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Sewage Farming: Benefits and Adverse Effects.

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ABSTRACT

Under the umbrella of international water scarcity, it became an obligation to reuse low quality water in farming. Both raw and treated sewage effluent are now extensively reused in irrigating crops in several parts of the world. It was apparently recognized that sewage farming has both beneficial and adverse impacts on the soil ecosystem as well as on the safety of harvested crops that affects both human and animal health. At the time being there are many innovated biotechnologies that proved its usefulness in combating the adverse impacts of sewage farming. The relevance of these narrative biotechnologies is in spite of everything experienced at diminutive scale due to their economic feasibility. On the other hand, sewage farming reimbursement the soil ecosystem and ameliorate its chemical physical and biological conditions as well. Our main intention is to maximize sewage farming benefits and combating there its adversative impacts. It sounds that sewage farming will be a foremost requisite in the near future at many areas all over the world.
Keywords: contaminants**;** potential toxic elements (PTEs); irrigation; phyllosphere.

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INTRODUCTION

Since antiquity, man used sewage effluent in agricultural purposes at a limited scale. Planned reuse of sewage effluent gained its worth only two or three decades ago, when the demands for water dramatically increased due to technological advancement, population growth, and urbanization, which put great stress on the natural water resources.

Sewage farming started early in the 16th century in Germany (1531) and steadily extended to other parts in the world as it started in USA, France, India, Australia, Mexico, and Egypt respectively in 1871, 1872, 1877, 1893,1904 and 1930. In Egypt, the first installed sewage farm was installed in 1930 at El-Gabal Al-Asfer near Cairo and sewage farms gradually disseminated in other regions at Abu-Rawash, Luxor, El-Saff, Isamailia and Alexandria. Nowadays many developing countries, e.g., Bahrain, Jordan, Kuwait, Qatar, Saudi Arabia, Peru, South Africa, Tunis, and UAE are using treated sewage effluent in farming. On the other hand, some countries like Chili, Iran, India, Afghanistan, Algeria, Morocco, Syria and Lebanon are still using raw sewage effluent in farming. At the time being, sewage farming represents one of the substantial natural water resources that should be well managed, rather than discarded as irrigation with adequately treated sewage effluent might not seem to present any significant or unacceptable risks.Nevertheless, irrigation with sewage effluent must be applied with proper precautions to protect human health and the environment .

In Egypt, there are two main types of sewage effluent;, the first is sole domestic effluent, and the second is mixed domestic and industrial effluent. In most cases, the industrial effluent contains potential toxic elements (PTEs) along side with persistent organic contaminants (POCs) together with many pathogenic microorganisms such as parasites, bacteria, fungi and viruses. If raw sewage effluent was used in irrigation with only primary treatment, and this is most dominant case in Egypt, the agricultural products will be contaminated with the above mentioned hazardous contaminants which enter the food chain causing several adverse consequences.

Management and reuse of sewage effluent is one of the major challenges that Egypt had to deal with in the coming few decades and beyond, as it represents one of the vital environmental issue at political, technical and research levels as well. It is worthy to mention that huge amounts of the sewage effluent is still disposed raw in the couldals and drains allover Egypt, and hence reaches the soil and causes severe adverse contamination consequences.

Despite sewage farming represented an appropriate and beneficial mean of disposal sewage effluent; it is always associated with numerous risks arising from the dissemination of enteric pathogens as well as certain inorganic and organic constituents in the environment. The outlets of sewage farming had not been yet fully evaluated. Hence, it should be excised under restricted precautious conditions to ensure safe and effective use. Setting a national strategy for sewage farming should take into account all alternatives. Sustainable sewage effluent management in combination with high-efficiency treatment for the purpose of reuse is the only way to meet this challenge. The international and Egyptian scientific literature on the health and environmental impacts as well as the agronomic benefits of sewage effluent reuse in farming is being found in AGRICOLA, AGRIS, International BIOSIS Preview, CAB ABSTRACTS, EiCompendex Plus, Pollution Abstracts, and the Aqualine database. These sources cover the following key points:

1. Impacts of PTEs in soils irrigated with sewage on crops, animal health and the human diet.
2. Nitrogen and phosphorus dynamics and potential effects on water resources.
3. Pathogenic contamination of soils irrigated with sewage and implications for human and animal health.
4. Organic contaminants.
5. Different philosophical approaches adopted for regulating agricultural reuse of sewage effluent in relation to contaminants.
6. International data on soils irrigated with sewage potential toxic elements content. The present article aims at compiling the available data, knowledge and experience on sewage farming in Egypt.

Sewage farming had been for some decades a matter of interest to both environmentalists and agronomists as well, to the farmers as a means of disposing sewage effluent safely and to the later as a renewable source of irrigation water, nutrients and organic matter.

Sewage farming, however, is always associated with beneficial and adverse impacts on man and environment. Our responsibility is to maximize the beneficial impacts and combats the adverse ones using the most recent achievements in science and technology.

Beneficial impacts

Under Egyptian semi-arid weather, the organic matter content of soils is very low, not exceeding 2% in best cases. The dependence exclusively on mineral fertilizers is unsound practice. Swage farming could be advantageous due recycling nutrients and organic matter to soil. Application of sewage effluent to soils had a marked effect on improving their physical, chemical and biological properties [1].

Sewage effluent contains appreciable amounts of nitrogen, phosphorus and other plant nutrients and these nutrients are not removed in conventional treatment processes to a great extent. Sewage effluent provides supplementary source of water for crop irrigation. In sewage farming, the need for inorganic fertilizers could be significantly reduced or even completely eliminated [2]. In addition to agronomic benefits, sewage farming has a potential environmental and health revenues including reduced degradation of water resources, improved downstream water quality, reduced disease vectors in aquatic ecosystems and decreased expenditure on public health.

