Annex 8

Public Health Concern of Using Treated Wastewater

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Reuse of treated wastewater for agriculture use are very close related to the public health concern, either to the farmers, the consumers, as well as the indirect contact i.e. the family, neighboring area, etc. Although, as mentioned at the groundwater analysis section, the recovered water will not contain bacteria that can affect the public health, as the water will be self-cleansed by the infiltration, however, this annex explain the public health concern of using treated wastewater as well as the parameters has to be taken into consideration for reuse purpose of treated wastewater for agriculture.

The recovered water in this study is considered as a groundwater which already has both wastewater treatment and Self Aquifer Treatment (SAT) which accordingly will have minimum impact on the public concern. As it is confirmed from the groundwater water quality measurement result as well as groundwater modeling, the public health in this regard has less significant impact for reuse purpose. However, public health concern of using treated wastewater, including the standard and guidelines and the epidemiological concern were assessed during the preparation of the SESIA.

The standards and guidelines used in this assessment, beside the Palestinian standard for wastewater reuse for agriculture is mainly Egyptian standard in comparison with Israeli and FAO and WHO standards and guidelines.

1. Parameters of Importance in Agricultural Use of Marginal Quality Water

1.1. Parameters of Health Significance

1.1.1. Microbiological Parameters

Pathogenic organisms give rise to the greatest health concern in agricultural use of marginal quality water. The major source of water contamination with or effective on-site disposal has led to widespread contamination of drainage channels, particularly in those areas where piped water is available through house connections. The situation is especially critical in the area where high population densities, impervious soils and high ground water table make the application of low cost on-site sanitation options difficult.

The major pathways of pathogens are to groundwater, internal or external contamination of crops and translocation to grazing animals.The risk of groundwater contamination by pathogens involves movement of bacteria or viruses to aquifers that are then used for drinking purposes without further treatment.

Concerns with respect to crop-contamination focus mainly on surface contamination and then persistence of pathogens until consumed by man or animals or the internal infection of the plant via the roots.The survival of pathogenic organisms in soil or on crops is highly variable and depends on many factors such as moisture, shade, ambient temperature and the organic content of the immediate environment as summarized in Table 1.

Table 1 Survival of excreted pathogens (at 20-30°C)

Type of pathogen	Survival times in days			
	In feces, night soil and sludge	In fresh water and sewage	In the soil	On crops
Viruses				
Enteroviruses	<100 (<20)	<120 (<50)	<100 (<20)	<60 (<15)*
Bacteria				
Faecal Coliforms	<90 (<50)	<60 (<30)	<70 (<20)	<30 (<15)
Salmonella spp.	<60 (<30)	<60 (<30)	<70 (<20)	<30 (<15)
Shigella spp.	<30 (<10)	<30 (<10)	-	<10 (<5)
Vibrio cholerae	<30 (<5)	<30 (<10)	<20 (<10)	< 5 (<2)
Protozoa	<30 (<15)	<30 (<15)	<20 (<10)	<10 (< 2)
Entamoebahistolytica cysts	<30 (<15)	<30 (<15)	<20 (<10)	<10 (< 2)
Helminths	Many	Many	Many	<60 (<30)
Ascarislunbricoides eggs	Months	Months	Months	

*** Figures in brackets show the usual survival time.**
Source: Feachem et al. (1983)

Under favorable conditions, viruses may survive for several months in soil and perhaps 2 or 3 weeks on crops (WHO, 1989). Pathogenic protozoa are less persistent in the environment where survival beyond 2 weeks is unusual. These organisms are particularly sensitive to elevated temperatures (Feachem et al, 1938). Fecal bacteria generally have limited survival expectancy in water but may persist in most organic rich soils for months. (WHO, 1981)

On crops, the limited availability of water and effects of the ultra violet component of sunlight rapidly reduces the number of viable bacteria. Helminth ova represent probably the most serious problem since their prolonged survival within the environment is well documented. The most persistent are Ascarisova which may survive for a year or more in moist organic environments (Feachem et al, 1978).

It is also known that many viruses and bacteria that are pathogenic to man are more infectious when inhaled than when ingested (WHO, 1989). This led to concern with regard to aerosol transfer of disease where sewage effluents were employed in spray irrigation. Research sponsored by the USEPA which measured the aerosol transfer of viruses and bacteria around an activated sludge wastewater treatment plant, found that the zone of influence is limited to 250 meters in that case. Other research has come up with a distance of 1.2 km (WHO 1973). Nevertheless it is now commonly accepted that spray irrigation with biologically contaminated water should be prohibited in order to minimize the threat of disease transmission by this route .In general, the health impact of pathogens in irrigation water has been ranked in the order of priority shown in Table 2. (Shuval et al. 1986).

Table 2 Relative Health Impact of Pathogenic Agents

High Risk (high incidence of excess infection)	Helminthes(*Ancylostoma*, *Ascaris*, *Trichuris* and *Taenia*)
Medium Risk (low incidence of excess infection)	Enteric Bacteria *(Cholera vibrio, Salmonella typhosa, Shigella* and possibly others)
Low Risk (low incidence of excess infection)	Enteric viruses

The following microbiological parameters are particularly important from the health point of view:

1.1.2. Indicator Organisms

Coliforms and Faecal Coliforms

The Coliform group of bacteria comprises mainly species of the genera *Citrobacter, Enterobacter, Escherichia* and *Klebsiella* and includes Faecal Coliforms, of which *Escherichia coli* is the predominant species. Several of the Coliforms are able to grow outside of the intestine, especially in hot climates; hence their enumeration is unsuitable as a parameter for monitoring wastewater reuse systems. The Faecal Coliform test may also include some non-fecal organisms which can grow at 44°C, so the *E. coli* count is the most satisfactory indicator parameter for marginal quality water use in agriculture.

Faecal Streptococci

This group of organisms includes species mainly associated with animals *(Streptococcus bovis* and *S. equinus),* other species with a wider distribution (e.g. *S.faecalis* and *S. faecium,* which occur both in man and in other animals) as well as two biotypes *(S. faecalisvarliquefaciens* and an a typical *S. faecalis* that hydrolyzes starch) which appear to be ubiquitous, occurring in both polluted and non-polluted environments. The enumeration of Faecal Streptococci in effluents is a simple routine procedure but has the following limitations: the possible presence of the non-faecal biotypes as part of the natural microflora on crops may detract from their utility in assessing the bacterial quality of wastewater irrigated crops; and the poorer survival of Faecal Streptococci at high than at low temperatures. Further studies are still warranted on the use of Faecal Streptococci as an indicator in tropical conditions and especially to compare survival with that of Salmonellae.

