Research Journal of Environmental and Earth Sciences 4(10): 917-922, 2012
ISSN: 2041-0492

Submitted: September 17, 2012 Accepted: October 18, 2012 Published: October 20, 2012

Potential of Waste Water Sludge as Environmental-Friendly Manure after UV-Treatment

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Abstract: Due to exponential population increase in developing world, the wastewater and solid waste generation has tremendously increased and their management has become a serious health and environmental issue. A large amount of sewage sludge generated by sewage treatment plants however, can be re-used after proper segregation and treatment as fertilizer and for energy production. Hence, this study was carried out to find out the potential use of sludge produced at Islamabad Capital Territory (ICT) Sewage Treatment Plant (STP) as organic fertilizer. For this purpose, chemical analysis of the waste water was carried out to determine the quality of raw waste water (influent) and treated waste water (effluent) intermittently. Furthermore, post-wastewater treatment, sewage sludge was analyzed for its chemical characteristics, i.e., for Total Nitrogen (TN), Total Phosphorous (TP) and Organic Matter (OM) contents; and microbial analyses for the presence of Total *Coliforms*, Fecal *Coliforms* and *E. Coli* was also carried out sewage sludge was exposed to sunlight for 0, 3 and 6 months. The results were with commercial compost (control) similar characteristics. According to the results, pH, EC, TSS, COD and BOD_5 were found very high in the influent however, after the waste water treatment; the effluent quality was found within the limits of National Environmental Quality standards (NEQs). On the other hand, TN, TP and OM content remained high in sewage sludge as compared to the controls. In order to enumerate harmful microbes in sewage sludge, microbial analyses for Total *Coliforms*, Fecal *Coliforms* and *E. coli* was carried out in pre-treated, UV-post-treated and control sludge samples. According to the results, the Total and Fecal *Coliforms* were found very high (>16000 MPN/g) whereas, *E. Coli* population remained between (7000-12000 MPN/g). The most important aspect noted in this study was: as the sludge aged, this figure (7,000, 12,000, and 1,600 MPN/g after 0, 3 and 6 months of exposure to sunlight (UV-light). However, the number of microbes was above NEQs Standard. From the results, it can be concluded that sewage sludge has the potential to be used in greenbelts, forests and can also be applied for some restricted agricultural purpose after ample sunlight exposure.

Keywords: Natural manure, reuse potential, sludge, UV-light treatment, waste water

INTRODUCTION

Waste Water Treatment of domestic and industrial effluents has become an imperative component of new urban planning and infrastructure. However, during the process of waste-water treatment, large amount of waste water sludge (*aka.* Biosolids) is left out or produced (APHA, 1998; Snyman, 2008). Sludge disposal is rapidly becoming a major environmental issue in both developed and developing countries with the increase in number of wastewater treatment plants. The suspended and dissolved solids generated in the wastewater treatment process are called sludge or sewage sludge and also known as biosolids (Chatha *et al*., 2002). Sludge is produced in primary, secondary and advance treatment processes of waste water and hence is called primary sludge, secondary sludge, tertiary or chemical sludge. It a biologically active mix of water, organic matter, inorganic solids, dead and alive micro-organisms and traces of contaminants and therefore, requires careful management not only after removal process but also during the treatment process. The treatment methods for sewage sludge include conditioning, thickening, dewatering, stabilization and disinfection and thermal drying.

Historically, sewage sludge was considered as a waste that is to be disposed off at the least possible cost (APHA, 1998) and therefore, it was traditionally dumped at landfill sites, in holes, at any unoccupied surface and in drainage systems. Current disposal methods include: land application or spreading, land filling and incineration. However, due to the presence of essential components like nitrogen, phosphorous and organic matter in sewage sludge, it is increasingly being applied on land in most of the developing countries (Wang, 1997). It reduces the high cost of setting modern sanitary landfills and also the difficulty of finding suitable sites for landfills (even in developed

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countries) beside its potential benefit for enhancing soil characteristics. This sludge is useful for conditioning the soils in forests (silvi-culture), restoring and rejuvenating the top soil on previously used industrial and mining sites and also helps in the nourishment of domestic lawns and gardens (Wang, 1997; Chatha *et al*., 2002; Droffner and Brinton, 1995).

