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DEWATERING THE SLUDGE GENERATED FROM WATER TREATMENT PLANTS WITH TWO HYDROCYLONES IN SERIES

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A large quantity of sludge is generated each year from the water treatment plants in Egypt. Some plants dispose the generated sludge into the Nile river, the others which far from the Nile river banks dispose the sludge in the nearest site beside the plant. The pumped sludge contains at least 96 % water, which causes certain environmental problems and health hazards in the future. The future trend of sludge management, are to convert the produced sludge into useful materials. One of the industrial centrifugal separators is the hydrocyclone. It has been used widely in industry for dewatering suspensions, such as liquid clarification, slurry thickening (or both simultaneously), and solid washing.

The present work focused on the use of one stage or two stage hydrocyclone as dewatering tool for thickening, the sludge generated from water treatment plant of New Assiut City (Assiut, Egypt). The effect of feed concentration on dewatering performance of the hydrocyclone was studied using two identical hydrocyclones each of 50 mm diameter. The obtained results show that, using one stage hydrocylone is not effective in thickening the sludge. To improve overall recoveries of thicker sludge and clearer overflow simultaneously, two stages hydrocyclone connected in series are used. The overall recovery of the whole system is better than the recovery of any of the individual cyclones used within 20—24 % when diluted feed solid concentration less than 2 % was used. It is hoped that this work will lead to an improvement in the utilization of the hydrocyclones in dewatering the sludge generated from fresh water treatment plants.

KEYWORDS: *Water treatment sludge, Hydrocyclone, Dewatering.*

1. INTRODUCTION

In water treatment plants, large quantity of waste residuals are generated due to the nature of the unit operations involved in treating the raw source water [1-2]. These waste streams or residuals consist primarily of the sludge from the sedimentation process and the back wash water from filtration process [2]. Most of the chemical agents added during the process of water treatment also end up in these waste streams. Of all the options of fresh water sludge (FWS) treatment, land disposal has been the most popular mode [2, 3,4]. Ponding is another alternative for landfill disposal, as a temporary storage of waste solids. Where suitable land area is available, this technique is both inexpensive and efficient when compared to other methods [2,5]. Some authors [5] mentioned that the volume of sludge removed from sedimentation tanks in fresh water treatment plants plus the quantity of backwash water from cleaning granular media filters is generally from 2-5 % of the processed water, other studies [1-2] mentioned that the quantity of sludge generated in ranges from 2 to 10 % of the plant throughput, for example, more than 2.4×10^7 tons water treatment plant sludge is generated each year in Taiwan [6] .

Dewatering of alum sludge is a difficult task. In the past, the sludge was discharged into water source, like a river or a lake [3]. Recycling the water treatment plant sludge is usually an attempt to reduce its volume, make it harmless and stable, recover useful contents and facilitate its safe disposal without imposing burden to environment [6]. The objective of a residual dewatering facility could be two fold: to produce a waste stream which has a more solid consistency, and to recover and recycle water associated with the residuals [2].

Dewatering equipment is designed to remove water in much shorter time than nature would by gravity [7-8]. Hydrocyclones can be used for dewatering of solid-liquid suspensions in many industries [9-12]. By the proper choice of the dimensions and operating conditions, it is possible for a hydrocyclone to act as a thickener. The cyclone must then operate in such a way that the underflow contains all solid particles and little liquid, so the overflow may contains the greater part of the liquid [13]. However, the separation in a hydrocyclone between solids and liquids is incomplete. A fraction of the solids report to the overflow rather than the underflow, and a fraction of the water in the feed reports to the concentrated underflow stream [14]. Some researchers [10,15-17] had shown that two stage hydrocyclone connected in series is required to give maximum concentration simultaneously with maximum clarification.

In Egypt, a large quantity of sludge is generated each year from fresh water treatment plants. However quantitative information about sludge generated is not available. Most of the water treatment plants in Egypt discharge the sludge into the Nile River with no treatment which causes certain environmental problems and health hazards [18]. Some plants which far from the Nile River dispose the sludge to the available space beside the plant. The pumped sludge outside the plant contain at least 96 % water and left to dry naturally by air and sun heat till the next washing time of sedimentation tanks. The accumulation of the coagulated sludge constitutes environmental problem and must be removed.

