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Assessment of The Quality of Treated Sewage Sludge (Doha, Qatar)

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Abstract: This study aims at evaluating the quality of currently produced sewage sludge in Doha, State of Qatar. Doha urban areas are currently served by two tertiary wastewater treatment plants at Al-Neaaga (Doha south plant) and Al-Sailiyah (Doha west plant). Industrial areas around Doha are getting wastewater treatment facilities where extra amounts of sludge will be generated. Sludge is composed of primary and secondary sludge and sedimented sand filters backwash. It undergoes further treatment by drying beds for Doha south plant and centrifugation for Doha west plant. Doha south plant produced 190 m^3/d sludge, Doha west plant produced 110 m^3/d sludge, and industrial region plant produced 16 m^3/d sludge. Samples were collected weekly for two months before and after drying beds from Doha south plant, after centrifuge and after storage from Doha west plant, and from industrial region plant. Samples were analyzed chemically and microbiologically. The results revealed that sludge produced by the three plants had heavy metals concentration way below the EPA ceiling limits for land application. On the other hand, the microbiological characterization of the product classified it as class B sludge according to EPA classification which requires significantly reduction of pathogen. *Ascaris lombricoides* and *Toxocara cati* were the most dominant ova detected. The sludge produced needs monitoring and further treatment before its application on land.

INTRODUCTION

Sewage sludge is the solid, semisolid, or liquid residue generated during treatment of domestic sewage.[(1)] Sludge, also known as biosolids, is composed mostly of human waste that is treated to reduce the prevalence of disease-causing bacteria.[(2)]

The use and disposal of biosolids is always preceded with treatments to ensure regulatory requirements are met, public health and the environment are being protected, to facilitate handling and to reduce costs.[(3)]

The use of sewage sludge as soil amendments or for land reclamation has been increased to reduce the

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volume of sewage sludge that must be landfilled, incinerated, or disposed of at surface sites.(1)

The sludge treatment processes focus on the removal of water and the destruction of pathogens. The treatment processes prepare biosolids specifically for intended methods of use or disposal.(3)

The best practical environmental option for the management of sewage sludge is its beneficial application to agricultural land.(4) Biosolids are applied to agriculture and non-agriculture lands as soil amendments, because they can improve the chemical and physical properties of soils and they contain nutrients and trace elements important for plant growth.(1,5) Sewage sludge, if applied inappropriately can also be potentially harmful to the water and soil environment and human and animal health.(4)

However, careful use of sewage sludge is necessary to ensure pathogenic, nutrients, and heavy metals do not contaminate ground water.(6) Care should always be taken when applying sewage sludge to land to prevent any forms of adverse environmental impacts. Sludge application rates must be adjusted and under certain circumstances, spreading might have to be discontinued.(7)

Qatar mediates coast of the Arab Gulf, which is a peninsula extending to the north in the Gulf waters. The total area of islands, including 11493 Km^2. It is divided administratively into ten municipalities. Doha is the most important city, the capital, is the potential and commercial center for state of Qatar and is located in the mid-eastern Coast of the peninsula of Qatar. The population of Qatar is 743 thousand people, 80% are concentrated in Doha. Its climate is desert moderate, characterized by long hot summer with temperature range of 25-46^{0}C and winter short little rain.[8,9]

Doha urban areas are currently served by two tertiary wastewater treatment plants at Al-Neaaga and Al-Sailiyah. Industrial areas around Doha are getting wastewater treatment facilities where extra amounts of sludge will be generated.

Sludge is composed of primary sludge, secondary sludge, and sand filters backwashing liquid sedimentation. It undergoes further treatment by drying beds for Doha south plant and centrifugation for Doha west plant.

Doha south plant produced 190 m^3/d sludge with solid concentration of 16%, Doha west plant produced 110 m^3/d sludge with solid concentration of 70%, and industrial region plant produced 16 m^3/d sludge with no treatment.

This study aims at evaluating the quality of currently produced sewage sludge in Doha, state of Qatar.

MATERIAL AND METHODS

Samples were collected weekly for two months before and after drying beds from Doha south plant, after centrifugation and after storage from Doha west plant, and from industrial region plant.

Samples were analyzed physico-chemically and microbiologically at Environmental Studies Center Laboratories, Qatar University according to listed references from 10 to 17 as presented in table (1).

RESULTS AND DISCUSSION

Doha west plant:

The primary sludge (generated from primary sedimentation tank) which contains 3-7% solids and secondary sludge (generated from secondary biological treatment processes) which contains 0.5-2% solids are mixed and thickened by adding polymer and using air at the Dissolved Air Flotation (DAF) unites. Then it is sent to sludge consolidation tank. The settled sludge is pumped from this tank to anaerobic digesters. Finally, sludge from secondary digesters is fed to drying beds. The sludge samples were collected before and after drying beds.

1- Before drying beds

Table (2) represented the Physico-chemical characterization of sludge samples taken before drying beds. The water content ranged between 84.58-88.76%, nitrite average was 0.0002%, nitrate was 0.0011%, and ammonia average was 0.0039%. Phosphorus average was 17.93%. The average value of TOC was 25.05 % and Calcium was 5926 ppm.

The application of liquid or dewatered sludge on land is one of the most effective and attractive methods because it has a relatively high content of nutritive elements such as Ca, Mg, P, N, and organic carbon. However, there is a risk that toxic consituents in sludge, such as trace metals and chlorinated hydrocarbons, may accumulate in soil and contaminate ground water, crops, and enter the food chains. (18)

Sewage sludge may contain appreciable amounts of chlorinated hydrocarbons. The samples were analyzed for TPH_s and PCB_s; they were detected in a concentration ranging between 543-1264 ppm for TPH_s and 0.0-0.138 ppb for PCB_s.

The trace metals measurements in sludge samples collected before drying beds recorded the following order for the highest values: Iron (13116 ppm)> Selenium (2195 ppm)> Copper (1031 ppm) and this order for the lowest values: Mercury (1.71 ppm)< Arsenic (7.64 ppm)< Molybdenum (17.88 ppm). All measured metals were in compliance with the EPA exceptional quality for un-restricted land application except Selenium which recorded a relatively high value as presented in table (2a).

