaching method because it provides high quality water at a rather slow rate (Figure 5)

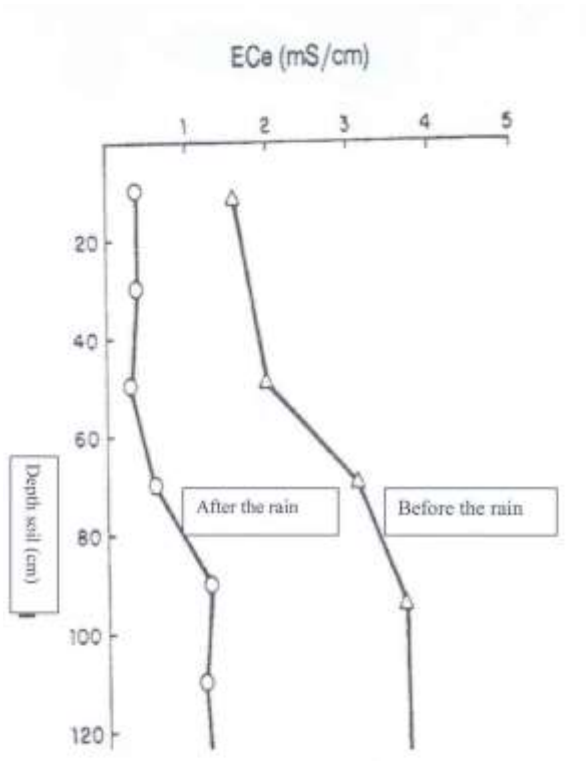

Figure 5. *Soil salinity (Ece) in sand/clay soil* before and after 150 mm of rain [9]

2.4 Mixing with fresh water

Mixing processed liquid waste with conventional water is an option available to the landscape architects for the irrigation needs of urban green areas. If waste has an increased electric conductivity, then it can be mixed with low electric conductivity fresh water to achieve acceptable salinity irrigation water [10], [11], [12]. This technique allows to save large quantities of fresh water, since we use as much fresh water as necessary to have the mix salinity to acceptable levels to use in the above areas. The mix salinity is calculated with formula (c):

$$\{[EC_{WA} \times Q_A / (Q_A + Q_B)] + [EC_{WB} \times Q_B / (Q_A + Q_B)]\} = EC_{W\,mix} \qquad (c)$$

where letters A and B stand for water to be mixed, EC_W is the electric conductivity of water in dS/m and Q are the quantities of water mixed.

2.5 Alteration with other quantities of water

Another practice for re-using processed low quality waste is to use it alternatively with fresh water and not by mixing the two. This practice saves fresh water as we use fresh water and processed liquid waste successively.

With respect to salinity, alteration of water use has better results than mixing [11], [12]. A disadvantage is the need to have a dual network of water supply.

2.6 Changing the Irrigation method

The irrigation method substantially affects the degree of utilization of the water and the concentration of salts in the soil.

In urban green areas drip and spray irrigation methods are mainly used.

Figure 5 shows the distribution of salts in the soil when using drip and spray irrigation.

With spray irrigation water is applied on the whole surface of the soil and moves vertically, thus removing salts from the root zone, provided that satisfactory drainage is available.

With drip irrigation water moves in three directions and salts accumulate at the perimeter of the wet bulb formed under each drip.

2.7 Evaluate water quality standards for landscape use

In addition to salinity, there are a number of chemistry issues that should be evaluated when designing or maintaining a landscape planting using poor quality irrigation water. These issues are divided into three sections. Permeability, specific ion toxicity, and miscellaneous.

Permeability is a measure of the infiltration rate into the soil and is evaluated by the degree the salinity (EC) and sodium absorption rate (SAR) of the water. Unless balance by a sufficient amount of calcium, sodium build up in the soil can prevent water from entering the soil. SAR is a measure of this calcium / sodium relationship.

Specific ion toxicity refers to the problem that occurs when ions accumulate in plants and results in damage. The most common toxicity problems are due to ion concentrations of sodium chloride and boron. Problems with these chemicals can occur from high soil concentrations, or be the result of sprinkler irrigation when the ion is absorbed directly through the leaf.

