

Seasonal Variability and Wastewater Treatment Efficiency in Federal Capital Territory, Abuja

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Abstract: The study examined efficiency and seasonal variations in municipal wastewater treatment in Federal Capital Territory, Abuja. Wastewater treatment data from year 2015 to 2018 were analysed and compared with National Environmental Standard and Regulations Enforcement Agency permissible limit. The data were analysed to determine if seasonal variations exist in the performance of the wastewater treatment plant. The study was undertaken in the wastewater treatment plant located at Wupa, Abuja. The result obtained show that in 2015 a high reduction in biochemical oxygen demand (BOD) (84.6%) and chemical oxygen demand (COD) (85.4%) with excellent pH value (7.3pH, 90.8%) was achieved. In 2016, there was a significantly high level of treatment in Faecal Coliform (99.1%), BOD (93.4%), total suspended solids (TSS) (91.7%), COD (87.6%), and Ammonia (71.5%). In 2017, the level of treatment for BOD, COD and TSS were 97.2%, 95.7% and 95.4% respectively. While in 2018, removal efficiency of BOD was 95.2%, COD 91.6% and TSS 90.6%. The result also revealed that the observed values of the biochemical parameters are considerably lower when compared with the National Environmental Standards, Regulations and Enforcement Agency (NESREA) standards (i.e., $p < 0.05$). The seasonal comparative result shows that the BOD total in dry season is significantly higher compared to the rainy season ($t^* = -3.553$, $p = 0.001 < 0.05$). The average COD in rainy season is slightly lower compared to that in dry season, and however, statistically insignificant ($t^* = -1.690$, $p = 0.098$). The TSS and pH values in rainy season are slightly and insignificantly lower compared with the values in the dry season. Continuous monitoring is recommended.

Keywords: Wastewater, Wastewater Treatment, Seasonal Variability, Treatment Efficiency

1. Introduction

Municipal wastewater treatment facility which ought to be part of the urban mechanism have been often times seen to be lacking in many cities in Nigeria. In cities where such facilities are found, maintaining standard treatment level becomes an issue of concern. While [1] noted an abysmal lack of wastewater treatment facilities in Nigeria, [2, 3] assessed different institution based treatment plants and discovered that discharged effluents are not sufficiently treated.

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Territory Abuja shows a significant reduction compared to results obtained for influent samples but was below NESREA standard [4]. Saminu et al [4] asserted that the downstream water of Wupa River is not fit for consumption and as such needs further purification. This calls for an analysis on the treated effluent being released into river Wupa. Such analysis will either indict or vindicate the treated effluent as the source of the downstream pollution of River Wupa. Naidoo [5] stated that water quality of rivers in South Africa has deteriorated to the extent that they have been deemed to be of poor quality for human consumption and of limited associated uses. The poor quality is largely due to the discharges of inadequately treated wastewater into rivers as

well as other indiscriminate activities. Naidoo [5] has pointed out the propensity of inadequately treated wastewater to pollute rivers.

Continues monitoring of wastewater treatment facilities is vital as such facilities are known to fail over time due to poor maintenance amongst others. Also, Velusamy et al, Joel et al and Skoczko et al [6–8] asserts that wastewater treatment efficiency could vary with seasons. As such, effect of seasonality should be considered in wastewater treatment.

Joel et al [7] evaluated seasonal variation on performance of conventional wastewater treatment systems from four different points during the dry and wet seasons of the year 2013 in Kenya. According to the result obtained, Analysis of Variance showed that there was significant difference in all the parameters quantified at all the points of treatment during the two seasons. The various stages of wastewater treatment plant under study were effective during the two seasons. However, wet season recorded lower figures for most of the parameters.

