وزارة المياه والري
سلطة المياه

الرقم 7/2/5877
التاريخ
الموافق 20/3/2025

To: All Bidders

Subject: Addendum no.2
for Tender No. (4/2025) Expression of Interest (EOI) Sludge-to-Energy Investment

Dear All:

Please find attached addendum No.2 to the above mentioned project, this addendum is issued as a response to the bidders inquires and it will be considered as a part of the tender's documents.

Sincerely yours,

Acting Secretary General/WAJ
Eng.Wael Aldwiri

مساعد الأمين العام لشؤون العطاءات والأسول
المهندسة نجوى أحمد العرابي

CC: ASG/Tenders and assists

Responses To Clarification Requests No. 2_– Tender No. 4/2025 – Expression of Interest (EOI) Sludge-to-Energy Investment

#	Requested Clarification	Clarifications / Answers
1.	**If the project must solve the problem of producing clean water from domestic and industrial waste?**	No, please refer to Project Description in MOU and TOR (scope if EOI)
2.	**What it will be the use of the purified water at the end of the treatment?**	The Question is not relevant to the subject project
3.	**What is the situation today, how this waste water is managed?**	Not relevant, this EOI is related to produced Stabilized sludge
4.	**If the waste water from cooking & shower and the waste water from the toilets is managed separately?**	Not relevant, this EOI is related to produced Stabilized sludge
5.	**If there is a main aqueduct in the country to distribute drinkable water and another one to collect the waste water.**	Not relevant, this EOI is related to produced Stabilized sludge
6.	**If each house or industry will have (or already have) their own treatment facility OR the treatments will be for a full village or town?**	Not relevant, this EOI is related to produced Stabilized sludge
7.	**What are the waste water quantities?**	Not relevant, this EOI is related to produced Stabilized sludge
8.	**If drinkable water will be available for restoring the cleaned waster. (This will be the process we would like to implement)**	Not relevant, this EOI is related to produced Stabilized sludge
9.	**If an environmental impact assessment (EIA) and an EIA report, respectively, were already addressed?**	The EIA shall be established by private party and provide to water authority of Jordan (WAJ) the innovative project feasibility
10.	**can you please provide us with the quantities of the sludge per location, type and dryness**	Attached is the study analysis containing integrated information about the quality of sludge from one of the large scalers WWTP and another small scaler However, the investor through the feasibility study shall perform all needed tests. For the quantity and dryness level, please find attached herewith data on the sludge quantity per location

Sludge Resources According to Quality							
		2020-2021	2025	2030	2035	2040	2050
Digested Sludge	Average (ton/annually)	74,097	110,679	118,111	127,271	133,480	153,155
Non-Digested Sludge	Average (ton/annually)	37,998	20,616	24,811	29,172	62,939	81,616
Sludge Resources Per Geographic Location							
		2020-2021	2025	2030	2035	2040	2050
Sludge from Ekider Cluster (Northern WWTPs)	Average (ton/annually)	19,280	23,421	26,878	32,163	42,296	57,265
Sludge from Ghabawi WWTP	Average (ton/annually)	-	-	26,930	26,930	26,930	26,930
Sludge from Samra	Average (ton/annually)	71,552	81,224	84,390	87,642	100,140	109,527
Sludge from Ghabawi Cluster (Middle WWTPs excluding Samra and Ghabawi)	Average (ton/annually)	21,262	20,943	22,840	27,152	53,982	67,980
Total (tons/annually)		**112,095**	**125,588**	**161,037**	**173,887**	**223,349**	**261,702**

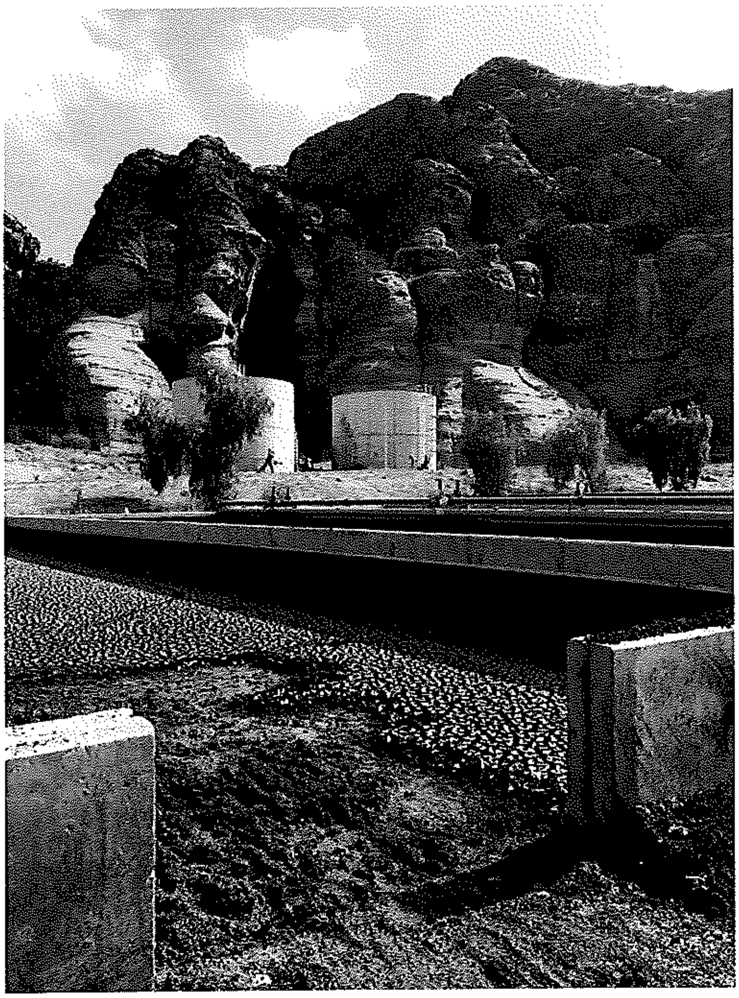
* These data represent sludge production from **Northern WWTPs (11)** and **Middle WWTPs (12).**

* Currently: **Digested** sludge is produced from **2** WWTPs. In **2025-2027**, **additional 6 (total 8)** WWTPs will have digested sludge.

* By 2040, there will be **5 new** WWTPs installed in the **Middle** region , and **4** WWTPs in the **Northern** Region.

* Sludge from Ekider cluster and Ghabawi WWTP will be dried to TS=85%, while sludge from Samra and Ghabawi Cluster will be dried to 50-60%.

*** All sludge quantities shown in the tables are at dryness = 85%.**



SLUDGE LAB-ANALYSIS

ABSTRACT

THIS REPORT INCLUDES INFORMATION ABOUT THE CHEMICAL, PHYSICAL AND MICROBIAL ANALYSIS OF SLUDGE PRODUCED IN SELECTED WASTEWATER TREATMENT PLANTS AT LEAST FOR THE LAST 3 CONSECUTIVE YEARS, IN ADDITION TO THE LAB RESULTS OF THE MINISTRY OF ENVIRONMENT'S MONITORING PROGRAM BETWEEN 2008 - 2015.

سلطة المياه WATER AUTHORITY

Ministry of Water & Irrigation وزارة المياه والري

التعاون الألماني DEUTSCHE ZUSAMMENARBEIT

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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List of Abbreviation

EC	Electrical Conductivity
EU	European Union
GHG	Greenhouse Gas Emission
GIZ	The Deutsche Gesellschaft Fur Zusammenarbeit GmbH
JS	Jordanian Standard
JSMO	Jordan Standards and Metrology Organization
MoA	Ministry of Agriculture
MPN	Most Probable Number
PFU	plaque-forming unit
RSS	Royal Scientific Society
SSM	Sustainable Sludge Management project
TVS	Total Volatile Solid
TFS	Total Fixed Solid
USA	United State of America
USEPA	United States Environmental Protection Agency
WAJ	Water Authority of Jordan
WWTP	Wastewater Treatment Plant

Disclaimer

The quality analysis samples that were presented in this report are for sludge quality for sludge samples that were collected by the GIZ-SSM project from the last sludge treatment stage in three wastewater treatment plants: As Samra, Mutah Mazar, and Wadi Mosa. The analysis program started in Dec.2021, samples were collected on bi-monthly basis and will continue until December 2024. Samples were analyzed by the RSS Laboratories.

This report is a working document and will continue to evolve. Observations will be further analyzed as the sludge quality profile develops.

1. Background

In recent years, sludge management practices in Jordan have been a source of concern for many sectors. To begin with, the Water Sector in Jordan has been widely affected by the operational needs and costs for handling and disposing of generated sludge from wastewater treatment plants, given the restrictions on further reuse alternatives. Mainly the costs required for transferring and disposing of sludge is highly affecting the Water Companies' budgets and add operational constraints on the already strained systems.

There are 31 Wastewater Treatment Plants (WWTPs) in Jordan. The largest being As-Samra, is treating around 60% of the total wastewater generated in the country. Out of the total facilities, only three WWTP utilize sludge as an energy source through sludge digestion and biogas production processes, namely As-Samra, Al Shallaleh and Aqaba WWTPs. The remaining 28 WWTPs do not implement proper sludge management plans. Given that there are no allowed reuse options for treated sludge, current disposal practices of sludge depend on the final level of treatment in WWTPs, whether in drying beds, or thickened sludge. As such, WWTPs, are forced to either stockpile dried sludge on site or dispose of dried sludge in landfills or transfer thickened/liquid sludge to the Ekaider WWTP in the North of Jordan. Such practices are creating major health and environmental risk that contributes to Greenhouse Gas (GHG) emissions.

