Chemical, physical and biological characteristics of sewage water (sludge and effluent)

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ABSTRACT:

The application of swage water to environment increased the availability of plant nutrient and caused the harmful effect of hazardous heavy metals, organic pollutant and pathogenic agent. This study was carried out to defined the term of sewage water (sludge and effluent), effective sludge treatment processes, identify of the general characteristics of swage water which including physical, chemical, biological characteristics in different location.

1- INTRODUCTION:

Increasing waste production by human activities increased the problem of how to get rid of these wastes without causing undesirable impact on the environment and humans. **In** principal land disposal is more popular than other means, including landfills, incineration and dumping at sea, because it is relatively inexpensive. Moreover, sewage dumped in coastal waters must receive primary treatment, and that dumping at sea should have been ceased by 1998 according to the European Union (EU) directives (Be~k *et al.,1995).* Furthermore, application of sewage sludge to agricultural land may be desirable in that it can improve the physical, chemical and biological characteristics of soils (Katterman and Day, 1989) and provide the growing plants with essential elements such as N, **P,** Sand micronutrients, which can increase crop yield. However, in practice of land disposal, needs are subjected to careful control because of the potential presence of undesired constituents in the sludge, such as heavy metals and organic contaminants and pathogens.

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2- BASIC INFORMATION OF SEW AGE *SLUDGE:*

2.1-Dejinition of Sewage ***Sludge:***

Sewage sludge is the residue collected after treatment of the contents of urban and rural sewers and drainage systems. This must be disposed off safely and economically. Utilization of sludge as a fertilizers of agricultural land is usually the most economic disposal route for inland sewage treatment. It works and also benefits farmers by providing a cheap manure.

2.2-Quantity of Sewage Sludge:

In Egypt, the total amount of sewage sludge at the year 1999 is approximately 400,000 ton dry solid (tds). The estimated annual amount of dried sludge that will be produced by the year 2005 is expected to be about 2 million ton (Abd El -Nairn *et al.,* 1997). In United Kingdom (UK), at 1991, it is estimated that 1.11 million ton of sludge (dry solids) are producted annually (CES, 1993) and within the European Union (EU), at 1991, the total amount is approximately 6.5 million ton of the sludge (dry solids) are produced annually (Hall and Dalimier, 1994). The increase by the year 2006 in UK is 2.15 tds and in EU is 8.9 tds (CES, 1993; Hall and Dalimier, 1994 and MAFF, 1991).

2.3-Sewage Sludge Treatments:

Sludge may be produced by one or more sewage treatment processes. Raw or primary sludge is produced by gravity settlement after initial screening of litter and grit removal. Subsequent biological treatment of the settled sewage, by the activated sludge process or percolating filters process, will give a secondary sludge largely composed of bacteria and usually co-settled with the primary sludge. This sludge can be applied to land without further treatment, but most sludges are treated to reduce bulk and to avoid potential problems from odour and pathogens. Such treatment processes affect the properties of the sludge products making them more amenable for reuse or disposal to particular outlets, and can influence their agronomic value.

We can summarize the effective sludge treatment processes according to department of the environment (DoE), 1989a. in the following:

Process	Description
1- Sludge pasteurization	Minimum of 30 minutes at 70°C or 4 hours at 55 °C , followed in all cases by primary Mesophilic anaerobic digestion.
2-Mesophilic anaerobic digestion	Mean retention period of at least 12 days primary digestion in temperature range 35 °C± 3 °C or at least 20 days primary digestion in temperature range 25 °C± 3 °C , followed in each case by a secondary stage wich provides a mean retention period of at least 14 days.
3- Thermophilic aerobic digestion	Mean retention period of at least 7 days digestion. All sludge to be subject to a minimum of 55°C for a period of at least 4 hours.
4-Com posting(windrow or aerated piles)	The compost must be maintained at 40 °C for at least 5 days and 4 hours during this period at a minimum of 55°C within the body of the pile followed by a period of maturation adequate to ensure that the compost reaction process is substantially complete.
5-Lime stabilization of liquid sludge	Storage of untreated liquid for a minimum period of 3 months.
6-Liquid storage	Storage of untreated liquid for a minimum period of 3 months.
7-Dewatering and storage	Conditioning of untreated sludge with lime or other coagulants followed by dewatering and storage on the cake for a minimum period 3 months. If sludge has been subject to primary mesophilic anaerobic digestion storage to be for minimum period of 14 days.
8-Irradiation	Using gamma radiation for treated sludges (600 K rad (6 K Gy) at dose rate of20.5 rad/sec.).