A large number of enteric bacteria and viral pathogens may be excreted by infected individuals and may therefore be present in untreated sewage. Since a large number of these pathogens become associated with wastewater solids, many are not completely removed during sewage treatment processes and are merely transferred to wastewater sludge. The latter are further digested anaerobically or aerobically to stabilize sludge solids.[19,20] the anaerobic biological reactions are carried out by microorganisms. Both anaerobic and facultative bacteria degrade the organic solids by converting them into soluble substances and gaseous products.[21] It is well established that anaerobic digestion of sludge does not completely remove bacterial or viral pathogens.

Table (2b) presented the microbiological characterization of sewage sludge samples collected before drying beds. It was noticed that total coliform average was 1.56E+09 MPN/gds, fecal coliform average was 1.55E+09 MPN/gds and total Nematoda ova average was 4.11E+05 ova/4gds.

Total coliform value was approximately the same of the fecal coliform value, because sewage sludge is composed mostly of human waste and fecal coliform associated with feces from warm blooded vertebrates. These values were higher than the EPA permissible limits (class A and B) for reuse in agriculture.

The examination of samples for the Nematoda species eggs showed that ***Ascaris lombricoides, Toxocara cati*** and ***Hymenolopis nana*** were the most dominant which were detected in all samples collected, while ***Hymenolopis diminuta*** and hookworms were detected in 75% of samples. On the other hand, ***Fasciola hepatica*** and ***Taenia saginata*** were detected in 50% only from samples. It was noticed that the following descending order was detected for the highest values: ***Ascaris lombricoides*** (9.63E+04 ova/4gds)> ***Taenia saginata*** (4.91E+04 ova/4gds)> ***Toxocara cati*** (4.51E+04 ova/4gds)> ***Hymenolopis diminuta*** (4.47E+04 ova/4gds)> hookworms (4.39E+04 ova/4gds)> ***Hymenolopis nana*** 4.03E+04 ova/4gds)> ***Fasciola hepatica*** (1.47E+04 ova/4gds). The lowest values were detected in the following ascending order: ***Echinostoma*** (1.68E+03 ova/4gds) < ***Paragonium westermani*** (3.23E+03 ova/4gds) < ***Trichuris trichura*** (3.75E+03 ova/4gds) as shown in figure (1).

Black *et al*.,[23] stated that some Ascaris eggs (23%) were destroyed during anaerobic digestion, ***Trichuris*** and ***Toxocara*** eggs were not destroyed. The total nematode count was far higher than EPA limits class A, where no limits were stated for class B.

2- After drying beds

Sludge drying beds, the most widely used method of sludge dewatering, rely on natural evaporation and percolation to dewater the solids.(24) As presented in table (3), the water content ranged between 7.88-37.45% with an average of 23.46%.

Water removal from the sludge improves efficiency of subsequent treatment processes, reduces storage volume, and decreases transportation costs.(24)

Ammonia nitrogen percent average was 0.005%; Nitrate was 0.006% while nitrite was not detected in all samples, this indicates that nitrite was converted into nitrate. Phosphorous percent average was 17.92%, TOC was 22.62%, and Calcium was 3882 ppm.

It was noticed that the nutritive elements (Ca, P, and organic carbon) were lower in drying samples than in wet samples (before drying beds).

The trace metals detected in samples collected after drying beds had the following highest values order: iron (28289 ppm)> copper (973 ppm)> nickel (580 ppm)> zinc (441 ppm) and the following order for the lowest values: Mercury (2.09 ppm)< Arsenic (22.53 ppm)< Molybdenum (26.44 ppm)< Cadmium (32.60 ppm).

Generally, the trace elements values detected in samples collected after drying beds were higher than values detected in samples collected before drying beds. This may be due to that the two types of samples were collected at the same day and this explained that the wet sample differed than the dry sample, wet sample produced in a day and the dry sample produced in several days before.

However, the most trace elements values detected were complying with the limits of EPA(A) for unrestricted land application, except for Ni, Se, and Mo. Se, and Mo was in compliance with EPA ceiling limits for land application, while Ni average value were higher than the limits (A&B) as presented in table (3d). Ni was detected in 50% samples with higher values.

The values of heavy metals recorded were higher than their concentrations detected in Finland's sludge except for Cr, Pb, and Zn. Cd, Cu, Fe, and Ni were higher and Cr, Hg, Pb, and Zn were lower than sewage sludge in Kuwait.[25] The high concentration of heavy metals in sludge used for land application poses, however, serious problems, since high concentration may result in heavy metal accumulation in cultivated soils.[26] The effects of accumulation of heavy metals in soil are long lasting and even permanent.[27] Heavy metals in sludge can not be removed by common sludge treatment methods such as aerobic or anaerobic digestion.[26]

Toxic persistent organics were represented in the TPHs and PCBs. In case of TPHs, their concentrations were further reduced by drying process as they lost those volatile components by air drying action from 832 ppm to 183 ppm. As the PCBs are more persistent, their concentration increased upon drying.

With respect to sludge microbiological quality as presented in table (3b), total coliform and fecal coliform averages were the same (8.69E+07MPN/1gds), and total nematode ova average was (1.28E+05 ova/4gds). These values were lower than values of samples collected before drying beds, but it is still way higher than the permissible limits of EPA.

The results of coliform bacteria were higher than that stated by Carringoton *et al*.,[28] who recorded 1.4E+06 for thermo tolerant coliform in raw sludge and also higher than Claudia *et al*.,[29] who detected 1E+04 to 1E+05 for total coliform in secondary sludge and 1E+04 for fecal coliform.

Thermotolerant coliform can survive in faeces and need 70-100 days for 90% inactivation in low temperature range and 15-35 days in high temperature range.[30]

The examination of samples for the Nematoda species eggs showed that ***Ascaris lombricoide*** and ***Toxocara cati*** were the most dominant as detected in all samples collected (100%). ***Ascaris lombricoides*** are parasitic round worm and can cause human disease known as Ascariasis. Contaminated vegetables and water is the primary route of infection. Transmission also comes through municipal recycling of wastewater into crop field. Deposition of ova in sewage hints at the degree of Ascariasis incidence.[31] Ascaris need 100-400 days for 90% inactivation in low temperature range and 50-200 days in high temperature range.[30] Toxocara infective eggs survive for years in the environment, and humans typically ingest the eggs orally by eating with contaminated hands.[32] ***Trichuris trichura,*** hookworms, ***Hymenolopis nana*** and ***Taenia saginata*** were detected in 50% of samples. On the other hand, ***Fasciola hepatica*** and ***Hymenolopis diminuta*** were detected in only 25% of samples.