Therefore, it is necessary to shift the views of sludge from being a mere waste component to becoming a valuable resource. Landfill disposal methods of sludge generated from WWTPs are becoming less appealing and unsustainable, several innovative and cost-effective methods for handling and reusing sludge could be implemented instead to utilize the nutrients and recyclable materials of sludge which would rather have been discarded. While the agricultural sector is rather reluctant and opposes the use of sludge products (e.g., compost additives, fertilizer and/or soil conditioner), industry is considering usage as energy carrier, raw material or additive for industrial processes.

The "Sustainable Sludge Management Project" (SSM) in Jordan, implemented by the Deutsche Gesellschaft für Zusammenarbeit GmbH (GIZ), with the support of the German Government, is supporting the Water Authority of Jordan (WAJ) in improving the ecological and economic sustainability of sewage sludge management in Jordan, through developing quality profile for sludge produced in a selected number of WWTPs. Aiming at having a deeper understanding of the seasonal impact on sludge quality, the key parameters affecting the utilization of sludge, esp. for industrial uses, as previous studies and current Jordanian standards focus only on either the operational parameters or sludge quality parameters concerning the land application.

2. Overview of Sludge Quality Parameters

Most of Jordan's WWTPs are secondary treatment plants that achieve nutrient and pathogen reduction through activated sewage sludge processes and generate solid residuals of Class B microbial quality[1].

Although the United States and the European Union have different environmental policies concerning sludge management and reuse options, they both have quite similar sewage sludge regulations. The EU 1986 Directive (86/278/EEC) on the Use of Sewage Sludge in Agriculture (which has received significant improvement over the last twenty years) is the EU's primary policy on sludge management. Both the 86/278/EEC and the USA federal regulations address pathogen reduction, the potential for accumulation of persistent pollutants in soils (heavy metals

[1] EPA (1994). A Plain English Guide to the EPA Part 503 Biosolids Rule, United States Environmental Protection Agency, Office of Wastewater Management (4204), EPA/832/R-93-003, Washington, D.C.

and persistent chemicals), and application of appropriate amounts of nutrients. One notable difference is that the EU directive generally limits rates of applications of treated sludge to lower amounts than are allowed in the USA.

In Jordan, standards for reuse of biosolids are established by the Jordan Standards and Metrology Organization (JSMO). The JS: 1145:2016 for recycling of biosolids in Jordan was adopted from the 1993 version of the CFR 503 standards developed by the United States Environmental Protection Agency (USEPA, 1993).

The Jordanian Standard (JS) for the reuse and disposal of treated sludge No. (1145:2016) established numeric limits, management practices, and operational standards to protect public health and the environment. Concentrations of 10 heavy metals (As, Cr, Cd, Cu, Pb, Hg, Mo, Ni, Se and Zn) are typically monitored in sewage sludge according to the JS (1145:2016), which classifies treated sludge according to some microbiological and physical aspects into three types (as shown in Table (1)); Type I and Type II can be used as soil amendment and Type III is to be disposed of in sanitary landfills.

Hence, the JS: 1145:2016 standard is more rigid today than the 1999 modified CFR 503 standard[2] since the later has 12 alternative treatment processes that can be utilized in the treatment process to generate Class A designated biosolids. The goal of these treatment processes is to reduce pathogen densities below-specified detection limits for three types of organisms: Salmonella sp. <3 (MPN per 4 grams total solids), enteric viruses < 1 (PFU {plaque-forming unit} per 4 grams total solids), and helminths < 1 (viable organism per 4 grams total solids).

Table 1: Sludge Quality Parameters - JS:1145:2016

Parameter	**Unit**	**Concentration/ Sludge types**		
		Type I	**Type II**	**Type III**
Arsenic (As)	mg/kg Dry Weight	41	75	75
Cadmium (Cd)	mg/kg Dry Weight	40	40	85
Chromium (Cr)	mg/kg Dry Weight	900	900	3000
Copper (Cu)	mg/kg Dry Weight	1500	3000	4300
Mercury (Hg)	mg/kg Dry Weight	17	57	57
Molybdenum (Mo)	mg/kg Dry Weight	75	75	75
Nickel (Ni)	mg/kg Dry Weight	300	400	420
Selenium (Se)	mg/kg Dry Weight	100	100	100
Lead (Pb)	mg/kg Dry Weight	300	840	840
Zinc (Zn)	mg/kg Dry Weight	2800	4000	7500
Moisture Content	%	10	40	-
TFCC	MPN/g - CFU/g	1000	2,000,000	-
Salmonella spp.	MPN/g - CFU/g	3	-	-
IPN* eggs	Egg/4g	1	-	-
Viruses	Unit/4g	1	-	-

[2] USEPA .U.S. Environmental Protection Agency. (1999) Federal Register: February 19, 1993. 40 CFR Part 503; as amended at 64 FR 42571. USEPA. U.S. Environmental Protection Agency (1999). Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge. EPA/625®-92/013. Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.

On the other hand, many industries have shown interest and are considering using sludge products (dried sludge, palleted sludge, sludge-based biochar) as an energy carrier, raw material, or additive for industrial processes. Therefore, it is imperative to assess the quality of sludge against certain parameters that affect the processes and products of these industries.

Several cement factories are considering using sludge as an energy carrier to replace the traditional fuel (petcoke & coal) and have provided the SSM project with the Minimum & Maximum requirements of alternative fuel as shown in table 2.

Table 2: Alternative Fuel Requirements for Cement Factories

Parameter	Limits/ Unit
Net Caloric Value (NCV)	3000 – 7500 Kcal/kg
Gross Heat of Combustion	Declare
Total Moisture	3-10 %
Ash Content (550°C)	Maximum 14%
Sulphur Content	Maximum 5.00 %
Volatile Matter	8%- 26 %
Hard Grove Value (HGI) Index Point	Above 50
Size	0-50 mm
Alkalinity as $CaCO_3$	Declare

In addition to these parameters, the Project assessed the quality of sludge products against the parameters listed in Ministry of Agriculture instructions for the Registration, Production, Import, Analysis and Sale of Agricultural Fertilizers and Plant Growth Regulators and the Jordanian standards for Fertilizers and Soil Conditioners (MoA Inst. 6Z0 - 2021, and JS 962/2011).

Table 3: Fertilizers and Soil Conditioners Quality Parameters.

Parameter	Limits for each type of fertilizers/ Unit						
	Organic Soil Conditioner	**Phosphate fertilizers**	**Potassic fertilizers**	**Chemical Fertilizer**	**Organic fertilizer**	**Peat moss**	**The Pot**
Fe_2O_3, SO_3, SiO_2, Al_2O_3, MnO, SrO, TiO_2, Na_2O, CuO, BaO, ZnO,				Declare			
Cao				Not less than 10 %			
Mgo							
SO_4							
Total Fixed Solids – TFS					50% * *	Less than 10%	60% * *
Total Volatile Solids (TVS)				Declare			
Total Nitrogen (TN)	1.5 %*						
Water Soluble Chloride Cl %				Declare			
P_2O_5		18% as mono superphosphate*					
		45% as triple superphosphate*					
		52 % as Phosphoric acid*					
Organic Carbon					30 – 65%	Not less than 85%	Not less than 50%
K_2O			50% as K_2SO_4 *				
			60 % as KCl *				
Bulk density						Less than 0.3 g/cm^3	Less than 0.7 g/cm^3
The elemental analysis (CHNS)				Declare			
Conductivity					Less than 10 dS/m	Less than 2 dS/m	
Cobalt (Co)				Declare			
Boron (B)				Declare			
° Not less than. * * Not more than							

Many of the above-mentioned fertilizers quality parameters were considered for sludge quality analysis, yet sludge can't be directly assessed against these standards. The main objective here is to get a comprehensive analysis of all parameters, to compare the impacts of sludge application to lands.

3. Sludge Analysis

3.1 Sampling

Since July 2020, a quality profile was prepared through collecting Twenty-four sludge samples from three wastewater treatment plants (WWTPs):

- Mutah–Mazar WWTP (8 samples) as non-digested Sludge.
- As Samra WWTP (8 samples) as a digested sludge.
- Wadi Mosa WWTP (8 samples) as non-digested Sludge.

The samples were collected regularly (almost every two months) and analyzed in the laboratories of the Royal Scientific Society (RSS). The sludge samples were collected from the drying beds according to the U.S. EPA guidelines (EPA, 1989)[3]. The samples were analyzed using the international standard procedures as follows:

- The "Standard Methods for the Examination of Water & Wastewater", online 2011 for chemical and physical parameters.
- The Most Probable Number (MPN) method for fecal coliforms using a documented In-House Method SOP71/02/03/04/43 based on EPA 1680: 2014.
- For Salmonella, "Salmonella in Sewage Sludge (Bio-solids) using documented In-House Method SOP71/02/03/04/44 based on EPA 1682: 2014.
- Assays for helminths ova were conducted using a Documented In-House Method SOP 71/02/03/04/45 based on EPA/625/R-92/013: 2003.
- Conventional cell culture methods used to detect human enteric viruses.
- All Samples were tested for the above-mentioned quality parameters.

3.2 Quality Results and Observations

3.2.1 Mutah Mazar WWTP

3.2.1.1 Physical and Chemical Analysis

Table 4 below shows that the moisture content is high for the samples in wintertime, therefore the sludge during wintertime can't be classified as Type I sludge as per Jordanian standards (1145:2016). Table 4 also shows the values of Gross Heat of Combustion for Mutah Mazar WWTP sludge are high in 2022 and the beginning of 2023, which could be attributed to the high concentration of the TVS.