However, sludge contains heavy metals and microorganisms that could pose a severe risk to humans and ecosystems. It can result in air pollution, i.e. emission of carbon dioxide and methane gas from landfills; water pollution, i.e., percolation and run off of heavy metals to ground water and close water bodies; and soil pollution i.e., bioaccumulation and biomagnifications of heavy metals. In addition, the presence of microorganisms, i.e., *bacteria*, viruses, *protozoa* and *helminthes*, in sludge is a serious issue of concern (Straub *et al*., 1993; EU (European Commission, 1998). It is imperative to determine by the microbial population of waste water sludge before its application on land. Therefore, wastewater treatment plants have been established in urban centers and industrial cities of Pakistan during past decade. Although studies related to applications of treated wastewater or treated sludge (biosolids) have been carried out, but very few studies on the potential benefits of sludge application in agriculture, soil fertility, land reclamation and most of all, the environment-friendly disposal have been suggested. This study was carried out to find out the potentials use of sewage sludge as an organic fertilizer in Pakistan. For this purpose, sludge generated after wastewater treatment plant was analyzed for its chemical characteristics, i.e., Total Nitrogen content (TN), Total Phosphorous content (TP) and Organic Matter content (OM). Furthermore, microbial analyses for the presence of Total *Coliforms*, Fecal *Coliforms* and *E. coli* were also carried out.

MATERIALS AND METHODS

Material: This study has been conducted on the monitoring of wastewater and the production of sewage sludge at municipal Sewage Treatment Plant (STP) located in I-9 Sector Islamabad. The Plant has a total capacity to handle 10-17 Million Gallon of waste water per Day (CDA, 2008). Whereas Sludge generation capacity was found approximately 40,000-50,000 dry tons of sewage sludge annually.

Sample collection: Waste water and sludge samples were collected in sterilized bottles and sterilized polythene bags, respectively, during 2010. Waste water was collected on daily basis in the month of January, April and October 2010 and sludge was collected in July, September and December, 2010 and stored at refrigeration temperature for further analyses (APHA, 1998).

Waste water samples: Physic-Chemical characteristics of wastewater (influent and effluent) were determined and included the measurement of pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), Carbon Oxygen Demand (COD) and Biological Oxygen Demand (BOD) (FDCO, 2005; Gerba and Smith, 2005).

Sludge sample: The samples were collected from three sludge bed i.e., 2, 4 and 6 (STP-Bed-II, STP-Bed-IV and STP-Bed-VI) and have been labeled as STP-sludge 2, STP-sludge 4 and STP-sludge 6. Samples were divided in three sub-samples (a, b and c) for determination of Nitrogen, Phosphorous and organic matter contents. Experimental samples were compared with the control (commercially available compost), which was collected from one of the nursery in Islamabad. Two kg of the compost sample was collected for N, P and OM content determination. Chemical analyses of sludge were carried out for the presence of Total Nitrogen (TN) by Kjeldahl System, Total Phosphorous (TP) by Spectrophotometer (Spectronic 20, Inc., USA) and Organic Matter (OM) contents using Furnace Method (Gerba and Smith, 2005).

Microbial analyses: Microbial Analyses of waste water and sludge were performed for the presence/absence of *Total* and *Fecal Coliforms* and *E. coli* (Ngole *et al*., 2006).

RESULTS AND DISSCUSION

Physic-chemical analyses of waste water: The effluent quality is dependent on the treatment processes and five major parameters, i.e., pH, Electrical Conductivity (EC), Total Suspended Solids (TSS), Carbon Oxygen Demand (COD) and Biological Oxygen Demand (BOD). The data of influent and effluent was determined on monthly basis and was compared with International standards (Table 1).