Clostridium perfringens

This bacterium is an exclusively faecal spore-forming anaerobe normally used to detect intermittent or previous pollution of water, due to the prolonged survival of its spores. Although this extended survival is usually considered to be a disadvantage for normal purposes, it may prove to be very useful in wastewater reuse studies, as *Clostridium perfringens* may be found to have survival characteristics similar to those of viruses or even helminth eggs.

Pathogens

The following pathogenic parameters can only be considered if suitable laboratory facilities and suitably trained staff are available

a. *Salmonella* spp. Several species of *Salmonellae* may be present in raw sewage from an urban community in a tropical developing country, including *S.typhi* (causative agent for typhoid) and many others. It is estimated (Doran et al. 1977) that a count of 7000 *Salmonellae*/litre is typical in a tropical urban sewage with similar numbers of Shigellae, and perhaps 1000 *Vibrio cholera*/litre.BothShigellasppand V. *cholera* are more rapidly killed in the environment, so if removal of *Salmonellae* can be achieved, then the majority of other bacterial pathogens will also have been removed.

b. *Enteroviruses.* May give rise to severe diseases, such as Poliomyelitis and Meningitis, or to a range of minor illnesses such as respiratory infections. Although there is no strong epidemiological evidence for the spread of these diseases via sewage irrigation systems, there is some risk and it is desirable to know to what extent viruses are removed by existing and new treatment processes, especially under tropical conditions. Virus counts can only be undertaken in a dedicated laboratory, as the cell culture techniques required are very susceptible to bacterial and fungal contamination.

c. *Rotaviruses.* These viruses are known to cause gastro-intestinal problems and, though usually present in lower numbers than *enteroviruses* in sewage, they are known to be more persistent, so it is necessary to establish their survival characteristics relative to *enteroviruses* and relative to the indicator organisms in wastewaters. It has been claimed that the removal of viruses in wastewater treatment occurs in parallel with the removal of suspended solids, as most virus particles are solids-associated. Hence, the measurement of suspended solids in treated effluents should be carried out as a matter of routine.

d. *Intestinal Nematodes.*It is known that nematode infections, in particular from the roundworm *Ascarislumbricoides,* can be spread by effluent reuse practices.

1.1.3. Chemical Pollutants

Until recently, concerns about the quality of water used for irrigation have focused largely on salinity (Environment Council of Alberta, 1982). In addition, concern over the potential impacts of specific variables such as selenium, boron, chloride, and a number of metals and other trace ions (which may originate in irrigation waters) on agricultural crops has resulted in the development of irrigation water guidelines for these elements by the Saskatchewan Water Corporation (1988). The potential health and environmental effects of pesticides, industrial pollutants, and other environmental contaminants in irrigation waters, have not been adequately addressed.

The potential impact of organic contaminants such as pesticides is of obvious immediate concern to the farmers (and the consumers) since the use and re-use of irrigation water containing pesticide residues may adversely affect sensitive crop species. For those contaminants that are persistent and do not degrade (e.g., heavy metals), concentrations causing adverse effects to crops may be reached due to accumulation in the soil environment. Since It is impractical to include chemicals of every body's choice and to establish maximum permissible levels for hundreds of organic chemicals that could sometimes be present in marginal quality water only in minute quantities, the WHO (1995) selected substances that appeared frequently in irrigation water (Table 4A.18). Many of these chemicals are of industrial origin. Since partially treated and untreated wastewater are frequently discharged into agricultural drains they have to be considered in the development of the guidelines.

Table 3 Chemicals Frequently Suggested for Regulations

Inorganic Substance	Organic Compound	
As	Aldrin	Hexachloroethane
Ba	Benzene	Pyrenes
Be	Benzo(a) pytene	Lindane
Cd	Carbon Tetrachloride	Methoxychlor
Cr	Chlorodane	Pentachlorophenol
Cyanide	Chlorobenzene	PCBs
F	Chloroform (THMs)	Tetrachloroethane
Pb	Dichlorodethanes	Tetrachloroethylene
Hg	Dichlorophenols	Toluene
Ni	2,4-D	Toxaphene
Se	Dieldrin	2,4,5-T
Ag	Heptachlor	Trichloroethane
	Hexachlorobenzene	Trichlorophenol

1.1.4. Heavy Metals Fate and Transport

Understanding the distribution of toxic metals in aquatic ecosystems is important to the assessment of environmental and human health risks from irrigation water.

It is important to know whether the trace metals are (i) in solution or adsorbed on solids; (ii) in organo-metallic or hydroxide forms; or (iii) in the crystal structure of suspended materials. Without such precise distribution data, techniques for removing and development of guidelines for these harmful elements cannot be designed effectively.

Particulate matter has been recognized to be the major means of transport of metals through aquatic ecosystems and one of the major pathways of pollutants to biota. It has been indicated that the highest concentrations (mg/kg metal in solid) occur in the colloids and, the lowest in the dissolved solids. The metal content of coarse particles occupies an intermediate position, with the dissolved material having a lower concentration. Except for iron and manganese, the metals are about 2 to 10 time more enriched in the course particles relative to the dissolved solids. The capacity of minerals to hold dissolved metals is different for each type of clay mineral. For example the cation exchange capacity (determined by the number of negatively charged sites on clay mineral surfaces) ranges from a few milli equivalents per hundred grams (me/100g) of mineral for kaolinite clay to more than 100 me/100g for montmorillonite clay. Typical estuaries sediments, which are mixtures of clay, silt and sand minerals, have exchange capacities ranging from 15 to 60 me/100g (Krone, 1963).

The various chemical and biochemical transformations that metals may undergo in the aquatic environment deserve attention. Chemical changes may affect their biological availability or toxicity, which may be either enhanced or reduced. Knowledge of such processes is often essential for the understanding of health effects of these substances, whether physical, chemical or microbial transformations.

It is becoming increasingly apparent that microbial processes may be important and even dominating factors in the distribution of specific metals (Ford et al, 1992). Interactions between microorganisms and metals can be conveniently divided into three distinct processes, all of which may be important with respect to metal distribution in natural waters:a) intracellular interactions, (b) cell surface interactions, and (c) extracellular interactions (Ford et al, 1995).

Probably the most widely recognized microbial interaction with toxic metals in the aquatic environment is the microbial methylation of mercury. Although receiving less attention than mercury, methylation of other toxic metals, with subsequent volatilization, may also occur in the aquatic environment. Methylation has been shown for tin, arsenic, lead, selenium, tellurium, thallium, and antimony (Thayer et al, 1982).

A number of authors have shown that metal binding to cell surfaces is an important factor in the distribution of metals in natural waters (Sigg, 1987 and Xue, 1988). Algal surfaces contain functional groups (e.g. carboxylix, amino, thio, hydroxo, and hydroxy-carboxylix groups) that can interact with metal ions (Xue, et al. 1988).