Moreover, Table 4 below shows the concentration of Total Nitrogen (TN) in the sludge samples which is higher than the minimum requirement of Organic Soil Conditioner (not less than 1.5%).

[3] EPA POTW Sludge Sampling and Analysis Guidance Document, U.S. EPA-Office of Water Office of Wastewater Enforcement & Compliance, August 1989, Document No.: PB93-227957.

Table 4: Physical and Chemical Analysis Results for Mutah Mazar WWTP.

Physical Analysis											
Date		Bulk Density (g/cm3)	Boron (mg/kg)	Gross Heat of combustion (cal/g)	Water Soluble chloride (mg/kg)	TVS %	Moisture Content %	Alkalinity (mg/kg)	TFS %	TN %	EC (us/cm)
	Fertilizer Standard Limit	----	Declare	More than 3000	-----	---	Type I less than 10% Type 2 less than 40 %	Declare	---	Not less than 1.5 %	Less than 10 dS/m
6-Dec-21		0.94	0	4316	0.382	64.5	53.10	11500	35.5	6.64	1730
24-May-22		0.47	50.39	4213	2620	74.5	8.26	2190	25.5	7.02	1280
9-Aug-22		0.48	33.21	4324	0	74.6	9.21	4640	25.4	7.54	1050
29-Sep-22		0.53	41.47	3490	0.33	51.4	6.34	0.5	48.6	5.36	2120
27-Nov-22		0.45	21.27	4054	0.119	58.8	15.40	2990	41.2	6.14	1280
9-Feb-23		0.81	33.82	3816	0	66	13.40	4190	34	6.2	573
15-Jun-23		0.67	15.8	3498	0	33.1	12.7	2570	66.9	5.67	620
17-Sep-23		0.58	14.52	3494	0	51.7	5.0	4730	48.3	4.74	1800

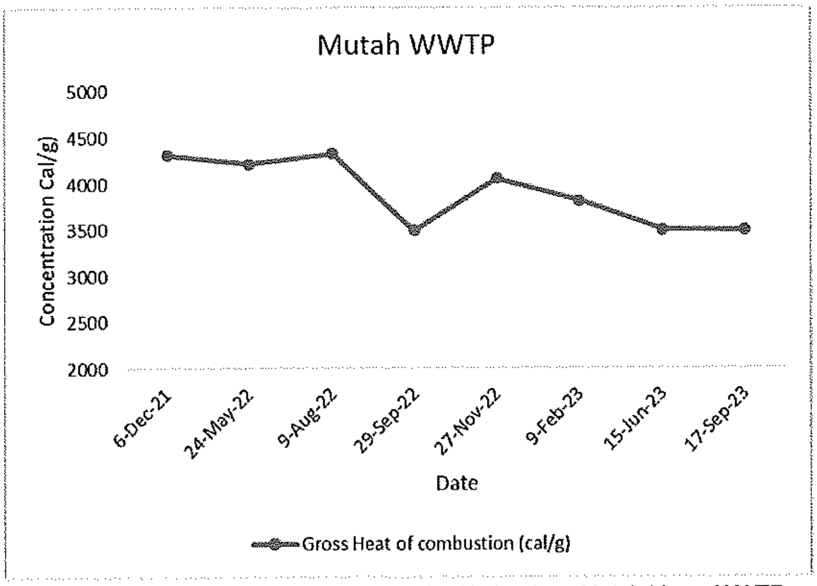

Figure 1: Gross Heating of Combustion for Sludge from Mutah Mazar WWTP

Figure 2 below represents the inverse relationship between the concentration of Total Volatile Solid (TVs) and Total Fixed Solid (TFS) of the Mutah Mazar sludge samples.

The Moisture content concentration in figure 2 is high in wintertime due to the sludge drying technology in the WWTP is an open drying bed.

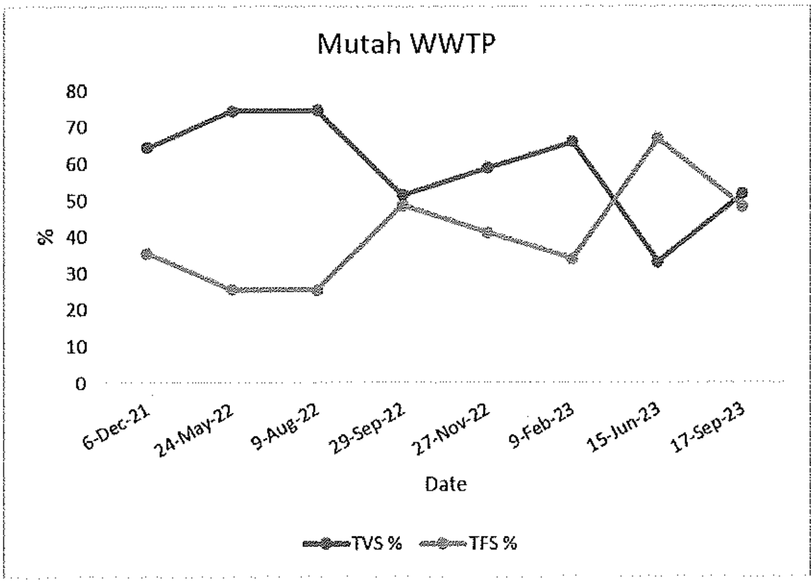

Figure 2: Total Volatile Solid (TVs), Total Fixed Solid (TFS) Concentration Values for Mutah Mazar WWTP.

3.2.1.2 Heavy Metals Content

Table 5 5: Heavy Metals Concentration for Sludge Samples from Mutah Mazar WWTP.

Date		Heavy Metals										
		Lead (mg/kg)	Nickel (mg/kg)	Cobalt (mg/kg)	Chromium (mg/kg)	Selenium (mg/kg)	Molybdenum (mg/kg)	Copper (mg/kg)	Arsenic (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)
	Standard Limits (Type I)	300	300	Not considered in JS 1145: 2016	900	100	75	1500	41	1000	40	17
6-Dec-21		16.06	23.6	--	27.26	--	--	--	10	698.76	5	1
24-May-22		48.43	26.91	5	29.84	10	6.85	166.3	10	924.6	5	1
9-Aug-22		17.56	27.49	5	23.63	44.86	22.27	88.25	10	781.82	5	1
29-Sep-22		13.66	50.75	5.36	138.22	32.71	20.86	90.64	10	738.18	5	1
27-Nov-22		14.76	28.35	5	38.49	42.82	20.17	88.11	10	768	5	1
9-Feb-23		16.65	28.92	5	44.61	34.42	17.49	91.53	10	806.1	5	1
15-Jun-23		18.34	222.37	31.9	259.42	24.49	12.88	92.86	10	584.35	5	1
17-Sep-23		18.95	90.85	5	57.88	36.5	23.42	114.9	10	964.1	5	1

Table 5 above represents the concentration values of heavy metals for sludge of Mutah Mazar WWTP. The values are below the limitation of the JS (1145:2016). The table also shows the concentration of Arsenic, Cadmium and Mercury values are fixed due to the minimum achievable reading of the analytical instrument (10, 5 and 1 mg/kg respectively).

The Cobalt concentration is represented by-default during the analysis of the heavy metal's concentration in the laboratory, as well as the Cobalt concentration, however they are not considered in JS 1145:2016.

For Copper, Selenium, and Zinc, Figure 3 below shows that there are minor variations between concentrations of these metals over the year with some abnormal results for copper on 24-May-22, and for Zinc on 24-May-22, 15-Jun-23, and 17-Sep-23.

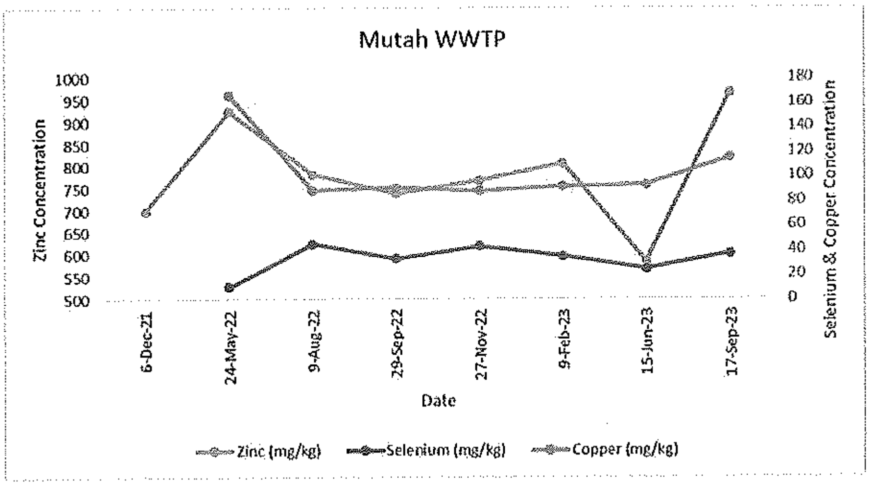

Figure 3: Zinc, Selenium, and Copper Concentration Values for the Sludge of Mutah Mazar WWTP.

It is observed that the variation in concentration values of Molybdenum, Nickel, Chromium, and lead is insignificant during the year, although there are abnormal results for the concentration of Chromium on 15 Jun 23 and Nickel on 15 Jun 23 while for lead on 24 May 23 as illustrated in Figure 4 below.

