Study of Issues in Sludge Disposal and Management in Wastewater Treatment Plants

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Abstract: *Improper methods of treatment, disposal and management of sludge generated by wastewater treatment plants has become a major environmental issue at present. This research focuses on identifying the environmental impact cause by the methods used when disposing and reusing the produced sludge as fertilizer, by the Biyagama CWWTP, Ratmalana/ Moratuwa WWTP, Ja-Ela/ Ekala WWTP and Raddolugama sewerage treatment plant. The sludge samples collected from the dumpsites were tested for heavy metals, nutrients, and organic compounds present in it. After analyzing the constituents present in the sludge, the issues in respective treatment plants and its procedures were identified. Moreover, the possibility of using the sludge as construction material, fertilizer and whether it satisfy the requirements to use as a fertilizer for crops cultivated for human consumption were discussed. In addition, a model limitation scale for the sludge standards was introduced through this study after observing various limitations maintained in other international standards. As per the results, only sludge from Raddolugama Plant was assured as safe for land application and sludge in Biyagama plant was found to be the most suitable for fertilization among the others although other minor hitches were found. Conclusively, ecofriendly and sustainable solutions were suggested to improve the sludge qualities and overcome the issues found and proposed how sludge could be utilized for greater uses than wasting a valuable asset.*

***Keywords**: Sludge, Wastewater treatment plant, Sludge Disposal, Sludge management, Sludge fertilizer, Heavy metal contamination*

1. Introduction

Sri Lanka is a developing or an emerging country with a lower middle income status(World Bank Country and Lending Groups – World Bank Data Help Desk, no date). Massive amounts of wastewater are produced as industry progresses and population growth increases demand for food and water. According to the Central Environmental Authority (CEA), Sri Lanka's main industrial parks produce about 30 million cubic meters of wastewater annually (Jayalal and Niroshani, 2007). After being properly treated in a Wastewater Treatment Plant (WWTP), the treated effluent must be properly disposed of. Depending on the wastewater constituents and the standards that must be met for each disposal method, the method of treatment and the chemicals used during the treatment process may differ.

Screening, grit removal, primary settling (coagulation and flocculation), activated sludge treatment, filtration, and disinfection are the most common phases in wastewater treatment.

Sludge is an inevitable by-product of water treatment, and it can get produced at any above mentioned stage, albeit the clarification stage is the main source of sludge production (Turovskiy and Mathai, 2005)(Anjithan, B C L

Athapattu, N Ratnayake, 2015). Sludge, which is categorized as an industrial waste, comes in a variety of forms, including slurry, semi-solid, and solid, depending on the coagulants and other chemicals used to treat it. Even while sludge is a nutrient-dense waste product, it also includes pathogens and heavy metals that can harm the environment if disposed of without first being treated. Sludge treatment and disposal can also be highly costly. As a result, finding environmentally safe and cost-effective sludge removal and management strategies has become critical in recent years. Sludge management is the process of reducing the amount of sludge that must be disposed of.

The most common sludge treatment methods are conditioning, thickening, dewatering, stabilization and disinfection, and thermal drying. After the treatment process, it is disposed to the environment. There are several disposal alternatives, which are currently in use. They are; land spreading, incineration, landfilling, discharging to water courses and use as a soil conditioner or fertilizer for agricultural use.

On the other hand, these processes for treatment and disposal could be harmful to the public's health and the environment. Raw sludge frequently contains toxic compounds like heavy metals, pathogenic microorganisms, organic pollutants, as well as nutrients, grease, and fat. These substances have the potential to disrupt the ecosystem and living things when they are introduced into natural soil or water bodies. Some experts have emphasized the most common dangers connected with employing sludge as a fertilizer or soil conditioner. They are the risks of atmospheric pollution from gases such as ammonia and nitrous oxide, nutrient pollution from excess nitrogen and phosphorus, and soil contamination from chemical or biological contamination (Rorat et al., 2019)(Nkoa, 2014). These toxic contaminations could even increase pre- existing environmental problems (Rorat et al., 2019).

