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Economics of Sludge and Water Effluent Management of Wastewater Treatment Plant

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Abstract— **The Guheshwori Wastewater Treatment Plant (GWTP) was used for the study work. The main objective of the research work was to analyze the economic benefits of sludge and water effluent management of the Wastewater Treatment Plant (WWTP). The Cost Benefit Analysis methodology was used and analyzed to meet the research objectives. The Wastewater treatment plant has significant environmental benefits as well as monetary values that can be generated from water effluent, sludge effluent, and plant visit fares, which indicates the revenue generation from the wastewater treatment plant. This study takes a ground-breaking strategy to economically value wastewater treatment in Nepal. A helpful indication of the viability of wastewater treatment will be the comparison of the benefits of WWTP with the operating costs of the treatment process. On a dry mass basis, the finished sludge had a total nitrogen content of 3.58 percent, a total phosphorus content of 1.54 percent, and a potassium content of 0.15 percent. After pathogen reduction sludge can be used in agricultural fields as fertilizer leading to high monetary values for GWTP. Plant visit fares from the visitors also can generate monetary value. Similarly, water effluent can be used in watering the parks, irrigation, and cleaning, and after turbidity reduction can be used in concreting and curing. The Guheshwori Waste Water Treatment Plant requires a yearly total of around NRs. 4,49,94,639 to operate. If we merely sale 5% of the treated water NRs. 94,03,130, 10% of the treated water NRs. 1,88,08,085, 50% of the treated water NRs. 9,40,28,380, and 100% of the treated water NRs. 18,80,61,870 can be generated. From the GWTP wastewater treatment plant's sludge, 57,34,202 may be produced yearly. There is a potential income generation of about NRs. 12,02,500 from the plant visit fares. To close these disparities, Government of Nepal (GoN) must enact legislation on the optimal use of WWTP effluent, the protection of water sources, public health, and environmental economics. The welfare concept of economics concept states the maximum utilization of the reuse of the resources of the effluents from the Guheshwori Wastewater Treatment Plant, NBV>1 can be achieved from an environmental economics viewpoint alongside achieving Sustainable Development Goals SDGs Goals 6, 8, and 11.**

I. INTRODUCTION

Nearly 60% of the sewage sludge generated in the US is currently used on land (Kendir et al., 2015) (Li et al., 2011). This figure is more than 40% in Europe and about 50% in China (Kendir et al., 2015) (Liu et al., 2015). Even though urban areas acquires only about 3% of the land of the world, more than half of the whole population of the world dwells in the urban area. And the trend of the population moving to urban areas is increasing globally leading to an increment in the production of wastewater. Thus it can be inferred that sewage production is increasing globally and so is sludge. For sustainable management of sludge, the application of sludge on land is gaining popularity. Owing to the current shortage of water in natural sources and urban areas, as well as the pollution caused by sludge on water bodies, a suggestion is put up that enables choices to be made about an effective regeneration and reuse process (Urrea Vivas et al., 2023).

Farmers are known to use wastewater irrigation in much bigger regions in the Kathmandu Valley on agricultural land that is situated within city centers and on the outskirts of urban areas (Rutkowski et al., 2007). An investigation is underway on the technique of utilizing wastewater from Bhaktapur's Hanumante river, a tributary of the Bagmati river. The study observed the wastewater consumption patterns of fifty-five local farming households, the majority of which are small farmers owning 0.23 hectares of land on average. Year-round irrigation with effluent from the Hanumante River is a practice followed by 64% of agricultural settlements. However, just 20% of farmers claimed that using wastewater had increased agricultural yield (Hettiarachchi et al., 2016) . In a tiny portion of Khokana, a densely populated medieval Newar town in the Karyabinayak Municipality of the Lalitpur district, there are seven community wastewater irrigation systems. Each system has an irrigated area of between 0.26 and 7.76 hectares. It was discovered that the research area's wastewater was utilized to grow vegetables, which is a significant source of financial revenue for the local population. Farmers also believed that the wastewater's high nutrient's content would favorably impact crop productivity (Hettiarachchi et al., 2016). Due to rapid urbanization in Kathmandu valley large buildings are being built day by day, a number of municipal parks are also being made which require a high amount of water. Due to high impermeable road and concreting, more extraction from ground water then recharge water from the source can be shifted to the effluent water from the treatment plant.