Supplementation clay and sandy soils with raw effluent, decanted sewage neither effluent nor dried sludge increased total bacteria, streptomycetes, fungi, *Aztobacter*, N-fixing *Clostridia*, cellulose decomposers and coliform bacteriaas well as nitrogen and organic matter contents. Slight changes were recorded in water holding capacity and the capacity of the exchangeable cations in soils irrigated with sewage effluent [3]. Also, appositive trend of a gradual decrease in calcium carbonate content in soils irrigated with sewage effluent was recognizedby [4] and he found thatthelonger the period of irrigation with sewage effluent the higher the decrease occurred. The $CaCO_3$ content decreased from 1.21% in the surface layer of the non-cultivated soils to 1.12%, 0.84%, 0.71% and 0.66% insoils irrigated with sewage effluent for 7, 12, 23, and 40 years, respectively. He ascribed these changes to the washing out of $CaCO_3$ from the sandy soil by sewage effluents. On the other hand, the organic matters in the top soil layer (0-15 cm) increased from 0.05% in non-cultivated soils to 3.25%, 4.38%, 4.93% and 5.63% for the soils irrigated with sewage effluent for 7, 12, 23, and 40 years, respectively. This increase is mainly rendered to the fact that effluent contained appreciable amounts of suspended matter that caused soil enrichment. He added that the average soil pH was 7.83 in non-cultivated soil decreased to 6.47, 6.12, 6.09 and 6.07 in the soils irrigated with sewage effluent for 7, 12, 23, and 40 years, respectively. The electric conductivity in soil ranged from 0.95 to1.11 mmohcm^{-1} at 25 ^{O}C. The mean values of Mg, Na and K were 67, 322 and 63 mgL^{-1} respectively and were 208, 125, 354 and 14 mg L^{-1}, respectively for HCO_3^-, Cl^-, $SO_4^{--}$and NO_3^-. In his study, it is worthy to state that all studied parameters displayed slightly higher levels in the summer compared to winter seasons, with some exceptions reported in EC, Na^+ and SO_4^{--} parameters. These parameters were the highest cation and anion respectively without great variation between the values in both summer and winter.

The treated wastewater irrigation has led to important supply in organic carbon (+100%), phosphorus (+80%) and in most essential nutrients (N, Mn, Zn) [5].

Irrigating of El-Gabal Al-Asfer sandy soils with sewage effluents besides supplementing the soil with extra micro-flora, led to increase the nutrients and organic matter compared to soils un-irrigated with sewage effluent [6]. The applied treatments seemed to support the proliferation of native micro-organisms. The obtained data related with the changes in the microbial population intensities of the main soil physiological groups as affected by irrigation with sewage effluents for different periods are given in Table (1).

Use of sewage effluent for irrigation, improved the organic carbon and fertility status of soils, build up total N, available N, available P, available K and available S in the surface (0–15 cm depth) soil [7], and caused a progressive significant in change in soil pH[8].

Adverse impacts

Sewage farming was always associated with varied soil contamination problems resulting from inadequate management at land application sites. The main problems are associated with the invasion of PTEs and toxic organics in the food chain, bad odors, erosion and run-off leachate and enteric pathogens.

Sewage farming might generate serious odors if the site and application rates are not properly managed. Bad odor problems begin at the point of initial sewage handling and continue after their application to soil. The degree of offensive odor depends upon the type and nature of sewage effluent, any pretreatment prior disposal and how it is managed after it is applied.

Table 1. Microbial population in soils irrigated with sewage for different periods (Counts per gm oven dry basis)[6].

Properties	Period of irrigation with sewage (years)								
	0	**2.5**	**5**	**10**	**15**	**20**	**30**	**45**	**60**
Bacteria 10^5	5	111	119	145	250	299	400	550	620
Streptomycs10^3	1	38	164	192	200	233	360	573	591
Fungi 10^3	8	43	50	49	62	87	97	107	127
PDB 10^3	2	7	11	18	30	48	70	76	80
Aztobacter 10^3	1	7	38	17	14	12	8	2	2
Azospirillum10^3	9	40	60	100	170	60	40	30	20
Clostridia 10^2	9	40	300	29	22	18	11	5	4
Nitrifiers 10	9	206	94	186	60	42	30	19	15
ACD 103	14	17	23	27	60	23	30	30	35
Coliforms 10	0	22	197	361	421	374	274	100	95
Fecal *E.coili*	0	19	1`83	175	150	137	88	36	42

PDB: phosphate dissolving bacteria; ACD: Aerobic cellulose decomposers

If sewage disposal is done improperly, the dissemination of enteric pathogens exists. It can lead to a public health hazards. The transmission might occur through groundwater, surface run-off, aerosols formed during application as well as with direct contact with the effluent and raw edible harvests from a sewage farm. As infectious microorganisms do not penetrate plant tissues, the dissemination of enteric pathogens through crops grown in a sewage farm arises from the contamination of the phyllosphere. When contaminated edible crops are eaten raw, infection is probable. The survival of enteric pathogens in sewage farms is controlled by a set of environmental factors, i.e., temperature, moisture, ultraviolet light etc. But generally, they survive for shorter times on plant surfaces than in soils. To avoid disease transmission, it is recommended that effluent not be applied to soil when crops are to be grown for raw consumption. When humans have little physical contact, the presence of enteric pathogens might be of less concern. The soil has the ability to filter and inactivate pathogenic microorganisms. Worth mentioning, there is a significant possibility of increased nitrate nitrogen contents in groundwater and biomagnifications of PTEs and toxic organics in the food chain. Certain PTEs are also known to be toxic to specific crops.

The main adverse impacts of sewage farming are soil contamination and mineral imbalance, fortifying PTEs and POCs, including salt deposition, soil clogging, crop contamination, livestock infection, groundwater contamination, raising water table, surface water contamination, public health deterioration and natural habitat degradation.

The survival of enteric pathogens in soils irrigated with sewage water for varied periods was studied [3, 6]. He found them able to persist alive in the soil for varying periods (Table 2) and concluded that vegetables eaten raw should not be cultivated in a sewage farm to avoid the enteric pathogen contamination. They concluded that while fecal *E. coli* gave positive results in all soils irrigated with sewage soils, they decreased gradually and disappeared fairly within two months. He added that sewage farming increased total soluble salts [3].

In Asuit Governorate, Egypt, soil irrigation with sewage effluent contained in their surface layer higher iron, manganese, copper, zinc, cadmium, nickel and lead compared to the other soils due to irrigation with sewage effluent. The same trend of results for PTEs content was emphasized in different plant samples [9]. While [10] stated that, the potential problems associated with sewage farming are odors, public health and veterinary hazards due to enteric pathogens, surface and groundwater contamination and accumulation of PTEs in soils and crops. They added that it was noticed that PTEs were greatly dissolved in the aqueous phase of plants rather than in the oil phase. They confirmed that cadmium and lead were dissolved in water phase rather than the oil phase of plants in greenhouse experiments, as the oil plants contained low content of cadmium and lead which were less than the permissible level to humans.

The level of PTEs indicated that the highest existence was recorded for iron and the lowest one was for cadmium in the sewage effluent with slight variations noticed during the successive months of the year. The level of PTEs in summer was slightly higher than in winter due to higher rate of evaporation during primary treatment in hot summer months [4]. The contents of cupper, zinc, and cobalt in soils irrigated with sewage soils [4] were within the permissible limit according to WHO [11] while other PTEs existed over the permissible limits.