With the aim of analyzing the adverse effects of improper disposal of sludge and proposing suitable disposal and management methods with minimum environmental impact, the Central Wastewater Treatment Plant (CWWTP) at Biyagama Export Processing Zone (BEPZ), Ratmalana/ Moratuwa Wastewater treatment plant, Ja- Ela/ Ekala Wastewater treatment plant at Ekala Industrial Zone and Raddolugama Sewerage treatment plant were selected for this study. Observing the current methods of disposal of sludge in these selected treatment plants to identify the wrong approaches followed in them and their effects on the environment, identifying the constituents of the produced sludge, introducing a scaling for limitations of sludge parameters suitable for Sri Lanka and to identify effective methods to reuse, disposal and management in sludge were the main objectives when conducting this research. In order to achieve these, sludge and water samples were collected from selected locations and were tested for different physical and chemical parameters. Then the results were analyzed comparatively with standard limitation for land application of sludge and reusability of sludge as a fertilizer and the recommendations were given accordingly.

2. Methodology

A. Site Visitation and Collection of Data

Biyagama CWWTP, which is situated in the Biyagama Export Processing Zone, is currently maintained by the NWSDB. BEPZ is split into two sections: Block A and Block B. Block A companies send their treated effluents to the CWWTP's aeration lagoons, whereas Block B industries discharge their effluents to the Oxidation ditch. However, enterprises must meet particular water quality requirements in order to be permitted to transport their wastewater to the CWWTP. The biological treatment at CWWTP is based on the activated sludge process. The produced sludge is then solar dried and then used for land filling, fertilizer or dumped to dump yards.

The biological treatment method used by the Moratuwa and Ja-Ela WWTPs both involves recycling activated sludge. The squeezed sludge from the belt filter is solar dried in greenhouses while the final effluent is discharged into the Dandugam River and sludge is utilized for composting or landfilling.

Raddolugama sewerage plant, which was commissioned to treat the toilet and kitchen wastewater that is discharged from the Housing schemes in that area, undergoes the same biological treatment as in Moratuwa and Ja- Ela WWTPs. The final sludge is solar dried to use as a fertilizer.

B. Collection of Sludge Samples

From the Biyagama CWWTP, samples were collected from the lagoon inlet, oxidation ditch inlet, ditch settling tanks, ditch clarifier drying bed, settling tank outlets and flocculation pond. From the Moratuwa, Ja- Ela and Raddolugama Treatment plants, sludge samples from the Belt filter press were taken. For the purpose of comparison of the sludge quality over the time, some past sludge reports were also collected from the Moratuwa and Biyagama WWTPs.

C. Laboratory testing and Analysing Data

The collected samples were then sent to laboratories to get tested for parameters which consisted color, moisture, odour, sand content, pH, Nitrogen content (N), Phosphorus content (P2O5), Potassium content (K2O), Magnesium content (MgO), Calcium content (CaO), Organic carbon, C/N ratio, Heavy metals (Hg, Mo, As, Cd, Cr, Cu, Pb, Ni, Zn, Se), Salmonella and Coliform (E-coli).

For the testing of the sludge, standard methods such as APHA, CPSD- AN 00581, SLS 516, SLS 645, SLS 1246, USEPA methods, AOAC 999.10 (2012), AAS method were followed according to the respective parameters. As per these guidelines, the calculations were done to find the concentrations of each parameter.

$$\text{mg Ca/L} = \frac{A \times B \times 400.8}{\text{mL sample}}$$

$$\text{Calcium hardness as mg CaCO}_3\text{/L} = \frac{A \times B \times 1000}{\text{mL sample}}$$

where:

A = mL titrant for sample and

B = mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant at the calcium indicator end point.

Figure 1. Example calculation of Ca concentration as per APHA3500 - Ca B method Source : (APHA, 2012)

For the analysis of the results to check whether the sludge parameters lie within the tolerance limits and whether the sludge from any WWTP pose any threat to the environment and the living organisms, most common codes that are used worldwide and in Sri Lanka were used. They were, European Standards (European Commission, Council Directive 86/278/EEC of 12 June 1986), SLS standards (Specification for compost from Municipal Solid Waste and Agricultural Waste), and US EPA standards (40 CFR Part 503).