Influent: For the month of January i.e., in winter the average flow was 6 million gallons per day. The average PH for influent was 7.6, the average Electrical conductivity was 664.12 µs, the average Total Suspended Solids (TSS) were 269.42 mg/L, the average Chemical Oxygen Demand (COD) was 250.5 mg/L and BOD was 159.3 mg/L. In April the average flow was 8 million to 10 million gallons per day and average PH was 7.57, the average Electrical conductivity was 666.2 µs, the average Total Suspended Solids (TSS) were 261.27 mg/L, the average Chemical Oxygen Demand (COD) was 286.52 mg/L and BOD was 167.56 mg/L. In *October* the average PH was 7.52, the average Electrical conductivity was 662.37 µs, the average Total Suspended Solids (TSS) were 202.37 mg/L, the average Chemical Oxygen Demand (COD) was 253.47 mg/L and BOD was 161.62 mg/L.

Table 1: European union and NEQs of wastewater quality standards

Wastewater quality standards for inlet and outlet			
		European union standards	National Environmental Quality standards (NEQs)
PH	Power of hydrogen	-	6-10
EC	Electric conductivity	-	-
TSS	Total suspended solids	250 mg/L (inlet) 35 mg/L (outlet)	400 mg/L (inlet) 150 mg/L (outlet)
COD	Chemical oxygen demand	440 mg/L (inlet) 125 mg/L (outlet)	400 mg/L (inlet) 150 mg/L (outlet)
BOD	Biological oxygen demand	200 mg/L (inlet) 25 mg/L (outlet)	250 mg/L (inlet) 80 mg/L (outlet)
MLSS	Mixed liquid suspended solids	-	2000-3000 mg/L

EU (European Commission, 1998)

Table 2: Total Nitrogen (TN) content in sewage sludge of STP

Type of samples	Sample ID	Total nitrogen (%)	Mean
Experimental	STP sludge 2a	0.55	0.566667±0.016997
	STP sludge 2b	0.56	
	STP sludge 2c	0.59	
	STP sludge 4a	0.45	0.47±0.01633
	STP sludge 4b	0.49	
	STP sludge 4c	0.47	
	STP sludge 6a	0.53	0.546667±0.016997
	STP sludge 6b	0.57	
	STP sludge 6c	0.54	
Control	Compost 1a	0.30	0.296667±0.004714
	Compost 1b	0.29	
	Compost 1c	0.30	

Effluent: The average PH for effluent in *January* was 7.63, whereas average electrical conductivity for effluent after treatment was 640.75 µs. Most of the suspended solids were removed after the treatment so average of suspended solids was 23.2 mg/L. After treatment of wastewater, COD was reduced to 115.5 mg/L and BOD was reduced to 54.67 mg/L. The average PH in April for effluent was 7.55, whereas average electrical conductivity for effluent after treatment was 640.57 µs. Most of the suspended solids were removed after the treatment so average of suspended solids was 28.95 mg/L. After treatment of wastewater, COD was reduced to 129.12 mg/L and BOD was reduced to 48.87 mg/L. In October the average PH for effluent was 7.62, whereas average electrical conductivity for effluent after treatment was 619.5 µs. Most of the suspended solids were removed after the treatment so average of suspended solids was 13.75 mg/L. After treatment of wastewater, COD was reduced to 113.12 mg/L and BOD was reduced to 46.45 mg/L. The overall average of the data remained within the limits of National Environmental Quality standards (NEQs) (Table 1) and slightly above the European standards (EU (European Commission), 1998) (Table 1). Hence the efficiency of treatment plant was 90-98%.

Chemical analyses of wastewater sludge: Nitrogen, Phosphorus and organic matter are the most important components of any type of fertilizers (Peterson and Wistinghausen, 1979). The sludge samples were assayed for the same components and the results are compared with standard fertilizers and discussed below.