The accumulation of PTEs and phosphorus in all soils irrigated with sewage soils was emphasized [12]. The quality of groundwater at the farm was adversely affected by sewage farming due to the accumulation of PTEs, boron, nitrogen and phosphorus as well as enteric pathogens. Some areas in the farm became water logged but treated with sand. The adverse environmental impacts of sewage farming at El-Gabal Al-Asfar farm were also studied by Baseline Matrix using certain weight for each studied parameters. Results showed that raising the level of groundwater in the farm resulted in logging the soil in many parts of the farm (Table 3). Also, a noticeable increase in nutrients, pathogens PTEs, boron, pesticides and soil salinity was recorded, besides detecting a variety of organic toxins in soils irrigated with sewage soils.
The survival of enteric pathogen in soil existed for shorter period compared to their survival on the phyllosphere are shown in Table (13).

The soil irrigated for 75 years with sewage effluent showed increment in the total content of the tested PTEs compared to control. The obtained values were (316.9, 276.4, 19.72, 9.31, 43.81 and 213.3 ugg^{-1} soil for zinc, copper, cobalt, cadmium, nickel and lead) respectively. They added that all values were remarkably over the safe values of these PTEs that should be found in soils [14].

PTEs comprise a group of minerals that had no known function in the body and, in fact, are harmful. Today mankind is exposed to the highest levels of these PTEs in recorded history. PTEs are now everywhere and affect everyone on planet Earth. They had become a major cause of illness, aging and even genetic defects [15].

Table 2.Survival of fecal *E.coli* in sandy soils irrigated with sewage effluent

Period of irrigation with sewage (years)	Time (days)			
	0	15	30	60
	10^5	10^3	10^2	0
Soils un-irrigated with sewage	4	200	200	0
2.5	21	40	2	0
5.0	20	5	22	0
10	22	19	12	0
20	26	52	32	0
44	2	2	8	0

Table 3. Survival of pathogens in soil [12].

Pathogen	Survival time (days)	
	In soil	On plant phylopshere
Virus	15-60	20-100
Coliforms	15-30	20-70
Salmonella	15-30	20-70
Shigella	5-10	10-20
Vibrio cholera	2-5	10-20
Endameba histolitica	10-15	3-10
Ascaris Eggs	Several months	Several months

An undesirable bioavailability of PTEs as well as a significant decrease in microbial biomass carbon (-78.2%), soil respiration (-82.3%), phosphatase activity (-59.12%) and dehydrogenase activity (-59.4%) in soils irrigated with sewage effluents was recorded [7]. They attempted to identify sensitive soil indicators under sewage irrigation, and found that both microbial biomass and carbon content to be the most sensitive indicators.

Contaminants in soils irrigated with sewage

Although there is a strong possibility of agronomic and economic benefits of sewage farming, long-term contaminants could be slowly introduced and accumulated in the soils and cause a potential risk to soil quality and productivity. There are three main types of contaminants that are regularly found in soils irrigated with sewage soils i.e. potential toxic elements (PTEs), persistent organic contaminants (POCs) and enteric pathogens. The level of soils irrigated with sewage effluentcontamination depends on the type and efficiency of treating sewage effluent used in irrigation. In Egypt, there are varying combinations of domestic and industrial effluents which had different adverse impacts on soils. No doubt, the treatment process does not remove all enteric pathogens or PTEs and POCs. The movement of the main types of soil contaminants and their characteristics are presented in Table 4.

Table 4. Types of main soil contaminants and their movement in soil [16].

Contaminants	TDS	PTEs	NO_2	*E. coli*	Organic contaminants	
					Pesticides	Petroleum
Main source	N,A,D*	N, I	A,D	D	I	I,A
Solubility	+	+/-	+	+	+/-	-
Drinking water standard	1000 ppm	depends	50ppm	1/100 ml	0.0005 ppm	0.0005 ppm
pH	-	-	0	-	0	0
Redox potential	-	-	-	-	0	0
Organic matter	-	-	-	-	-	-
Clay content	-	-	-	-	-	-
CEC	-	-	0	-	0	0

*N: Natural; D: Domestic; A: Agriculture; I: Industrial, **+: Positive effect;-: Negative effect; 0: No effect; +/- Depend on conditions

Sources of contamination

There are several sources of soil contamination, some are natural and others are manmade. On the other hand, there are also effective available techniques to combat soil contamination and rehabilitate contaminated land resources particularly those modern techniques of bioremediation using microorganisms and plants as accumulators of contaminants. The three main modes of contaminants degradation in soil are biological degradation by means of microorganisms, inorganic breakdown by means of inorganic reactions such as hydrolysis and redox reactions, and photo inorganic breakdown by means of ultraviolet or visible light. The fat of contamination depends on some important features such as soil characters, as well as on cultivated plants, methods of application and the climate etc.

There are two main sources of soil contamination; point source that are an observable, specific, and confined discharge of contaminants into soil, and non-point sources that are the diffuse discharges of contaminants throughout the natural environment.

Inorganic contaminants

PTEs are natural constituents of the Earth's crust, but human activities had drastically altered their geo-inorganic cycles and bioinorganic balance. PTEs contamination is responsible for several environmental and agricultural problems and risks to human health, including decreased soil microbial activity, fertility and yield losses. The concentrations of PTEs in contaminated soils are often greater hundreds times than that required to exert a toxic effect on the majority of higher plants. PTEs could affect the biosphere for long periods and could be leach through the soil layers leading to the contamination of the water table.

Consequently, the use of edible parts of contaminated plants contain high levels of PTEs, might pose a serious risk to human and animal health.

PTEs contamination in agricultural soils is a major environmental problem that could reduce both the productivity and the safety of plant products as food and feeds. PTEs of concern to sewage farming include mainly selenium, molybdenum, arsenic, vanadium, and boron. Sewage effluent quality control requirements for PTEs are stringent and are usually prescribed in parts per million. However, the control of PTEs is complex and difficult and they must be periodically assessed on a case-by-case basis.

PTEs are not degraded biologically and it persists in the environment indefinitely. Once accumulated in the soil, PTEs inversely affect the microbial compositions, including plant growth promoting rhizobacteria in the rhizosphere, and their metabolic activities. In addition, the elevated concentration of PTEs in soils and their uptake by plants adversely affect the growth, symbiosis and consequently the yields of crops by disrupting the physiological process, such as, photosynthesis, or by inactivating the respiration, protein synthesis and carbohydrate metabolism.

