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WASTEWATER REUSE FOR IRRIGATION. SALINITY ISSUES ON COASTAL CITIES

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Abstract

The continuous global population growth increases the demand for water which, in arid and semi arid regions like the Mediterranean and the Balkans is considered as a limited resource. Future demands will not be met by traditional water resources like surface and ground water. In order therefore to handle increased water demand, the treated wastewater originating from municipal wastewater treatment plants has to be developed and offered to farmers for agricultural irrigation.

Since public health is an important aspect in wastewater reuse, this study was carried in order to investigate the difficulties resulting from the degraded quality of treated sewage on humans and the environment as well its public acceptance.

Its effects on soils were investigated by investigating wastewater-irrigated areas in terms of profile investigations and comparing the results to similar profiles irrigated with groundwater. Treated wastewater qualities were also investigated by carrying a complete risk assessment. Public acceptance faces serious problems and therefore its real effects on humans and plants were examined with emphasis on known research in Cyprus. Salinity is a major wastewater reuse problem, especially in coastal cities like Larnaca in Cyprus, and is investigated. Results suggest that problems could become very serious if corrective measures are not taken. Proper salinity management methods are suggested.

Keywords: wastewater, wastewater reuse, salinity, SAR, irrigation.

INTRODUCTION

Cyprus is located at the east Mediterranean, 75 km south of Turkey, 105 km west of Syria, 380 km north of Egypt, 380 km east of Rhodes (Greece). Cyprus is the third largest island in the Mediterranean with a population of 700,000. It is dominated in its topography by two mountain ranges, the Troodos range in the central part of the island, rising to a height of 1,952 m and the Pentadaktylos range in the north of the island, rising to a height of 1,085 m. Cyprus has a typical Mediterranean climate with mild winters, long hot, dry summers and short autumn and spring seasons. The average annual rainfall is about 500 mm and ranges from 300 mm in the central plain and the south-eastern parts of the island up to 1,100 mm at the top of the Troodos range and 550 mm at the top of Pentadaktylos. The variation in rainfall is not only regional but annual and often two and even three-year consecutive droughts are observed.

With many countries facing severe water shortages, reusing water for irrigation and industrial purposes is becoming more favourable [1, 2, 3].

In planning and implementation of water reclamation and reuse, the intended water reuse application dictates the extend 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 Km2 due to its semiarid climate faces a problem of inadequacy of water for both its domestic and irrigation needs.

Since the mean annual rainfall over the island is 500 mm ,4600 million cubic meters of water fall 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 analyzed into 67% surface runoff and 33% groundwater, whilst in the outgoing, one may include 37% of losses in the sea, 30% pumpage and flow from springs, 21% mean annual yield of the dams and 17% as diversions for spade irrigation from the streams.

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

WASTEWATER REUSE PERSPECTIVES AND STANDARDS

Currently 25 wastewater treatment stations are in operation which are producing about 20MCM/yr. Treated wastewater is being used for watering of football fields, parks, and hotel gardens totalling to 1.5 MCM/yr, and 3.5 MCM/yr of treated sewage is used for crop irrigation.

It is estimated that by the year 2012 an amount around 30MCM/yr of treated wastewater will be available for landscape agriculture and crop irrigation.

WATER QUALITY CRITERIA FOR IRRIGATION

Current water quality criteria were developed in the era of abundant fresh water supplies. The objectives were simple criteria that would avoid problems under most conditions. These criteria currently reject waters that in *some* instances can be detrimental. Often the criteria have been developed into regulatory standards, further restricting use of low quality waters. In many instances use of recycled and brackish water, currently considered unsuitable, can result in some reduction in potential yield. Nonetheless, this can be acceptable and still desirable if the absolute yield is considered in the context of society needs and grower profitability. This may require incentives for the farmers to exchange fresh water for saline and degraded waters, or to compensate for needed amendments. The criteria do not consider that in many regions, the crop water requirements can be met by a combination of rain, fresh water and saline water, thereby diminishing the predicted salinity impact when considering the saline water. The criteria also do not consider that in Mediterranean climates winter rain leaches the soil. Thus, salinity is low in the early stages of plant growth which are often the most salt sensitive, suggesting that the criteria overestimate salt damage. Use of degraded waters may either reduce yield or cause additional management expenses. Treated wastewaters have elevated pH, alkalinity, and sodium, relatively low Ca/Mg ratios, high concentrations of dissolved organic matter, all adverse to infiltration and soil structure, as well as ion imbalances and elevated concentrations of potentially toxic elements. Use of these waters may require periodic application of amendments and/or leaching, utilizing new knowledge about factors affecting infiltration and crop production. Environmental concerns about recycled water include plant uptake of toxic elements, pharmaceuticals, endocrine disrupters etc. as well as off-site impacts to discharge areas.

Water suitability for irrigation and sodicity hazard related to infiltration has been established primarily from laboratory experiments, These are almost all based on packing sieved and ground soil into columns for short term experiments of saturated hydraulic conductivity with waters of decreasing electrical conductivity (EC) and constant sodium adsorption ratio (SAR) [6]. As mentioned above, rain is an important factor in the soil water budget of most irrigated areas and it impacts the soil chemical and physical conditions.