Extracellular interactions with toxic metals range from the potential to leach metals from sediments by production of acidic metabolites to the formation of colloidal sized extracellular polysaccharide metal complexes implicated in mobilization and transport of toxic metals in soils (Black et al, 1986 and Chammgathus et al, 1988). Indirectly, toxic metals closely associated with iron oxide (Cd and Zn) have been shown to be solubilized by enzymatic reduction of the ferric iron (Francis et al, 1990).

Synergism is a phenomenon in which the combined effects of two agents are greater than that of each taken independently. Two metals mixed in water may have a lethal effect, while either alone would be relatively innocuous. Because of the variety in effluents discharged into receiving water bodies, the potential for synergistic effects is large.

Competition between essential and non-essential metals having similar chemical properties may take place. At low levels of the competing metals, the essential metal will win in the competition for binding sites. However, as levels of the nonessential metals rise, it will begin to interfere with the normal function of the essential metals. Thus, the essential metals have a capacity to protect the cells against low levels of metals contaminants, but at higher levels the protection fails. Interference with the normal function of the essential metal results in a toxic outcome.

Lead and calcium ions are sufficiently similar that some degree of competition occurs. Hexavalent chromium, in the form of the oxy-anion, gains entrance to the cell on the sulfate carrier. Once inside the cell, the chromate oxy-anion undergoes reduction, with the production of highly reactive toxic intermediates believed to be ultimately responsible for the carcinogenic action of hexavalent chromium (Wetterhahn, et al. 1993).

1.1.5. Uptake by Crops

Cadmium

Although Cadmium (Cd) is considered to be a nonessential element for plants, it is effectively absorbed by both root and leaf systems. In most cases a linear relationship between Cd in plant material and growth medium has been reported. Nevertheless several soil and plant factors affect the uptake of Cd.

In nearly all publications on the subject, soil pH is the major influence controlling both total and relative uptake of Cd. Kabata-Pendias (1984) reported results indicating that the relative uptakes of Cd by rice seedlings was the greatest within the pH range of 4.5 to 5.5. However, there are contradictory results which show that when Cd becomes more mobile in alkaline soil due to the formation of complexes or metal chelates, the plant uptake of Cd may beindependent of pH. The accumulation of cadmium in Maize is dependent on soil pH. The higher the soil pH, the less cadmium was taken up by the plants (Street et al. 1977). Addition of $CdCl_2$ to elevate soil concentrations to between 20 and 30 ppm resulted in decreased germination and yield of some plants (Kabata-Pendias et al. 1984).

The most important biochemical characteristic of Cd ions is their affinity for sulfhydryl groups of several compounds. In addition, Cd shows an affinity for other side chains of proteins and for phosphate groups.

Dabin et al. (1978) andBraude et al. (1980) has reported that cadmium will most likely be concentrated in the protein fractions of plants.

There are no known enzymes that require Cd for their normal activity. Cadmium has been shown to induce cysteine and methionine synthesis (Roucoux and Dabin 1977). Cadmium has been implicated in the inhibition of the formation of anthocyanin and chlorophyll in plants (Cunningham et al. 1975, and Baszynski et al., 1980). This in turn may lead to the interference with metabolism of micronutrients, inhibition of photosynthesis, disturbance of transpiration and CO2 fixation, and alteration of the permeability of cell membranes.

In general, symptoms induced by elevated Cd content are growth retardation, root damage, chlorosis of leaves, and red-brown coloration of leaf margins or veins. The maximum permissible rate of cadmium addition to soil should depend strongly on the soil pH (Kabata-Pendias and Pendias 1984). USEPA (1979) guidelines regulating cadmium lifetime application rates state that a total of 20 kg of cadmium per hectare can safely be applied to soils with cation exchange capacity of 0.20 mol(+) kg^{-1}.

Crops grown on cadmium contaminated soils may accumulate cadmium in amounts sufficiently large to be of public health concern (Kabata-Pendias and Pendias, 1984). A soil to plant accumulation ratio of 0.15 for the fruit/seed of the crop and 0.55 in the vegetative plant parts has been reported by Baes et al. (1984).

Copper

The literature has reported that there is a relationship between the concentration of the metal measured in the growth medium and in the plant. The copper mobility in the plant tissues strongly depends on the level of copper supply. Copper when absorbed through root systems is transported into the xylem and phloem saps for distribution in the plant (Tiffin, 1972). There appears to be a correlation with concentrations of amino acids. A considerable portion of copper in green tissues appears to be bound to platocyanin and in some protein fractions.

The biochemical functions of copper indicate a potential role in disease resistance. Copper is generally complexes with organic compounds of low molecular weight and with proteins. Copper occurs in the compounds with no known functions as well as in enzymes having vital functions in plant metabolism. Copper plays an important role in photosynthesis, respiration, carbohydrate distribution, nitrogen reduction and fixation, protein metabolism, and cell wall metabolism. Copper influences water permeability of xylem vessels and thus controls water relationships. Copper controls the production of DNA and RNA, and its deficiency greatly inhibits the reproduction of plants.

Finally Copper is involved in the mechanisms of disease resistance (Kabata-Pendias and Pendias, 1984).

Prediction of the copper content of soil that results in toxic effects on plants is difficult. Generally, before phytotoxic symptoms are evident the level of copper accumulation in the palnt will pose a human health risk. Baes et al. (1984) reported a soil to plant accumulation ratio in the fruit/seed of the plant of 0.25 and 0.40 in the vegetative plant parts.

Iron

Iron uptake by plants is metabolically controlled and can be absorbed as Fe^{3+}. Fe^{2+}or as iron chelates. At normal pH levels iron organic complexes apparently play an important role in plant nutrition. Generally roots adsorb Fe^{2+}cation (Kabata-Pendias and Pendias, 1984). In plant tissues iron has been identified as citrates and soluble ferro-dioxine. Iron uptake is generally dependent on soil pH, concentrations of calcium and phosphorus and the ratios of several heavy metals.

The metabolic function of iron is key to energy transformation needed for several cell processes, including: organic iron complexes are involved in the mechanism of photosynthetic electron transfer, non-heme proteins are involved in the reduction of nitrites and sulfates, chlorophyll formation seems to be influenced by iron concentrations, iron is implicated in nucleic acid metabolism, and catalytic and structural roles of iron are also known. Iron occurs in heme and nonheme chloroplasts. A soil to plant absorption factor of 0.001 has been reported for the fruit/seed of the plant and 0.004 for the plant parts by Baes et al. (1984).

High soil concentrations of iron can cause phytotoxic effects when soils are acidic, low in phosphorus, acid sulfate soils, and flooded soils. A 500 ppm soil concentration in a paddy soil solution has been reported to kill rice seedlings.