Soil quality criteria give numerical levelsonly for some PTEs such as chromium, lead, cadmium, mercury, selenium and cupper which usually had concentrations below the guideline level in raw sewage. PTEs contaminants are existed in the soil in five inorganic pools, soluble, exchangeable, adsorbed, and organically chelated or complexes. The PTEs applied with sewage effluent tend to be accumulated as organic complexes (pyrophosphate extractable form) and to a lesser extent as inorganic precipitates (acid oxalate extractable). They added that the organically complexed fraction represented the main reservoir. Prolonged application of sewage farming shifted the equilibrium for most PTEs towards the organically complexed fraction. They concluded that $CaCO_3$ in significant amount would suppress the availability of most PTEs due to their adsorption and co- precipitation on carbonate [8].

Chromium is mainly found in oxidation state, the trivalent form had a great tendency to coordinate with oxygen and nitrogen legends, and the hexavalent form is the most toxic of the oxidation status of chromium. The total chromium concentration in soil ranges between 5-1000 ppm with an average of 100-300 ppm. Soluble chromium is very low in soil solution ranging between 0.04-2.60% of the total content reaching 0.1-214.0 ppm. The exchangeable soluble chromium could be easily absorbed by plants and metabolized by microorganisms. About 80% of chromium is accumulated in the surface soil (0-10 cm). The toxicity of chromium depends upon its oxidation state. When chromium binds with calcium carbonate it is fixed in surface soils while CrO_4 is less mobile in calcareous soils and always combined with soluble divalent and trivalent cations or bended with carboxylic or phenolic groups of organic matter, its content ranges between 63.53 to 1.82 ppm depending on the type of growing plants.

Lead had an oxidation status of II & IV, its salts might be slightly soluble in water (chlorides and bromides) or almost insoluble (carbonates and hydroxides). The total lead in uncontaminated natural soils ranges from more than 1.0 to 20 ppm. The average content in organic soils is about three times greater than mineral soils. In arid region soils, lead exists in different forms i.e., exchangeable, sorbed, organic, carbonate and sulfide fractions. Most of the lead was found in surface layer, the organic matter presence in this layer binds about 45-65% of total lead which decreases by depth. Also, soils having high $CaCO_3$ content had a minor role in bending lead, not exceeding 6% of total lead. Contrary with this result, the presence of active $CaCO_3$ in soils increased Pb fixation [17].

Cadmium exists in soils as a stable divalent ions i.e., Cd $(NH_3)_6$ and Cd (CN) or forms stable compounds such asCdS. It forms insoluble compounds usually hydrated with carbonate, arsenate, phosphate or oxalate. Cadmium exists in different forms in soil , i.e., exchangeable, adsorbed on clay and organic matter, hydrous oxides of iron, manganese, aluminum reducible, hydrous oxides, co-precipitated with carbonate, phosphate, sulphate, organic binding, fixed with the crystalline lattices of mineral particles.

Mercury could be found in three stable oxidation statuses 0, I and II, as well as in stable mercury sulfates or in the form of organic and inorganic complexes. It exists in non-contaminated soils at 0.1 ppm and might reach 15 ppm in contaminated soils. It is very unstable in soil and might volatilize and easily converted to an organic form or chelated with humic acid in a soluble form. The mercury II inorganic complexes might be combined with chloride and hydroxides reaching 207 ppm in soil solution. The mercury mobility is mainly affected by soil pH, organic matter, texture and type of minerals.

Selenium naturally leaches from the soil, but becomes concentrated where leachates from highly irrigated soils accumulated toxic levels in shallow groundwater regions.

Copper is an essential element and enzyme co-factor for oxidases (cytochrome oxidase, superoxide dismutase) and tyrosinases, however, plants could accumulate toxic levels. At super optimal levels, copper is highly toxic to plants and copper ligands in plants are citrate, PC, PC, and PTE lothioniens.

PTEs similar to arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc are commonly found in soils irrigated with sewage effluent in parts per million levels. Total PTEs load in the soils irrigated with sewage soils is generally about 0.5 to 2.0% of total dry weight, but in some cases it reaches up to 4% Specifically, the PTEs content in soils irrigated with sewage soils irrigated with industrial effluents often exceeds the maximum limit by several tenfold. They, therefore, concluded that it must be removed before final soil application to prevent environmental contamination and health hazards [18].

Acidic conditions in soil often enhance the solubility of PTEs. An increase in the dissolved concentration of PTEs might represent toxicity and contamination problems in soils under acidic conditions [19].

The total content of a given PTEs in soils is considered impractical expression for its uptake by plants because only certain fractions of an element are phytoavailable. The bioavailability and mobility of PTEs in soil strongly depend on their physic-inorganic forms in soils [20].Therefore, it is important to understand inorganic the fractionation of PTEs in order to assess PTEs availability and toxicity to crop plants in a contaminated soil. The concentration and distribution of available forms of cadmium, nickel, chromium, lead and zinc in soils irrigated with sewage effluent ranged from 0.02 to 0.22 for cadmium, 1.67 to 5.97 for lead, 2.89 to 9.14 for zinc, 0.05 to 0.33 for chromium and 3.07 to 8.22 for cupper ($mgkg^{-1}$). These values, however, could be drastically changed in hyper accumulator plants.

The fractionation of cadmium, cobalt, nickel and lead in soil irrigated with sewage effluent might rank as follow: organic > residual > oxides > carbonate > exchangeable [21]. In the polluted soils, Cd was distributed in soil in the order residual> organically complexes =Fe-Mn oxides > carbonate-bounded > exchangeable > water soluble fraction [22].

Longterm irrigation with sewage effluent resulted in significant build-up of DTPA extractable zinc (314%), cupper (102%), iron (715%), manganese (197.2%), cadmium (203%), and nickel (1358%) and lead (15.2%) compared to adjacent rain-fed reference soil [7].

Organic contaminants

POCs are organic compounds that are resistant to environmental degradation through inorganic, biological, and photolytic processes. Because of this, they had been observed to persist in soils irrigated with sewage soils, to be capable of long-range transport, to bioaccumulation in human and animal tissue, be biomagnified in food chains, and to had potential significant adverse impacts on human health.

The Governing Council of UNEP decided in 1995 to begin investigate POCs, and prepared a short list of the following twelve POCs, known as the 'dirty dozen' aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and toxaphene. Since then, this list had generally been accepted to include such substances as carcinogenicpolycyclic aromatic hydrocarbons (PAHs) and certain brominated flame-retardants, as well as some organo PTElic compounds such as tributyltin (TBT).The groups of compounds that make up POCs are also classed as PBTs (Persistent, Bioaccumulative and Toxic) or TOMPs (Toxic Organic Micro Contaminants). Though there are a few natural sources of POCs, most .Organic contaminants might be arranged according to their magnitudes in soils irrigated with sewage soils as residual=oxides (27%)>carbonate (21.35%)>exchangeable= organic (11%) [23].