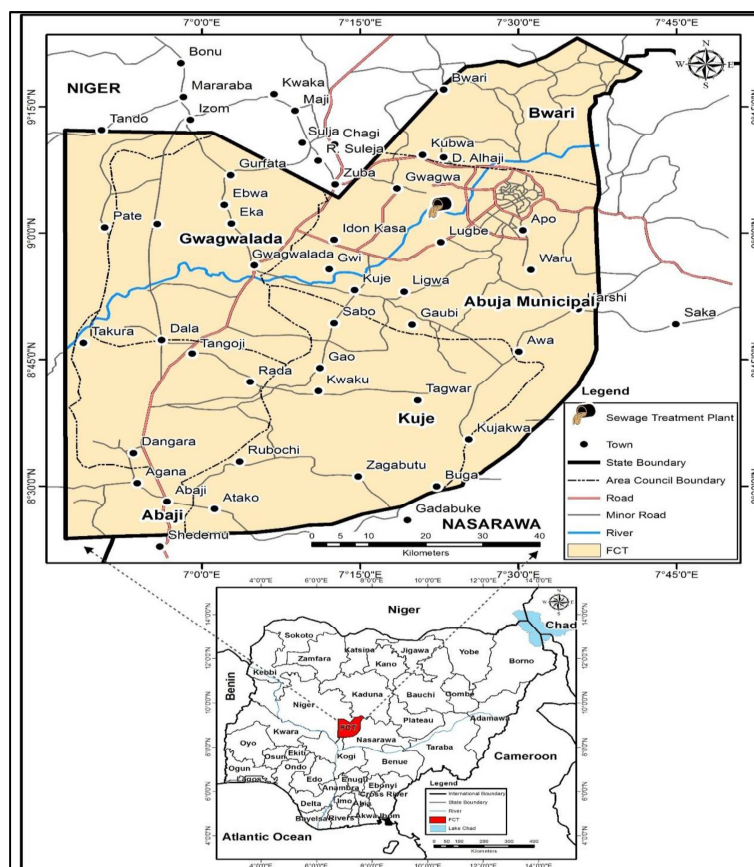
In like manner, Golovko et al [9] studied seasonal removal efficiency of 16 pharmaceuticals and personal care products in a wastewater treatment plant in Ceske Budejovice, Czech Republic, over a period of 1 year. There were significant seasonal trends in the observed removal efficiency with reduced efficiencies in colder months.

Velusamy et al [6] analysed samples of treated wastewater effluent from three different sites of Coimbatore during two

consecutive seasons. Seasonal variations indicated that the most of the nutrients and salts are abundant at pre-monsoon (pre-rainy season) and the physical characters like TSS (600 mg/L) are more at post-monsoon.

Skoczko et al [8] aimed their study at determining seasonal changes in industrial wastewater treatment effectiveness in 2014 and 2015. Studies were carried out in wastewater treatment plant in Bystre near Gizycko which receives a mixture of domestic and dairy wastewater. Seasonal changes were observed for biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total nitrogen removal effectiveness. The result showed that the effectiveness of treatment was higher for summer period than for autumn and winter. Summer and spring shared almost similar result.

According to Trias et al [10], seasonal variability including temperature and precipitation can have substantial impact on treatment efficacy and effluent water quality. Trias et al [10] examined seasonal impacts of temperature on swine wastewater (Agricultural wastewater) quality and treatment efficacy at a farm in East Leicester, Nova Scotia, Canada. During warm temperatures denitrification was noticeable in the anaerobic conditions, which would reduce the TSS removal rate from 76.6% in moderate temperatures to 42.1% in the warmest period recorded. Rainfall improved final effluent water quality, although this was shown to be through dilution rather than improvement of treatment efficacy.



Source: Audu (2016)

Figure 1. FCT, Abuja.

2. Materials and Method

2.1. Study Area

Abuja is located on Latitudes 8°21'N to 9°18'N and longitude 6°46'E to 7°37'E. Abuja has a total landmass of about 8000km². Abuja is bounded in the east by Nasarawa State, north by Kaduna State, west by Niger State and south by Kogi State. The city is divided into six area councils which are Abuja Municipal, Gwagwalada, Kuje, Abaji, Kwali and Bwari Area Councils. See Figure 1 for map of Abuja. Abuja has two seasons, the rainy and dry seasons which begins from April to October and from November to March respectively. The area records its highest temperature of about 34°C during the dry season, during the rainy season the maximum temperature drops to about 24°C [12]. The total annual rainfall is in the range of 1100mm to 1600mm [12].