3. Results and Discussion

A. Comparison of the Sludge Parameters and Their Concentrations

Based on graph above, it is evident that among the heavy metals studied, Zn and Cu have higher concentrations in 2021, while Mn has the highest concentration in 2020. Because the CWWTP only uses a biological treatment method, this could have been caused by a company sending pre-treated water to the CWWTP. This could be due to not adhering to the BOI tolerance limits while sending effluent to the CWWTP.

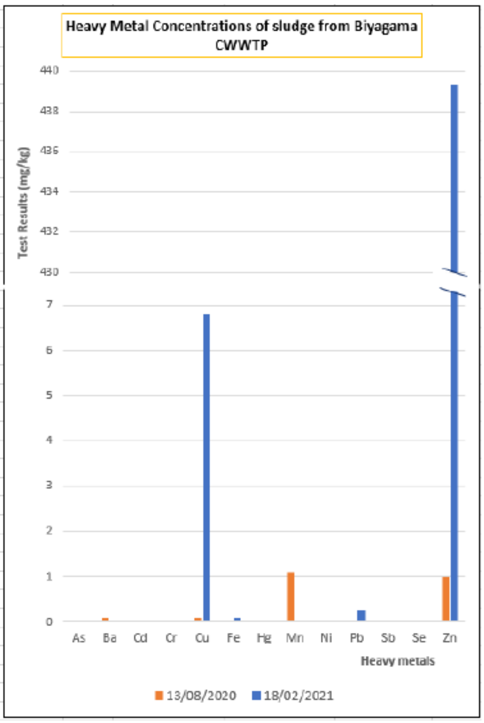

Figure 2. Heavy metal concentrations of sludge from Biyagama CWWTP

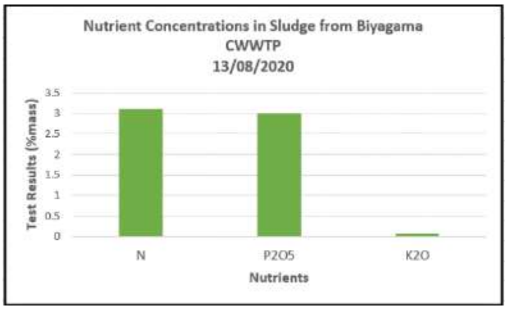

Figure 3. Nutrient Concentrations in sludge from Biyagama CWWTP dated 13/08/2020

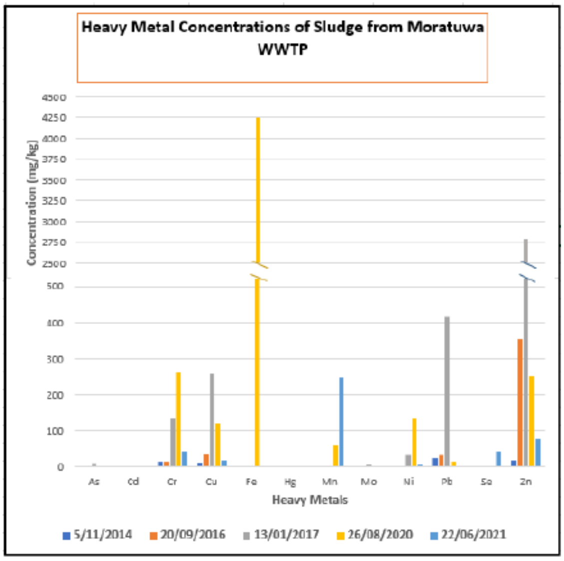

Figure 4. Heavy metal concentrations in sludge from Moratuwa WWTP

The most protruding element concentrations in this graph is displayed in the sludge sample dated at 26/08/2020. The iron contents have risen up to 4250 mg/kg. The sludge sample dated at 13/01/2017, also show some increase in the heavy metal concentrations compared to the other days. However, it is safe to say that the Moratuwa Plant has managed to decrease these parameters over the time, as of 22/06/2021 results show comparatively lower metal concentrations.