In the United States, 75% of sewage sludge samples were positive with

Ascaris. In Frankfort, Indiana, 87.5% of the sludge samples were positive with ***Ascaris***, ***Toxocara***, ***Trichuris***, and hookworm.[31]

It was noticed that the following descending order was detected for the highest values:

Ascaris lombricoides (5.31E+04 ova/4gds)> hookworm (1.28E+04 ova/4gds)> ***Echinostoma*** (9.28E+03 ova/4gds) > ***Eurytrema pancreatica*** (7.03E+03 ova/4gds)> ***Fasciola hepatica*** (7.00E+03 ova/4gds)> ***Toxocara cati*** (5.54E+03 ova/4gds). The lowest values were detected in the following ascending order: ***Hymenolopis diminuta*** (3.25E+02 ova/4gds)< **Taenia *saginata*** (6.75E+02 ova/4gds)< ***Paragonium westermani*** (3.25E+03ova/4gds)< ***Trichuris trichura*** (3.58E+03 ova/4gds) as shown in figure (1). Generally, the different species ova count for samples collected After drying beds was lower than for samples collected before drying beds.

A WHO report on the risk to health microbes in sewage sludge applied to land identified salmonella and ***Taenia*** as giving rise to greatest concern. The numbers of pathogenic and parasitic organisms in sludge can be significantly reduced before application to land by appropriate sludge treatment and the potential health risk is further reduced by the effects of climate, soil microorganisms, and time after the sludge is applied to the soil.[28,33]

Doha south plant:

Flow of sludge from the activated sludge balancing tank is sent to the DAF building. From there it is fed to thickening centrifuges. A polymer is added to assist higher efficiency of sludge solid separation. Four thickening centrifuges are operated to give a sludge which is sent to the aerobic digesters. The aerated stabilized sludge is further dewatered by centrifugation aided by polymer addition. The dewatered sludge is directed via a conveyor to a trailer located outside the building. The sludge samples were collected after centrifugation and after storage.

1-After centrifuge**:**

The physiochemical analytical results of sewage sludge collected after centrifugation showed that (table 4a) the water content ranged between 79.82-83.11%, ammonia average was 0.0023%, nitrite was 0.0005%, and nitrate 0.0007%. Phosphorus average was 21.19%. The average value of TOC was 28.60% and Calcium was 4710 ppm.

It was noticed that moisture content, ammonia, and nitrate were lower than detected in samples collected from Doha west before drying beds. TOC and Phosphorus were higher while calcium was lower.

The anaerobicaly- digested sludge has high ammonia- nitrogen content which is readily available to plants and can be of particular benefit to grass land. The organic matter in sludge can improve the water retaining capacity and structure of some soils, especially when applied in the form of dewatered sludge cake. [34]

TPH_s range was 114-557 ppm and PCB_s range was 0.0-0.2810 ppb. In comparison with samples collected from Doha west before drying beds, TPH_s was lower while PCB_s was higher.

The trace metals recorded the following order for the highest values: Iron (6054 ppm)> Copper (1017 ppm)> Zinc (783 ppm) which differentiate from samples of Doha west; and this order for the lowest values: Mercury (1.22 ppm)< Arsenic (3.43 ppm)< Molybdenum (6.52 ppm). Generally, the most elements were detected in lower values than samples of Doha west. All elements values were in compliance with EPA permissible limits which were far below the limits as presented in table (4a).

The microbiological analytical results illustrated that table (4b), total coliform average was 3.93E+11MPN/1gds, fecal coliform average was 1.37E+11MPN/1gds, and total nematode ova average was 7.10E+05 ova/4gds. These values were higher than values of Doha west before drying beds. This indicates that anaerobic digestion was superior to digestion in reducing pathogen density levels which agrees with Ponugoti *et al*.[35]

The Nematoda species eggs showed that ***Ascaris lombricoides, Toxocara cati,*** hookworms, and ***Fasciola hepatica*** were the most dominant which were detected in all samples collected (100%), while ***Trichuris trichura*** was detected in 60% of samples. Black *et al*.,[23] stated that the aerobic digestion destroyed 38% of Ascaris and 11% of ***Trichuris***. ***Toxocara*** eggs were resistant to both anaerobic and aerobic digestion processes.

Results demonstrated the following descending order for the highest values: Hookworms (1.66E+05ova/4gds)> ***Ascaris lombricoides*** (9.64E+04 ova/4gds)> ***Fasciola hepatica*** (8.28E+04 ova/4gds)> ***Hymenolopis nana (***8.0E+04 ova/4gds)> ***Trichuris trichura*** (4.21E+04 ova/4gds).***Taenia saginata*** (1.26E+02 ova/4gds) was the lowest value detected as shown in figure (2).

2-After storage:

As presented in table (5a), the water content ranged between 17.66-84.09%, the upper limit was detected in 20% of the samples only. The water content in general decreased by storage but still was higher than the values in case of Doha west samples. The reduction in sludge water content reduces its soluble components migration through ground layers.

Ammonia nitrogen percent average was 0.0035 and Nitrite was 0.0003. Nitrites slightly decreased by air drying during storage which indicates the need for further stabilization by aerobic action, this can be achieved by upside down displacement of the stored sludge. Nitrate was not detected in most of the samples, which indicate prevailing anaerobic conditions during storage as it is converted into nitrites and ammonia. Phosphorous percent average was 21.27%, TOC was 29.23%, and Calcium was 4793 ppm.

It was noticed that the nutritive elements values (Ca, P, and organic carbon) slightly increased in stored samples as detected in higher values than in case of Doha west. Phosphorous is one of the essential nutrients for plant growth and is required in relatively large quantities by plants.(37) Sewage sludge is a potential source of nitrogen and phosphorous for crop production.

The application of sewage sludge at controlled rate can improve the physical and chemical properties of soils as it possesses excellent soil amendment properties.(38) Calcium ion is important to soil conditioning process as it offsets the effect of sodium in the soil and prevent its agglomerating effect for soil particles leading to higher water retention in the root zone and root rotting due to lack of oxygen in agglomerated soil.

The trace metals detected in collected samples after storage had the following high values in descending order: Iiron (6526 ppm)> Copper (1026 ppm)> Zinc (781 ppm)> Nickel (46.69 ppm) and the ascending order for the lowest metal concentrations: Mercury (1.41 ppm)< Arsenic (3.07 ppm)< Molybdenum (6.45 ppm)< Cadmium (6.66 ppm).