Wastewater management is a new problem, particularly in metropolitan areas of low-income nations like Nepal (Hamal et. al, 2020). Although the produced sludge has been regularly disposed of, research for the agricultural use of sludge from the WWTP has not have been conducted in the context of Nepal, specifically the Guheshwori wastewater treatment plant (32.4 MLD). Since new wastewater treatment plants i.e. at Khodku (Balkumari) 17.5 MLD, Dobhighat 37+37 MLD and Sallaghari 14.2 MLD are under construction (KUKL PID, GoN 2023) and will be in operation within a few years. These wastewater treatment plants will produce effluent in terms of sludge and water. Sludge production is going to increase and the disposal of sludge from these treatment plants will draw issues at government and public levels as usual. So, if fertilizer values of sludge can be used and water effluent can be reused in terms of curing, watering parks, cleaning it can be a good source of revenue for the WWTP and GoN and finally will help in resource recovery and green and sustainable environment. Even though the nation is endowed with a lot of water, the Kathmandu Valley has long suffered from a lack of water (Hamal et. al, 2020). In order to address this issue, research is being done to determine the financial benefits of reusing water.

(Chen & Wang, 2009) Two options are considered for the cost and benefit analysis of this project. Option 1 makes the assumption that treated water in the service area will only be used for gardening, whereas option 2 makes the assumption that treated water will also be used to replenish the artificial pond, which would otherwise require tap water twice a month to maintain a satisfactory level of pond water quality for aesthetic reasons. If the environmental benefits are disregarded (Option 1), it is obvious that NBV > 0 cannot be obtained when only a small portion of the treated water (18.723%) is reused for gardening despite without accounting for the environmental benefit. NBV > 0 is achieved better for (Option 2) when 100% of the treated water is reused, not only for gardening and other purposes but also for replenishing the artificial pond.

(Molinos-Senante et al., 2010) A sample of 22 WWTPs in the Valencian area of Spain are the subject of an empirical application. The entire benefits from wastewater treatment are compared to the operating expenses for each sample WWTP to determine net profit. The sum of the environmental advantages and revenue from the sale of the treated water constitutes the overall benefit of wastewater treatment. Three potential scenarios' net profits have been calculated: No sale of treated water, 50% sale of treated water, and 100% sale of treated water are the three options. The net profit for all of the WWTPs in the three scenarios is positive on average, reaching its peak if all of the recovered water is sold. This indicates that the wastewater treatment is advantageous from both an environmental and financial standpoint.

II. OBJECTIVES

The main objective of this study is to evaluate the economic value of the sludge and the wastewater effluent of the GWTP.

III. MATERIALS AND METHODS

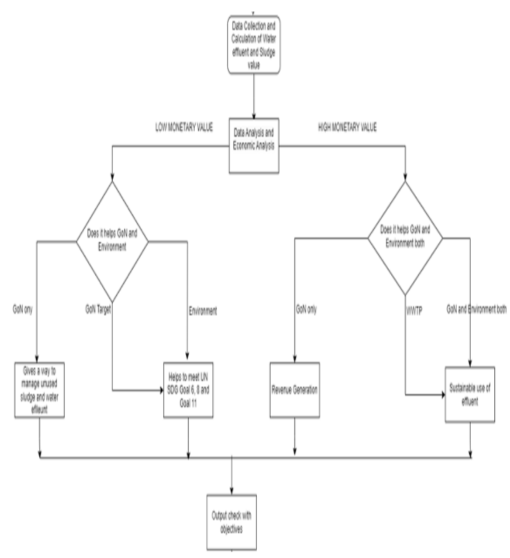

Fig. 1. Conceptual Framework

Fig.1 shows the conceptual framework of the research work conducted for meeting the objectives. The effluent water and the sludge of the Guheshwori Waste Water Treatment Plant was chosen for conducting the research works. The conceptual framework shows that research was conducted into two ways i.e. Option 1 the output showing low monetary value and Option 2 the output having high monetary values. Generally, the environmental benefits are included in the low monetary value section. Revenue to the Government of Nepal, Wastewater treatment plant, and Sustainable use of effluent i.e. welfare economics are studied in this research work whose procedure is shown in fig 3.1 conceptual framework.