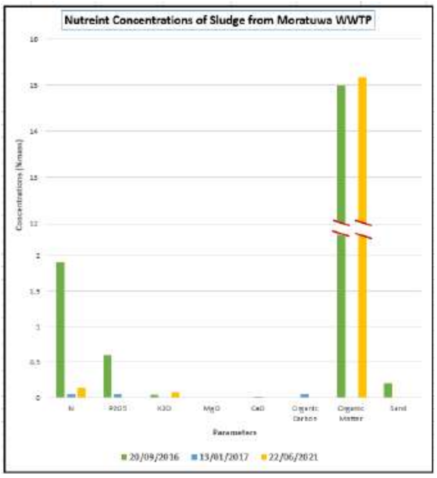

Figure 5. Nutrient concentrations of sludge from Moratuwa WWTP

Organic matter concentration in both 2016 and 2021 samples shows the peaks in those respective years.

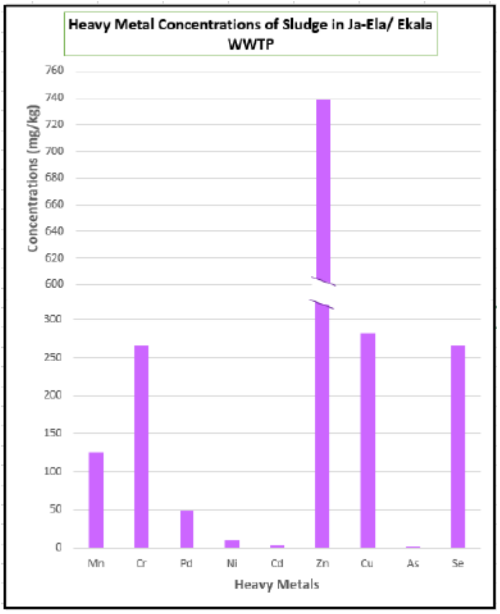

Figure 6. Heavy metal concentrations in sludge from Ja- Ela WWTP dated at 22/06/2021

The Zn level in the sludge sample has risen dramatically to 738.9 mg/kg, which could be attributable to the WWTP receiving extremely polluted industrial effluents or some factories exceeding the tolerance limits for industrial wastewater (effluents) discharged in to the common wastewater treatment plant, Biyagama.

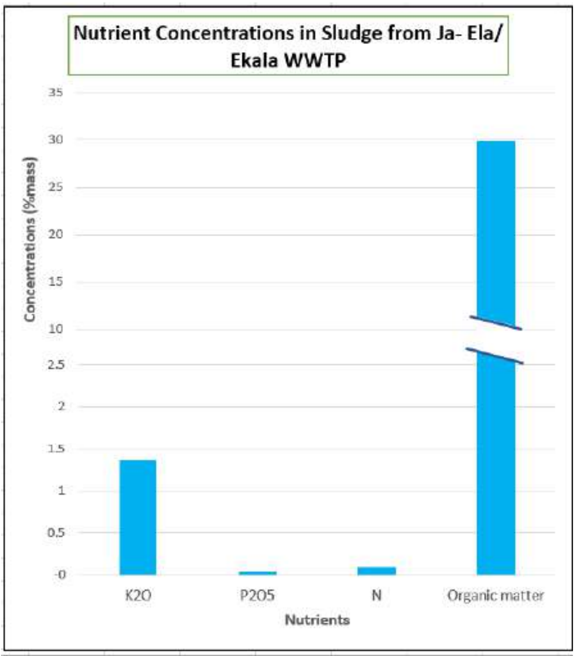

Figure 7. Nutrient concentrations of the sludge in Ja- Ela WWTP

The solar dried sludge sample from the Sewerage treatment facility suggests rather large quantities of Organic matter, as seen in the graph below. This is to be expected from a plant that handles domestic wastewater that has a high concentration of human excreta, food, and waste, among other things. It could also suggest that the treatment plant's efficiency in eliminating organic materials is low. Moratuwa WWTP sludge parameters show that the nutritional content of the sludge is lower than the SLS mandated limits. Although there is a noticeable improvement in the parameters as compared to previous Moratuwa WWTP reports. As a result,

Table 1. Comparison of sludge parameters with EU and EPA standards for suitability for land ap