The results of the heavy metals concentration as Iron, Copper, Selenium, and Mercury were higher than those present in samples collected after centrifugation (before dewatering). On the other hand, all other metals slightly decrease after storage. In comparison with Doha west drying samples, all values were lower except for Copper, Zinc, and Selenium. In compliance with the EPA stated limits, all the metals examined were way below than category (A) limits for un-restricted land application except for selenium which was in compliance with the ceiling (B) limits for land application as represented in table (5a).

The concentrations of TPHs were further reduced by storage as they are lost as volatile components from 393 ppm to 226 ppm. As the PCBs are more persistent their concentration slightly increased from 0.0975 to 0.10 ppb upon storage.

The microbiological characteristics shown in table (5b), indicated that total coliform average was 1.84E+09 MPN/gds, fecal coliform average was 9.63E+08 MPN/gds, and total nematode ova average was 1.38E+05 ova/4gds. Those values were lower than the values of samples collected before storage.

Storage allows time for the environment to further reduces pathogenic bacteria. Similar values were higher than those values detected for samples collected from Doha west plant after drying beds. The values of fecal coliform and nematode ova were higher than the EPA permissible limits for dry sludge reused in agriculture class B and A, respectively.

Biosolids with class B can be applied on grain and forage crops, pastures, grass land, fallow land, and lumber land. Fecal coliform testing is recommended for all treatment processes to significantly reduce pathogenic performance. (38)

The parasites of concern for possible transmission from sludge amended soils are ***Ascaris lombricoides,*** hookworms, ***Toxocara*** sp***, Trichuris trichura, Hymenolopis nana, Taenia saginata, Strongloides,*** and ***Echinococcus granulosa.***(37)

The results showed that ***Ascaris lombricoides*** was the only one detected in all samples collected (100%), ***Trichuris trichura*** and ***Fasciola hepatica*** were were detected in 80% of the samples, while hookworms, ***Toxocara cati,*** and ***Hymenolopis nana*** were detected in 60% of samples. It was noticed by the following descending order for the highest values: ***Ascaris lombricoides*** (7.78E+04 ova/4gds)> ***Toxocara cati*** (2.23E+04 ova/4gds)> ***Trichuris trichura*** (9.26E+03/ ova 4gds)> hookworms (9.03E+03/ ova 4gds) as shown in figure (2). Some species were not detected after storage and others were detected in lower values than stored samples. This indicates that storage reduces the nematode ova.

The samples collected after drying beds in Doha west had too many species and although the diversity of species was low, their values were higher and still much higher than the EPA permissible limits.

Industrial plant:

Sludge generated at domestic wastewater treatment plant in the industrial area is just thickened to be sent to other treatment plants for further processing. The plant does not receive any industrial processing wastewater.

The physiochemical analytical results of sewage sludge samples collected from domestic wastewater treatment plant in the industrial region revealed that (table 6a) water content ranged between 89.99-91.38%, ammonia average was 0.0027%, and nitrite was 0.0028%. Phosphorous average was 10.88 ppm, TOC average was 26.53 ppm and Calcium was 4033 ppm.

The samples representing the highest water content, had the lowest nutritive elements values. It needs further treatment and dewatering before the sludge reuse in land application.

The trace metals were detected in the following descending order: Iron (9954 ppm)> Zinc (1150 ppm) > Copper (713 ppm)> Chromium (52.23 ppm)> Nickel (50.00 ppm) and the following order for the lowest values: Mercury (0.95 ppm)< Arsenic (4.03 ppm)< Molybdenum (6.95 ppm).

It was noticed that, Chromium, Zinc, and Lead concentrations were higher than the values detected in the samples collected from Doha west plant before drying beds but the other reaming metals were smaller. On the other hand, all metals values were higher than in samples collected from Doha south plant after centrifugation except Copper and Mercury. The concentration of all measured metals were below the EPA permissible limits, A , for un-restricted land application except Selenium which complied with EPA ceiling limits for land application (B) as presented in table (6a).

The microbiological characterization, table (6b), showed that total coliform average was 1.58E+10 MPN/gds, fecal coliform average was 1.57E+10MPN/gds, and total nematode ova average was 8.07E+06 ova/4gds. These values were lower than values of samples collected from Doha west before dewatering. While dewatered samples collected from Doha south plant recorded higher values of total and fecal coliform. However these values were higher than the EPA limits.

Nematode species recorded six species in all samples collected (100%) from this plant, as follows: ***Ascaris lombricoides*** (4.46E+06 ova/4gds)> ***Toxocara cati*** (4.50E+05 ova /4gds)> ***Hymenolopis diminuta*** (3.03E+05 ova/4gds)> hookworms (1.76E+05 ova /4gds)**>** ***Trichuris trichura*** (1.66E+05/ ova 4gds)> ***Fasciola hepatica*** (1.48E+05/ ova 4gds) as shown in figure (3). These values were the highest values detected for the three plants.

The microbiological previous results for the three plants explained that the sludge produced was classified as class B which requires reduction of the density of bacteria and ova and prevention of exposure to it after sludge reuse or disposal.

RECOMMENDATIONS

The reuse of such sludge in land application must be subjected to the following considerations:

Environmental protection:

- Care should always be taken when applying on land to prevent any adverse environmental impacts,
- Vehicles used in sludge transfer should be carefully selected for their local suitability and routes chosen so as to minimize inconvenience to the public,
- Enclosed tankers should be used for transporting to control odor,
- Sludge should be used in accordance with the requirements of the pollution control authority as well as of good farming practice.

Monitoring requirements:

- Prior to application onto land, it is to be analyzed for the metals and the level of pathogenic organisms as specified by EPA,
- Composite soil samples to be collected from the land and analyzed also for metals,
- All of the drinking water wells located within 500 meters from the land boundary shall be monitored,
- Records related to the quantity of sludge applied onto the land, application rate, results of sludge, soil, and water quality analysis shall be maintained,
- The monitoring requirements adjusted based on the frequency of sludge application onto land.

Application requirements:

- Legal description of the land to be used, together with plans showing topography, watercourses, general soil classification, water wells within one kilometer, radius of the land, residences, and other buildings,
- The quantity that will be applied onto land and application rate,

- Application should not take place during or immediately after a rainfall,
- Animals shall not be grazed on the land for 30 days after application,
- It must apply below the surface of the land,
- Restrictions are placed on the site where it is applied to prevent exposure to it.