Lepidium and sequential supercritical fluid extraction (SSFE) with carbon dioxide as extraction solvent are used for the determination of PAHs availability to plants [24]. They found that only naphthalene, phenanthrene and, in some cases, pyrene accumulated in plants from contaminated soils. Accumulation experiments with spiked industrial soils showed that other PAHs, for example anthracene, fluorene and even high weight PAHs like benzo(a)pyrene, also could be taken up by plants. SSFE extraction data were compared to accumulated amounts of PAHs in the plants. Strong correlations were found for phenanthrene between plant accumulation and extractability under very mild extraction conditions. For naphthalene, accumulation did not correlate with its extractability in the industrial soils. Supercritical fluid extraction appears to be a promising tool to estimate phenanthrene availability to plants, but further studies for the evaluation of other PAHs were recommended. This could be helpful for the determination of the feasibility of phytoremediation applications on industrially contaminated soils.

On an average basis, the highest amount of the studied PTEs associated with organic fraction: 52.7, 49.4, 71.1, 46.1, 38.8 and 44.4% for zinc, cupper, cobalt, cadmium, nickel and lead, respectively. While, the iron-manganese oxides bound fraction was the dominated form of zinc (27%), cupper (32.7%), nickel (34.4%) and lead (27.5%). Also, for all the studied PTEs recoveries from the sequential extraction procedure was within 86.7 to 92.9% for their total concentration [14].

Biological contaminants

Pathogens are microorganisms and parasites that could cause illness in humans and animals. Great potential for soil contamination comes from receiving untreated sewage effluent. Localized contamination of soil could also result from animals in feedlots, corrals, exercise yards, pastures, and rangelands. Other non-point sources of pathogens include wildlife and septic tanks.

Irrigation with untreated sewage effluent could represent a major threat to public health (of both humans, and livestock), food safety, and environmental quality. Soils are apt to contamination with pathogens as a result of irrigation with sewage effluent. The main sources of pathogenic germs particularly eggs and cysts of ascaris, ancylostoma, Tania and pathogenic protozoa fall within helminthes. Raw sewage effluent had been implicated as an important source of health risk for chronic, low-grade gastrointestinal disease as well as outbreaks of more acute diseases including cholera and typhoid. A primary exposure route for the urban population in general is the consumption of raw vegetables that had been irrigated with sewage effluent.

It is widely known that it is not practical to establish the presence or absence of all pathogenic organisms in sewage effluent in a timely fashion. For this reason, the indicator organism concept was established many years ago to allow monitoring of a limitednumber of microbiological constituents. The microbiological organisms (pathogens and indicator microorganisms) that are usuallyanalyzed for to establish the presence or absence of health hazards are bacteria (feacal coliform, *E. coli, Shigella*, total coliform, *Streptococcus, Clostridium erfringens, Salmonella*), Enteroviruses, Bacteriophages (Fþ, somatic), Helminthes and Nematodes (Ascaris Hookworm, Ancylostoma, Tania eggs), protozoa and cysts. Epidemiological studies conducted did not establish definitive adverse health impacts attributable to the use of appropriately treated sewage effluent for irrigation.

Regulatory agencies generally rely on tests for fecal coliform bacteria to indicate contamination. Although fecal coliforms themselves are not pathogenic, they indicate that pathogens could exist and possibly flourish. Ratios of fecal coliform to fecal *Streptococci* concentrations might be used to distinguish human from animal waste pollution. Contamination could occur when the daily rate of fecal deposition exceeds the ability of vegetated buffers, soil, and solar radiation (sunshine) to either filter out or inactivate the pathogenic microorganisms.

Helminthiases are common diseases transmitted through helminthes egg ingestion from vegetables irrigated withsewage effluent. Helminthiases eggs are resistant to chlorine, ultraviolet (UV) light and ozone. Infective doses are very low (1–10 eggs/L) compared to those forbacteria. Ascaris is the most common helminthiases found insewage effluent, and it is also the most resistant tosewage effluent treatment and medications.The physical properties of helminthiases eggs (20–80 mm, specific density1.238 – 1.036) greatly influence their removal from sewage effluent. As a part of suspended solids, *helminthiases* eggs might be removed by means of treatment processes such as settlers, lagoons, coagulation-flocculation, and filtration.

No strong evidence had been found to suggest that population groups residing near sewage effluent treatment plants or soils irrigated with sewage soils aresubject to increased risk from pathogens resulting from aeration processes orsprinkler irrigation. Adverse health effects had been detected only in association with the use of raw or poorly settled or decanted sewage effluent.

The potential effects of secondary sewage effluent on natural and artificially constructed calcareous soils in greenhouse and field lysimeters, and in soil columns as well were determined [25]. The leachate from one field lysimeter contained increased fecal coliform (FC) counts than sewage effluent. Leachate coliform counts were decreased or not significantly changed in two field lysimeters. Soil column drainage samples showed a decrease in coliform counts. Preferential flow of coliform bacteria might indicate long term effects that might affect the sustainability of the practice. Higher values of relative increase in FC counts in lacustrine or calcareous soils cultivated with soybean and corn (summer field crops) than in those cultivated with faba bean and wheat (winter field crops) was recorded [5]. They attributed the differences due to more the relatively higher temperature in summer than in winter, which would stimulate the bacterial population, especially in the soil of the upper layer relative to that of the lower layer and also related to a higher concentration in the water used for the irrigation.

The ecological and survival characteristics of bacterial, viral and parasitic pathogens vary under environmental conditions, indicating that probably no single indicator microorganism could predict the presence of all enteric pathogens for all types of waters and different host- associated fecal pollution. If there are true correlations between indicator microorganisms and pathogens, it is necessary to findout to what extent and under which circumstances these microorganisms could be used as reliable indicators of fecal pollution. Application of conventional and alternative fecal indicators had greatly enhanced our microbial source tracking abilities to predict and reduce health risk associated with the use of sewage effluent. New fecal pollution molecular-based techniques had shown that combined use of conventional and fecal indicator microorganism's alternative indicators for fecal pollution increased both the detection sensitivity and alternative indicators of fecal pollution and associated pathogens [26].