The aim of the present work is to study the feasibility of hydrocyclone process for thickening the alum sludge generated from fresh water treatment plant of New Assiut city (13 km from the Eastern bank of the Nile river), since classical process for sludge thickening may require more space and longer processing time to produce higher sludge concentration than hydrocyclone process. It is hoped that this work will lead to an improved understanding and more efficient utilization of the hydrocyclone in dewatering the sludge generated from fresh water treatment plants.

2. EXPERIMENTAL WORK

2.1. Materials

The used sample was a dry alum sludge obtained from the field site of New Assiut City water treatment plant (300 lit/sec). The average density of the material is 1.55 g/cm^3. The obtained sample was dried in dry furnace at 105 °C for 24 hours and then ground to pass 315 micron sieve size. The particle size distribution of the sieve analysis is shown in figure 1.

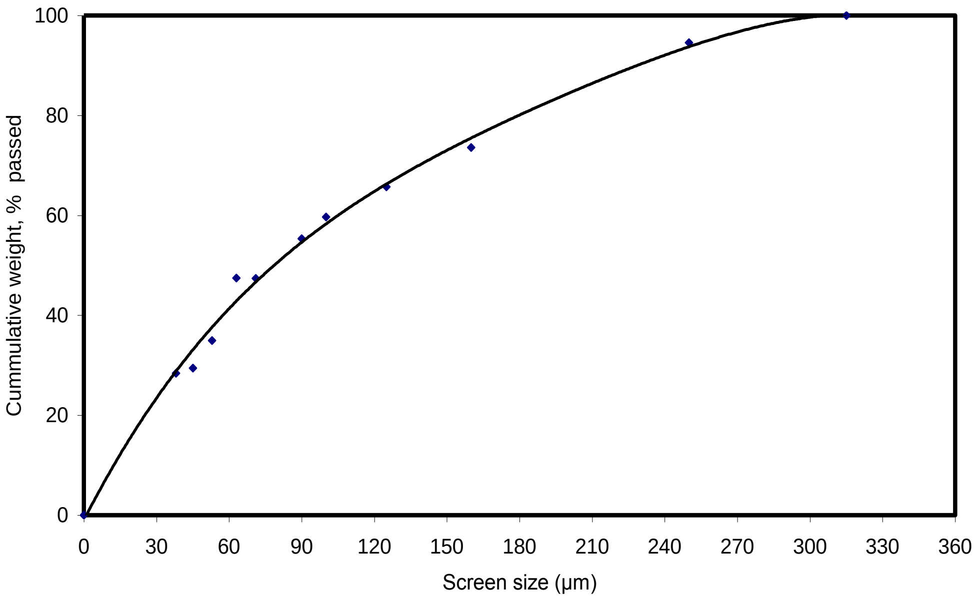


Fig. 1 : Particle size distribution of the sludge sample.

2.2. Apparatus

The experimental work was carried out using two Perspex identical hydrocyclones. The dimensions of each hydrocyclone were adjusted to optimum geometry for optimal separation according to the observations of many authors [13, 19 - 23]. The geometry of the hydrocyclone used in the present experimental work is shown in Table 1 and Fig. 2.

2.3. Procedure

In the first series of tests, single stage hydrocyclone circuit was used in sludge thickening as shown in figure 3. The cyclone was coupled into a system around which slurry of the desired concentration could be circulated. At the beginning of each test the system was allowed to run for a few minutes to ensure homogenous slurry, then timed samples (10 second) of the overflow and underflow streams were taken simultaneously in graduated containers. Slurry, solids and water quantities of the two products were determined to calculate the material balance sheet of the feed, overflow and underflow streams.

Table 1 : Dimensions of hydrocyclone used in the Experimental work..

Part name	symbol	Dim., mm.
Hydrocyclone body diameter	D	50
Cylindrical part length	H	65
Inlet diameter	D_i	10
Overflow diameter	D_o	16
Underflow diameter	D_u	6
Vortex finder length	I	20
Overall length	L	195
Cone angle	Θ	14°