Nitrogen content: Nitrogen content was calculated using *Kjeldahl* system. The STP Bed-II (Sample: STP-sludge 2a, b, c) was selected because the sewage sludge was not too old and was having high moisture content as compared to STP-Bed IV and Bed VI (Table 2). Since it was newly added sludge, no vegetation in the bed was observed.

According to the results, the nitrogen content in three random samples of STP-Bed-II sewage sludge (Sample: STP-sludge 2a, b, c) was 0.55, 0.56 and 0.59%, respectively. Some of the characteristics of this sludge bed were as follows: dried, high moisture contents, dark in color, without vegetation and not too old (Table 2).

The STP Bed-IV (Sample: STP Sludge 4a, b, c) was 2-3 months older and was totally dried due to the exposure to the sunlight. At some places algal bloom was visible. It was expected that due to sun exposure the nitrogen content in this bed will be lower. N-contents were found in three replicate samples as: 0.45, 0.49 and 0.47%, respectively (Table 2). The STP Bed-VI (Sample: STP Sludge 6a, b, c) was 4-6 months old and it was evident due to the excessive growth of vegetation in the bed. The vegetation was approximately 1.5 to 2 ft tall. The nitrogen content in this bed was 0.53, 0.57 and 0.54%, respectively. The nitrogen content from these three beds was compared with the control (commercially available compost). N-content in sewage sludge was found higher when compared to the control (Table 2).

It is evident from previous studies that plants require nitrogen in the form of ammonia or nitrites and nitrates. In Pakistan, Oranges, cotton and grapes are

Table 3: Nitrogen requirements for various crops

Crop	N-requirement (kg/ha/season)
Alfalfa	538
Orange	297
Cotton	200
Grapes (fresh)	140
Grapes (wine)	30-60

Wang (1997)

Table 4: Total Phosphorous (TP) content in sewage sludge of STP

Types of samples	Sample ID	Total phosphorus (%)	Mean
Experimental	STP sludge 2a	1.04	1.07
	STP sludge 2b	1.10	±0.024495
	STP sludge 2c	1.07	
	STP sludge 4a	1.33	1.346667
	STP sludge 4b	1.37	±0.016997
	STP sludge 4c	1.34	
	STP sludge 6a	1.16	1.173333
	STP sludge 6b	1.19	±0.012472
	STP sludge 6c	1.17	
Control	Compost 1a	0.42	0.423333
	Compost 1b	0.43	±0.004714
	Compost 1c	0.42	

Table 5: Organic Matter (OM) content in sewage sludge of STP

Sample type	Sample ID	Organic matter (%)	Mean
Experimental	STP sludge 2a	8.13	8.156667
	STP sludge 2b	8.18	±0.020548
	STP sludge 2c	8.16	
	STP sludge 4a	7.23	7.25
	STP sludge 4b	7.27	±0.01633
	STP sludge 4c	7.25	
	STP sludge 6a	7.95	7.936667
	STP sludge 6b	7.97	±0.033993
	STP sludge 6c	7.89	
Control	Compost 1a	6.13	6.133333
	Compost 1b	6.14	±0.004714
	Compost 1c	6.13	

widely grown crops. Table 3 shows nitrogen requirements for various crops in kg/ha in each season. So there is a possibility for sludge bended with soil in such crop-growing regions could enhance the N-contents of soil.

Phosphorus contents: The second major essential element in plant nutrition is Phosphorus. It is responsible for the healthy growth of plants, strong roots, fruit and flower development and greater resistance to disease. As discussed earlier, the STP Bed-II (Sample: STP sludge 2a, b, c) was not too old and was having high moisture content as compared to others. Hence, the phosphorous content in three random samples of sewage sludge from same bed was 1.04, 1.10 and 1.07%, respectively (Table 4). However, STP Bed-IV (Sample: STP sludge 4a, b, c) contained even higher phosphorous content i.e., 1.33, 1.37 and 1.34%, respectively and the algal bloom was clearly visible. Whereas, in STP Bed-VI (Sample: Sludge 6a, b, c), due to the excessive vegetation the phosphorous rate decreased to 1.16, 1.19 and 1.17%, respectively which could be taken up by plants (Table 4).