Sewage farming Norms

There are many norms limited justifying the reuse of sewage effluent in farming. Some of these norms were set by international organizations others were set by national authorities in different countries. National standards should consider the current situation of the SETP sewage effluent treatment plants (SETP) and the problems, which they suffer from. In many cases, sewage effluent quality standard had been adopted from other countries with no consideration of their suitability for local conditions. Borrowing over-stringent standards could cause an unnecessary fear of prosecution or disease and thus squander resources by discouraging reuse of sewage effluent. For example, it is not suitable to adopt the sewage effluent standards of other developed countries, where they use tertiary treatment processes and implement restricted guidelines to achieve several reuse purposes. A more realistic set of standards, which are totally adequate to safeguard public health, would be based on the WHO and FAO guidelines. These norms are different according to the varied ecosystems of application.

In Egypt, there several official bodies responsible for sewage farming, those are Ministry of Agriculture and Land Reclamation, Ministry of Water Resources and Irrigation, Ministry of Housing, Utilities and New Communities, Ministry of Planning, Ministry of Health, Sate Ministry of Environmental Affairs and Ministry of local Administration. The most Egyptian sewage farming norms were set by ministry of housing in 2004**,** however, the need for cooperation between those governmental bodies is urgent. The following Tables (6-11) summarize the main norms related to sewage farming practices**.**

In the current project, the accepted critical levels of PTEs in soils will be as follows:

- Maximum accepted background will be (in ppm) 5 for arsenic, 0.06 for cadmium, 100 for total chromium, 0.03 for mercury and 10 for lead.
- Background range will be (in ppm) 1-50 for arsenic, 0.01-0.07 for cadmium, 1-1000 for total chromium, 0.1 for mercury and 2-200 for lead.
- Superfund site goals will be (in ppm) 5-65 for arsenic, 3-20 for cadmium, 6.7-375 for total chromium1.0 for mercury and 200-500 for lead.

Table 6.Ranges of limit values for PTEs in soils irrigated with sewage soils under EC and US legislation (mg kg^{-1} ds)

Parameter	European Commission Directive 86/278/EEC	US EPA Rule 503
Zinc	2500 – 4000	2800 - 7500
Copper	1000 – 1750	1500 - 4300
Nickel	300 – 400	420
Cadmium	20 – 40	39 - 85
Lead	750-1200	300 - 840
Mercury	16 – 25	17 - 57

Table 7.Critical concentration (ppm) of constituents in TSE used for irrigation [27],[28].

Element	Long Term (less than 20 years)	Short term (more than 20 years)
TSS	500	2000
Zn	2.0	10.0
Cu	0.2	5.0
Cd	0.01	0.005
Cr	0.1	1.0
Pb	0.05	0.075
Ni	0.2	2.0
Co	0.05	0.5
B	0.75	2.0
AS	0.1	0.2

Table 8. Ranges of limit values for PTEs in soils irrigated with sewage soils under EC and US legislation (mg kg^{-1} ds)

Parameter	European Commission Directive 86/278/EEC	US EPA Rule 503
Zinc	2500 - 4000	2800 - 7500
Copper	1000 - 1750	1500 - 4300
Nickel	300 - 400	420
Cadmium	20 - 40	39 - 85
Lead	750-1200	300 - 840
Mercury	16 - 25	17 - 57

Table 9. Mean concentrations and ranges of PTEs and nutrients in soils irrigated with sewage soils.

PTEs (mg kg^{-1})	Abu Rawash		Helwan		Berka
	Mean	Range	Mean	Range	
Zinc	1726	113-4639	2488	155-8097	368
Copper	243	83-516	342	119-988	634
	99	25-212	97	23-188	68
	26	4.6-50	124	15-312	3.2
Lead	269	38-509	68	50-302	552
Mercury	5.6	0.5-15	-	-	-
Cobalt	38	3.1-689	8	2-11	9
Arsenic	11	4-25	-	-	-
Selenium	6	4-8	-	-	-
Manganese	436	93-581	-	-	-
Iron%	1.29	0.10-1.78	6680	0.11-2.49	1.77
Nitrogen%	1.22	0.93-1.72	1.41	1.27-1.67	1.82
Phosphorus%	1.43	1.29-1.59	1.37	0.27-1.44	-
Potassium%	0.79	0.13-1.10	0.63	0.12-0.80	0.18

Table 10. Mean concentrations and ranges of PTEs and nutrients in soils irrigated with sewage soils in Egypt

Determinations	Units	Abu Rawash		Helwan		Berka
		Mean	Range	Mean	Range	
Zinc	mg kg^{-1}	1726	113-4639	2488	155-8097	368
Copper	mg kg^{-1}	243	83-516	342	119-988	634
Nickel	mg kg^{-1}	99	25-212	97	23-188	68
Cadmium	mg kg^{-1}	26	4.6-50	124	15-312	3.2
Lead	mg kg^{-1}	269	38-509	68	50-302	552
Mercury	mg kg^{-1}	5.6	0.5-15	-	-	-
Cobalt	mg kg^{-1}	38	3.1-689	8	2-11	9
Arsenic	mg kg^{-1}	11	4-25	-	-	-
Selenium	mg kg^{-1}	6	4-8	-	-	-
Manganese	mg kg^{-1}	436	93-581	-	-	-
Iron	%	1.29	0.10-1.78	6680	0.11-2.49	1.77
Nitrogen	%	1.22	0.93-1.72	1.41	1.27-1.67	1.82
Phosphorus	%	1.43	1.29-1.59	1.37	0.27-1.44	-
Potassium	%	0.79	0.13-1.10	0.63	0.12-0.80	0.18

Table 11. Maximum level for accumulated potential elements in soil (kg/hectare) [17].

Country	**Ca**	**Cu**	**Cr**	**Pb**	**Hg**	**Ni**	**Zn**
Canada	0.8- 4.0	100-200	50-210	50-100	0.2-1.0	12-36	150-370
France	5.4	210	360	210	2.7	60.0	750.0
Germany	8.4	210	210	210	5.7	60.0	750.0
Netherlands	2.0	120	100	100	2.0	20.0	400.0
Sweden	0.075	15	5	1.5	0.04	2.5	50.0
United Kingdom	5.0	280	1000	1000	2.0	70.0	560.0
USA	5-20	125-500	-	500-2000	-	50-200	250-1000

Monitoring programs

To confirm the enforcement of environmental protection measures, monitoring and supervision of activities should be closely undertaken. Monitoring activities should include regular sampling and analysis of the quality of soil at a frequency of sampling. The ecosystem is defined as a unit of vegetation which includes not only the plants of which it is composed but the animals habitually associated with them, and also all the physical and chemical components which together form recognizable self-contained entity. The core of this concept is the inclusion of physical, chemical and biological components in the system and the constraint that the majority of the interactions occur within the recognizable self-containment and define the frontier between adjacent ecosystems. These do not mean that all interactions must be internal to a properly defined ecosystem.