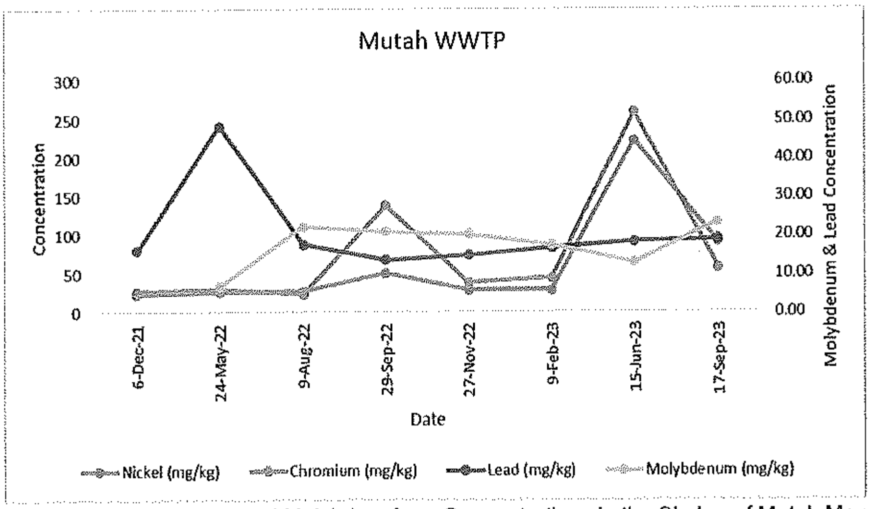

Figure 4: Lead, Nickel, Chromium, and Molybdenuform Concentrations in the Sludge of Mutah Mazar WWTP.

3.2.1.3 Oxides Analysis

Table 6 6: Oxides Analysis for Sludge Samples of Mutah Mazar WWTP.

Date	Oxides metals														
	K2O %	CaO %	Fe2O3 %	SO3 %	SiO2 %	MgO %	MnO %	Al2O3 %	SrO %	ZnO %	BaO %	CuO %	P2O5- %	TiO2 %	SO4 %
Fertilizer Standard Limit	50% as K_2SO_4 60 % as KCl	Not less than 10%	Declare			Not less than 10%	Declare						18% as mono superphosphate 45% as triple superphosphate 52 % as Phosphoric acid	Declare	Not less than 10%
6-Dec-21	0.297	6.1	1.29	0.28	5.8	1.31	0.011	1.76	0.025	0.091	0.013	0.013	5.9	0.32	--
24-May-22	0.360	5.7	1.24	0.452	4.9	1.4	0.012	1.47	0.024	0.041	0.023	0.012	5.4	0.277	0.14
9-Aug-22	0.538	9.6	1.08	1.45	3.5	0.98	0.01	1.25	0.02	0.11	0.02	0.02	3.31	0.24	0.20
29-Sep-22	0.753	5.62	1.29	0.91	4.81	0.75	0.01	1.36	0.02	0.09	0.01	0.01	3.17	0.2	0.54
27-Nov-22	0.733	6	1.21	0.79	4.39	1.15	0.01	1.28	0.03	0.11	0.02	0.01	5.19	0.18	0.59
9-Feb-23	0.521	6.6	1.62	0.8	6.2	1.17	0.01	1.8	0.03	0.1	0.02	0.01	4.1	0.32	0.45
15-Jun-23	0.660	--	--	--	--	--	--	--	--	--	--	--	--	--	0.24
17-Sep-23	0.469	10.2	2	1.3	8.3	1.21	0.017	2.7	0.042	0.142	0.03	0.016	5	0.41	0.43

There is a variance in the concentration values of k2O, MnO, SrO, MgO, ZnO, BaO, CuO, SO4 and TiO2 in the sludge samples of Mutah Mazar however, the results can be considered as fixed concentrations as the variation in concentrations is less than 1% for each Oxide metal as illustrated in Figure 5. According to table 3 of Fertilizers and Soil Conditioners Quality Parameters, sludge of Mutah Mazar WWTP contains a low concentration of CaO, SO4, and MgO.

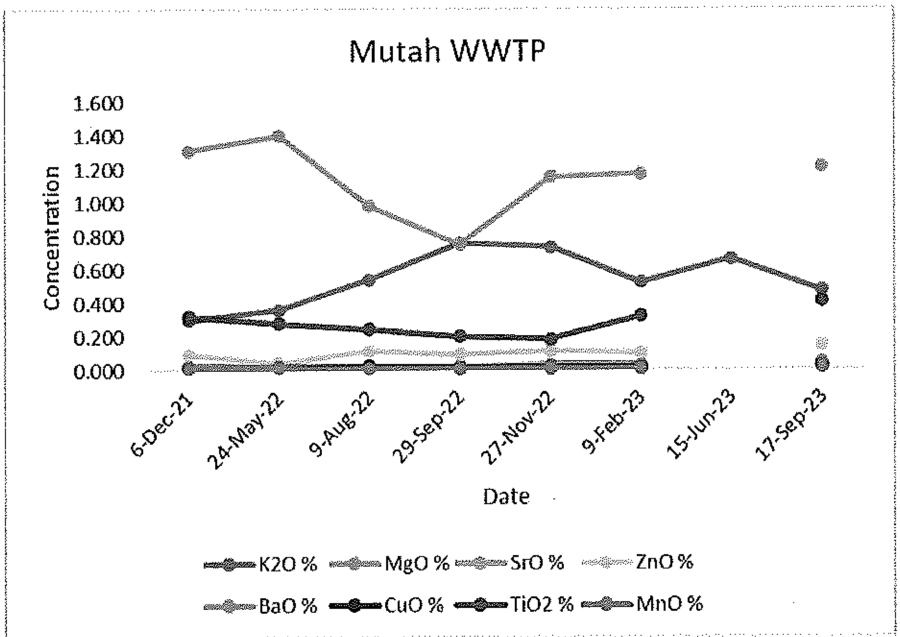

Figure 5: K2O, MnO, SrO, MgO, ZnO, BaO, CuO, and TiO2 Concentration Values in Mutah Mazar Sludge Samples.

Figure 6 below represents the concentration of Fe2o3, So3, SiO2, CaO, Al2O3, Al2O3, and P2O5. The concentration values are approximately constant with some minor variations for each parameter during the year, although there is an abnormal concentration value for CaO on Aug 9th, 2022.

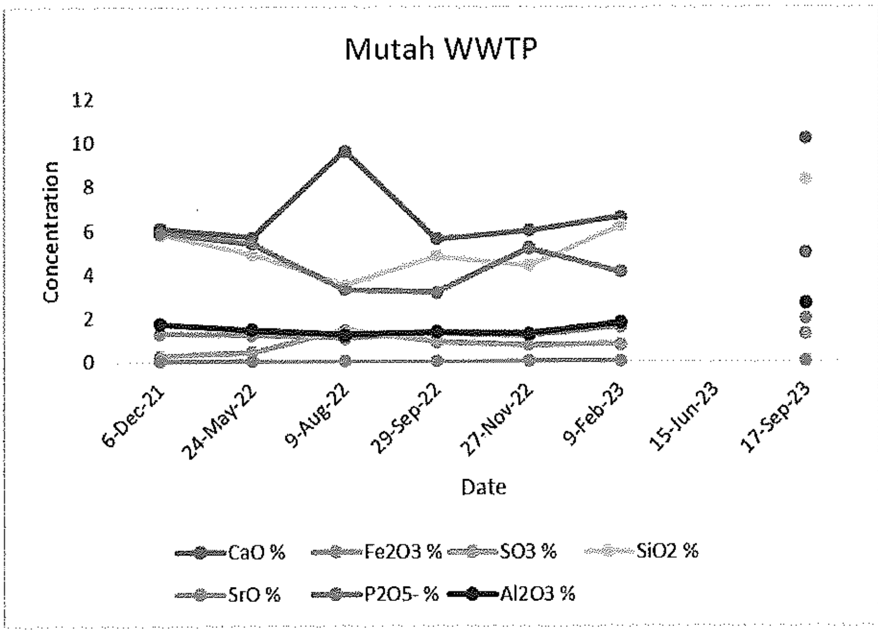

Figure 6: Fe2o3, So3, SiO2, CaO, Al2O3, Al2O3, and P2O5 Concentration Values for Mutah Mazar WWTP Sludge.

3.2.1.4 Microbial Analysis

Table 7 7: Microbial Content for the Sludge of Mutah Mazar WWTP.

Microbial Analysis							
Date			Ascaris Ova (Ova/4g DW)	Enteroviruses	Fecal Coliforms (MPN/g DW)	Salmonella (MPN/g DW)	Moisture Content (%)
	Standard Limits	Type I	1	1	1,000	3	10
		Type II	--	--	2,000,000	---	40
6-Dec-21			0	0	510,000	0.14	53.10
24-May-22			0	0	53.74	0.07	8.26
9-Aug-22			0	0	26.41	0.07	9.21
29-Sep-22			0	0	1,800	9.79	6.34
27-Nov-22			0	0	20.38	0.077	15.40
9-Feb-23			0	0	195	0.07	13.40
15-Jun-23			0	0	4,000	0.88	12.7
17-Sep-23			0	0	1,800	3.658	5

Table 7 above represents the values of Ascaris Ova and Enteroviruses which are below the standard's maximum allowable limits and approximately have a fixed value during the year. For salmonella, most of the samples are below the maximum allowable limit except for two abnormal results on 29-Sep-22, and 17-Sep-23. Furthermore, the Fecal Coliforms results are over the maximum allowable limits for type I sludge in the samples on 6-Dec-21, 29-Sep-22, and 15-Jun-23.due to the high moisture content for these samples. However, although the moisture content for the sludge sample on 17-Sep-23 is low, the Fecal Coliforms count is high for this sample that may be due to several reasons such as cross contamination during the sample collection and storage process.