Likewise, when phosphorous content from these three beds was compared with the control (commercial compost), the sewage sludge had more phosphorous content than the available compost. It can be concluded that the STP Sludge was higher in N and P contents that are essential for plant growth and microbiological life in the soil.

Organic Matter (OM): Carbon (organic matter) is not available in the basic chemical structure of inorganic fertilizers. It is usually referred to as manufactured, synthetic or mineral commercial, inorganic fertilizers and is produced from the naturally occurring substances of nitrogen, phosphorus and potassium (Piontek and Nguyen, 2000; Shaban, 1999). It acts as a soil improver and agricultural land is normally treated with sludge. The chemical nature of the sludge organic matter (mainly easily degradable organic compounds) induces a fast mineralization in soil (US-EPA, 1994; Wang, 1997). Interestingly, the organic matter content present in wet sludge bed (STP Sludge-Bed-II, 2a, b, c) was more than the other two dry sludge beds (STP Sludge Bed-IV; sample 4a, b, c and STP Sludge Bed-VI and 6a, b, c) (Table 5). In second bed (STP Sludge Bed-II, Sample: 2a, b, c), the OM content was 8.13, 8.18 and 8.16% whereas, in fourth (STP Sludge Bed-IV, Sample: 4a, b, c) and sixth bed (STP Sludge Bed-VI, Sample: 6a, b, c) the OM contents were: 7.23, 7.27, 7.25, 7.95, 7.97 and 7.89%, respectively (Table 5). Since, the vegetative growth in the sixth bed (STP Sludge Bed-VI) was excessive, the organic matter had slightly decreased or could be consumed by the plants. Whereas in control (commercial compost) the content was 6.13, 6.14 and 6.13% which are clearly lower than the nutrients available in sewage sludge (Table 5). It has been previously reported that microbial population may vary in sludge due to the source of waste water being fed to the STP. Furthermore, microbial population that is supported by the supply of oxygen (aerobes) is different from anaerobes. Further study was conducted to identify the microbial population present in the sludge.

Microbial analyses in sewage sludge: A comparison of microbial population, i.e., *Total Coli forms* (TC), *Faecal Coli forms* (FC) and *E. Coli* (EC) from sludge samples studied in summer, fall and winter 2010, has been depicted in Fig. 1.

The temperature and humidity content remained high during June and July and so as the microbial population especially in case of *Coliform* population which was above 16000 CFUs. In fall 2010, there was no significant different in microbial reduction However, *E. coli* population significantly decreased in winter (Fig. 1). The factors that are affecting the microbial population are temperature, moisture contents, rainfalls, solar radiations and chemical activity and reactions in

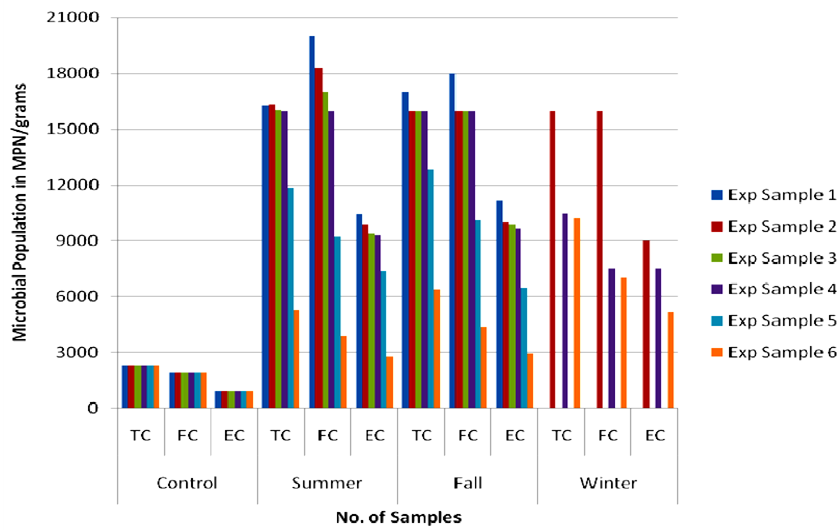

Fig. 1: Microbial population of sewage sludge during summer, fall and winter 2010-11