Further treatment:

Alternative processes to significantly reduce pathogens:

- Air drying or storage for a period of at least 3-monthes.
- Composting with temperatures greater than 40 degrees for five days.
- Lime stabilization to a pH greater than 12 for two hours.
- Heat drying.

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Table (1a): Physico-chemical Methods used for analysis of sludge samples

No.	Parameter	Analytical reference	Technique
1	Water Content Total Organic Carbon	MOOPAM[10]	Gravimetric Digestion/Titration
2	Sodium , Calcium, Metals	USEPA 3051 and USEPA 6020[11]	ICP/MS
3	Mercury	USEPA 600/4[12]	CVAAS
4	Total Petroleum Hydrocarbons (TPHs)	UNEP-20[13]	GC-FID
5	Polychlorinated Biphenyls	SW-846-8082[14]	GC-ECD
8	Nitrite, Nitrate, Ammonia-N, Total Phosphorus	Physico-chemical Analysis of Aquatic Sediments[15]	Spectrometry
11	Total Kjeldahl Nitrogen	SM 4500[16]	Distillation/Titration
13	Solids	SM 2540 G[16]	

Table (1b): Microbiological Methods used for analysis of sludge samples

No.	Parameter	Analytical reference	Technique
1	Total coliform	SM- 9221D[16]	MTT
2	Fecal coliform	SM- 9222D[16]	MTT
3	Parasites ova	USEPA 600/1-87-014[17]	Flotation

Table (2a): Physico-chemical analysis of Sludge samples collected from Doha West Plant before Drying Beds Data is calculated based on dry basis of sludge regardless of its stage for all samples

Parameter	Unit	Minimum	Maximum	Average	EPA Limits*	
					A	B
Water Content	%	84.58	88.76	87.15		
Nitrite-N	%	0.0002	0.0003	0.0002		
Nitrate-N	%	ND	0.0012	0.0011		
Ammonia-N	%	0.0033	0.0048	0.0039		
Total Phosphorus	%	0.01	36.13	17.93		
TOC	%	23.02	27.50	25.05		
Sodium (Na)	ppm	3100	17607	7429		
Calcium (Ca)	ppm	50	8679	5926		
TPHs	ppm	543	1264	832		
PCBs	ppb	0.0000	0.1380	0.0361		600 Parasitic eggs?
Heavy Metals:						
Chromium (Cr)	ppm	35.18	41.17	37.26	1200	3000
Iron (Fe)	ppm	6164	32207	13116		
Nickel (Ni)	ppm	41	946	272	420	420
Copper (Cu)	ppm	757	1174	1031	1500	4300
Zinc (Zn)	ppm	50	845	624	2800	7500
Arsenic (As)	ppm	2.58	17.83	7.64	41	75
Selenium (Se)	ppm	<0.0005	6529	2195	36	100
Molybdenum (Mo)	ppm	14.75	22.29	17.88	18	75
Cadmium (Cd)	ppm	<0.0005	49.65	34.93	39	85
Lead (Pb)	ppm	31.63	49.65	38.48	300	840
Mercury (Hg)	ppm	1.49	1.95	1.71	17	57

* US EPA Limits for using sewage sludge in agriculture, A stands for: Exceptional quality limits for un-restricted land application, B stands for: Ceiling limit for land application Un-restricted use indicates the sludge up to the listed limits could be used for beneficial use considering the accumulation application rates should not be exceeded.

Table (2b): Microbiological analysis of Sludge samples collected from Doha West Plant before Drying Beds.

Parameter	Average	Maximum	Minimum	EPA Limits	
				Class A	Class B
Total Coliform **(**MPN/1gds)	1.56E+09	6.10E+09	1.30E+07		
Faecal Coliform **(**MPN/1gds)	1.55E+09	6.10E+09	8.50E+06	1.00E+03	2.00E+06
Total Nematodes (Ova/4gds)	4.11E+05	7.74E+05	6.59E+04	<1(unit)	-

MPN: Most Probable Number gds: gram dry solids

Table (3a): Physico-chemical analysis of Sludge samples collected from Doha West Plant after Drying Beds

Parameter	Unit	Minimum	Maximum	Average	EPA Limits	
					A	B
Water Content	%	7.88	37.45	23.46		
Nitrite-N	%	0.000	0.000	0.000		
Nitrate-N	%	0.001	0.015	0.006		
Ammonia-N	%	0.004	0.006	0.005		
Total Phosphorus	%	0.15	36.29	17.92		
TOC	%	14.16	26.22	22.62		
Sodium (Na)	ppm	4270	22579	11886		
Calcium (Ca)	ppm	43	7781	3882		
Volatile Solids	%	35.20	58.01	50.03		
Fixed Solids	%	41.99	64.80	49.97		
TPHs	ppm	143	207	183		
PCBs	ppb	0.00006	0.62000	0.15523		600
Heavy Metals:						
Chromium (Cr)	ppm	9.72	104.61	51.61	120	3000
Iron (Fe)	ppm	5676	58488	28289		
Nickel (Ni)	ppm	46	1192	580	420	420
Copper (Cu)	ppm	757	1170	973	150	4300
Zinc (Zn)	ppm	43	860	441	280	7500
Arsenic (As)	ppm	3.07	68.27	22.53	41	75
Selenium (Se)	ppm	13	79.94	36.95	36	100
Molybdenum (Mo)	ppm	17.06	47.78	26.44	18	75
Cadmium (Cd)	ppm	19.20	46.60	32.60	39	85
Lead (Pb)	ppm	34.10	46.60	40.96	300	840
Mercury (Hg)	ppm	1.53	2.44	2.09	17	57

Table (3b): Microbiological analysis of Sludge samples collected from Doha West plant after Drying Beds

Parameter	Average	Maximum	Minimum	EPA Limits	
				Class A	Class B
Total Coliform **(**MPN/1gds)	8.69E+07	3.30E+08	4.30E+05		
Faecal Coliform **(**MPN/1gds)	8.69E+07	3.30E+08	4.30E+05	1.00E+03	2.00E+06
Total Nematodes (Ova/4gds)	1.28E+05	2.27E+05	4.09E+04	<1(unit)	-

Table (4a): Physico-chemical analysis of Sludge samples collected from Doha south plant after Centrifuge