3.2.2 Wadi Mosa WWTP

3.2.2.1 Physical and Chemical Analysis

Table 8 8: Physical and Chemical Analysis Results for Wadi Mosa WWTP.

Physical Analysis											
Date		Bulk Density (g/cm 3)	Boron (mg/kg)	Gross Heat of combustion (cal/g)	Water Soluble chloride (mg/kg)	TVS %	Moisture Content %	Alkalinity (mg/kg)	TFS %	TN %	EC (us/cm)
	Fertilizer Standard Limit		Declare	More than 3000			Type I less than 10% Type II less than 40 %	Declare		Not less than 1.5 %	Less than 10 dS/m
6-Dec-21		0.97	0	2936	0.23	67.7	81.60	13700	32.7	5.61	850
29-Sep-22		0.54	47.52	3340	0.34	66.1	77.60	0.6	33.9	6.2	900
2-Jun-22		0.32	19.39	4357	0	77.1	16.80	4170	22.9	6.37	1330
11-Aug-22		0.39	19.14	3917	1970	74.7	6.82	2730	25.2	6.96	1390
27-Nov-22		0.5	32.71	3577	0.185	58	76.80	6090	42	7.98	541
9-Feb-23		0.86	44.61	3544	0	52.3	59.00	3630	47.7	5.3	690
15-Jun-23		0.66	30.5	2918	0	46.1	22.20	5720	53.9	5.72	1480
17-Sep-23		0.43	18.14	3090	0	47.2	8.79	1480	52.8	4.17	1210

Table 8 above shows that Moisture Content values are high for most of the samples taken during the wintertime therefore, the sludge can't be classified as Type I sludge as per JS (1145:2016). For Gross Heat of Combustion, the table shows that the calorific content in the sludge of Wadi Mosa WWTP is higher than 3000 cal/g for most of the samples. Furthermore, the table shows that the concentration of Total Nitrogen (TN) in the sludge samples is higher than the minimum requirement of Organic Soil Conditioner (higher than 1.5%).

Figure 7 below represents the quality of Wadi Mosa sludge for Gross Heat of Combustion, where the results are convergent.

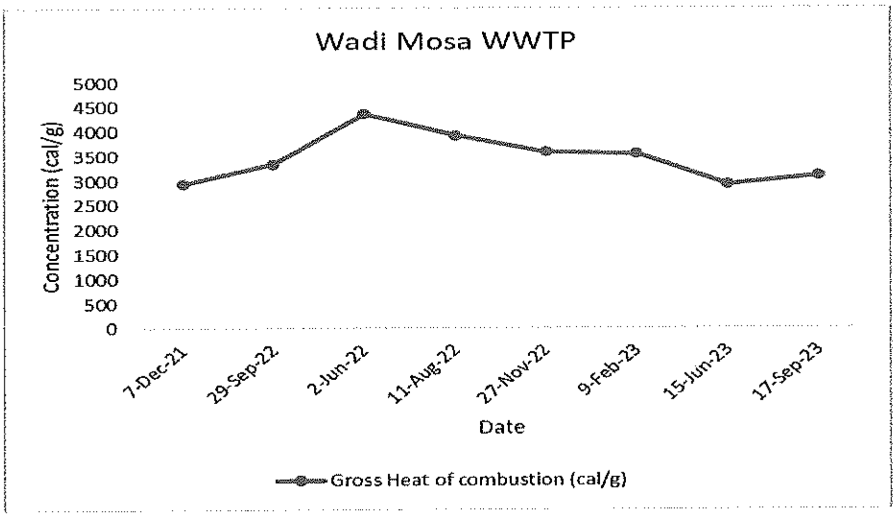

Figure 7: Gross Heating of Combustion Values for Sludge Samples of Wadi Mosa WWTP.

Figure 8 below represents the inverse relationship between the concentration of Total Volatile Solid (TVs) and Total Fixed Solid (TFS) for Wadi Mosa sludge samples.

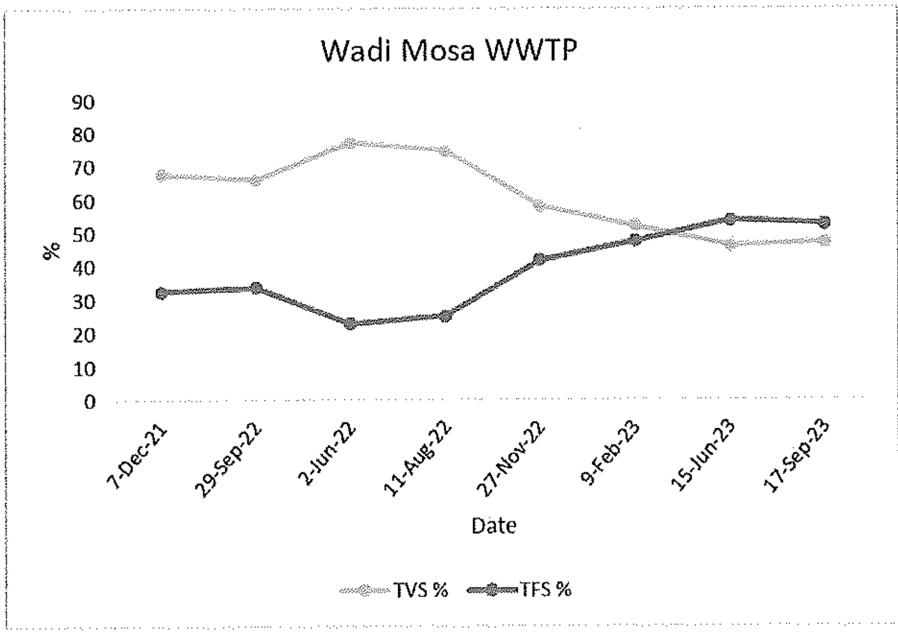

Figure 8: Total Volatile Solid (TVs) and Total Fixed Solid (TFS) Concentration for Wadi Mosa WWTP.

3.2.2.2 Heavy Metals Content

Table 9 9: Heavy Metals Concentration in Sludge for Wadi Mosa WWTP.

Date		Heavy Metals										
		Lead (mg/kg)	Nickel (mg/kg)	Cobalt (mg/kg)	Chromium (mg/kg)	Selenium (mg/kg)	Molybdenum (mg/kg)	Copper (mg/kg)	Arsenic (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)
	Standard Limits	**300**	**300**	**Not considered in JS 1145: 2016**	**900**	**100**	**75**	**1500**	**41**	**1000**	**40**	**17**
6-Dec-21		19.61	22.55	--	--	0.352	--	--	10	899.69	5	1
29-Sep-22		13.7	41.74	5	185.94	15.67	23.92	99.6	10	699.28	5	1
2-Jun-22		12.79	23.71	5	46.61	19.15	23.3	86.64	10	670	5	1
11-Aug-22		11.33	12.15	5	14.99	18.67	23.52	49.53	10	624.7	5	1
27-Nov-22		14.16	17.94	5	43.89	15.52	27.71	92.71	10	633.3	5	1
9-Feb-23		15.01	26.82	5	49.08	20.15	37.53	97.57	10	768.5	5	1
15-Jun-23		15.2	22.18	5	38.96	20.6	29.53	97.87	10	653.51	5	1
17-Sep-23		16.58	27.08	5	37.86	15.46	15.48	91.1	10	702.5	5	1

Table 9 above represents the heavy metals concentration values for Wadi Mosa sludge. The results show that heavy metals concentration values are below the JS 1145:2016 limits. Moreover, the Arsenic, Cadmium, Cobalt and Mercury concentration are fixed due to the minimum achievable reading of the analytical instrument (10, 5, 5 and 1 mg/kg respectively).

Copper, Selenium, and Zinc concentration values represented in Figure 9 below show a minor variation over the year with an abnormal result for Copper concentration on 11 Aug 22.

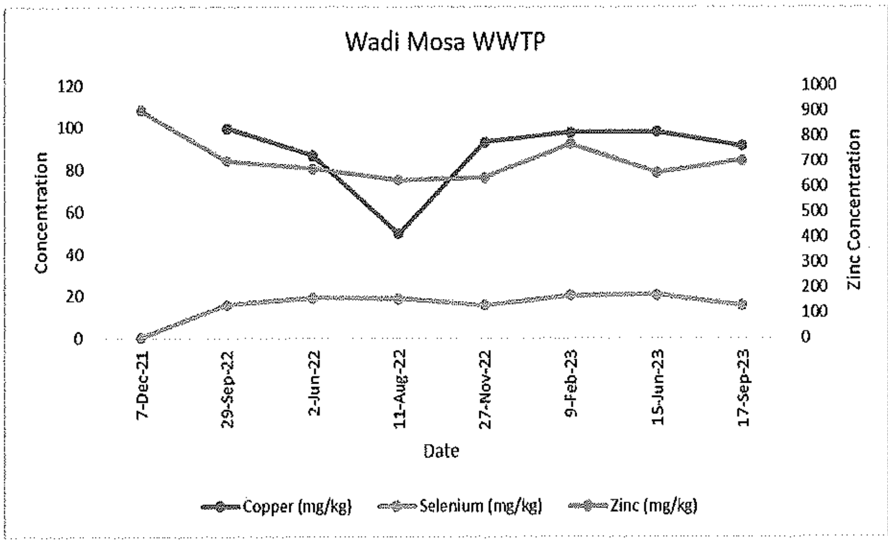

Figure 9: Zinc, Selenium and Copper Concentration Values for the Sludge of Wadi Mosa WWTP.