Table 6: Microbiological quality guidelines and standards for application of wastes to land

Reference	Reuse conditions	Faecal Coliforms (CFUs)
WHO (1989)	• Crops likely to be eaten raw	≤1000/100 mL
	• Pasture and fodder and industrial crops	NR*
Blumenthal *et al.* (2000)	• Crops likely to be eaten raw	≤1000/100 mL
	• Spray irrigation of pasture and fodder and industrial crops	100000/100 mL
USEPA 1993	• Unrestricted irrigation of municipal class A sewage sludge	<1000/g total Solids (dry weight)
	• Application of municipal class B sewage sludge	$<2\times10^6$/g total solids(dry weight)

*: NR, no standard recommended; **: Standard for fecal or total Coliforms; Gerba and Smith (2005)

sludge. The data of microbial population was compared with WHO standards (Table 6).

Previous studies suggest that the microorganisms concentration increases during summer and decreases in winter, whereas it shows no significant changes during the autumn or fall season (Peterson and Wistinghausen, 1979). Sewage sludge contains significant numbers of *viral*, *bacterial*, *protozoan*, *fungal* and *helminthes* pathogens (US-EPA, 1994; Straub *et al*., 1993). Furthermore, it is a known that sewage sludge composts contain *salmonellae* and *Faecal coliforms* (Ngole *et al*., 2006). An obstacle to the use of organic fertilizer from sewage sludge may be the survival of enterobacteria (Piontek and Nguyen, 2000; Shaban, 1999; Straub *et al*., 1993). It was observed that *Salmonella typhimurium* and *Escherichia coli* survived for 9 days at 60°C in food waste compost or sewage sludge compost (Droffner and Brinton, 1995). In current study, Fig. 1 clearly shows the huge amount of microbial population available during summer 2010 while there is no significant change in fall 2010. The age of the sludge used and the rate at which it was applied to the soils initially determined the population of *E. coli*. The study suggests that reduction observed in *E. coli* population in sludge mixtures is caused by reduction in pH and moisture content and soil types. In winter the microbial activity is at decline due to low moisture content and slow chemical reactions and degradation in sewage sludge. However, control was found to keep population at similar level throughout the seasons.

CONCLUSION AND RECOMMENDATIONS

Sewage sludge is a valuable resource in agriculture due to its agronomic properties (Wang, 1997), however, sewage sludge must be pasteurized or sterilized to eliminate *enterobacteria*. The results of current study indicate the needs to manage and monitor the microbial activity in waste water sludge before its use. Natural UV-light from the sun or exposure through artificial means could help to inhibit microbial growth in soil. Further UV-treatment/sunlight exposure can be enhancing besides employing inversion of sludge in order to expose and reduce microbial population. Further analyses of sludge for other microbes like *Achromobacter*, *Chromobacterium* and *Pseudomonas* etc. should be done as these bacteria are responsible for the de-nitrification of soil (Wang, 1997). In addition, inversion of sludge may expose and increase the process of microbial death in short period of time. Further studies should also be conducted to know the effect of time-dependent UV exposure for microbial removal, as well. In addition, in order to make the sewage sludge safer especially for agricultural produce, heavy metals detection should also be done in order to reduce the chances of biomagnifications and bioaccumulation.

ACKNOWLEDGMENT

This study would not be possible without the support and cooperation of Capital Development Authority (CDA) Sewage Treatment Plant (STP) and the research funding provided by Higher Education Commission (HEC) Pakistan under FFHP research Project.

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