Broadly, ecosystems contain five main functional categories of component organism. At the base, driven by the input of nutrients, carbon dioxide and solar energy are the green plants or primary producers, using the sun's energy to make carbohydrates. On them feed herbivorous animals or secondary producers. In turn these sustain carnivores, forming a tertiary "trophic level" sometimes the chain is longer as when an insect –eating bird is the prey of a larger predator like a hawk.

But the flow of energy through an ecosystem should not be thought of as simply following a straight line from plant to herbivore to carnivore. Much plant material is deposited, along with animal body wastes and carcasses, as dead matter on the ground or the bed of water body. Here it sustains component of the ecosystem, the decomposers chiefly bacteria and fungi. In turn those are consumed by microbivores, which might themselves sustain higher predators. All these components play their part in the biogeochemical cycles.

The safe use of soils irrigated with sewage soils in agriculture necessitates continuous evaluation for ecosystems morphological, hygienic, inorganic and physical as well as their aesthetical characteristics. The physical-inorganic qualities are important parameters for the evaluation of the fertilizing value and the value of the soils irrigated with sewage soils. The most important nutrients, which could be found in soils irrigated with sewage soils, are nitrogen, phosphorous and potassium. Too high or too low pH-values as well as too high contents of salts, expressed by the contents of chloride and sulfate lead to negative impacts on agriculture. The accumulation of lead, cadmium and chrome in soils and plants are potential hazards for the health of plants, animals and humans. The hygienic safety, presence of pathogens in soils irrigated with sewage soils is vital elements in sewage reuse strategies.

The aesthetical quality is an important criterion for the successful sales management and advertisement of the soils irrigated with sewage soils products. A product that had excellent inorganic-physical and hygienic qualities is often hard to promote if it shows bad aesthetical qualities (odor, consistence, color).

Monitoring includes observation of ecosystems performance, checking the quality of affected natural systems, and observing and recording environmental impact as quality changes occur. No doubt, a comprehensive monitoring system will be required in sewage farms to ensure that proper renovation of sewage effluent is occurring and environmental degradation is not going on. Some monitoring requirements are similar to those required for conventional programs. One example is the monitoring of sewage effluent quality at various stages prior to application. Other monitoring requirements are generally unique to land application systems.

Monitoring of soils irrigated with sewage soils serves several important functions as it provides data to prove that the land application systems complies with standards of water quality and environmental safety, reveals any inadequacies in the original design of the system, provides data which could be used in the design of future land application systems and provides information needed for careful day-today management of the sewage farm. Any sewage farm should have a monitoring program for observing and evaluating the ecosystem performance. Sewage effluent composition, groundwater quality, soil conditions and plant constituents would be monitored in an optimum sampling program. The monitoring program should specifically designed for local conditions including site and sewage effluent characteristics, proposed rate of application, types of crops supposed to be grown therein. A few more details regarding monitoring were proposed by [29] and are exhibited here.

Sewage effluent analyses: A periodic sewage effluent analysis confirms that it is acceptable and provides a record of nutrients and metal addition to soils. The frequency of sampling will depend upon effluent characters and variability. The recommended analyses includes total solids, total, ammonia and nitrate nitrogen, total phosphorus, total potassium, copper, zinc, nickel, lead, cadmium and stable organics.

Renovated sewage effluent: Monitoring of renovated sewage effluent might be required for either ground water or recovered water or both. Recovered water includes run-off from overland flow or water from recovery wells or under drains. Generally, nitrate nitrogen is the parameter that must be closely observed in ground water. To assess the overall impact of the system, changes in ground water quality can be compared with the quality of background wells. Monitoring wells might be designed and locate to meet the specific geologic and hydrologic conditions at each site. Consideration should be given to geologic soil and rock formations existing at the sewage farm, depth to an impervious layer, and direction of flow of ground water and anticipated rate of movement, depth of seasonal high water table and an indication of seasonal variations in ground water depth and direction of movement. Also, nature, extent and consequences of mounding of ground water which could be anticipated to occur above the naturally occurring water table, location to nearby streams and swamps, potable and non-potable water supply wells might be valuable.

Background data should be obtained from wells in the same aquifer beyond and within the anticipated area influence of the system and compared with subsequent data to assess the impact. In addition to background sampling, ground water samples should be collected at perimeter points in each direction of ground water movement from the farm. Perimeter wells must intersect flow lines and must be of optimum depth. Samples might be taken monthly during the first two years of farming. Later on they might be modified. Sampling procedures might be a measured amount of water equal to or greater than three times the amount of water in the well and/or gravel pack should be exhausted from the well before taking a sample for analyses.

In the case of very impermeable soils, the well may have to be exhausted and allowed to refill before a sample is collected. Pumping equipment should be thoroughly rinsed before use in each monitoring. Water pumped for each monitoring well should be discharged to the ground surface away from the well to avoid recycling of flow in high permeability soil areas. Samples must be collected, stored and transposed to the laboratory in a manner that avoids contamination or interference with subsequent analyses.

Water samples collected might be analyzed for chlorides, conductivity, pH, total hardness, alkalinity, total nitrogen, ammonia nitrogen, nitrate nitrogen, total phosphorus, methyl blue active substances, total organic carbon and PTEs and POCs. An example of the operational and the compliance monitoring schedule for an irrigation system is given in table 12, showing the most important constituents to be monitored and the frequency of sampling.

In addition to the changes in quality, changes in ground water levels should be also monitored. The effect of increased levels should be assessed with respect to changes in the hydro geologic conditions of the areas. Changes in ground water movement and the appearance of seeps and perched water tables should be noted, and system modifications, such as reducing application rates in the area, should be undertaken. If the water is to be reused, analysis of additional parameters might be required by public health agencies (Table 13). Monitoring of the flow rate of recovered water might be important for system control and may also be needed as a result of water rights considerations.

Vegetation: When vegetation is grown as apart of the treatment system, monitoring might be required to optimize growth and yield. Plant tissues composition is a sensitive and meaningful indicator of impacts, provides useful information on plant nutrients deficiencies and toxicities, and indicated potential health hazards in food-chain crops. The basic principles underlying plant tissue sampling are common to both forestry and agricultural species. But specific methodology is unique to bothpractices. Although the use of vegetable crops is not recommended on soils irrigated with sewage effluent, diagnostic tissues for these crops are vital. Sampling the mature grain or forage is the preferred method of monitoring from the point of view of PTEs impact on the human food-chain. The major emphasis is presented on elements given in Table 14. So far limits have not been set for allowable concentration, therein some major guidelines.