Parameter	Unit	Minimum	Maximum	Average	EPA Limits	
					A	B
Water Content	%	79.82	83.11	81.79		
Nitrite-N	%	0.0004	0.0008	0.0005		
Nitrate-N	%	ND	0.0010	0.0007		
Ammonia-N	%	0.0007	0.0035	0.0023		
Total Phosphorus	%	0.11	38.64	21.19		
TOC	%	26.20	29.71	28.60		
Sodium (Na)	ppm	852	2429	1684		
Calcium (Ca)	ppm	4501	4932	4710		
TPHs	ppm	114	557	393		
PCBs	ppb	ND	0.2810	0.0975		600
Heavy Metals:						
Chromium (Cr)	ppm	36.54	47.08	41.23	1200	3000
Iron (Fe)	ppm	4965	6446	6054		
Nickel (Ni)	ppm	44.55	50.33	46.96	420	420
Copper (Cu)	ppm	966	1094	1017	1500	4300
Zinc (Zn)	ppm	694	872	783	2800	7500
Arsenic (As)	ppm	2.37	4.61	3.43	41	75
Selenium (Se)	ppm	<0.0005	65.45	35.77	36	100
Molybdenum (Mo)	ppm	4.42	9.63	6.52	18	75
Cadmium (Cd)	ppm	<0.0005	7.77	7.77	39	85
Lead (Pb)	ppm	30.78	53.35	39.63	300	840
Mercury (Hg)	ppm	0.93	1.64	1.22	17	57

Table (4b): Microbiological analysis of Sludge samples collected from Doha south plant after Centrifuge

Parameter	Average	Maximum	Minimum	EPA Limits	
				Class A	Class B
Total Coliform (MPN/1gds)	3.93E+11	1.40E+12	1.20E+06		
Faecal Coliform (MPN/1gds)	1.37E+11	5.60E+11	1.20E+06	1.00E+03	2.00E+06
Total Nematodes (Ova/4gds)	7.10E+05	1.76E+06	8.46E+04	<1(unit)	-

Table (5a): Physico-chemical analysis of Sludge samples collected from Doha south plant after Storage:

Parameter	Unit	Minimum	Maximum	Average	EPA Limits	
					A	B
Water Content	%	17.66	84.09	45.86		
Nitrite-N	%	0.0000	0.0004	0.0003		
Nitrate-N	%	ND	0.0002			
Ammonia-N	%	0.0024	0.0058	0.0035		
Total	%	0.09	36.15	21.27		
TOC	%	25.84	32.47	29.23		
Sodium (Na)	ppm	1068	2352	1452		
Calcium (Ca)	ppm	4195	5245	4793		
Volatile Solids	%	62.57	77.12	69.20		
Fixed Solids	%	22.88	37.43	30.80		
TPHs	ppm	107	354	226		
PCBs	ppb	ND	0.26	0.10		
Heavy Metals:						
Chromium (Cr)	ppm	33.61	45.63	41.10	1200	3000
Iron (Fe)	ppm	5887	7350	6526		
Nickel (Ni)	ppm	40.70	50.97	46.69	420	420
Copper (Cu)	ppm	926	1124	1026	1500	4300
Zinc (Zn)	ppm	689	899	781	2800	7500
Arsenic (As)	ppm	1.97	3.62	3.07	41	75
Selenium (Se)	ppm	5.35	75.90	39.76	36	100
Molybdenum	ppm	5.01	8.17	6.45	18	75
Cadmium (Cd)	ppm	<0.0005	10.17	6.66	39	85
Lead (Pb)	ppm	30.15	41.93	34.80	300	840
Mercury (Hg)	ppm	1.14	1.96	1.41	17	57

Table (5b): Microbiological analysis of Sludge samples collected from Doha south plant after Storage:

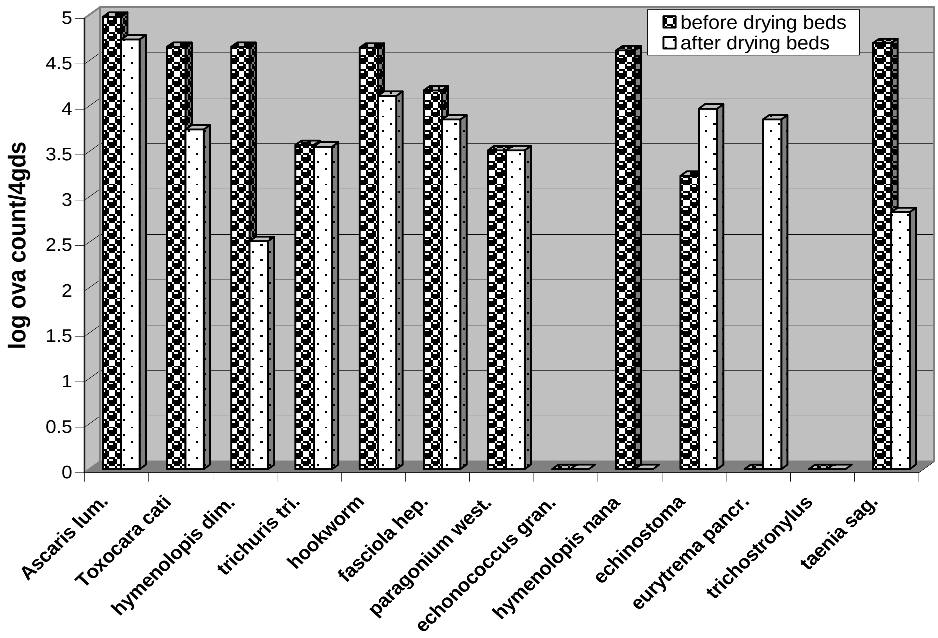
Parameter	Average	Maximum	Minimum	EPA Limits	
				Class A	Class B
Total Coliform (MPN/1gds)	1.84E+09	9.20E+09	1.00E+06		
Faecal Coliform (MPN/1gds)	9.63E+08	4.80E+09	5.30E+05	1.00E+03	2.00E+06
Total Nematodes (Ova/4gds)	1.38E+05	4.43E+05	9.88E+03	<1(unit)	-

Table (6a): Physico-chemical analysis of Sludge samples collected from Industrial Area plant after thickening:

Parameter	Unit	Minimum	Maximum	Average	EPA Limits	
					A	B
Water Content	%	89.99	91.38	90.74		
Nitrite-N	%	0.0003	0.0074	0.0028		
Nitrate-N	%	ND	0.0003			
Ammonia-N	%	0.0022	0.0033	0.0027		
Total	%	0.11	32.40	10.88		
TOC	%	24.41	28.85	26.53		
Sodium (Na)	ppm	912	1989	1566		
Calcium (Ca)	ppm	3756	4394	4033		
TPHs	ppm	158.00	690.70	501.87		
PCBs	ppb	0.20	0.27	0.23		600
Heavy Metals:						
Chromium (Cr)	ppm	42.78	62.81	52.23	1200	3000
Iron (Fe)	ppm	9119	11114	9954		
Nickel (Ni)	ppm	47	53	50	420	420
Copper (Cu)	ppm	681	772	713	1500	4300
Zinc (Zn)	ppm	1043	1216	1150	2800	7500
Arsenic (As)	ppm	2.67	5.48	4.03	41	75
Selenium (Se)	ppm	44.15	56.15	49.40	36	100
Molybdenum	ppm	5.55	8.92	6.95	18	75
Cadmium (Cd)	ppm	<0.0005	4.65		39	85
Lead (Pb)	ppm	46.31	51.26	48.45	300	840
Mercury (Hg)	ppm	0.88	1.04	0.95	17	57

Table (6b): Microbiological analysis of Sludge samples collected from Industrial plant Area after thickening:

Parameter	Average	Maximum	Minimum	EPA Limits	
				Class A	Class B
Total Coliform (MPN/1gds)	1.58E+10	4.60E+10	1.20E+08		
Faecal Coliform (MPN/1gds)	1.57E+10	4.60E+10	1.00E+06	1.00E+03	2.00E+06
Total Nematodes (ova/4gds)	8.07E+06	1.91E+07	1.71E+06	<1(unit)	-



Figure(1): Nematodes detected in sludge samples collected from Doha west plant

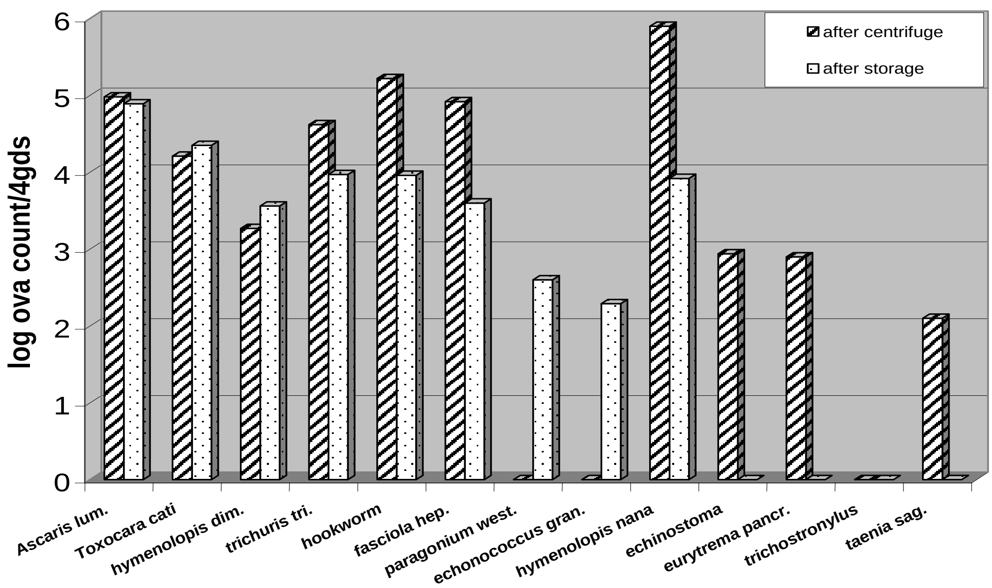
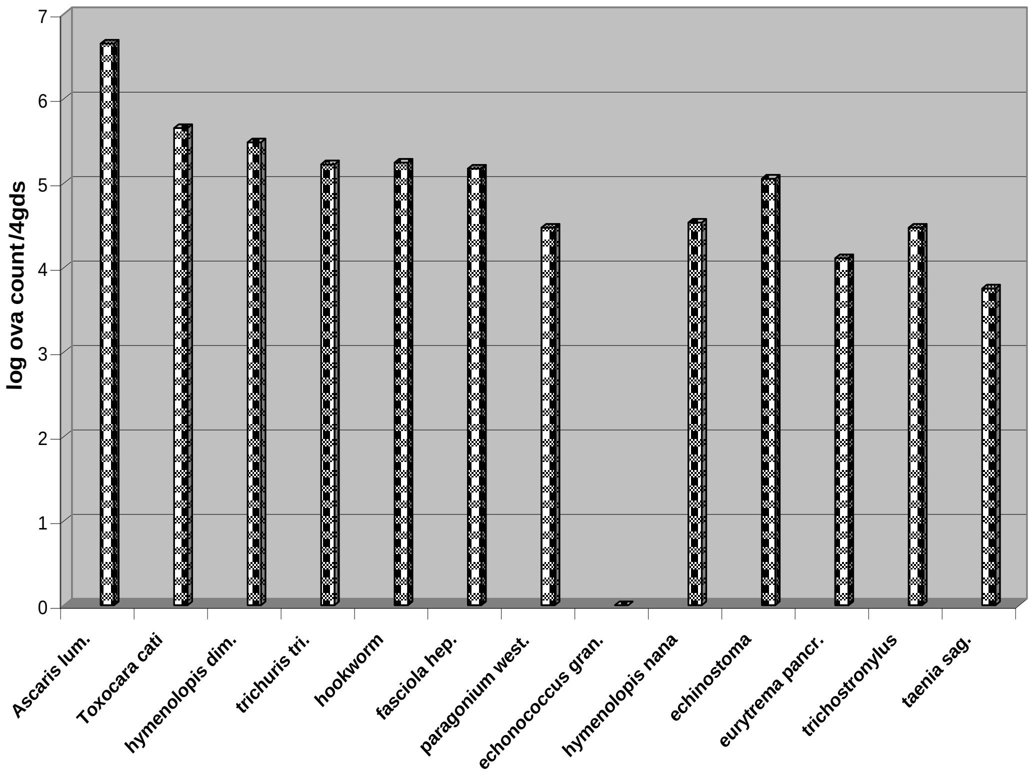


Figure (2): Nematodes detected in sludge samples collected from Doha south plant



Figure(3): Nematodes detected in sludge samples collected from industrial region plant