IV. Economic Evaluation of Sludge and Water Effluent Management

The total cost for the operation of the Guheshwori wastewater treatment plant includes the cost for the payable bill of energy i.e. electrical energy to NEA. Similarly, for the operation of the wastewater treatment plant it requires human resource (i.e. labor) which needs expenses for functioning. Likewise for the continual checking of the parameters of the water effluent and sludge laboratory works also cost some money. This GWTP is currently being operated by "Va Tech WayBag Limited" India Contractor Company. So, as per contact agreement between GoN and Contractor for the human resource management, chemical purchase, materials cost all are included in yearly payable amount and contractor has to manage all from that amount.

Benefits from the GWTP can be classified into two heading one with non-monetary values and another with monetary values. Non-monetary benefits cannot generate any sorts of economic value but gives sustainable and green environmental benefits only. Environmental benefits are related with the welfare economics and optimum utilization of the resources. Monetary values can generated high economic values i.e. in terms of cash flows (inflow and outflow) if managed properly. Reuse of water effluent for non -potable uses, irrigation, gardening, curing, concreting, mixing can reduce the natural water source stress and can generate high revenue. Likewise, if the sludge is reused either by making fuel form anaerobic digester or by making compost manure can be used as fertilizer in agricultural field can generate revenue. Also, students from diploma, undergraduate level, graduate level, PhD level form civil engineering stream, public health, environment stream, medical stream can visit plant and by taking some charge from individual head can generate revenue which can reduce operation cost of the wastewater treatment plant.

Economists believe that sustainable economic growth increases human welfare. Environmental economics is basically based upon Willingness to Pay and Willingness to Accept Concept. (Urrea Vivas et al., 2023) provides an example of a circular economy by utilizing economic cost-benefit analysis (ACB) and net present value (NPV) approaches to determine the viability of repaying the initial investment costs and operating expenses during the WWTP's useful life. Due to its interactions with all economic sectors, water is essential for economic growth. Particularly in the water industry, the circular economy is now regarded as a basic concept for environmental management. Cost Benefit Analysis tool is used to determine the economic evaluation of the WWTP. The goal of the cost-benefit analysis is to determine if implementing different ideas would be financially feasible (Molinos-Senante et al., 2010). In wastewater treatment, an economically viable WWTP shows that all benefits from the process exceed total costs, proving that wastewater treatment is a cost-effective procedure in addition to being environmentally beneficial (Molinos-Senante et al., 2010). Figure 4.1 shows the total costs incurred and benefits generated from the wastewater treatment plant.

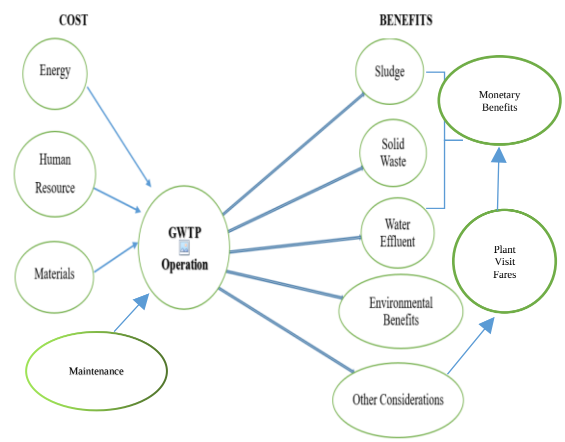

Fig. 2. Economics of GWTP Operation

V. Cost Benefit Analysis and Net Profit

The Cost Benefit Analysis is designed to examine the economic viability involved with putting various plans into action (Molinos-Senante et al., 2010). A net benefit value (NBV) model for cost-benefit analysis is $NBV = Bi - Ci$, where Bi is the value of the benefit item i and Ci is the value of the cost item i, both represented in the same monetary unit. An economic viability assessment will be given to a project if the computed result for a given system is $NBV > 0$, and an economically inviable assessment will be given if the calculated result is $NBV < 0$. The advantages of the project will expand as will the NBV (Chen & Wang, 2009).

An economically viable WWTP in the field of wastewater treatment indicates that all advantages accruing from this process outweigh its overall expenses, demonstrating that wastewater treatment is a beneficial procedure not just from an environmental point of view but also economically (Molinos-Senante et al., 2010). In the case of GWTP reusing of the sludge and reclaimed water generates revenue which when compared with the expenses of the GWTP results cost benefit analysis. Figure 4.1 shows the cost incurred in the operation of the WWTP and the benefits or revenue which we can generate from the WWTP.