Parameters	Test Results (mg/kg)									Standard Limitations (mg/kg)	
	Biyagama WWTP		Moratuwa WWTP					Ja- Ela/ Ekala WWTP	Raddolugama WWTP	EN Standards	EPA Standards (max)
	13/08/2020	18/02/2021	5/11/2014	20/09/2016	13/01/2017	26/08/2020	22/06/2021	22/06/2021	22/06/2021		
As	0.001	ND		3.6	7.1	<2.5	<2.0	<2.0	<2.0		41
Cd	ND	ND	ND	ND	2.9	0.8	<3.0	<3.0	<3.0	1 - 3	39
Cr	0.002	ND	13.4	14.2	133	262	44.1	265.1	63.6	1000	1200
Cu	0.1	6.81	11.9	37.7	259	120	17.2	282.0	11.5	50 - 140	1500
Hg	ND	ND	ND	1.8	ND					1 - 1.5	17
Mo					4.9						-
Ni		ND	3.2		35	134	<4.0	9.4	<4.0	30 - 75	420
Pb	ND	0.27	25.2	32.7	417	15	<2.0	48.8	<2.0	50 - 300	300
Se	ND				ND	2.5	44.1	265.1	63.63		100
Zn	1.0	439.33	17.0	353	2785	250	76.7	738.9	67.4	150 - 300	2800

Table 2. Comparison of sludge parameters with SLS and EU standards for suitability of the sludge generated from the WWTPs to use as a fertilizer for agricultural purposes

Parameters	Units	Test Results									Standard Limitations		
		Biyagama WWTP		Moratuwa WWTP					Ja- Ela/ Ekala WWTP	Raddolugama WWTP	SLS Standards		EN Standards
		13/08/2020	18/02/2021	5/11/2014	20/09/2016	13/01/2017	26/08/2020	22/06/2021	22/06/2021	22/06/2021			
pH					6.7	5.8					6.5 - 8.5		
Organic Carbon	%mass					0.06					20	min	
Organic Matter	%mass				15			15.18	29.88	50.02			
N	%mass	3.1			1.9	0.06		0.15	0.09	0.31	1.0	min	
P_2O_5	%mass	3.0			0.6	0.058		0.01	0.04	0.02	0.5	min	
K_2O	%mass	0.07			0.04	0.001		0.08	1.36	0.15	1.0	min	
MgO	%mass					0.012					0.5	min	
CaO	%mass					0.021					0.7	min	
As	mg/kg	0.001	ND		3.6	7.1	<2.5	<2.0	<2.0	<2.0			
Ba	mg/kg	0.1											
Cd	mg/kg	ND	ND	ND	ND	2.9	0.8	<3.0	<3.0	<3.0	10	max	20 - 40
Cr	mg/kg	0.002		13.4	14.2	133	262	44.1	265.1	63.6	1000	max	-
Cu	mg/kg	0.1	6.81	11.9	37.7	259	120	17.2	282	11.5	400	max	1000 - 1750
Fe	mg/kg	0.02	<0.1				4250						
Hg	mg/kg		ND	ND	1.8	ND					2	max	16 - 25
Mn	mg/kg	1.1					63	249.5	125.9	385.6			
Mo	mg/kg					4.9							
Ni	mg/kg		ND	3.2		35	134	<4.0	9.4	<4.0	100	max	300 - 400
Pb	mg/kg	ND	0.27	25.2	32.7	417	15	<2.0	48.8	<2.0	250	max	750 - 1200
Sb	mg/kg	0.01											
Se	mg/kg	ND				ND	2.5	44.1	265.1	63.63			
Zn	mg/kg	1.0	439.33	17	353	2785	250	76.7	738.9	67.4	1000	max	2500 - 4000
Faecal Coliform	per g				>110	ND					free		
Salmonella	per 25g		absent		absent	absent					free		
Color			Black			Black					Brown/ Grey to Dark black		
Moisture Content						0.061					<25%		
Odour			unpleasant			unpleasant					Shall not have any unpleasant Odour		
Sand Content	%mass				0.2	0.012					<10%		