2.2. Method

Data on treatment of municipal wastewater for the period 2015 to 2018 were collected from already documented records of Abuja Environmental Protection Board on municipal wastewater treatment. To evaluate the system performance with respect to the removal efficiency of biochemical parameters. Statistical calculation of the efficiency of Wupa wastewater treatment plant was done using the Vitez, et al formula [13]. According to [13] the pollutant removal efficiency of a plant is defined as the ratio between removed concentration of pollutants and their initial concentration as given by:

$$\text{Efficiency (\%)} = \frac{C_i - C_e}{C_i} \times 100$$

Where:

C_i is concentration of the influent (mg/l)

C_e is concentration of the effluent (mg/l)

Also obtained values were compared with World Health Organisation (WHO) and National Environmental Standard and Regulations Enforcement Agency (NESREA) standards respectively. T-test and Mann-Whitney test was used to check for seasonal variations in treatment.

3. Result

3.1. Performance Evaluation/Removal Efficiency of Biochemical Parameters

Results of removal efficiency of biochemical parameters and its estimated variance from WHO and NESREA Standards are as presented in tables 1 through 10. As shown in the result in table 1, estimates of efficiency of the biochemical parameters are high, indicating a high level of treatment of wastewater. The result for year 2015 show a high reduction in BOD (84.6%) and COD (85.4%) with excellent pH value (7.3pH, 90.8%). The amount of dissolved oxygen also improved, showing that the effluent discharge can support plant growth and aquatic life. Saliently, the researcher observed that there were minute treatment in Ammonia, and Phosphate for the year 2015. Result of the effluents is clearly below permissible discharge limits.

Table 1. Result of removal efficiency of biochemical parameters for year 2015.

Year	Parameters	Influent (year total)	Influent (Year av.)	Effluent (Year total)	Effluent (Year av.)	Discharge Limit	Efficiency $\left(\frac{\text{Inf.} - \text{Eff.}}{\text{Inf.}}\right) \%$
2015	BOD total (mg/L)	1569.43	130.7858333	241	20.08333333	30	84.6%
	COD (mg/L)	3343.8	278.65	489.6	40.8	100	85.4%
	TSS (mg/L)	2400.3	200.025	220.5	18.375	30	90.8%
	pH	88.07	7.339166667	87.76	7.313333333	6-9	0.4%
	DO (mg/l)	39.3	3.275	81.97	6.830833333	NS	108.6%
	Nitrate as N (NO ₃ -N) (mg/l)	24.72	2.06	66.91	5.575833333	20	-170.7%
	Phosphate as P (PO ₄ -P) (mg/l)	20.71	1.725833333	20.48	1.706666667	5	1.1%
	Ammonia as N (NH ₄ -N) (mg/l)	21.69	1.971818182	36.17	3.014166667	10	-66.8%
	Faecal Coliform (MPN/100ml)	>19200	>1600	486	40.5	200	97.5%

Source: Author's computation, 2019

The result in table 2 shows a high level of treatment in parameters like BOD, COD, TSS, Phosphate, Ammonia, and Faecal Coliform, while there are little or no treatment in Nitrate for the year 2016 in FCT, Abuja. Particularly, there are significantly high level of treatment in Faecal Coliform (99.1%), BOD (93.4%), TSS (91.7%), COD (87.6%), and

Ammonia (71.5%), while the level of treatment efficiency in Phosphate was moderate (about 51.6%) for the year 2016. This result shows a continued pattern in efficiency from 2015. The effluent series in comparison with the discharge limits are observably low.

Table 2. Result of removal efficiency of biochemical parameters for year 2016.

Parameters	Influent (year total)	Influent (Year av.)	Effluent (Year total)	Effluent (Year av.)	Discharge Limit	Efficiency $\left(\frac{\text{Inf.} - \text{Eff.}}{\text{Inf.}}\right) \%$
2016	BOD total (mg/L)	1380.8	115.0666667	91.4	7.616666667	93.4%
	COD (mg/L)	2928.2	244.0166667	362.4	30.2	87.6%

<i>Parameters</i>	<i>Influent (year total)</i>	<i>Influent (Year av.)</i>	<i>Effluent (Year total)</i>	<i>Effluent (Year av.)</i>	<i>Discharge Limit</i>	<i>Efficiency ($\frac{Inf. - Eff.}{Inf.}$) %</i>
TSS (mg/L)	1702.67	141.8891667	141.12	11.76	30	91.7%
pH	88.67	7.389166667	84.98	7.081666667	6-9	4.2%
D. O (mg/l)	52.7	4.391666667	83.3	6.941666667	NS	-58.1%
Nitrate as N (NO ₃ -N) (mg/l)	27.6	2.3	89.7	7.475	20	-225.0%
Phosphate as P (PO ₄ -P) (mg/l)	51.2	4.266666667	24.8	2.066666667	5	51.6%
Ammonia as N (NH ₄ -N) (mg/l)	59.9	4.991666667	17.1	1.425	10	71.5%
Faecal Coliform (MPN/100ml)	>19200	>1600	172.7	14.39166667	200	99.1%