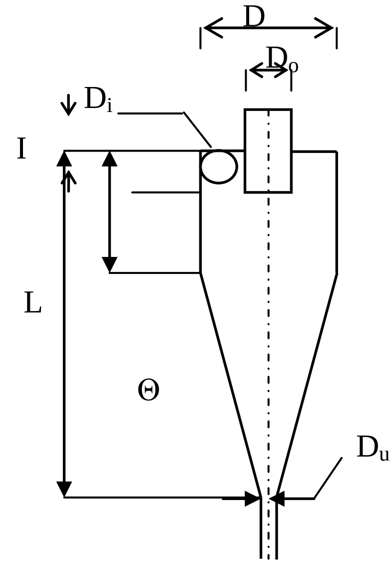


Fig. 2 : Illustration of the hydrocyclone geometry

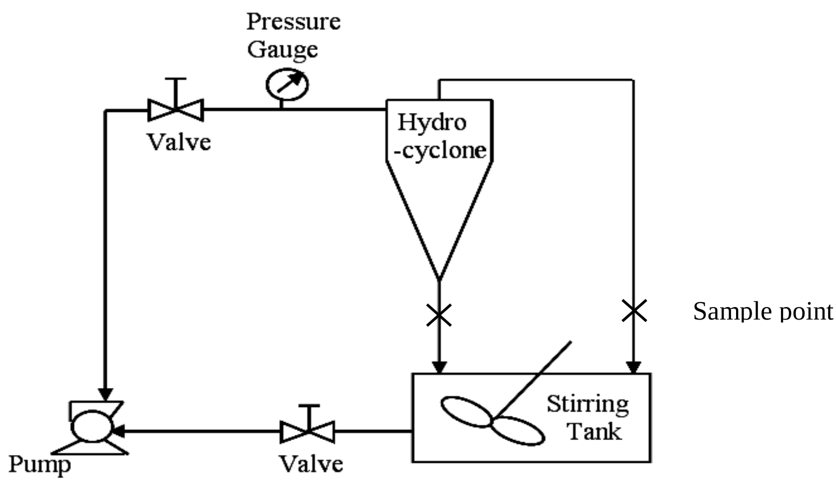
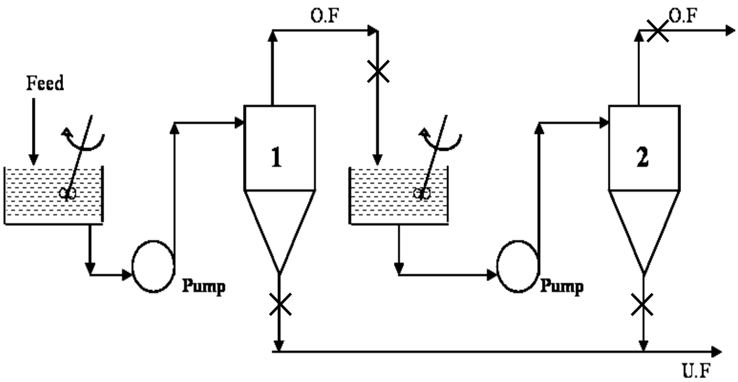


Fig. 3 : Schematic diagram of the experimental setup of single stage.

The effect of feed concentration on dewatering performance of the hydrocyclone was studied. The feed concentration was varied to five levels, i.e., 0.5, 1, 2, 3 and 4 % by weight. In the second series of tests, two stage hydrocyclone connected in series as shown in figure 4 were used to improve the overall recoveries of thicker sludge and clearer overflow simultaneously. The overflow streams of the first unit was pumped as a new feed to the second unit.



Sample points

Fig.4 : Two stage hydrocyclone in series connection

3. QUANTIFYING DEWATERING PERFORMANCE

In order to assess the dewatering performance of a hydrocyclone the following parameters are required to calculate [9, 14, and 24]:

R_w = Water flow rate in overflow / Water flow rate in feed.
R_s = Solids in underflow / Solids in feed, by volume.
R_v = Volumetric flow rate in underflow / Volumetric flow rate in feed.
$E = R_s – R_v / 1 – R_v$.
$CE = [(X_f – X_o) / X_f] \times 100$

Where :

R_w : Water recovery from the feed to overflow.
R_s : Solids recovery from the feed to underflow also called gross efficiency or solid elimination efficiency.
R_v : Volumetric recovery of slurry to the underflow, also called the flow ratio.
E : Hydrocyclone efficiency also called thickening efficiency or centrifugal efficiency.
CE : Clarification efficiency, also called clarification number of water or separation index.
X_f : Feed solids content by weight
X_o : Overflow solids content by weight

4. RESULTS AND DISCUSSION

The main operating variable studied in the present work is the effect of the feed concentration of suspension on the dewatering performance of hydrocyclone.