Lead

Airborne lead is readily taken up by plants through foliage. A number of studies have shown that lead deposited on the leaf surface is absorbed by these cells with a significant translocation into plant tissues (Kabata-Pendias and Pendias, 1984). Lead from soil is not easily translocated into edible portions of plants.

There is no evidence that lead is essential for the growth of any plant species. Some data suggest that some lead salts have a stimulation effect on plant growth while other reports have shown an inhibitory effect (Kabata-PendiasandPendias, 1984). Subcellular effects include the inhibition of respiration and photosynthesis due to the disturbance of the electron transfer reactions.

A relatively minor effect on lead concentrations in plants has been reported for the contamination of soil due to agricultural processes. Vegetables grown in areas of high lead concentrations such as urban and industrial areas may present a health risk to humans who consume them (Kabata-Pendias and Pendias, 1984). Baes et al. (1984) reported a soil to plant accumulation ratio in the fruit/seed of the plant of 0.009 and 0.045 in the vegetative plant parts.

Zinc

Soluble forms of zinc are readily available to plants with a linear uptake from both solution and soils. The presence of high calcium to zinc ratios in soil greatly reduces zinc uptake. Although Zn, Zn^{2+} and Zn-organic chelates are the primarily absorbed forms.Kabaa-Pendias and Pendias (1984) reported that only Zn2+ was absorbed by Maize roots. Zinc is generally bound to soluble low molecular weight proteins. Zinc bound to xylem fluids and other tissue extracts may indicate high mobility in the plant. However, some literature regards zinc as highly mobile while other data suggest intermediate mobility. Baese et al. (1984) reported a soil to plant accumulation ratio in the fruit/seed of the plant of 0.90 and 1.50 in the vegetative plant parts.

1.2. Parameters of Agricultural Significance

The quality of irrigation water is of particular importance in arid zones where extremes of temperature and low relative humidity result in high rates of evaporation, with consequent deposition of salt, which tends to accumulate in the soil profile. The physical and mechanical properties of the soil, such as dispersion of particles, stability of aggregates, soil structure and permeability, are very sensitive to the type of exchangeable ions present in irrigation water.

Traditionally, irrigation water is grouped into various quality classes in order to guide the user to the potential advantages as well as problems associated with its use and to achieve optimum crop production. The water quality classifications are only indicative guidelines and their application will have to be adjusted to conditions that prevail in the field. This is so because the conditions of water use in irrigation are very complex and difficult to predict.

The suitability of water for irrigation will greatly depend on the climatic conditions, physical and chemical properties of the soil, the salt tolerance of the crop grown and the management practices. Thus, classification of water for irrigation will always be general in nature and applicable under average use conditions.

Many schemes of classification for irrigation water have been proposed. Ayers and Westcot (FAO, 1985) classified irrigation water into three groups based on salinity, sodicity, toxicity and miscellaneous hazards. These general water quality classification guidelines help to identify potential crop production problems associated with the use of conventional water sources. *The guidelines are equally applicable to evaluate Marginal quality water for irrigation purposes in terms of their chemical constituents, such as dissolved salts, relative sodium content and toxic ions.* Several basic assumptions were used to define the range of values in the guidelines and more detailed information on this is reported by Ayers and Westcot (FAO 1985).

The effect of sodium ions in irrigation water in reducing infiltration rate and soil permeability is dependent on the sodium ion concentration relative to the concentration of calcium and magnesium ions (as indicated by SAR) and the total salt concentration, as shown in the guidelines. This emphasize the fact that soil permeability (including infiltration rate and surface crusting) hazards caused by sodium in irrigation water cannot be predicted independently of the dissolved salt content of the irrigation water or that of the surface layer of the soil.

Many of the ions which are harmless or even beneficial at relatively low concentrations may become toxic to plants at high concentration, either through direct interference with metabolic processes or through indirect effects on other nutrients, which might be rendered inaccessible. They are not normally included in routine analysis of regular irrigation water, but attention should be paid to them when using marginal quality water, particularly if contamination with industrial wastewater discharges is suspected. These include Aluminium (A1), Beryllium (Be), Cobalt (Co), Fluoride (F), Iron (Fe), Lithium

(Li), Manganese (Mn), Molybdenum (Mo), Selenium (Se), Tin (Sn), Titanium (Ti), Tungsten (W) and Vanadium (V). Heavy metals are a special group of trace elements which have been shown to create definite health hazards when taken up by plants. Under this group are included, Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Mercury (Hg) and Zinc (Zn).

Morishita (1985) has reported that irrigation with nitrogen-enriched polluted water can supply a considerable excess of nutrient nitrogen to growing rice plants and can result in a significant yield loss of rice through lodging, failure to ripen and increased susceptibility to pests and diseases as a result of over-luxuriant growth. He further reported that non-polluted soil, having around 0.4 and 0.5 ppm cadmium, may produce about 0.08 ppm Cd in brown rice, while only a little increase up to 0.82, 1.25 or 2.1 ppm of soil Cd has the potential to produce heavily polluted brown rice with 1.0 ppm Cd. Table 4A.19 presents phytotoxic threshold levels of some selected trace elements.

Table 4 Guidelines for Interpretation of Water Quality for Irrigation

Potential irrigation problem		Units	Degree of restriction on use		
			None	Slight to moderate	Severe
Salinity					
Ec_w[1]		dS/m	< 0.7	0.7 - 3.0	> 3.0
or					
TDS		mg/l	< 450	450 - 2000	> 2000
Infiltration					
SAR[2] = 0 - 3 and EC_w			> 0.7	0.7 - 0.2	> 0.2
	3 -6		> 1.2	1.2 - 0.3	>0.3
	6-12		> 1.9	1.9 - 0.5	> 0.5
	12-20		> 2.9	2.9 - 1.3	> 1.3
	20-40		> 5.0	5.0 - 2.9	> 2.9
Specific ion toxicity					
Sodium (Na)					
	Surface irrigation	SAR	< 3	3 - 9	> 9
	Sprinkler irrigation	me/I	< 3	> 3	
Chloride (Cl)					
	Surface irrigation	me/I	< 4	4 - 10	> 10
	Sprinkler irrigation	me/l	< 3	> 3	
Boron (B)		mg/l	< 0.7	0.7 - 3.0	> 3.0
Trace Elements					
Miscellaneous effects					
Nitrogen (NO_3-N)[3]		mg/l	< 5	5 - 30	> 30
Bicarbonate (HCO_3)		me/I	< 1.5	1.5 - 8.5	> 8.5
pH		Normal range 6.5-8			

Source: FAO(1985).