Source: Author's computation, 2019

In the year 2017, as shown in table 3, the level of efficiency of the biochemical parameters, including BOD, COD, TSS, and Faecal Coliform still remained significantly high. The implication is that those parameters were well

treated. On the other hand, parameters such as Ammonia, and Phosphate did not receive enough treatment for the year 2017. Compared with the discharge limits, all the effluent series are substantially below the limits.

Table 3. Result of removal efficiency of biochemical parameters for year 2017.

<i>Parameters</i>	<i>Influent (year total)</i>	<i>Influent (Year av.)</i>	<i>Effluent (Year total)</i>	<i>Effluent (Year av.)</i>	<i>Discharge Limit</i>	<i>Efficiency ($\frac{Inf. - Eff.}{Inf.}$) %</i>
BOD total (mg/L)	1971.1	164.2583333	55.77	4.6475	30	97.2%
COD (mg/L)	5180	431.6666667	220.5	18.375	100	95.7%
TSS (mg/L)	3068.1	255.675	140.3	11.69166667	30	95.4%
pH	86.44	7.203333333	83.48	6.956666667	6-9	3.4%
2017 D. O (mg/l)	50.3	4.191666667	80.9	6.741666667	NS	-60.8%
Nitrate as N (NO ₃ -N) (mg/l)	34.8	2.9	90.1	7.508333333	20	-158.9%
Phosphate as P (PO ₄ -P) (mg/l)	41.4	3.45	27.47	2.289166667	5	33.6%
Ammonia as N (NH ₄ -N) (mg/l)	46.3	3.858333333	23.8	1.983333333	10	48.6%
Faecal Coliform (MPN/100ml)	>19200	>1600	169	14.08333333	200	99.1%

Source: Author's computation, 2019

For the year 2018, as presented in table 4, the level of treatments of the biochemical parameters were all positive, indicating an observable treatment level during the year. Particularly, the treatment level ranges from 95.2% in BOD and Faecal Coliform respectively to 2.8% in pH. However,

there was high efficiency in treatment levels of the biochemical parameters in the year. The effluent series for all the wastewater treatment parameters are below discharge limits.

Table 4. Result of removal efficiency of biochemical parameters for year 2018.

<i>Parameters</i>	<i>Influent (year total)</i>	<i>Influent (Year av.)</i>	<i>Effluent (Year total)</i>	<i>Effluent (Year av.)</i>	<i>Discharge Limit</i>	<i>Efficiency ($\frac{Inf. - Eff.}{Inf.}$) %</i>
BOD total (mg/L)	1387.5	115.625	66.09	5.5075	30	95.2%
COD (mg/L)	3233.2	269.4333333	271.66	22.63833333	100	91.6%
TSS (mg/L)	2061.5	171.7916667	193.84	16.15333333	30	90.6%
pH	86.64	7.22	84.24	7.02	6-9	2.8%
2018 Nitrate as N (NO ₃ -N) (mg/L)	69.2	5.766666667	48.76	4.063333333	20	29.5%
Phosphate as P (PO ₄ -P) (mg/L)	36.3	3.025	19.23	1.6025	5	47.0%
Ammonia as N (NH ₄ -N) (mg/L)	64.66	5.388333333	12.29	1.024166667	10	81.0%
Faecal Coliform (MPN/100ml)	>19200	>1600	926.2	77.18333333	200	95.2%

Source: Author's computation, 2019

The annual comparative result of the effluents shows that there is a significant variation in BOD total between 2015 and 2018 ($p=0.001<0.05$). Particularly, the mean estimate detrended from 20.08mg/l in 2015 to 4.65mg/l in 2017 and rose to 5.51mg/l in 2018. The COD series was slightly different across the years. Specifically, the average value dropped

from 40.80mg/l in 2015 to 18.38mg/l in 2017, and rose to 22.64mg/l in 2018. The insignificant difference in trends was also ascertained in distribution of DO and Phosphate for the period ($p>0.05$). Meanwhile, a significant variation exists in trend of series of TSS, Nitrate, Ammonia, and Faecal Coliform for the period ($p<0.05$).