*2.4-Sewage **Sludge** Use:*

The option currently available for dealing with the sludge include application to agricultural land, incineration, land reclamation, landfill, forestry, sea disposal and dedicated sacrificial land. Most of the product sludge in Egypt is used in agriculture as a source of organic manure and nutrients or as a soil conditioner for the new land (Abd El -Nairn *et al.,* 1997). Agricultural use represents the largest outlet for sludge in UK accounting for 55% of the sludge disposal within the EU is considered accounting for 37% of total EU sludge production (CES, 1993; Hall and Dalimier, 1994 and MAFF, 1991).

3- CHARACTERISTICS OF SEWAGE SLUDGE:

Sludges are heterogeneous materials, varying in composition from one city to another and even from one day to the next in the same city. The composition of sewage sludge is mainly dependent upon the population density and their habits, in addition to the proportion and nature of community's industrial base. The scientific literature can be conveniently divided according to the potential environmental effects of the four principal groups of sludge components which include: 1. Major plant nutrient elements (nitrogen, phosphorus and potassium), 2. Potentially toxic heavy metals, 3. Organic pollutants and 4. Pathogenic agents.

3.1- Major Plant Nutrients:

In Egypt, many scientific literatures were done to analyze the sewage sludges collected from different locations (Table 1). The data showed that the sewage sludge contains appreciable amounts of N, P and K and have significant inorganic fertilizer replacement value for these major plant nutrients.

Concentrations of plant macronutrients in sewage sludges vary widely; averaging median concentrations of a "typical" sewage sludge would contain 3.2% N, 1.4%Pand 0.23%K. Except for K, these nutrient values are similar to those of animal manures (Hue, 1992). Potassium content of sewage sludge is inherently low because most K compounds are water soluble and remain in the sewage effluent or in the aqueous fraction during sludge dewatering. By the same mechanism, a portion of inorganic N, particularly NH_4, that is enriched during sludge digestion, can be lost. However; organic N by far is the largest fraction (50 to 90%) of the total N in any sludge. Unlike N, only 10 to 30% of the total P in anaerobic sludges is organic P (Sommers *et al.,* 1976). The remaining P is inorganic, in the forms of Ca, Fe, and Al phosphates, and P is sorbed on amorphous material of Fe, Al and Mn hydrous oxides (Sommers, 1977).

Table (l): The chemical composition of sewage sludge at different locations in Egypt

Variables	Abu-rawash	Gabla-Asfar	Helwan	Suez	Alexandria	Kafr El-Sheikh	Fayoum	Range	average
pH (1 :2.5)	6.7	6.8	6.8	6.8	7.1	6.06	6.5	6.06-7.1	
EC (mm ohs/cm)	3.7	4.11	9.5	4.8	2.8	5.53	-	2.8-9.5	59
Organic matter %	52	44.5	46.5	35.6	49.3	31.0	44.1	31-52	43
Total carbonate%	-	3.00	-	-	4.1	3.74	-	3.0-41	36
Total-N%	1.8	2.00	2.15	1.2	2.6	1.72	2.45	1.2-2.6	1.9
Total-P%	0.9	-	0.89	0.82	0.50	-	-	0.50-0.9	0.77
Total-K%	0.17	-	0.33	0.157	0.15	-	-	0.15-0.33	0.20
Available-N (ppm)	1036	-	-	464	-	-	-	464-1036	750
Available- P (ppm)	114	464	153	106	152	770	148	106-770	272
Available- K (ppm)	-	390	345	-	897	-	1000	345-1000	658

(El-Keiy, 1983; El-Sokkary, 1993; Derar and Eid 1996; Badawy and Helal 1997; Aboulroos *et al.*, 1989; Badawy and El-Motaium 1999; El-Gendi *et al.*, 1997; Badawy and Helal, 2002 and Eissa, 2001).