[1] *EC_w means electrical conductivity in deci-Siemens per metre at 25°C*
[2] *SAR means sodium adsorption ratio*
[3] *NO_3-N means nitrate nitrogen reported in terms of elemental nitrogen*

Table 5 Threshold Levels of Trace Elements for Crop Production

	Element	Recommended maximum concentration (mg/l)	Remarks
Al	(aluminium)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity.
As	(arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be	(beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd	(cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co	(cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr	(chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu	(copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F	(fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe	(iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment and buildings.
Li	(lithium)	2.5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn	(manganese)	0.20	Toxic to a number of crops at few-tenths to a few mg/l, but usually only in acid soils.
Mo	(molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni	(nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH.
Pd	(lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se	(selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. As essential element to animals but in very low concentrations.

	Element	Recommended maximum concentration (mg/l)	Remarks
Sn	(tin)		
Ti	(titanium)	-	Effectively excluded by plants; specific tolerance unknown.
W	(tungsten)		
C	(vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn	(zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

Source: Adopted from National Academy of Sciences (1972) and Pratt (1972)

The maximum concentration is based on a water application rate which is consistent with good irrigation practices (10 000 m^3 per hectare per year). If the water application rate greatly exceeds this, the maximum concentrations should be adjusted downward accordingly. No adjustment should be made for application rates less than 10 000 m^3 per hectare per year. The values given are for water used on a continuous basis at one site. (Source : Adopted from National Academy of Sciences (1972) and Pratt (1972))

2. Evaluation of Nationaland International Irrigation Water Quality regulations and Guidelines

2.1. Chemical Guidelines

Based on the analysis of available guidelines, it was determined that two general approaches have been used to establish human health-related chemical limits for land application of marginal quality water. The two approaches are (NAWQAM, 2004):

First Approach: Preventing Pollutant Accumulation in Soil.

This approach equates pollutant input to pollutant output. Conceptually, no net accumulation of pollutants is permitted in the receiving soil; therefore, numerical limits are set to prevent the pollutant concentration of the soil from rising during the course of land application, which maintains the soil's original ecological and chemical integrity. When these requirements are met, the sustainability of the soil to maintain any future land uses is guaranteed, and the transfer of pollutants up the food chain is kept to a minimum. Implementation of this approach requires enforcement of the following measures:

(i) Pre-treatment of industrial wastewater to prevent pollutants from entering the wastewater collection and treatment system, then receiving water bodies.

(ii) Requiring municipal wastewater to undergo complete treatment to remove pollutants prior to discharge into agricultural drains.

(iii) Setting very stringent pollutant loading limits for soils.

An advantage of using this approach to develop regulations is that detailed knowledge of exposure pathways and the dose-response relationships are not needed. The numerical limits for pollutants may be calculated by simple mass balances by matching pollutant input from irrigation water with pollutant outputs and the results tend to be universally applicable. The net cost of mitigation measures and disposal, however, will be high because more advanced technologies must be employed in treating point sources of pollution prior to discharge into agricultural drains, or a large land area is required to accommodate the treatment of irrigation water.

Second Approach: Taking Maximum advantage of the Soil's Capacity to assimilate, and Detoxify Pollutants

The primary principle underlying the second approach in setting numerical limits is that the capacity of soil to attenuate pollutants should be utilized fully. Guidelines based on this approach set the maximum permissible pollutants loading and provide users the flexibility to develop suitable management practices for using marginal quality water. Under this scenario, pollutants concentrations in the soil, however, will rise eventually to levels considerably higher than the background levels, and future land uses may be restricted if accumulation of pollutants in soil is not managed.

The most comprehensive method of deriving the numerical limits for pollutant input is to establish first the acceptable daily human intake (ADI) for a particular pollutant and then quantitatively back track the pollutant transport through various environmental exposure routes and arrive at an acceptable pollutant concentration for the receiving soil. It has been determined that at least seven exposure pathways are involved, and each pathway requires a mathematical model. More importantly, each exposure pathway requires an exposure scenario to define the model parameters and to select input data for the computation. As globally representative exposure scenarios are almost impossible to define, this method has little practical utility.

According to WHO (1995), the pollutants concentrations in soil is a more suitable global reference point than the pollutant mass loading rate for assessing potential negative impacts of pollutants in soil, primarily because crop uptake of pollutants is a function of pollutant concentration in soil and because soil properties and environmental conditions are variable around the world. The same pollutant mass loading to soils with different background concentrations may result in different soil pollutant concentrations. After a detailed study, the WHO recommended the numerical values given in Table (6).

These guidelines, for maximum pollutant concentration in soils have been computed based on:

(i) acceptable daily dietary intake (ADI) of pollutants obtained from the literature,

(ii) an assumed global diet

(iii) pollutant exposure derived mainly from the consumption of those food groups that make up the major portion of the global diet (grain, vegetable, root/tuber, and fruit), and (iv) a limit on daily intake of pollutants from consumption of those food groups to 50% of the ADI.

It is worth mentioning that the maximum permissible concentrations of potentially toxic elements vary according to the pH of the soil. The department of the environment (1989) recommended the values presented in Table (7).

Table 6 Maximum Allowable Concentrations in Soil (mg/kg DW)

Inorganic Elements			
Constituent	**WHO Standards***	**DWIP**	**Canadian. 1999****
Arsenic	9		12
Barium	2900		750
Beryllium	20		
Cadmium	7	3	1.4
Chromium	3200		64
Fluorine	2600		
Lead	150	150	70
Mercury	5		6.6
Nickel	850		50
Selenium	140		
Silver	3		
Copper		140	63
Zinc		300	200
Vanadium			130
Organic Compounds			
Atrazine		2.9	
Aldrin	0.2		
Benzene	0.03		0.05
Benzo (a) pyrene	3		0.1
Chlorodane	0.3		
Chlorobenzene	ND		
Chloroform	2		
Dichlorophenols	ND		
2,4-D	10		
DDT (total)	ND		0.7
Dieldrin	0.03		
Hexachlorobenzene	40		
Hexachloroethane	2		
Pyrene	480		
Lindane	0.6		
Methoxychlor	20		
Pentachlorophenol	320		7.6
PCBs	30		0.5
Tetrachloroethane	4		
Tetrachloroethylene	250		0.1
Toluene	50		0.1
Toxapjene	9		
2,4,5-T***	ND		
2,3,7.8 TCDD ****	30		
Trichloroethylene			0.1
Ethy/benzene			0.1
Ethylene glycol			960
Phenol			3.8

*** 1995 ** 1999 ***Trichlorophenoxy acetic acid **** Tetrachloro-dibenzo-dioxine**

Table 7 Maximum Permissible Concentrations of Potentially Toxic Elements (PTE) in Soil After Application of Sewage Sludge and Maximum Annual Rates of PTE Addition over a 10 year period (kg/ha)[3]