REFERENCES

1. National Research Council. Biosolids Applied to land: Advancing standards and Practice. Washington: National Academic press; 2002.
2. Kevin A. sludge a hot topic in general assembly. Rappahannock News, 2007. Available from: http: // www.timescommunity.com /site/ tab4.cfm?newsid=17823944&BRD= 2553&PAG=64...
3. U.S. Environmental Protection Agency. 1994. Biosolids Generation Use and Disposal in the US. Washington, DC:EPA; Available:from:http://www.epa.gov/epaoswer/nonhw/compost/biosolid.pf via the Internet. Accessed on November 3, 2002.
4. Environmental Agency. The sludge regulations, 2007. Available from: http: //

www.netregs.gov.uk/netregs/sectors/1029415/1029681/1034816/?/lang.
5. Kelley WD, Martens DC, Reneau RB, Simpson TW. Agricultural Use of Sewage Sludge: A Literature Review. Bulletin 143, December 1984.
6. The good and the bad of applying sewage sludge to valley farms. News and events, 2003. Available at web site/http: // www.ucinthevally.org/articles/2003/aug8art1.
7. FAO. Waste water treatment and use in agriculture, 6. Agricultural use of sewage sludge. Available from: http://www.fao.org/docrep/T0551E/t0551e00.HTM
8. Alwatanyah Medical Enterprises co. Available from: http://www.alwatanyah.com.qa/ar/Qatar/
9. Qatar Airways. Available from: http://www.qatarairways.com/index.php?id=0,171,0,0,1,0&tab=2
10. Methodology Manual of Oceanographic Observations and Pollutant Analysis Methods (MOOPAM), ROPME.1999.
11. U.S. Environmental Protection Agency methods, 1990,1994.
12. U.S. Environmental Protection Agency (EPA). EPA report 600/4-79-020.1983.
13. UNEP. Determination of petroleum hydrocarbon in sediments. Reference methods for marine pollution studies. UNEP. No.20,1992.
14. USEPA. Test methods for evaluating solid waste physical/chemical methods, SW-846. EPA Publication; 1999.
15. Mudroch A, Azcue JM, Mudroch P. physico-chemical analysis of aquatic sediments. LEWIS Publishers, Press, Inc; 1997. 287.
16. American Public Health Association, American water Works Association, Water Pollution Control Federation. Standard Methods for the analysis of water and wastewater (20th ed). Washington, D.C.: American Public Health Association; 1999.
17. Yanko WA. Occurrence of pathogens in distribution and marketing municipal sludge .EPA 600/1-87-014, 1987.
18. Dacre JC. Potential hazard of toxic organic residues in sludge. In: Bitton G, Damron B, Edds GT, Davidson JM. Sludge: health risks of land application. Ann arbor, Michigan: Ann Arbor Science Pub; 1980. pp 85-102.
19. Smith JE, Young KW, Dean RB. Biological oxidation and disinfection of sludge. Water Res. 1975(9): 17-24.
20. Malina JF. Viral pathogen inactivation during treatment of municipal wastewater, 1976, pp: 9-23. In: Baldwin LB,Davidson JM, Gerber JF. Virus aspects of applying municipal waste to land. University of Florida, Gainesville.
21. Anonymous. Anaerobic sludge digesters. Available from: http:// www.microbiologyprocedure.com
22. Samuel RF, Gabriel B. Bacterial survival and association with sludge flocs during aerobic and anaerobic digestion of wastewater sludge under laboratory condition. App. And Env. Micro. 1983: pp174- 81.
23. Black MI, Scarpino PV, O,Donnell CJ, Meyer KB, Jones JV, Kaneshiro

ES. Survival rates of parasite eggs in sludge during aerobic and anaerobic digestion. Applied and Env. Micro. 1982; pp 1138-43.
24. USEPA. Land application of municipal sewage sludge guidelines. EPB 296, June 2004.
25. Samhan O, Ghobrial F. Ttrace metals and chlorinated hydrocarbons in sewage sludge of Kuwait. Water, Air, and Soil Pollution, 1987; 36: pp 234-46.
26. Dewil R, Baeyens J, Neyens E. Reducing the heavy metals content of sewage sludge by advanced sludge treatment methods. Env Eng Sci. 2006; 23(6): pp994-9.
27. Al-Enezi G, Hamoda MF, Fawazi N. Heavy metals content of municipal wastewater and sludges in Kuwait. J Env Sci and Health, part A. 2005; 39(2): pp 297-407.
28. Carrington EG, Pike B, Auty D, Morris R. Destruction of fecal bacteria, enteroviruses, and ova of parasites in wastewater sludge by aerobic thermophilic and anaerobic mesophilic digestion. Water Science and technology. Available from: http://www.cepis.ops-oms.org/muwww/fulltext/repind54/desfae/desfae.html.
29. Benatti CT, Granhen CR, Filho BP, Ribeiro MD. Operation of a slow rate anaerobic digester treating municipal secondary sludge. Electron J Biotechnology. 2002; 5(3). Available from: http:// www.scielo.cl.php?script=sci_serial8/pid=0717-3458&ing=en&nrm=iso.
30. Petterson SA, Ashbolt NJ. WHO guidelines for the safe use of wastewater and excreta in agriculture. Microbial risk assessment section (MRA review). Available from: http:// www.WHO.org.
31. Ascariasis. The free encyclopedia. Available from: http:// www.en.wikipedia.org/wiki/ascariasis
32. Toxocariasis. The free encyclopedia. Available from: http:// www.en.wikipedia.org/wiki/toxocariasis.
33. FAO. Wastewater treatment and use in agriculture: 6- agricultural use of sewage sludge. Available from: http:// www.fao.org/docrep/TOSSIE/tossie08.htm.
34. FAO. Wastewater treatment and use in agriculture: FAO irrigation and drainage paper 47, 1992. Available from: http:// www.fao.org/docrep/TOSSIE/tossie08.htm.
35. Ponugoti PR, Dahab MF, Surampalli R. Effects of different biosolids treatment systems on pathogen and pathogen indicator reduction. Water Env Research. 1997; 69 (7): 1195-206.
36. Kelly WD, Martens DC, Reneau RB, Simpson TW. Agriculture use of sewage sludge: A literature review. Bulletin 143; 1984 (December). A publication of Virginia Water Resources Research Center.
37. Asnold K, Dunn JH, Sievers D. Available from: http:// extension.Missouri.edu/explore/envqual/wq0424.htm.