3.2- Potentially Toxic Heavy Metals:

In fact, the concentrations of heavy metals in sludge are among the deciding factors for sludge utilization in lands because of its potential to damage crops and/or to enter the human food chain. Tables (2 and 3) show the survey of sewage sludge collected from different locations in Egypt and recent national survey of 209 wastewater treatment plants by the Environment Protection Agency (EP A) in USA and also by Council of the European Communities (CEC), 1986a in EU. The range and average values for sludges in Egypt show that the concentrations of heavy metals in sludges span many orders of magnitude (Table 3). Based on the results of sewage sludge research during the last 2 decades, (Chaney, 1990a and b) a "clean sludge" category has been proposed (Table 3), "Clean" sludge would have no limit on its application rate to land".

The ranges and average concentrations of the heavy metals in the sludges of Egypt are within normal range of clean sludges. Although, the total content of heavy metals in the sludge within agricultural soils is a potential risk for human safety, the mobile contents of the metals is an immediate risk due to its incorporation in the human food chain *via* growing plant and contamination of the groundwater due to the movement downward through the soil profile.

Table (2): Total heavy metals content (ppm) of sewage sludge at different locations in Egypt

Metal	Abu-rawash	Gabla-Asfar	Helwan	Suez	Alexandria	Kafr El-Sheikh	Fayoum	Range	average
Cd	8.5	4.5	26.3	-	9.1	-	-	4.5-26.3	12.2
Co	42	49	24.5	-	10.6	-	-	10.6-49.0	31.5
Ni	51	50	108	5.0	37	-	-	5.0-108	50.2
Pb	240	297	332	-	482	-	-	240-482	337.8
Cr	135	-	187	50	-	-	-	50-187	124
Fe	15658	6840	19302	5100	20900	16543	-	5100-20900	12910
Mn	414	476	368	165	251	341	120	120-476	305
Cu	290	631	1607	1I0	260	204	191	110-1607	470
Zn	1200	243	985	290	751	733	1I00	243-1200	757

(EI-Keiy, 1983; El-Sokkary, 1993; Derar and Eid 1996; Badawy and Helal 1997; Aboulroos *et al.*, 1989; Badawy and El-Motaium 1999; El-Gendi *et al.*, 1997; Badawy and Helal, 2002 and Eissa, 2001).

Table(3): Total concentration of selected heavy metals in D.S. sewage Sludge (mg/kg dry weight)

Element	**USA[a]**	**EU[b]**	**Egypt[C]**		**Maximum in proposed "clean sludge "[d]**
	Range	**Range**	**Range**	**Average**	
Cd	0.7-8220	1-3	4.5-26	12.2	18
Cr	2.0-3750	100-150	50-187	124	2000
Cu	6.8-3120	50-140	110-1607	470	1200
Hg	0.2-47.0	1-1.5	-	-	15
Ni	2.0-976	30-75	5.0-187	50	500
Pb	9.4-1670	50-300	240-482	338	300
Zn	101-49000	150-300	243-1200	757	2700

a) Kuchenritherm and McMillan, 1991 and Chaney, 1983b.; b) Limits from CEC, 1986a.

c) Aboulroos *et al.*, 1989; Badawy and EI-Motaium 2003; d) Chaney, 1990a.

3.3- Organic Pollutants:

In Egypt, there are no available data concerning the regulations and standard about the concentration of PCBs and P AHs in sewage sludge. This is due to shortage in studies relating to potentially toxic trace orgamcs.