In case of single stage unit: The experimental results showed that, the recovery of solids in underflow stream, R_s, (gross efficiency) is decreased by increasing the feed concentration due to increasing in the slurry viscosity, reducing the chance of solid particles discharged through the underflow exist as shown in Table 2 and figure 5. Similarly, both the recovery of water, R_w, in overflow stream and clarification efficiency, CE, decreases with increasing the feed concentration of suspension as shown in Figure 6. In contrast the flow ratio, R_v , of the slurry reported to the underflow streams is increased with increasing feed concentration as shown in Table 2.

Table 2: The effect of feed concentration on dewatering performance of the first stage hydrocyclone.

Solid % (w/w)	Dewatering performance				
	$R_{w,\%}$	$R_{s,\ \%}$	$R_{v,\%}$	$CE_{,\%}$	E, %
0.5	85.06	76.62	15.13	72.91	72.45
1.0	84.38	74.84	15.98	68.75	69.06
2.0	80.66	74.17	20.08	67.65	67.68
3.0	77.54	71.23	23.42	62.38	62.43
4.0	74.31	69.20	26.81	57.47	57.92

Results in Table 2 and figure 5 showed that, an increase in the feed concentration has negative effects on hydrocyclone separation efficiency, E, (thickening efficiency). The negative effect may be due to the crowding of solid particles in the conical part of the hydrocyclone, and had a tendency to leave via the overflow than underflow. The obtained results are supported by a similar observations mentioned earlier by many authors [10,13,14,20-22,25,26].

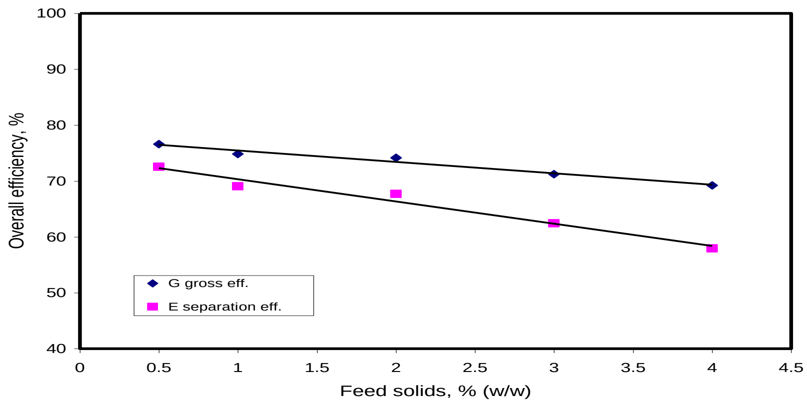


Fig .5 : The effect of feed concentration on overall efficiency of the first stage hydrocyclone.

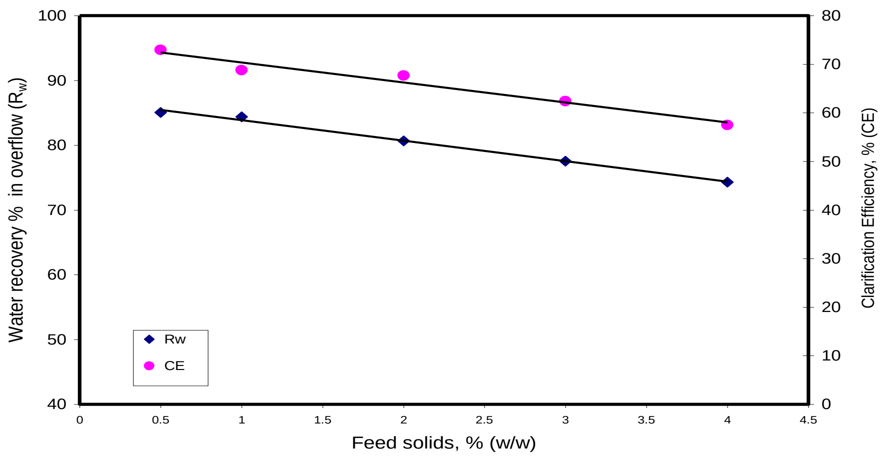


Fig .6 : The effect of feed concentration on water recovery and clarification efficiency of the first stage hydrocyclone .