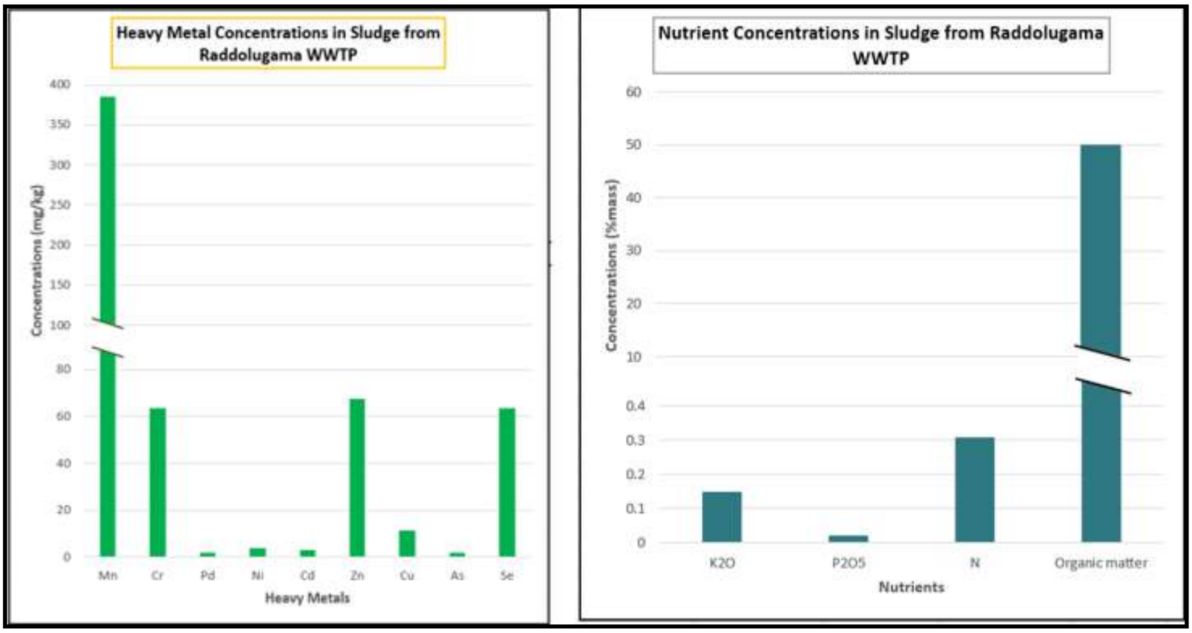

Figure 8. Heavy metal concentrations in sludge from Raddolugama Sewerage Treatment Plant dated 22/06/2021 and Nutrient concentrations of sludge from Raddolugama Sewerage Treatment Plant dated 22/06/2021

B. Analysis of the Suitability of Sludge for Land Application

From the results obtained, when compared with the European and US standards, it is apparent that only Raddolugama Sewerage treatment plant sludge can be assured as safe to use for land application.

C. Analysis of Suitability of Sludge to use as a Fertilizer for Agricultural Purposes

Based on the comparison of criteria, sludge from Biyagama CWWTP can be used as a fertilizer if an odour solution can be discovered. The most recent reports on the indicate nutrient insufficiency.

Analysis of the issues which may have caused the variations in sludge parameters and how it can be improved through the existing plant

The biological treatment is used as a secondary treatment in the Biyagama, Moratuwa, and Ja-Ela treatment plants, while the raw water is treated chemically at the manufacturers' in-house treatment plants. In most cases, raw water is first biologically treated to remove organic matter and nutrients, and then chemically treated to minimize heavy metals and other characteristics for better quality. This could also be the cause of the sludge's high heavy metal and nutritional content, as mentioned above. Another problem noted in this investigation is the lack of an adequate odour control system. To prevent air pollution, some countries use effective scent control technologies. Chemical scrubbers are used in Germany to deodorize waste air (Frechen, 1988). In Denmark, they use a more ecofriendly alternative for chemical scrubbing. That is bio scrubbing (Hansen and Rindel, 2001). There are many other methods such as Bio filtration, activated sludge diffusion, bio trickling filtration, activated carbon adsorption, regenerative incineration, and a hybrid technology (bio trickling filtration coupled with carbon adsorption) (Estrada et al., 2011).