Table 12.Example of operational monitoring schooled for an irrigation system.

Parameter	Applied effluent	Sampling Frequency at various points			
		Onsitewells	Backgroundwell	Perimeter wells	Adjacent lake
BOD	D	-	-	-	Q
COD b	Mc	Q	Q	Q	Q
R.Chlorine	2D	-	-	-	-
Feacal Coliform	M	Q	Q	Q	Q
Total Coliform	D	Q	Q	Q	Q
Nitrogen	M	Q	Q	Q	Q
PH	2Dd	Qd	Qd	Qd	Qd
Phosphorus	Mc	Q	Q	Q	Q
Suspended	D	-	-	-	-
Solids	-	-	-	-	-
Static water level	-	Md	Md	Md	-

D= one measurement per day; Q= one measurement per quarter; M= one measurement per month; 2D= one sample or measurement per day; C= continuous measurement and recording

Soils: In almost all cases, the application of sewage effluent to the soil will result in some changes in their characteristics. Consequently, some sort of soil monitoring will be necessary for some systems, with at least annual sampling recommended. Initial monitoring of soils provides a reference data specifying original conditions as well as necessary or tolerant effluent constituent additions which might be practiced. Subsequent soil analyses, chemical, microbiological and physical, indicated contamination build-ups, efficiency of plant uptake and removals, events of sewage effluent application and other environmental impacts. Standardized analytical procedures for sewage amended soil have not yet been established but the analytical procedures used for cultivated soils are generally sufficient and acceptable. Characteristics that are the commonly of interest include salinity, level of various elements, pH, cation exchange capacity.

Table 13.Suggested values for major inorganic constituents in water applied to the agricultural land.

Constituents	Safe	Problematic	Hazardous
Salinity (EC millimhos/cm)	<0.75	0.75-3.0	>3.0
Permeability EC SAR	>0.5 <6.00	>0.5 6.00-9.00	<0.2 >9.0
Specific ion toxicity from root absorption Na (as SAR) Cl (mg/l) B (mg/l)	<3.00 <4.00 <0.5	3.00-9.00 4.00-10.00 0.5-2.00	>9.00 >10.00 2.00-10.0
From foliar absorption Na (mg/l) Cl (mg/l)	<3.0 <3.0	>3.0 >0.3	- -
pH	6.5-8.4		

Table14.Suggested tolerance and toxic levels of PTEs in plants grown in a sewage farm (ppm)

Element	Tolerance level	Toxic level
Barium	200	-
Boron	150	>75
Cadmium	3	-
Cobalt	5	-
Copper	150	>20
Chromium	2	-
Lead	10	-
Manganese	300	-
Molybdenum	3	-
Nickel	3	>50
Vanadium	2	>10
Zinc	300	>300

The salinity of the soil, as measured by the electrical conductivity, is of extreme concern in Egypt. High levels of salinity are injuries to most plants in various degrees. Anotherrea of major concern is the sodium adsorption ratio (SAR). High values might adversely affect the permeability of soil. Levels of nitrogen, phosphorus, potassium, magnesium and calcium are also important. Levels of PTEs are of concern in many cases because of their effect on crop growth and crop marketability. Many PTEs are micronutrients that are required for the proper growth of plants. At high levels, however, they might be toxic to plants or animals in the food chain, as well as to humans.

The optimum soil pH range for retention of many sewage effluent constituents is the neutral range (pH 6-7). Because sewage effluent usually has a neutral pH, fluctuations in soil pH are uncommon but do sometimes occur. Any decrease in soil pH occurs could be corrected by the addition of lime. The cation exchange capacity is an important parameter because of its role in the chemical renovation of the water. The cation exchange sites may be occupied by ammonia, calcium, magnesium, potassium, sodium, and hydrogen ions. Competition for the available sites depends on the relative concentrations of these ions in the soil, and this competition is reflected in the quality of the renovated water. The change in percent of available sites occupied by each cation is the important trend to monitor. If one cation such as sodium, builds up excessively, remedial measures, such as adding amendments, should be considered.

In Greater Cairo area there is a regular sampling of soils irrigated with sewage soils to evaluate the quality criteria important for agricultural reuse (nutrients, PTEs, etc.). However, the quality and sensitivity of some of these analyses and their presentation must be questioned. There appear to be some confusion over, and no standardization of, methods for describing results (wet or dry solids basis, inappropriate or no units given, etc.). Conventionally, the concentrations of most constituents are expressed as mg/kg ds (dry solids), but many results are, or appear to be, given as g/kg and reported to only 2 decimal places. This approach, by rounding results up or through a lack of analytical sensitivity, results in course (or missing) quantification of certain PTE such as cadmium and mercury, which are of environmental concern at low concentrations in the mg/kg range.

The range of determinants that are reported is extensive (Table 15), but not all samples had been analyzed for these consistently. Indeed, not all of these are necessary on a regular basis, although perhaps are useful from time to time to monitor overall soils irrigated with sewage soils quality, but the extent of analysis depends on general soils irrigated with sewage soils quality, method of disposal and the sensitivity of the receiving environment. The determinants which had been reported are moisture, dry solids, organic carbon, carbon / nitrogen ratio, settlement, volatile acids, pH, conductivity (salinity), alkalinity, chloride, sulfide, total nitrogen, sodium, ammonia, nitrate, phosphorus, potassium, calcium, magnesium, iron, manganese, boron, zinc, copper, nickel, cadmium, lead, chromium, mercury, arsenic, selenium, silver and cobalt. There are some data on protozoa (*giardia, entamoeba*) trematodes (*schistosoma*), nematodes (*ascaris sp*) virus (*hepatitis*), bacteria (total bacteria, spore formers, total coliforms, fecal coliforms, *E. coli*, total *salmonella, shigella*).

Table 15. Monitoring program of soils irrigated with sewage soils [16].

Item	Sewage effluent	Well in the farm	Control well	Control lake
BOD	Daily	-	-	Every 3 month
COD	Monthly	Every 3 month	Every 3 month	Every 3 month
Residual Cl	Twice a day	-	-	-
Feacal coliforms	Monthly	Every 3 month	Every 3 month	Every 3 month
Total coliforms	Daily	Every 3 month	Every3 month	Every 3 month
N	Monthly	Every 3 month	Every3 month	Every 3 month
P	Monthly	Every 3 month	Every 3 month	Every 3 month
Suspended matter	Daily	Every 3 month	Every 3 month	Every 3 month

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