Table 5. Result of variations in outcome of the biochemical (Effluent) parameters from 2015-2018.

Variables	Period				Statistics		
	2015	2016	2017	2018	F-stat. /KW-H stat.	Prob.	Inference
	mean±std.	mean±std.	mean±std.	mean±std.			
BOD total (mg/L)	20.08±14.90	7.62±5.11	4.65±3.01	5.51±3.31	17.658	0.001	Sig.
COD (mg/L)	40.80±24.88	30.20±16.70	18.38±10.25	22.64±11.45	6.905	0.075	Insig.
TSS (mg/L)	18.38±7.63	11.76±2.66	11.69±4.36	16.15±5.27	7.731	0.006	Sig.
pH	7.31±0.08	7.08±0.23	6.96±0.12	7.02±0.06	22.448	0.000	Sig.
DO (mg/l)	6.83±0.29	6.94±0.12	6.74±0.58	-	4.172	0.124	Insig.
Nitrate as N ($\text{NO}_3\text{-N}$) (mg/l)	5.58±2.01	7.48±1.95	7.51±2.22	4.06±4.66	3.840	0.016	Sig.
Phosphate as P ($\text{PO}_4\text{-P}$) (mg/l)	1.71±0.84	2.07±0.71	2.29±0.67	1.60±0.41	2.654	0.060	Insig.
Ammonia as N ($\text{NH}_4\text{-N}$) (mg/l)	3.01±1.98	1.43±1.09	1.98±0.92	1.02±0.05	11.105	0.011	Sig.
Faecal Coliform (MPN/100ml)	48.69±83.84	14.39±9.06	14.08±7.06	77.18±87.97	22.063	0.000	Sig.

Note: KW-H=Kruskal-Wallis H test; F-stat.=Fisher's statistics

Source: Author's computation using SPSS 25.0 and MS-Excel

Result of the effluents in comparison with the WHO/NESREA standards indicates a statistically significant variation for the period ($|t^*| > 2.20$, $p < 0.05$). However, the estimate revealed that the observed values of the biochemical

parameters are considerably lower when compared with the WHO/NESREA standards (i.e., $p < 0.05$) for all estimates. (See table 6)

Table 6. Result of variations in the biochemical (Effluent) parameters in comparison with the WHO/NESREA Standards from 2015-2018.

Variables	Standard of wastewater treatments	WHO/NESREA Standards	Difference	t-cal. (p-value)
BOD total (mg/L)	9.46	40	-30.54	-8.496 (0.003)
COD (mg/L)	28.00	80	-52.00	-10.576 (0.002)
TSS (mg/L)	14.50	NS		
pH	7.09	6.5-8.5	-0.41	-5.234 (0.014)
DO (mg/l)	6.84	-		
Nitrate as N ($\text{NO}_3\text{-N}$) (mg/l)	6.16	50	-43.84	-52.768 (0.000)
Phosphate as P ($\text{PO}_4\text{-P}$) (mg/l)	1.92	4	-2.08	-13.091 (0.001)
Ammonia as N ($\text{NH}_4\text{-N}$) (mg/l)	1.86	50	-48.14	-111.540 (0.000)
Faecal Coliform (MPN/100ml)	38.56	400	-361.44	-23.765 (0.000)

Source: Author's computation (2019)

The various analysis as carried out by the researchers shows a positive performance of wastewater treatment in the FCT. This result is corroborated by the works of [14-16].