Potentially toxic element (PTE)	Maximum permissible concentration of PTE in soil (mg/kg dry solids) pH				Maximum permissible average annual rate of PTE addition over a 10 year period (kg/ha)[3]
	5.0 <5.5[1]	5.5<6.0	6.0-7.0	> 7.0[2]	
Zinc	200	250	300	450	15
Copper	80	100	135	200	7.5
Nickel	50	60	75	110	3
Cadmium	3[5]				0.15
Lead	300				15
Mercury	1				0.1
Chromium	400 (prov.)				15 (provisional)
*Molybdenum[4]	4				0.2
*Selenium	3				0.15
*Arsenic	50				0.7
*Fluoride	500				20

Source: Department of the Environment – Egypt (1989)

** These parameters are not subject to the provisions of Directive 86/278/EEC.*
[1] For soils of pH in the ranges of 5.0 < 5.5 and 5.5 < 6.0 the permitted concentrations of zinc, copper, nickel and cadmium are provisional and will be reviewed when current research into their effects on certain crops and livestock is completed.
[2] The increased permissible PTE concentrations in soils of pH greater than 7.0 apply only to soils containing more than 5 % calcium carbonate.
[3] The annual rate of application of PTE shall be determined by averaging over the 10-year period ending with the year of calculation.
[4] The accepted safe level of molybdenum in agricultural soils is 4 mg/kg. However, there are some areas in the UK where, for geological reasons, the natural concentration of this element in the soil exceeds this level. In such cases there may be no additional problems as a result of applying sludge, but this should not be done except in accordance with expert advice. This advice will take account of existing soil molybdenum levels and current arrangements to provide copper supplements to livestock.
[5] For pH 5.0 and above

The European Union (1999) adopted the values presented in Table 8 for soils and those presented in Table (9) for annual heavy metals loads which may be added to the soil. Most European countries have adopted values which are comparable to the EU limits or even stricter (Tables 10 & 11).

Table 8 Limit values for concentrations of heavy metals in soil (mg/kg dm)

Elements	EU 86/278 6<pH<7	5<pH<6	6<pH<7	PH>7
Cd	1-3	0.5	1	1.5
Cu	50 – 140	20	50	100
Hg	1 – 1.5	0.1	0.5	1
Ni	30 – 75	15	50	70
Pb	50 – 300	70	70	100
Zn	150 - 300	60	150	200

Source EU(1999)

Table 9 Limit values for amounts of heavy metals which may be added annually to soil, based on a ten year average

Elements				
	Directive 86/278/EEC	Until 31/12/2005	From 1/1/2005 until 31/12/2010	From 1/1/2010
Cd	150	50	25	10
Cu	12000	5000	2500	1000
Hg	100	50	10	5
Ni	3000	1500	500	300
Pb	15000	10000	5000	1500
Zn	30000	15000	5000	3000

Source: European Union(1999)

Table 10 Limit values for concentrations of heavy metals in soil in EU Directive and some European countries (mg/kg DW)

Elements	**EU Directive 86/278**	**Greece**	**UK**	**Germany**	**Finland**	**Belgium**	**France**	**Italy**	**Sweden**	**The Netherlands**
Cadmium (Cd)	1-3	1-3	3	1-1.5	0.5	1-3	2	1.5	0.4	0.8
Chromium (Cr)	-	-	400	100	200	100-150	150	-	30	100
Copper (Cu)	50-140	50-140	80-200	60	100	50-140	100	100	40	36
Mercury (Hg)	1-1.5	1-1.5	1-1.5	1	0.2	1-1.5	1	1	0.3	35
Nickel (Ni)	30-75	30-75	50-100	50	30	30-70	50	75	75	0.3
Lead (Pb)	50-300	50-300	300	100	60	50-100	100	100	40	85
Zinc (Zn)	150-300	150-300	200-450	150-200	150	150-300	300	300	75	140
Arsenic (As)	-	-	50	-	-	-	-	-	-	29
Fluorine (F)	-	-	500	-	-	-	-	-	-	-
Molybdenum (Mo)	-	-	4	-	-	-	-	-	-	-
Selinium (Se)	-	-	4	-	-	-	-	-	-	-

Source: IAWQ (1996)

DW "Dry weight "

Table 11 Limit values for annual loads of heavy metals in EU Directive and some European countries (kg/ha/y)

Element	EU Directive 86/278	Greece	UK	Germany	France	Austria
Cadmium (Cd)	0.15	0.15	0.15	0.016	0.06	0.025
Chromium (Cr)	-	-	15	1.5	3	1.25
Copper (Cu)	12	12	7.5	1.3	3	1.25
Mercury (Hg)	0.1	0.1	0.1	0.013	0.03	0.025
Nickel (Ni)	3	3	3	3	0.6	0.25
Lead (Pb)	15	15	15	1.5	2.4	1.25
Zinc (Zn)	30	30	15	2.5	9	5
Arsenic (As)	-	-	0.7	-	-	0.05
Fluorine (F)	-	-	20	-	-	-
Cobalt (Co)	-	-	-	-	-	0.25
Molybdenum (Mo)	-	-	0.2	-	-	0.05
Selinium (Se)	-	-	0.15	-	0.3	-

Source: IAWQ (1996)

2.2. Irrigation Water

Table (12) summarizes the numerical limits of the guidelines developed by several nations for irrigation water. It should however be mentioned that most of these criteria were developed specifically for wastewater irrigation, (Taiwan, Hungary, People's Republic of China, Saudi Arabia, Tunisia and Egypt).

As can be seen, the numerical limits in many parameters are identical, but in other cases they varied by one to two order of magnitude.

Table 12 National and International Guidelines for Irrigation Water Quality

	Unit	Canada	USA	Taiwan	Hungary	Peoples Republic of China			Saudi Arabia	Tunisia	FAO	DWIP	Egypt	Egypt Decree
		All Soils	Sandy Soils	All Soils	All Soils	Rice Paddy	Dryland	Vegetable	All Soils	All Soils	1992	1997	Law 48/1982	No.44/2000
Parameter		1999	1973	1978	1991	Undated	Undated	Undated	Undated	Undated			Article "65"	
pH				6.0-9.0	6.5-8.5	5.5-8.5	5.5-8.5	5.5-8.5	6-8.4	6.5-8.5			7-8.5	
TDS	mg/L	500-3500				1000-2000	1000-2000	1000-2000						2000
E.C.	umho/cm 25 °C			750						700				
S. S	mg/L			100		150	200	100	10	30				20
Chloride	mg/L	100-700[a]		175		250		250	280	2000				300
Sulfate	mg/l			200										
T. K. N	mg/l			1		12	30	30						
BOD	mg/l					80	150	80	10				10	20
COD	mg/l					200	300	150		90			6	40
Temperature	°C			35		35	35	35						
Al	mg/l	5	5	5	5				5		5			
As	mg/l	0.1	0.1	1	0.2	0.05	0.1	0.05	0.1	0.1	0.1		0.05	0.1
Ba	mg/l				4									
Be	mg/l	0.1	0.1	0.5	0.1				0.1					
B	mg/l	0.5-6.0[b]	0.75	0.75	0.7	10.0 - 30.0	7.0 - 3.0	1.0 - 3.0	0.5	3				3
Cd	mg/l	0.005	0.01	0.01	0.02	0.005	0.005	0.005	0.01	0.01	0.01	0.01	0.01	0.01