The Molybdenum, Nickel, Chromium and lead concentration values seem to have slight variation during the year with an abnormal result for Chromium concentration value on 29 Sep 22.

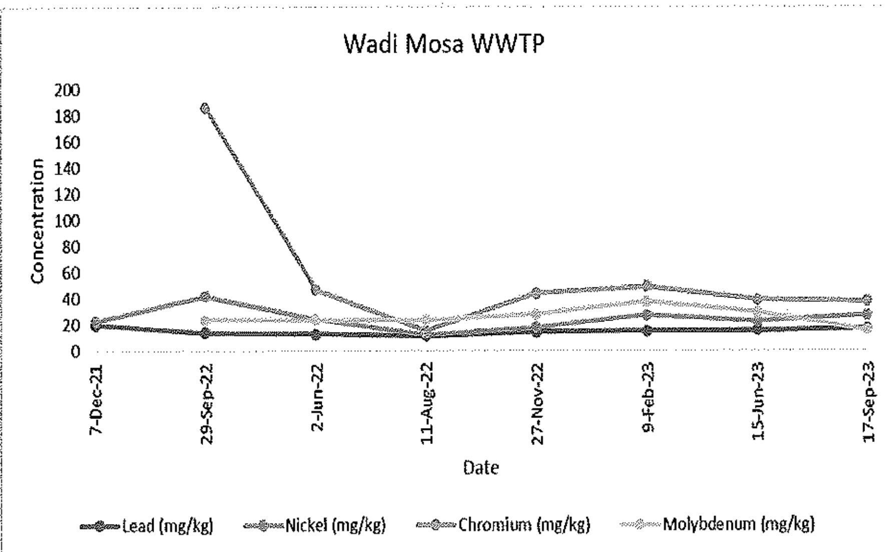

Figure 10: Lead, Nickel, Chromium, and Molybdenum Concentration Values for Sludge of Wadi Mosa WWTP.

3.2.2.3 Oxides Analysis

Table 10 *10*: Oxides analysis for Sludge of Wadi Mosa WWTP

Date	K2O %	CaO %	Fe2O3 %	SO3 %	SiO2 %	MgO %	MnO %	Al2O3 %	SrO %	ZnO %	BaO %	CuO %	P2O5- %	TiO2 %	SO4 %
	Oxides metals														
Fertilizer Standard Limit	50% as K_2SO_4 60 % as KCl	Not less than 10%	Declare			Not less than 10%	Declare						18% as mono superphosphate 45% as triple superphosphate 52 % as Phosphoric acid	Declare	Not less than 10%
6-Dec-21	0.124	8.9	1.33	1.55	5.9	1.64	0.024	1.89	0.028	0.028	0.041	0.018	4.7	0.4	
29-Sep-22	0.305	3.39	0.72	0.62	2.5	0.8	0.01	0.67	0.01	0.07	0.01	0.01	2.48	0.19	1.12
2-Jun-22	0.486	4.4	0.79	0.5	3.2	1.3	0.01	0.87	0.01	0.12	0.02	0.01	4.2	0.18	0.39
11-Aug-22	0.409	5.53	0.98	0.64	3.96	1.68	0.01	1.14	0.02	0.1	0.02	0.01	5.24	0.25	1.12
27-Nov-22	0.654	2.22	0.4	0.4	1.38	0.59	0.01	0.41	0.01	0.05	0.01	0.01	1.61	0.09	1.12
9-Feb-23	0.434	6.8	1.26	1	5.4	1.33	0.01	1.55	0.02	0.1	0.02	0.01	4.8	0.3	1.02
15-Jun-23	0.305														0.62
17-Sep-23	0.477	7.4	1.31	1.02	6.2	1.87	0.009	1.79	0.019	0.079	0.012	0.01	4.4	0.34	0.81

There is a variation in the concentration values for each of K2O, MnO, SrO, ZnO, BaO, CuO, and TiO2 in the sludge samples of Wadi Mosa during the year, however, the results can be considered as fixed concentrations as the variation in concentrations is less than 1% for each Oxide metal as illustrated in figure 11 below.

According to table 3 of Fertilizers and Soil Conditioners Quality Parameters, Wadi Mosa WWTP sludge samples contain low concentration of SO4, CaO, and MgO compared to the required concentration for Organic Fertilizer.

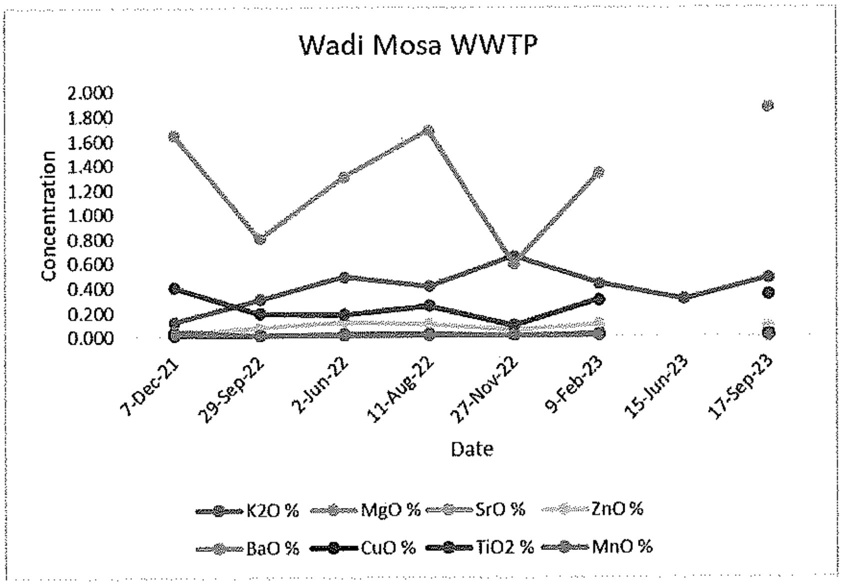

Figure 11: K2O, MnO, SrO, MgO, ZnO, BaO, CuO, and TiO2 Concentration Values for Wadi Mosa Sludge Samples.

Figure 12 represents that the concentration values of Fe2O3, SO3, SiO2, CaO, Al2O3, Al2O3, and P2O5 are approximately constant with some minor variation for each parameter.

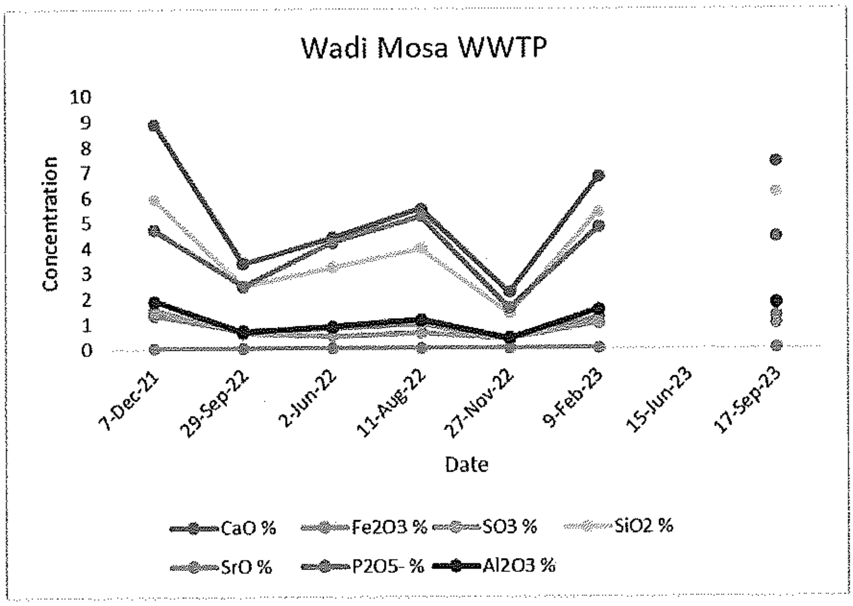

Figure 12: Fe2O3, SO3, SiO2, CaO, Al2O3, Al2O3, and P2O5 Concentration Values for Wadi Mosa WWTP Sludge.

3.2.2.4 *Microbial Analysis*

Table11: Microbial Content for the Sludge of Wadi Mosa WWTP.

Microbial Analysis							
Date			Ascaris Ova (Ova/4g DW)	Enteroviruses	Fecal Coliforms (MPN/g DW)	Salmonella (MPN/g DW)	Moisture Content (%)
	Standard Limits	Type I	1	1	1,000	3	10
		Type II	--	--	2,000,000	---	40
6-Dec-21			0	0	940,000	0.352	81.60
29-Sep-22			0	0	11,000,000	71.83	77.60
2-Jun-22			0	0	650,000	0.26	16.80
11-Aug-22			0	0	5,300	0.15	6.82
27-Nov-22			0	0	34,000	69.35	76.80
9-Feb-23			0	0	420,000	0.16	59.00
15-Jun-23			0	0	8,900	20.6	22.20
17-Sep-23			0	0	263,000	17.68	8.79

Table 11 above shows that the Ascaris Ova and Enteroviruses values are below the standard's maximum allowable limits and approximately have fixed value during the year, while all Fecal Coliforms results are above maximum allowable limits. For Salmonella, the samples on 29-Sep-22, 27-Nov 22, 15-Jun-23, and 17-Sep-23 are above the maximum allowable limits.