Besides beneficial plant nutrients, sewage sludge also contain hazardous organic pollutants that may enter the food chain and are of great public concern. The range of organic compounds known to exist in these matrices is extensive and diverse, and is potentially transferred to sludge- and compost-amended agricultural soils. From a review of literature, IAEA (2002), reported that 332 organic pollutants, potentially hazardous to human or environmental health, were identified in sewage sludges in Germany, forty-two of which are regularly detected in sludge by researchers. To ensure the safe and beneficial use of sewage sludge in agriculture, appropriated directives are needed. Procedures and limiting values defined in such directives would offer a national basis for recycling sewage sludge in agriculture. **In** order to satisfy these requirements, standardized tests have been developed.

Many of the organic compounds (>300) designated by the European Commission as "priority pollutants" due to their potentially toxic effects, are known to occur in sludge. **In** the specific context of wastewater and sewage sludge, this enormous number of organic chemicals, large in the environment, can be subdivided into several groups (Table 4). Of these, the halogenated aromatics, like polychlorinated biophenyls (PCBs), furans and dioxins, and polycyclic aromatic hydrocarbons (P AHs) are generally regarded as the most critical.

The survey of representative samples in Table 4 provides ranges of organic pollutants to be expected in sewage sludge. European sludges contain between 0.5 and about 10 mg PAH/kg, depending on the individual substance concerned; most of them arising from road and surface runoff. Comparable contents of PCBs were also found, though in exceptional cases of industrial pollution, readings of 1,000 ppm and more have been recorded. In the past, abundant quantities of organochlorine pesticides were also common in sewage sludge. Today, only traces well under 1 ppm, remain. More recently, phthalates have received the attention they deserve; up to several hundred ppm of these plasticizers have been found in sewage sludge.

Levels of over 1 g/kg dry matter have been recorded for nonylphenol; a toxic decomposition product of lkylphenolpolyethoxylate detergents present in effluents. It is a compound of great environmental concern, especially since estrogenic effects have been reported in fish, birds, and mammals. Adverse effects have also been shown for germination and growth of various plant species.

In developing the recent standards for the Use or Disposal of Sewage Sludge (Us EPA,1993a), the US EPA screened 200 pollutants and selected 18 organic pollutants of principal concern for further evaluation by the pathway risk analysis of environmental exposure (US EP A, 1992a).

The selection criteria consider: frequency of occurrence, aquatic toxicity, phytotoxicity, human health effects, domestic and wildlife effects, and plant uptake. With the exception of certain chemicals, such as Trichloroethylene, emphasis was placed on organic contaminants exhibiting moderate to high levels of the persistence in soil. These compounds with a high propensity to degrade or volatilize from soil are generally considered of less concern in sludge-amended agricultural land.

Table (4): Concentration ranges of the main hazardous compounds in sewage sludge*

Compound	**Range *1* Mean *(mg/kg* DM)**
Chlorinated Hydrocarbons	
PCBs	*0.05-1/0.5*
Lindane	*<0.01-0.07/0.02*
p,p'- DDT + p,p'- DDE	*<0.01-0.25/0.1*
PAHs	
Fluoranthene	*0.5-60/5*
Benzo(a)pyrene	*0.1-15/3*
Benzo(b)f1uoranthene	*0.1-14/3*
Phenolics	
Phenol	*0.002-300/2*
Pentachlorophenol	*0.03-850010.2*
Phthalates	
Di-(2-ethylhexyl)- phthalate	*2.4-320/80*
Surfactants	
LAS	*50-16,000/5,000*
Nonylphenol	*10-2,500/500*

*IAEA-2002

Limit values for PCBs = O.2mg *Ikg* DM

Content of UK sludges compares closely with the US values. For example, McIntyre and Lester (1984) analyzed 444 sludge samples from sewage treatment works in the UK and obtained median and 98^{th} percentile concentrations of PCBs in sludge of approximately 0.14 and 1.5 mg kg-l (dry solids), respectively. More recently, Alcock and lones (1993) reported the total between 0.106 and 0.712 mg/kg, with a mean value of 0.292 mg/kg. This implies that the overall concentrations of PCBs in UK sludges have dropped markedly in the last ten years. On this basis apparently there is minimal risk to the environment from PCBc applied to agricultural soils in sewage sludge.