VI. Results and Discussions

For the operation of the Guheshwori wastewater treatment plant, the most cost is taken up by electricity. The total cost is determined by summing up the all expenses of the treatment plant. The topic for the expenses of the plant includes electricity, human resources, and materials. Human resources charges, materials cost and other technical costs are collected in a single topic which GoN pays to the contractor for the operation of the plant. Electricity costs a minimum of 14 lakh for each month and this figure exceeds the consumption. Though the Nepal Electricity Authority NEA is providing the electricity cost of NRs. 4 per unit to GWTP, it has a total cost of NRs. 3,36,25,525 and this amount is paid by GoN to NEA. So, GWTP consumes high electric energy which generates high cost.

Also, according to the agreement between GoN and the Contractor based on the contract document, the contractor claims a total of NRs. 1,12,69,114 annually for the operation of WWTP.

A total of about NRs. 4,49,94,639 is required annually for the operation of the Guheshwori Waste Water Treatment Plant. Currently the maintenance cost is incurred into the amount of NRs. 1,12,69,114 contract between GoN and Contractor. Normally It costs about 15 to 25% of the total operation costs for maintenance.

The main nutrients present in today's commercial fertilizers are nitrogen, phosphorous, and potassium, or the "Big 3." The proportion of each nutrient by weight is shown in the product's N-P-K values. Wastewater effluent sludge contains Nitrogen Phosphorus and Potassium NPK in high amounts which are the main nutrients for the commercial fertilizer values. NPK values obtained after measuring in the laboratories are compared with the government of Nepal minimum required standards for the fertilizers. The government of Nepal has fixed the N, P, and K values in the manure as shown in Table 6.1.

Table VI.1 Government Standards for N, P, and K

S.N.	Composition	Government Standards (Minimum %)
1.	Nitrogen (N)	1.5
2.	Phosphorous (P)	0.5
3.	Potassium (K)	1.5

The final sludge from GWTP contained on a dry mass basis 3.58 percent total nitrogen, 1.54 percent total phosphorus, and 0.15 percent potassium (Magar, 2022). Comparing the N, P, and K values of GWTP sludge with the GoN guidelines shown in Table 6.1. N and P are quite higher in concentration so they can be used directly from N and P point of view. K is less then the GoN limits so the levels of K must be increased in the sludge introducing some Potassium Sulfate, Potassium Nitrate, and Sulfate potassium nitrate.

VII. DISCUSSIONS

A. Environmental Benefits

There are several environmental benefits linked with the wastewater treatment process (Hernández-Sancho et al., 2010). The advantages of environmental benefits from the wastewater treatment plant are not accounted directly by the market, it is considerably more difficult to quantify in monetary terms (Molinos-Senante et al., 2010). Due to weak policy guidelines, the absence of perfect knowledge, these environmental benefits are frequently not estimated since they are not determined by the market. However, a few number of research has been done on the economic assessment of environmental benefits, which is important to support an appropriate investment policy (Hernández-Sancho et al., 2010). GWTP treats about 32.4 MLD wastewater in peak conditions. As a result of which a large amount of treated water is added to the holy river Bagmati, aesthetic beauty of valley is reclaimed which are the major environmental benefits.

B. Economical Monetary Benefits

Economical monetary value needs to be categorized in terms of money supply i.e. net income, revenues and expenditures. Net Cash Flow and Net Present Value are the best tools to know the monetary values. Some of the monetary values from the WWTP are illustrated as:

1) Revenue Benefits

a) Water Effluent revenue

We will assume 4 scenarios for the reuse of the treated water effluent from the wastewater treatment plant. In scenario 1 we will sale 5% of the treated wastewater, in scenario 2 will sale 10% of the treated wastewater, Similarly, in scenario 3 we will sale 50% of the treated wastewater, in scenario 4 will sale 100% of the treated wastewater. NRs. 200 is the price taken in this study per tanker carrying 7000 liters. Normally, the market price for the tankers to supply drinking water to homes is NRs. 2000 and they pay about NRS. 700 to the office established for the source maintenance. Reusing 5% only we can generate revenue of NRs. 9403130, 10% reuse NRs. 18808085, 50% reuse NRs. 94028380 and 100% reuse NRs. 188061870. Practically, 100% reuse of water is not possible as Guheshwori is a holy place attached with Holy River Bagmati so we have to discharge some water in natural bodies. But, once if the Dhap dam comes in operation then we can reuse all the water effluent i.e. 100% which will generates maximum revenue from WWTP.