3.2.3 As Samra WWTP

3.2.3.1 Physical and Chemical Analysis

Table 12 11: Physical and Chemical Analysis Results for As Samra WWTP.

Physical Analysis											
Date		Bulk Density (g/cm3)	Boron (mg/kg)	Gross Heat of combustion (cal/g)	Water Soluble chloride (mg/kg)	TVS %	Moisture Content %	Alkalinity (mg/kg)	TFS %	TN %	EC (us/cm)
	Fertilizer Standard Limit		Declare	More than 3000			Type 1 less than 10% Type 2 less than 40 %	Declare		Not less than 1.5 %	Less than 10 dS/m
11-Nov-21		0.59	0	2896	0	62	14.90	719	38	4.63	1820
9-Aug-22		0.58	28.85	3263	0	59.3	27.10	6210	40.7	4.88	1300
29-Sep-22		0.56	37.15	2782	0.22	55.4	45.30	0.3	44.6	3.2	870
19-May-22		0.63	38.32	3181	2460	58.6	37.50	1490	41.4	3.93	1260
27-Nov-22		0.57	20.58	2443	0.16	47.6	54.00	1320	52.4	4.15	916
21-Feb-23		0.76	31.11	2451	0	44.4	32.80	1060	55.6	2.96	848
15-Jun-23		0.69	21.9	2603	0	49.6	16.4	1140	50.4	3.75	1300
17-Sep-23		0.7	23.02	2630	0	51.8	14.7	1250	48.2	3.82	1520

Table 12 above shows that the Moisture Content values are high for the samples during wintertime, therefore the sludge that has high Moisture Content can't be classified as Type I sludge as per JS (1145:2016). For Gross Heat of Combustion, the samples show that the calorific content for the sludge of As Samra is relatively stable and lower than the other 2 WWTPs as sludge in As Samra is digested sludge (produced after anaerobic digestion to generate Biogas). Furthermore, Table 9 above shows that the concentration of Total Nitrogen (TN) in the sludge samples is higher than the minimum requirement of Organic Soil Conditioner (higher than 1.5%).

Figure 13 below represents the gross heat of combustion values for As Samra WWTP sludge samples are low.

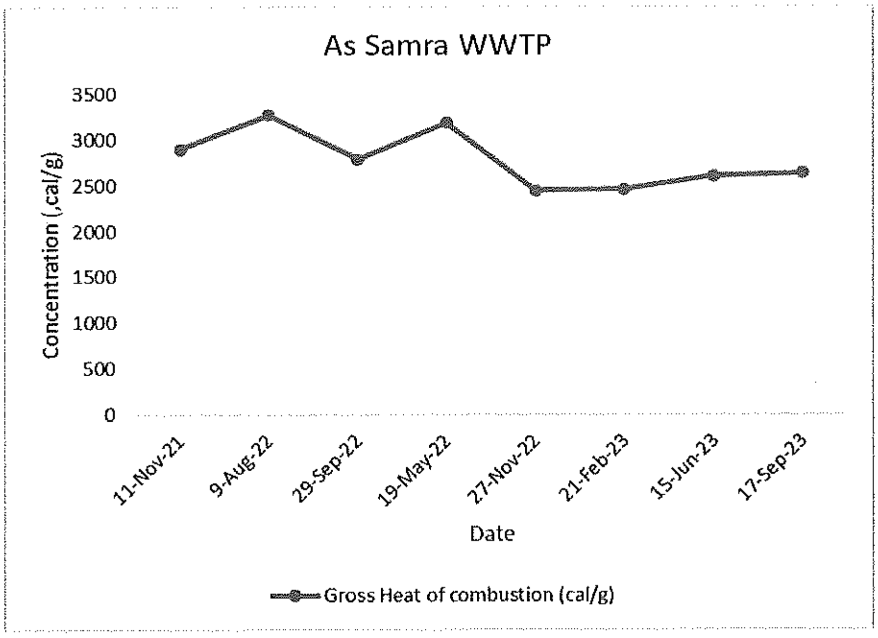

Figure 13: Gross Hearing of Combustion Values for Sludge Samples of As Samra WWTP Sludge Samples.

The TVS and TFS concentrations in the samples of As Samra WWTP are illustrated in figure 14 below.

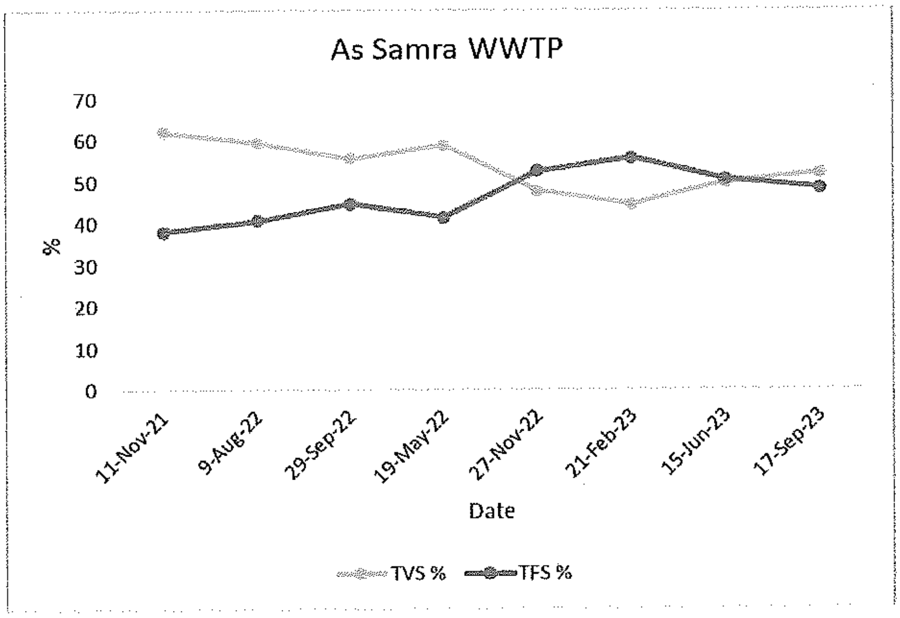

Figure 14: TVS & TFS Concentration Values for sludge of As Samra WWTP.

3.2.3.2 Heavy Metals Content

Table 13 12: Heavy metals analysis for sludge of As Samra WWTP

		Heavy Metals										
Date		Lead (mg/kg)	Nickel (mg/kg)	Cobalt (mg/kg)	Chromium (mg/kg)	Selenium (mg/kg)	Molybdenum (mg/kg)	Copper (mg/kg)	Arsenic (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)
	Standard Limits	300	300	Not considered in JS 1145: 2016	900	100	75	1500	41	1000	40	17
11-Nov-21		49.4	21.6	--	34.5	--	--	--	10	805.8	5	1
9-Aug-22		31.12	33.29	5	58.81	16.83	15.73	208.7	10	1252.06	5	1
29-Sep-22		17.5	21.02	5	47.46	10	11.24	144.74	10	726.47	5	1
19-May-22		55.82	29.99	5	52.88	10	7.93	182.4	10	1007.2	5	1
27-Nov-22		21.96	18.57	5	37.69	10	10.93	120.29	10	679.1	5	1
21-Feb-23		17.89	20.6	5	39.3	10	8.15	127.3	10	696.7	5	1
15-Jun-23		15.94	16.81	5	34.44	10	8.19	104.15	10	549.33	5	1
17-Sep-23		29.16	29.26	5	44.12	10	8.63	149.6	10	950.8	5	1

Table 13 above shows that heavy metals concentrations are below the maximum limits of JS (1145:2016). For Arsenic, Cadmium, Cobalt, Selenium and Mercury, the minimum achievable readings of the analytical instrument were 10, 5, 5, 10 and 1 mg/kg. The Selenium concentration in the sludge sample analyzed on 9-Aug-22 has an abnormal value.

For Copper and Zinc, the Figure below represents that the concentration of Copper is approximately Convergent, while there is some variation in Zinc concentrations.

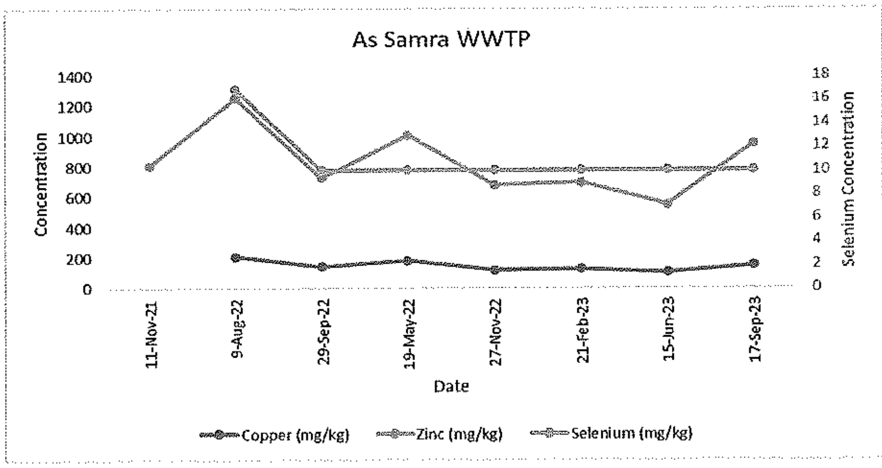

Figure 15: Zinc, Selenium and Copper Concentration Values for the Sludge of As Samra WWTP.