Parameter	Unit	Canada	USA	Taiwan	Hungary	Peoples Republic of China			Saudi Arabia	Tunisia	FAO	DWIP	Egypt	Egypt Decree
		All Soils	Sandy Soils	All Soils	All Soils	Rice Paddy	Dryland	Vegetable	All Soils	All Soils	1992	1997	Law 48/1982	No.44/2000
		1999	1973	1978	1991	Undated	Undated	Undated	Undated	Undated			Article "65"	
Cr (Total)	mg/l	0.01	0.1	0.1	5	0.1	0.1	0.1	0.1	0.1	0.1		0.01	0.1
Co	mg/l	0.05	0.05	0.05	0.05				0.05	0.1	0.05		1	0.05
Cu	mg/l	0.2-1.0	0.2	0.2	2	1	1	1	0.4	0.5	0.2	1		0.2
F (Total)	mg/l	1			1	2.0-3.0	2.0 - 3.0	2.0 - 3.0	2	3	1		0.5	
Fe	mg/l	5			0.1				5	5	5	5	1	5
Pb	mg/l	0.2	5	0.1	1	0.1	0.1	0.1	0.1	1		5		5
Li	mg/l	2.5	2.5	2.5	2.5				0.07		2.5			
Mn	mg/l	0.2	0.2	2	5				0.2	0.5	0.2		1.5	0.2
Hg	mg/l			0.005	0.01	0.001	0.001	0.001	0.001	0.001				
Mo	mg/l	0.01 - 0.05[c]	1.01	0.01					0.1		0.01			0.01
Ni	mg/l	0.2	0.2	0.5	1				0.02	0.2	0.2			0.2
Se	mg/l	0.02-0.05[d]	0.02	0.02		0.02	0.02	0.02	0.02	0.05	0.02			
Ag	mg/l				0.1									
V	mg/l	0.1	0.1	10	5						0.1			
Zn	mg/	1.0 - 5.0[e]	2	2	5	2	2	2	4	5	2	1	1	2
CN(Total)	mg/l				10	0.5	0.5	0.5	0.05				0.1	
Surfact (ABS)	mg/l			5	50	5	3	5					0.5	

	Unit	**Canada**	**USA**	**Taiwan**	**Hungary**	**Peoples Republic of China**			**Saudi Arabia**	**Tunisia**	**FAO**	**DWIP**	**Egypt**	**Egypt Decree**
		All Soils	**Sandy Soils**	**All Soils**	**All Soils**	**Rice Paddy**	**Dryland**	**Vegetable**	**All Soils**	**All Soils**	**1992**	1997	**Law 48/1982**	**No.44/2000**
Parameter		**1999**	**1973**	**1978**	**1991**	**Undated**	**Undated**	**Undated**	**Undated**	**Undated**			**Article "65"**	
Oil and Grease	mg/l			5	8								1	5
Benzene	mg/l				2.5	2.5	2.5	2.5						
Tar	mg/l				30									
Petroleum	mg/l				0.5	1	0.5	0.5						
Methanol	mg/l				0.1									
Trichloroacetylaldehyde	mg/l					1	0.5	0.5						
Propionaldehyde	mg/l					0.5	0.5	0.5						
Phenol	mg/l								2				0.02	
Atrazine	mg/l	0.01												
Hydrocarbons													1.5	
Coliforms fecal	cfu/100	100/100												
Coliform total	cfu/100	1000/100												

(a) Chloride guideline = 100-175 mg/l for almond apricots and plums
= 178-355 mg/l for grapes, peppers, potatoes and tomatoes
= 355-710 mg/l for alfalfa, barley, corn and cucumbers
> 710 mg/l for cotton, sorghum, sugar beets and sunflowers
= 180-600 mg/l for stone fruit (peaches, plums, etc.)
= 710-900 mg/l for grapes

(b) Boron guidelines = 0.5 mg/l for blackberries
= 0.5 – 1.0 mg/l for grapes, onions, garlic, sweet potatoes, sunflowers wheat, barely
= 1.0 – 2.0 mg/l for red peppers, potatoes, cucumbers
= 2.0 – 4.0 mg/l for lettuce, cabbage,
= 4.0 – 6.0 mg/l for sugar beets
= 6.0 mg/l for asparagus

(c)Molybdenum guideline= 0.05 mg/l for short-term use on acidic soils

(d) Selenium guideline = 0.02 mg/l for continuous use
= 0.05 mg/l for intermittent use

(e) Zinc guideline = 1.0 mg/l when soil pH < 6.5
= 5.0 mg/l when soil pH > 6.5

2.3. Microbiological quality guidelines for health protection

Following several meetings of environmental specialists and epidemiologists, a WHO Scientific Group on Health Aspects of Use of Treated Wastewater for Agriculture and Aquaculture arrived at the microbiological quality guidelines for wastewater use in agriculture shown in Table (13). These guidelines were based on the consensus view that the actual risk associated with irrigation with treated wastewater is much lower than previously thought and that earlier standards and guidelines for effluent quality, such as the WHO (1973) recommended standards, were unjustifiably restrictive, particularly in respect of bacterial pathogens (NAWQAM, 2004).

The new WHO guidelines (1989) are stricter than previous standards with respect to the requirement to reduce the numbers of helminthes eggs (Ascaris and Trichuris species and hookworms) in effluents for Category A and B conditions to a level of not more than one per litter. Also implied by the guidelines is the expectation that protozoa cysts will be reduced to the same level as helminthes eggs. Although no bacterial pathogen limit is imposed for Category C conditions where farm workers are the only exposed people, on the premise that there is little or no evidence indicating a risk to such workers from bacteria, some degree of reduction in bacterial concentration is recommended for irrigation water.

The WHO Scientific Group considered that the new approach to effluent quality would increase public health protection for the large numbers of people who were subjected to infection in areas where crops eaten uncooked are being irrigated in an unregulated and often illegal manner with raw wastewater. It was felt that the recommended guidelines, if adopted, would achieve an improvement and set targets which are both technologically and economically feasible. However, the need to interpret the guidelines carefully and modify them in the light of local epidemiological, socio-cultural and environmental factors was also pointed out.