b) Field Visit Revenue

Students studying civil engineering, environmental engineering, environmental science, public health, nursing, health assistant, and medical field must visit the treatment plant to enhance their knowledge and know the mechanism of wastewater treatment. In the current situation, this is the only existing wastewater treatment. Students from other districts out of the valley also come to visit this WWTP. Suppose all the students from the related field of Kathmandu Valley i.e. Kathmandu, Lalitpur, and Bhaktapur visit the plant then some sort of revenue can be generated. Currently, GWTP is taking NRs. 161 from each students. Take NRs. 250 per student that will generate some sort of benefits to the treatment plant which might help to reduce operation costs in a very small amount. Around, NRs. 12,02,500 amount of revenue can be generated from the field visit of the students.

c) Sludge and Solid Waste Revenue Benefit

Currently in the market it costs NRs. 100 per kg for manure, if the price per kg of sludge is kept NRs. 20 then a total of NRs. 57,34,202 can be generated annually from the sludge of the Wastewater treatment plant.

C. Policy Benefits

Although the produced sludge has been regularly disposed of, research for the agricultural use of sludge from the WWTP has not been conducted in the context of Nepal, specifically the Guheshwori wastewater treatment plant (32.4 MLD). Since new wastewater treatment plants i.e. at Khodku (Balkumari) 17.5 MLD, Dobhighat 37+37 MLD and Sallaghari 14.2 MLD are under construction (KUKL PID, GoN 2023) and will be in operation within a few years. These wastewater treatment plants will produce effluent in terms of sludge and water. Sludge production is going to increase and the disposal of sludge from these treatment plants will draw issues at government and public levels as usual. So, if fertilizer values of sludge can be used and water effluent can be reused in terms of curing, watering parks, and cleaning it can be a good source of revenue for the WWTP and GoN and finally will help in resource recovery and green and sustainable environment.

Currently, GoN has no specific guidelines for the reuse of water effluent and sludge management. Resolution 1096 of the Republic of Colombia from 2000, which mandates that wastewater be treated before being reused, became an essential regulatory instrument on the territory in order to profit via the commercialization of this resource, for the recovery of the costs related to water regeneration and reuse (Urrea Vivas et al., 2023). The current state of wastewater management in Nepal is deplorable; the laws in place are insufficient to allow for the reuse of wastewater and the creation of economic values from wastewater effluent management. Therefore, GoN must pass laws pertaining to the best use of WWTP effluent, the preservation of water sources, and public health, or environmental economics, in order to close these gaps.

D. Other Benefits

GWTP consists of anaerobic digestion which involves the decomposition of sludge in the absence of oxygen. This process produces gases like carbon dioxide, methane, and stabilized solid substances. Volume reduction is high and energy is recovered in the form of methane. This generated methane can be used as fuel for the operation of the GWTP and can help to reduce the operation cost which we lose in electricity.

VIII. CONCLUSIONS

This study was aimed to determine the environmental economics. From the results and discussion, It is concluded that maximum monetary benefit will be achieved if all the effluent from the WWTP is used.

Effluent water from WWTP can be used for curing, concreting and mixing, irrigation in agriculture fields and gardening. Street cleaning which helps to reduce water stress in natural sources and side wise increases the revenue of WWTP. Also, Sludge can be used as fertilizer for agriculture which increases the revenue of WWTP. It is concluded that, revenue can be generated from water effluent, sludge effluent and field visits of the treatment plant.

A total cost of NRs. 4,49,94,639 is spended by GoN for the operation of the GWTP each year which can be reduced by 63.68 % if we use the effluent at minimum rate and if we reuse the effluent at maximum rate then the NBV of the GWTP will be greater than 1 leading to the good revenue generation i.e. benefit of GWTP. It is concluded that the Net Cash Flow from the WWTP will include more income than the expenditures if we reuse the effluents from the WWTP.

Benefits are categorized as Non-Monetary and Monetary from the WWTP. Non-Monetary Benefits generally represents the environmental benefits leading towards welfare economics and maximum utilization of resources. Water will be reused such that growing water stresses in the natural sources will be reduced. Water reused must meet the water quality parameters and disposal guidelines so, we can conclude that the Sustainable Development Goal SDGs Goals 6 Safe Water and Sanitation is achieved. The water effluent before disposal is meeting the Government of Nepal disposal guidelines which also reflects that Sustainable Development Goal SDGs Goals 6 Safe Water and Sanitation is achieved. By generating revenues from the reuse of the water and converting sludge to fertilizers Goal 8 of SDG, Decent Work and Economic Growth is achieved. By the proper reuse of the sludge and solid materials Goals 11 Sustainable Cities and Communities is also achieved.