The Molybdenum and Nickel concentrations seem to be convergent during the years, while Lead and Chromium concentration values vary for the analyzed samples.

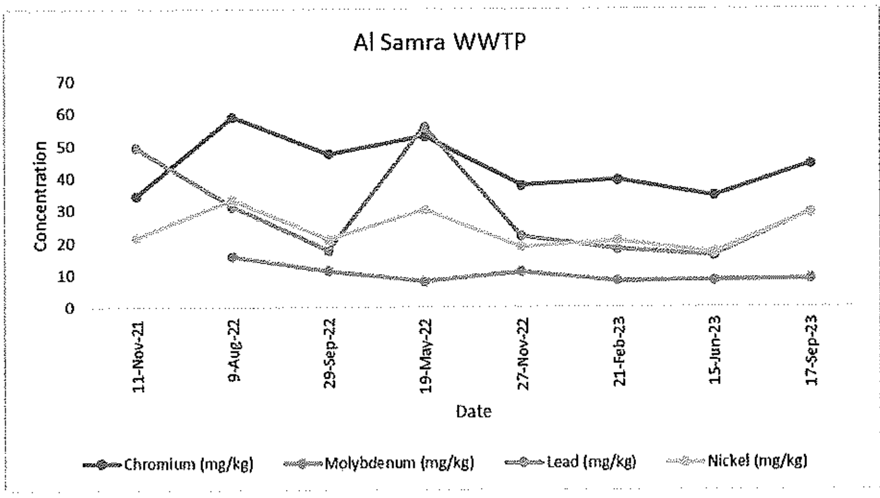

Figure 16: Lead, Nickel, Chromium, and Molybdenum Concentration Values for the sludge of As Samra WWTP.

3.2.3.3 Oxides Analysis

Table 14 13: Oxides Analysis for Sludge of As Samra WWTP

Date	Oxides metals: K2O %	CaO %	Fe2O3 %	SO3 %	SiO2 %	MgO %	MnO %	Al2O3 %	SrO %	ZnO %	BaO %	CuO %	P2O5- %	TiO2 %	SO4 %
Fertilizer Standard Limit	50% as K_2SO_4 60 % as KCl	Not less than 10%	Declare			Not less than 10%	Declare						18% as mono superphosphate 45% as triple superphosphate 52 % as Phosphoric acid	Declare	Not less than 10%
11-Nov-21	0.08	12.8	1.39	1.81	4.2	1	0.013	1.5	0.023	0.058	0.027	0.018	4.2	0.3	-
9-Aug-22	0.37	5.2	1.23	0.45	4.9	1.07	0.01	1.5	0.02	0.1	0.02	0.01	4.19	0.27	0.98
29-Sep-22	0.18	8.78	1.08	1.34	3.25	0.79	0.01	1	0.02	0.05	0.02	0.02	2.97	0.2	0.92
19-May-22	0.27	7	0.98	0.78	2.8	0.62	0.012	0.97	0.016	0.012	0	0.012	2.6	0.155	0.88
27-Nov-22	0.18	9.18	0.77	1.38	2.49	0.64	0.01	0.8	0.01	0.02	0.02	0.01	2.06	0.15	1.03
21-Feb-23	0.15	16.5	1.36	1.63	4	0.93	0.01	1.37	0.03	0.1	0.03	0.02	3.3	0.29	0.71
15-Jun-23	0.10	-	-	-	-	-	-	-	-	-	-	-	-	-	0.70
17-Sep-23	0.17	16	1.51	2.11	4.5	1.13	0.014	1.53	0.025	0.102	0.037	0.02	4.1	0.314	0.94

There is a minor variation of less than 1% for each in the concentrations of K2O, MnO, SrO, MgO, ZnO, BaO, CuO, and TiO2 in the sludge of As Samra, therefore, the concentrations can be considered fixed values as illustrated in Figure 17 below. According to table 3 of Fertilizers and Soil Conditioners Quality Parameters, As Samra sludge contains low oxide concentration values particularly for SO4, CaO, and MgO.

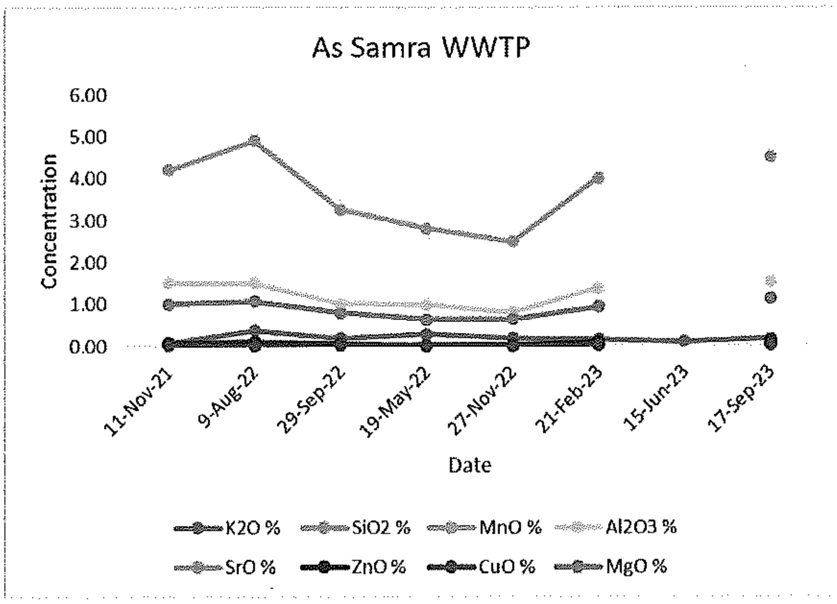

Figure 17: K2O, MnO, SrO, MgO, ZnO, BaO, CuO, and TiO2 concentration in As Samra Sludge Samples.

The Concentration of CaO varies in the sludge of As Samra as represented in Figure 18 below, while the same Figure represents that the concentrations of Fe2o3, So3, SiO2, Al2O3, Al2O3, and P2O5 are approximately convergent with some minor variations.

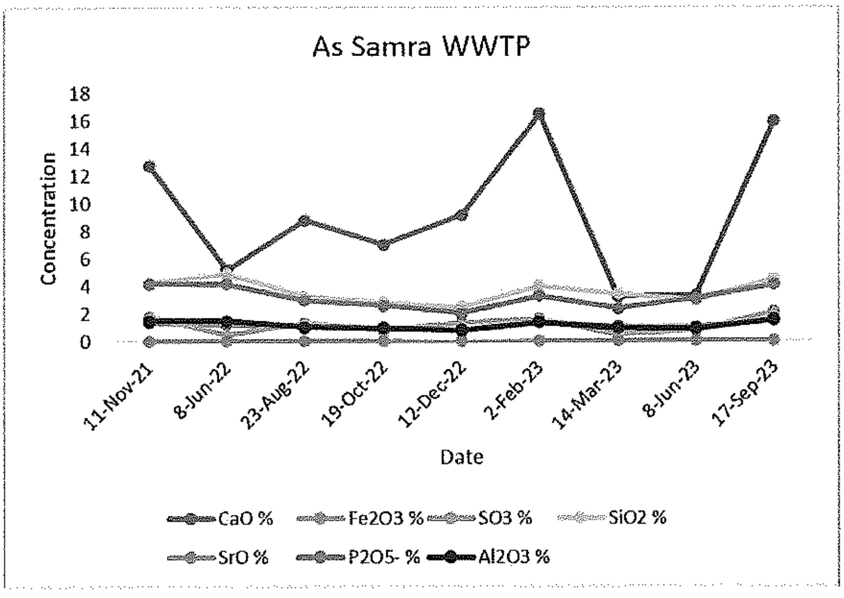

Figure 18: CaO, Fe2o3, So3, SiO2, Al2O3, SrO and P2O5 Concentration Values for As Samra Sludge.

3.2.3.4 Microbial Analysis

Table 15 14: Microbial Content for the Sludge of As Samra WWTP.

Microbial Analysis							
Date			**Ascaris Ova (Ova/4g DW)**	**Enteroviruses (Unit/4g)**	**Fecal Coliforms (MPN/g DW)**	**Salmonella (MPN/g DW)**	**Moisture Content**
	Standard Limits	**Type I**	**1**	**1**	**1000**	**3**	**10**
		Type II	**--**	**--**	**2000000**	**---**	**40**
11-Nov-21			0	0	8.23	0.076	14.90
9-Aug-22			0	0	18000	0.22	27.10
29-Sep-22			0	0	320000	0.13	45.30
19-May-22			0	0	1.49	0.01	37.50
27-Nov-22			0	0	170000	0.71	54.00
21-Feb-23			0	0	490	0.01	32.80
15-Jun-23			0	0	420	0.58	16.4
17-Sep-23			0	0	2820	18.93	14.7

Table 15 above represents that the Ascaris Ova and Enteroviruses are below the standard's maximum allowable limits and have convergent values during the year, while Fecal Coliforms results are above the maximum allowable limits for samples on 9-Aug-22, 29-Sep-22, 27-Nov-22, and 17-Sep-23. For Salmonella, the sample on 17-Sep-23 is above the maximum allowable limits and can be assumed to be an abnormal result.