When industries deliver their pre-treatment effluents to WWTPs, however, the standards are not evaluated on a daily basis. Furthermore, even if changes in parameters are detected at the treatment plant's inlet, the individual factory that has exceeded the stipulated limits cannot be identified promptly so that corrective action can be taken. As a result, this study recommends establishing a mechanism for requesting a daily report of the factory outlet wastewater quality characteristics to the WWTP. When raw water is sent from the inflow to the oxidation ditch at the Biyagama CWWTP, it does not pass through a grit chamber. This could lead to a high sand content in the sludge. The maturation pond in the plant is not effective as the pond is covered in dense vegetation allowing very low light penetration. This may lead to eutrophication and eventually pollution of water.

D. Proposing a Suitable Model Tolerance Limit Scale for Sri Lanka

Table 3. Modelled limitation scale for sludge in land application

Parameter	Unit	Limit Value (max)
pH		6 - 8.5
Cd	mg/kg DM	5
Cr	mg/kg DM	100
Cu	mg/kg DM	400
Hg	mg/kg DM	2
Ni	mg/kg DM	30 - 50
Pb	mg/kg DM	150
Zn	mg/kg DM	1000
As	mg/kg DM	20-10
Mo	mg/kg DM	20
Faecal Coliform	per g	free
Salmonella	per 25 g	free

4. Conclusion and Recommendation

This study focuses on finding environmentally and economically responsible ways to use or dispose of sludge produced as a byproduct of wastewater treatment. In order to examine the potential of sludge for use in agriculture as a fertilizer and the impact of land application, samples of sludge from four important treatment plants in Sri Lanka were evaluated for their qualities. Physical characteristics like color, moisture content, sand content, and chemical parameters like heavy metals and nutrients were examined in the sludge samples taken from the treatment plants, and these results were compared to EU, EPA, and SLS requirements.

The Biyagama facility's sludge, despite having an unpleasant smell, can be used as fertilizer, according to the findings. The other plants did not meet the necessary requirements. When it came to land application appropriateness, only the Raddolugama and Moratuwa treatment plants complied with EU and EPA regulations.

Sludge is a byproduct that is high in nutrients such as N, K, and P that are required for plant growth. As a fertilizer, sludge can be used directly as either a fertilizer or soil conditioner after treatment to obtain the necessary standards, or it can be mixed with compost to improve the nutrient quality. Moreover, at present, there is a promotion for production in Organic fertilizer in Sri Lanka with the limitations regulated for importing fertilizer by the current government. Hence this is an important opportunity to promote usage of sludge for fertilizer either by directly using as a fertilizer or soil conditioner after treating the sludge to obtain the necessary standards, or it can be mixed for compost and improve the nutrient quality, because sludge is a by product which is high in nutrients such as N, K, P which are needed for plant growth. Hence the sludge produced at Biyagama Plant can be used for fertilizer while adapting the odour control system used in the Moratuwa plant to solve its odour issue.

Sludge can also be used to create building supplies like cement and bricks. Since the sludge from Raddolugama and Moratuwa plants were tested positive for land applications, necessary treatments could be done to enhance its materialistic properties and use in raw material production or for landfilling. Recent research has revealed numerous promising advancements in sludge-based building materials.

Sludge is additionally employed in the creation of fuel. It is a good source for the manufacture of biofuel and can help with the current fuel problem and the high costs associated with utilizing it to generate energy.

Sludge must therefore be carefully handled and reused rather than being disposed of in landfills or dump yards. It represents a waste of a priceless resource. The correct treatment of sludge can reduce its negative impacts. However, laws for sludge treatment and disposal need to be addressed for disposing of sludge in any unfavourable ways that pose a harm to the organisms and environment.

Acknowledgment

First, my most heartfelt sincere gratitude is express to my supervisor Dr. TMWRMB Samarakoon for his constant support, encouragement, exemplary guidance throughout the period of the final year project. I would also like to extend my deepest gratitude to Eng. (Mrs.) Champika J. Ranasinghe, Mrs. Kalyani Boteju, Mr. K.K.S Upulsiri Perera, Mrs. N.M. Samaranayake, Mrs. Harsha De Thennakoon, Mrs. Sumudu Habarakaduwa and Eng. (Mr.) N.U.K.Ranatunga. Finally yet importantly, I would like to thank Department of Civil Engineering of General Sir John Kotelawala Defence University, Sri Lanka for providing all the laboratory facilities to conduct my research. I would like to appreciate the support provided by my fellow colleagues and everyone else who stood by me.

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