REFERENCES

[1] Chen, R., & Wang, X. C. (2009). Cost–benefit evaluation of a decentralized water system for wastewater reuse and environmental protection. Water Science and Technology, 59(8), 1515–1522. https://doi.org/10.2166/wst.2009.156

[2] Emmerson, R. H. C., Morse, G. K., Lester, J. N., & Edge, D. R. (1995). The Life-Cycle Analysis of Small-Scale Sewage-Treatment Processes. Water and Environment Journal, 9(3), 317–325. https://doi.org/10.1111/j.1747-6593.1995.tb00945.x

[3] Han, N., Zhang, J., Hoang, M., Gray, S., & Xie, Z. (2021). A review of process and wastewater reuse in the recycled paper industry. Environmental Technology & Innovation, 24, 101860. https://doi.org/10.1016/j.eti.2021.101860

[4] Hamal, S., Ydstebø, L. (2020). Wastewater Treatment Technologies in Nepal. International Journal of Creative Research Thoughts (ICJRT)., Volume 8, ISSN: 2320-2882

[5] Hernández-Sancho, F., Molinos-Senante, M., & Sala-Garrido, R. (2010). Economic valuation of environmental benefits from wastewater treatment processes: An empirical approach for Spain. Science of The Total Environment, 408(4), 953–957. https://doi.org/10.1016/j.scitotenv.2009.10.028

[6] Hettiarachchi, H., Ardakanian, R., & United Nations University (Eds.). (2016). Safe use of wastewater in agriculture: Good practice examples.

United Nations University, Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES).

[7] KUKL. (2018). NEP: Kathmandu Valley Wastewater Management Project, Initial Environmental Examination, Prepared by the Project Implementation Directorate, Kathmandu Upatyaka Khanepani Limited, Ministry of Water Supply, Government of Nepal for the Asian Development Bank: Package No: KUKL/WW/TP-01

[8] Molinos-Senante, M., Hernández-Sancho, F., & Sala-Garrido, R. (2010). Economic feasibility study for wastewater treatment: A cost–benefit analysis. Science of The Total Environment, 408(20), 4396–4402. https://doi.org/10.1016/j.scitotenv.2010.07.014

[9] Magar, K (2022). Characterization of Anaerobically Digested and Dewatered Sewage Sludge from Guheshwori Wastewater Treatment Palnt and Assessment for Agricultural USe. Institute of Engineering, Pulchowk Campus, Department of Civil Engineering. Master Thesis: 075/MSEnE/r/012/295.

[10] Rutkowski, T., Raschid-Sally, L., & Buechler, S. (2007). Wastewater irrigation in the developing world—Two case studies from the Kathmandu Valley in Nepal. Agricultural Water Management, 88(1–3), 83–91. https://doi.org/10.1016/j.agwat.2006.08.012.

[11] Urrea Vivas, M. A., Seguí-Amórtegui, L., Tomás Pérez, C., & Guerrero-García Rojas, H. (2023). Technical–Economic Evaluation of Water Reuse at the WWTP El Salitre (Bogotá, Colombia): Example of Circular Economy. Water, 15(19), 3374. https://doi.org/10.3390/w15193374

[12] Kendir, E., Kentel, E., & Sanin, F. D. (2015). Evaluation of Heavy Metals and Associated Health Risks in a Metropolitan Wastewater Treatment Plant's Sludge for Its Land Application. Human and Ecological Risk Assessment: An International Journal, 21(6), 1631–1643. https://doi.org/10.1080/10807039.2014.966590

[13] Li Q., Hua L., Xu X.-H., Wei D.-P., & Ma Y.-B. (2011). A review on environmental effects and control criteria of biosolid agricultural application: A review on environmental effects and control criteria of biosolid agricultural application. Chinese Journal of Eco-Agriculture, 19(2), 468–476. https://doi.org/10.3724/SP.J.1011.2011.00468

[14] Liu, J., Zhuo, Z.-X., & Sun, S. (2015). Concentrations of Heavy Metals in Six Municipal Sludges from Guangzhou and Their Potential Ecological Risk Assessment for Agricultural Land Use. Polish Journal of Environmental Studies, 24, 165–174. https://doi.org/10.15244/pjoes/28348