Miscellaneous issues include levels of nitrogen, clogging, pH, and residual chlorine. Nitrogen levels should be known as this will affect fertilization requirements. Clogging of drip and sprinkler systems can occur due to algae or slime growths, as well as high concentrations of suspended solids. PH or the degree of acidity or alkalinity of water, acts, as indicator of other serious chemical problems when it falls outside a normal range. Residual chlorine becomes a problem when it is present during overhead sprinkling of foliage. The following figure 6 shows the degree of restriction on use for these various issues.

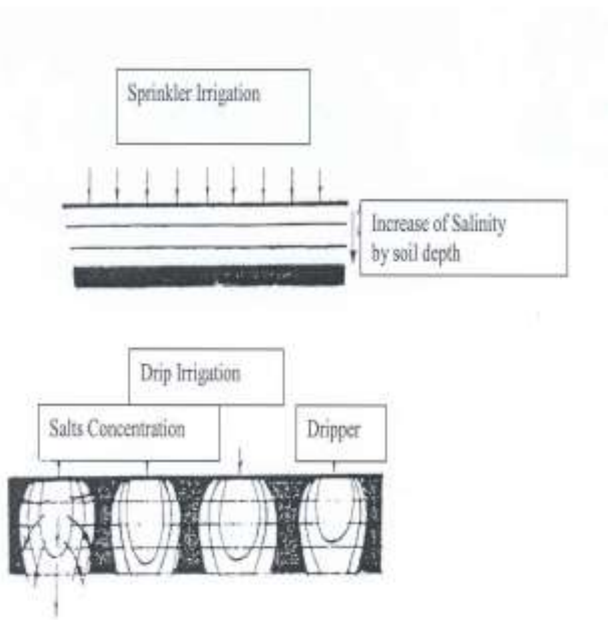

Figure 5. Concentration of salts in the soil *depending on the irrigation method* [10] .

Potential Irrigation Problem		Units	Degree of Restriction on Use: None	Slight to Moderate	Severe
Salinity	Ecw TDS	dS/m or mmho/cm mg/L	<0.7 <450	0.7-3.0 450-2000	>3.0 >2000
Permeability (SAR and ECw evaluated together)	SAR=0-3 3-6 6-12 12-20 20-40	ECw=	>0.7 >1.2 >1.9 >2.9 >5.0	0.7-0.2 1.2-0.3 1.9-0.5 2.9-1.3 5.0-2.9	<0.2 <0.3 <0.5 <1.3 <2.9
Specific Ion Toxicity	Sodium Surface irrigation Sprinkler irrigation Chloride Surface irrigation Sprinkler irrigation Boron	SAR mg/L mg/L mg/L mg/L	<3 <70 <140 <100 <0.7	3-9 >70 140-350 >100 0.7-0.3	>9 >350 >3.0
Miscellaneous Effects	Nitrogen Bicarbonate Residual Chlorine	mg/L mg/L mg/L	<5 <90 <1.0	5-30 90-500 1.0-5.0	>30 >500 >5.0

Figure 6. Degree of restriction of Permeability, specific ion toxicity, and miscellaneous [3]

3 Conclusions

The soil salinity problem can be addressed by using water originating from the processing of liquid waste. The application of the above three methods removes excess salts from the area of the root layer.

Depending on the electric conductivity of the water resulting from the processing of liquid waste the respective method is applied. In this way, we secure an additional water supply. We also save good quality water to be used later during maintenance in the pick summer period.

The methods of mixing with fresh water and alteration with other quantities of water are used mainly when the water resulting from processing has a rather high electric conductivity.

The method of pre-irrigation can also use water with high electric conductivity since the installation of plants in urban green areas is carried out at a later stage.

The water used for the methods of leaching and drainage should better have a low electric conductivity than in previous methods in order to prevent worsening the salinity problem.

Landscape designers must evaluate all aspects of water quality when considering the use of waste water as a source of irrigation in order to estimates water needs for acceptable aesthetic appearance of ornamental plant [13]. Special design considerations include type of irrigation system, soil characteristics, and specific plant tolerance.

Irrigation managers should regularly evaluate water quality to determine suitability of use. Sprinkler irrigation at night preferable to help avoid high ion concentrations on foliage. When sodium is consistently a problem, then special procedures such as the regular use of gypsum added to the water or incorporated into the soil may be necessary to correct permeability problems.

Drip irrigation systems and small orifice sprinklers may be subject to clogging. Remedies include filtration of water to remove algae or other solid material.

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