3.4- Pathogenic Agents:

The most common bacterial pathogens in sewage sludge are Salmonella, Shigella, and Campylobacter (Gerba, 1983 and El-Motaium *et al.*, 2000). Salmonella can cause salmonellosis; Shigella, dysentery; and Campylobacter, gastroenteritis. Although *Escherichia coli* belongs to the Shigella spp., it is not considered pathogenic. It is often used to indicate the adequacy (or inadequacy) of a treatment process in reducing pathogens because *E. coli* is abundant in sludge. More than 110 different viruses may be present is raw sewage and sludge and the number is increasing (Gerba, 1983 and Abo Soliman, 1997).

Enterviruses, which include Poliovirus, Echovirus, Coxsackievirus, and Hepatitis virus, can cause diseases from meningitis to infectious hepatitis. Provirus and Adenovirus may cause respiratory infection. Viruses tend to sorb strongly onto sludge, often causing their number to be undercounted (Gaus *et ai.*, 1991). Over 90% of total waste-borne viruses are either inactivated or adsorbed onto sludge during a treatment process (Metro, 1983, Table 5). Sorbed viruses remain active and may survive longer than virus free in waste water. However, infection is only possible when the virus is separated from sludge particles (Gerba and Bitton, 1984). Of the common protozoa that may be found in waste water and sewage sludge, only three species are of major significance for disease transmission to humans: Entamoeba histolytica, Giarda lambia, and Balantidium coli (Gerba, 1983). All three can cause mild to severe diarrhea.

Eggs of *Helminth parasites* (intestinal warms), including *Ascaris lumbricoides* (round worm) *Ancyclostoma duodenate* (hookworm) *Trichuris trichiura* (whipworm), and *Taenia saginata* (tapeworm), tend to settle out with sludge solids during primary waste water treatment (Gaus *et al.*, 1991). These organisms are of particular concern because they can survive many forms of sludge treatment, and they can infect humans and animal even at small numbers. Egypatian data on this subject are given in Table (6).

Table (5): Relative effect of various of sludge treatment in reducing numbers of different pathogens or their period of survival

process	Relative reduction		
	Poor	**Moderate**	**Good**
Raw sludge storage	Ascaris ova	Viruses	
	Taenia ova	Bacteria	
	Cryptosridum		
	oocytsts		
Digestion	Ascaris ova (1)	Hookworm ova	Viruses
		Bacteria	Entamoeba cysts
		Taenia ova	Heterodera cysts
			Cryptosporidium oocysts
Composting			Viruses
			Bacteria
			Fungi
			Helminth ova
Lime treatment	Ascaris ova		Bacteria
Heat treatment (2)			Viruses
			Cryptosporidium oocysts
			Bacteria
			Fungi
			Helminth ova
Irradiation		Ascaris ova	Viruses
			Bacteria

(1) Anaerobic digestion at temperatures> 36 ˚C will inactivate depending on exposure time.

(2) Includes normal drying and lime treatment.

Table (6): Most probable number of total and faecal coliform bacteria in liquid sewage sludge samples collected daily from Cairo treatment stations

Location	**Minimum**	**Maximum**	**Mean**
	Total coliform bacteria (MPNx 1010 per 100 ml)		
Abu-Rawsh	0.01	280	38.5
Helwan	190	560	279.5
	Faecal coliform bacteria (MPNx 108 per 100ml)		
Abu-Rawsh	0.14	201	23
Helwan	0.22	26	5.0

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