The result of the study carried out by [14] indicated that the temperature, pH, conductivity, total dissolved solids and dissolved oxygen of the wastewater from exit points showed a slight conformity to the WHO and FEPA standards. In another investigation carried out by [15] revealed that the mean removal efficiency for Total Coliform Count (TCC), Total Bacteriological Count (TBC) and Faecal Count (FC) were 99.6%, 89.9% and 98.9% respectively; all within the permissible limit of World Health Organization and Federal Ministry of Environment. The COD, BOD of the discharged effluent met the required effluent standards. There was significant differences between the pH, TSS, DO, COD and BOD of the influent and effluent. The study by [16] also revealed significant difference in influent and effluent samples. The final effluent concentrations as observed by [16] were all within the WHO and NESREA permissible discharge limits. Audu et al [11] in a study revealed that there was no adverse impact of the effluent water on the receiving water body

(River Wupa) in terms of physiochemical parameters as the treated effluent from the facility conformed to the specified discharge limits for WHO and NESREA.

3.2. Seasonal Variations

The seasonal comparative result shows that the BOD total in dry season is significantly higher compared to the rainy season ($t^* = -3.553$, $p = 0.001 < 0.05$). The average COD in rainy season is slightly lower compared to that in dry season, and however, statistically insignificant ($t^* = -1.690$, $p = 0.098$). The TSS and pH values in rainy season are slightly and insignificantly lower compared with the values in the dry season, respectively (TSS: $t^* = -1.149$, $p = 0.257$; pH: $t^* = -1.633$, $p = 0.109$).

The DO in rainy season is significantly higher compared to the value in dry season ($t^* = 2.765$, $p = 0.009$); Nitrate and Phosphate values in rainy season is slightly and insignificantly higher compared to the values in dry season (N: $t^* = 0.387$, $p = 0.701 > 0.05$; P: $t^* = 1.214$, $p = 0.231 > 0.05$). However, the Ammonia values in dry season is significantly lower compared with the values in rainy season (Ammonia: $t^* = -2.031$, $p = 0.042 < 0.05$) (Table 7).

Table 7. Result of seasonal variations in the biochemical (Influent) parameters from 2015-2018.

Variables	Rainy season (April to October)		Dry season (Nov. to March)		t-cal. (p-value)
	Mean	Standard deviation	Mean	Standard deviation	
BOD total (mg/L)	110.69	39.98	160.47	57.20	-3.553 (0.001)
COD (mg/L)	277.47	140.61	345.80	134.55	-1.690 (0.098)
TSS (mg/L)	177.70	63.69	212.85	143.79	-1.149 (0.257)
pH	7.26	0.14	7.32	0.11	-1.633 (0.109)
DO (mg/l)	4.40	1.24	3.33	0.97	2.765 (0.009)
Nitrate as N (NO ₃ -N) (mg/l)	3.35	2.19	3.12	1.78	0.387 (0.701)
Phosphate as P (PO ₄ -P) (mg/l)	3.31	1.39	2.85	1.09	1.214 (0.231)
Ammonia as N (NH ₄ -N) (mg/l)	4.59	2.38	3.25	1.72	-2.031 (0.042)
Faecal Coliform (MPN/100ml)	-	-	-	-	-

Source: Author's computation (2019)

A critical assessment shows that BOD, COD, pH, DO, and Phosphate do better in rainy season than in dry season, while the TSS, Nitrate, Ammonia and Faecal Coliform do better in dry season than in the rainy season.

Joel et al [7] evaluated seasonal variation on performance of conventional wastewater treatment systems from four different points during the dry and wet seasons of the year 2013 in Kenya. According to the result obtained, Analysis of Variance showed that there was significant difference in all the parameters during the two seasons. However, wet season recorded lower figures for most of the parameters. As seen in [8] who evaluated seasonal changes in industrial wastewater treatment effectiveness. The result showed that the effectiveness of treatment was higher for summer period than for autumn and winter. Summer and spring shared almost similar result. Similarly, results from [17] indicated that higher diclofenac removal efficiency was observed in summer season in both WWTPs. Although a consistency in diclofenac removal was observed in WWTP1, significant fluctuation was observed at WWTP2 based on seasonal evaluation.

4. Conclusion

The purpose of wastewater treatment is to remove physical, chemical, and microbiological contaminants which are harmful and pathogenic to the environment and humans. Where wastewater treatment plants exist, it is important that there is constant evaluation of its efficiency. Evaluating treatment efficiency will help in ensuring that discharge regulations are met, and also help to determine factors inhibiting effective treatment. This study has revealed that standard of wastewater treatment was high over the period 2015 – 2018. Irrespective of seasonality effect the treated effluent quality was maintained and remained within stipulated standard. Continued monitoring is therefore recommended.

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