Rain has an adverse impact related to the SAR of the soil water at the time of infiltration. Contrary to results from column studies, there were little differences in the infiltration results from the two salinity levels. Studies conclude that when considering rain as well as irrigation water, there is no threshold SAR value at which there is a reduction in soil infiltration. Any increase in SAR above the control results in a reduction in infiltration (Suarez et al. 2006, Suarez et al. 2008).

Similar results, but with less infiltration rate loss, has been observed under experiments with irrigation only (Suarez and Gonzalez in preparation). Long term changes in infiltration are also greater than the changes observed in short term laboratory column studies (Suarez et al., 2008). These results indicate a need to modify the Ayers and Westcot (1985) guidelines. The impact of decreasing infiltration depends on site-specific conditions. For example for sandy soils a 20% reduction in infiltration over the course of a year is not significant but for a clay soil with limited infiltration, the impact could result in a corresponding reduction in water availability and crop yield.

In addition to EC and SAR there are other important factors that impact water suitability related to infiltration. Elevated pH adversely impacts saturated hydraulic conductivity in column studies conducted at constant EC and SAR (Suarez et. al. 1984), as well as infiltration measured in outdoor plots [4]. Soils also differ in terms of their susceptibility to SAR, related to clay type, organic matter content, oxide content, among other factors. Climatic conditions (ET0), crop water demands, irrigation system, tillage and other management practices also impact the adverse effect of sodium on infiltration. Degraded waters generally contain increased levels of alkalinity (thus elevated pH) and often contain elevated concentrations of minor elements such as boron that may adversely affect crop growth. In many instances use of these waters may be judged unsuitable based on steady state considerations however transient conditions suggest conditions under which they may be used. Examples are given for model simulations using high boron waters for irrigation and suggestions for optimal management.

Treated wastewater values from ion analysis of the Larnaca wastewater treatment plant are shown in Table 1. These are presented as this paper concentrates on salinity issues like the effect of low quality waters on soils and their management.

The higher salinity values of this treated effluent is attributed to seawater intrusion into the sewers, rather than salinity in the initial fresh water, which is provided after desalinization and mixing with fresh groundwater.

SOLUTIONS & RECOMMENDATIONS

Soil salinity can now be actively monitored at the field scale. Remote sensing technology can be used to provide rapid and inexpensive detailed field salinity assessments and site specific management including evaluation of the need for amendments [6]. Using this technology in combination with modelling allows for site specific leaching and reclamation within a field. Reduction in the use of amendments and leaching water for sodic soil or saline soil reclamation can be achieved by blocking the fields into different gypsum requirement zones, based on variations in clay content and SAR. These technologies have already been commercialized using air imagery. Current amendment requirements to lower the soil exchangeable Na levels do not consider the significant calcium inputs from dissolution of calcite, thus overestimating gypsum requirements. This reduction in salt loading can be especially important if reclamation occurs in combination with high soil carbon dioxide.

Salt tolerance tables can be used to recommend suitable crops based on irrigation water salinity and avoidance of yield loss. Because salt tolerant crops are generally lower value crops, and often lower yielding crops, they should not be automatically recommended for saline conditions.

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.

Results suggest that problems detected are manageable and may be handled with proper techniques. Drop irrigation minimizes problems due to salinity [5]. Complete and continuous education of farmers seems to help in the acceptance of this valuable resource.

Table 1. *Treated wastewater analysis from the Larnaca wastewater treatment plant- together with comments based on FAO specifications [10]*

Indicators	Dimension		Restrictions on Use
Electrical Conductivity (salinity of the applied irrigation water), EC_w	mS/cm	3.75	**Severe Restriction on Use** (2 conservative limit) Yield potential: Corn (maize) ~78%; ~Alfalfa 70% (Acceptable for tolerant and semi-tolerant crops)
Total Hardness	$mgeqv/dm^3$	808	**Very High !!!**
Sulphate ($SO4^{--}$)	mg/dm^3	928	**High concentration!** (300 conservative limit).
Carbonate (CO_3^{--})	mg/dm^3	<6	OK
Bicarbonate (HCO_3^-) ***(overhead sprinkling only)***	mg/dm^3	296	OK (300 conservative limit) Severe Restriction on Use (foliar injury)
Sodium (Na^+)	mg/dm^3	550	**High concentration! Maize sensitive**; Alfalfa tolerant (foliar injury) (300 conservative limit).
Potassium (K^+)	mg/dm^3	29	OK!
Calcium (Ca^{++})	mg/dm^3	174	OK!
Magnesium (Mg^{++})	mg/dm^3	89	OK!
Iron (Fe)	mg/dm^3	<0.05	OK!
Manganese (Mn)	mg/dm^3	0.13	OK
Lead (Pb)	mg/dm^3	<0.1	**High concentration!** Can inhibit plant cell growth at very high concentrations (0.05 conservative limit).
Cadmium (Cd)	mg/dm^3	<0.025	**High concentration!** Conservative limits (0.01) recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans (0.01 conservative limit).
Mercury (Hg)	mg/dm^3	0.003	**High concentration!** 0.001 recommended conservative limit (0.001 conservative limit).

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