To improve solids recovery from liquid, the overflow stream of the first hydrocyclone was fed to the second hydrocyclone unit as shown in figure 4. The results of the recycled overflow are given in Table 5.

Table 5: The results of the recycled overflow stream of the first unit to the second unit .

Solid in feed(w %)	Dewatering performance				
	$R_{w,\%}$	$R_{s,\%}$	$R_{v,\%}$	$CE_{,\%}$	E, %
0.13	95.20	84.21	4.87	82.14	83.40
0.30	92.18	81.08	7.95	78.57	79.45
0.68	85.02	71.91	15.23	67.16	66.86
1.05	82.94	70.68	17.43	64.81	64.49
1.56	74.43	70.72	26.02	60.26	60.42

It is clear from Table 5 that there are improvement in recoveries of overflow water and underflow solids than that of the first hydrocyclone unit. This improvements may be attributed to the feed concentration of the second unit are more diluted than the feed of the first unit as shown in Table 5.

Combination of the results in Tables 4 and 5 was given in Table 6 to demonstrate the dewatering performance parameters of the two stage hydrocyclone operated continuously in series connection.

Table 6 : Combination the results of the two stage hydrocyclone connected in series.

Initial feed concentration %	Dewatering performance parameters				
	$R_{w,\%}$	$R_{s,\%}$	$R_{v,\%}$	$CE_{,\%}$	E, %
0.5	80.90	96.20	19.34	94.90	95.59
1.0	77.08	95.42	22.36	93.68	94.08
2.0	69.19	92.55	32.01	89.06	89.04
3.0	64.34	91.90	36.75	87.25	87.21
4.0	56.27	91.02	44.89	83.47	83.70

Comparing the dewatering performance of Table 2 and Table 6, shows that, there are a better improvement in dewatering performance of the two stage hydrocyclone connected in series compared with the performance of each unit used individually as shown in figures 7 and 8. For example, at low feed concentration 0.5 %, the thickening efficiency, E, increased from 72.56 % to 95.29 %, the gross efficiency, R_s, is increased from 76.62 % to 96.20 % and clarification efficiency, CE, is increased from 72.91 % to 94.90 %.

As expected, the water recovery in the overflow stream of the whole system is decreased slightly compared to the values of water recovery of the first hydrocyclone unit for clearer overflow. Also, it is noticed from Table 6 that, at low feed concentration, (0.5% to 2%), high solids recoveries were obtained and at high feed concentration, (3 % and 4 %) the solids recovery to the underflow was reduced.

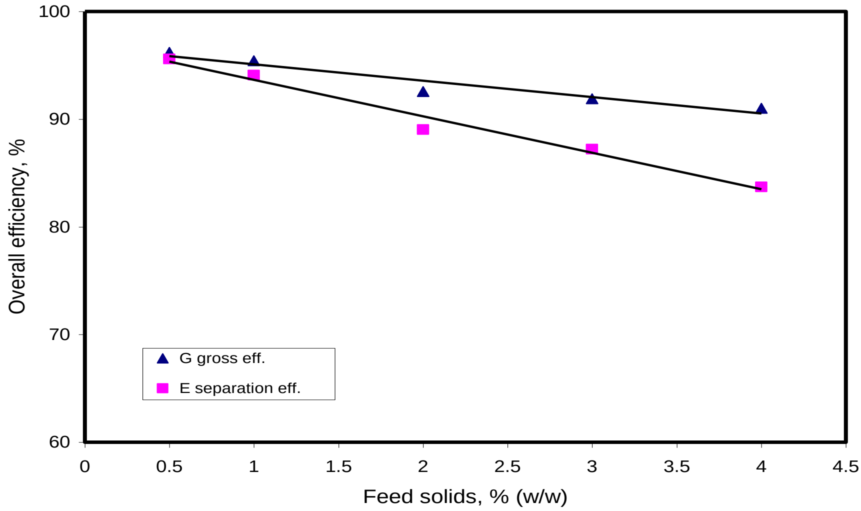


Fig. 7 : The effect of feed concentration on overall efficiency of the whole system.