Recent evidence of enteric infections in farming families in direct contact with irrigation water containing more than 106 FC /100 ml, suggests that a fecal coliform guideline should now be added for restricted irrigation (Ursula et al., 2000). A guideline level of 103 FC/100 ml has been recommended where adults are involved in flood/furrow irrigation and children are regularly exposed (through farm work or play).

The nematode egg guideline of £1 egg per liter is adequate if no children are exposed, but a revised guideline of ≤0.1 egg per liter is recommended if children are in contact with the wastewater through irrigation or play.

Table 13 Recommended Microbiological Quality Guidelines for Drainage Water Use in Agriculture [(a)]

Category	Irrigation Conditions	Exposed Group	Intestinal nematodes[(b)]	Fecal coliforms	
A	Irrigation of crops likely to beeaten uncooked, sports fields,public parks	Workers	(arithmatic mean no	(geometric mean	
		consumers,	of eggs per liter [(c)]	per 100 ml)	
		public	≤ 1	≤ 1000 [(d)]	
B	Irrigation of cereal crops, industrial crops, fodder crops and pasture and trees (e)	Workers	≤ 1	No standard recommended	
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	

[a]*In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account, and the guidelines modified accordingly.*

[b]*Ascaris and Trichuris species and hookworms.*

[c] *During the irrigation period.*

[d] *A more stringent guideline (<200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.*

[e] *In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.*

Source: WHO (1989)

3. Recommended Health Protection Measures

Health protection measures which can be applied in agricultural use of drainage water include the following, either singly or in combination (NAWQAM, 2004):

- Crop restriction
- Human exposure control and promotion of hygiene
- Treatment of drainage water. Although the drainage water is not within the scope of work of this ESIA, however, the general protection measures is included for reference.

3.1. Crop Restriction

Water of a high microbiological quality is needed for the irrigation of certain crops, especially vegetable crops eaten raw, but a lower quality is acceptable for other selected crops, where there is no exposure of the public. Crops can be categorized according to the exposed group and the degree to which health protection measures are required, as follows:

Category A. Protection required for consumers, agricultural workers, and the general public

This includes crops likely to be eaten uncooked, spray- irrigated fruits, and grass (sports fields, public parks and lawns).

Category B. Protection required for agricultural workers only

This includes cereal crops, industrial crops (such as cotton and sisal), food crops for canning, fodder crops, pasture and trees. In certain circumstances some vegetable crops might be considered as belonging to Category B if they are not eaten raw (potatoes, for instance) or if they grow well above the ground. In such cases it is necessary to ensure that the crop is not contaminated by sprinkler irrigation or by falling onto the ground, and that contamination of kitchens by such crops, before cooking, does not give rise to a health risk.

These measures will protect consumers but not farm workers and their families. Crop restriction is therefore, not adequate on its own; it should be complemented by other measures such as human exposure control.

Crop restriction is therefore feasible under conditions where:

- an irrigation project has a strong central management;
- there is adequate demand for the crops allowed under crop restriction, and they fetch a reasonable price;
- there is little market pressure in favour of excluded crops (i.e., those in Category A).

Adopting crop restriction as a means of health protection in reuse schemes will require a strong institutional framework and the capacity to monitor and control compliance with regulations and to enforce them. Farmers must be advised why such crop restriction is necessary and be assisted in developing a balanced mix of crops so that production of surplus of a specific crop is avoided.

3.2. Human exposure control

The objective of this approach is to prevent the population groups at risk from coming into direct contact with pathogens in the wastewater or to prevent any contact with the pathogens leading to disease. Four groups are at risk in agricultural use of marginal quality water (NAWQAM, 2004):

- agricultural workers and their families
- crop handlers
- consumers of crops, meat and milk
- those living near the areas irrigated with marginal quality water

Different methods of exposure control might be applied for each group.

Control measures aimed at protecting agricultural field workers and crop handlers include the provision (and insistence on the wearing) of protective clothing, the maintenance of high levels of hygiene and immunization against (or chemotherapeutic control) selected infections. Risks to consumers can be reduced through cooking the agricultural products before consumption and by high standards of foodhygiene, which should be emphasized in the health education associated with irrigation schemes.

Local residents should be kept fully informed on the use of drainage water in agriculture so that they, and their children, can avoid these areas.

Special care must always be taken to ensure that agricultural workers or the public do not use irrigation water for drinking or domestic purposes by accident or for lack of an alternative.

3.3. Treatment of Drainage Water

This can be carried out using oxidation ponds at a hydraulic retention time of 8-10 days or wetlands, provided land is available at the project area at a reasonable cost.

3.4. Institutional Framework

The incorporation of the use of drainage water into national water resources and agricultural planning is important, to obtain the maximum agricultural and aqua cultural benefits from the nutrients which wastewater contains. However, to safeguard public health and the environment and to ensure long-term sustainability, sufficient attention must be given to the social, institutional and organizational aspects of drainage water use in agriculture and aquaculture.

Since the use of drainage water touches on the responsibilities of several ministries and government agencies, the active involvement of the ministries of health, agriculture and public works (or their equivalents) is essential at the national level, if the potential benefits are to be achievedwithout endangering health and the environment. The responsibilities of this Committee should cover the following:

- developing a coherent national policy for drainage water use and monitoring the environmental and health impact of its implementation;

- defining the division of responsibilities between the respective ministries and agencies involved and the arrangements for collaboration between them;
- The responsible agency will generally deal with farmers through users associations, to which will be delegated the task of enforcing regulations. The agency will also have the important task of providing services to the users, including advice on and assistance with farm machinery, the supply of materials and equipment, agricultural credit, agricultural advisory services and training, marketing services and primary health care.

In general, the sustainability of this project will depend to a large extent on the administrative skills, responsibility and financial resources applied.

4. Development of a Monitoring Program

4.1. Objectives

Water quality monitoring plays an important role in water management to protect the environment and human health.

The main objectives of the monitoring program are:

- to assess the quality of water entering the area.
- to quantify the variation in irrigation and drainage water at the pilot area
- to assess the impact of the use of drainage water on crop production (quality & quantity).
- to assess the impact of the use of drainage water on the soil quality
- to provide the decision makers with the information required to propose and implement mitigation measures
- to develop public information and awareness programs on water quality

4.2. Parameters to be measured

Irrigation Water

All parameters presented in Table 14 should be measured twice a year, during the minimum and maximum flows in February & August respectively

Soil

The following parameters should be measured in the soil once a year:

Arsenic, Cadmium, Chromium, Lead, Nickel, Copper,Zinc, Atrazine

Crops

The following parameters should be measured in crops at the harvesting period:

Arsenic, Cadmium, Chromium, Lead, Nickel, Copper,Zinc, Atrazine

The collected data has to be stored in a data-base for further analysis, interpretation and development of information packages for the different stakeholders.

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