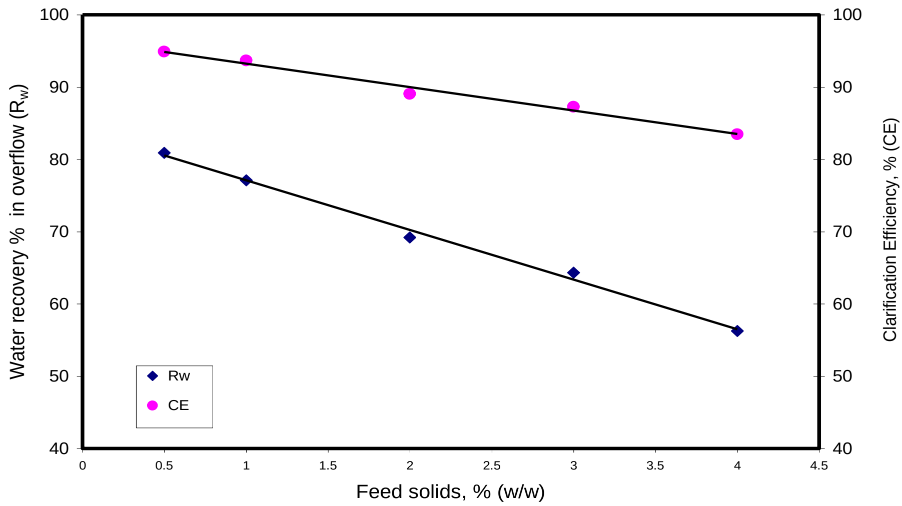


Fig .8 : The effect of feed concentration on water recovery & clarification efficiency of the whole system.

5. CONCLUSIONS

The following conclusions can be drawn from this study:

1) Thickening efficiency is sensitive to feed solids concentration.
2) The overall recovery of the whole system is better than the recovery of any of the individual hydrocyclone.
3) Acceptable recovery levels of solids and water in underflow and overflow streams respectively was obtained at low feed concentration (less than 2 % solids).
4) An additional benefit from connecting two hydrocyclones in series that it dilutes the feed to the second stage which improves the cyclone separation efficiency.

5) The obtained results proved that multiple hydrocyclones connected in series can be used effectively in dewatering operations of sludge generated from fresh water treatment plants.

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تغليظ الرويه الناتجه من محطات معالجه مياه الشرب باستخدام جهازي هيدروسيكلون متصلين على التوالى

تنتج محطات معالجه مياه الشرب فى مصر سنويا كميات كبيره من الرويه الناتجه من غسيل المروقات و المرشحات . وتتخلص المحطات المنشأه على ضفاف نهر النيل من هذه الرويه بضخها فى نهر النيل حيث انها تحتوى على نسبه 96 % فاكثر من الماء, اما المحطات البعيده عن مجرى نهر النيل تتخلص من الرويه بضخها الى المناطق المجاوره لها مما يؤثر سلبا على مستقبل البيئه المحيطه بها. والاتجاهات الحديثه للتخلص من الرويه هى اعاده تدويرها للاستفاده من المياه ومن الرويه المغلظه فى اغراض متعدده. ويعتبر جهاز الهيدروسيكلون من اهم اجهزه الطرد المركزى المستخدمه على نطاق واسع فى تركيز المواد الصلبه من الموائع. وهذا البحث يركز على استخدام جهازين للهيدروسيكلون معا متطابقين فى الابعاد و القطر الداخلى لكل منهما 50 مم وذلك لتغليظ الرويه الناتجه من محطه تنقيه مياه الشرب بمدينه اسيوط الجديده والتى تبعد حوالى 13 كم عن الضفه الشرقيه لنهر النيل. ولقد تم دراسه تاثير تغيير نسبة المواد الصلبه (رويه مجففه) بنسب تتراوح ما بين .5% الى 4 % كأحد عوامل التشغيل الهامه التى تؤثر على كفاءه الفصل فى جهاز الهيدروسيكلون.

ومن النتائج المعمليه يتضح ان استخدام جهازين للهيدروسيكلون متصلين على التوالى اكفأ فى الفصل من استخدام كل جهازعلى حده بنسبه تتراوح من 20-24 % . ونأمل أن تفيد هذه الدراسه المعمليه في امكانيه استخدام اجهزه الهيدروسيكلون فى تغليظ الرويه الناتجه من عمليات غسيل المروقات والمرشحات في محطات معالجة مياه الشرب للاستفاده منها ومن المياه المرتجعة فى أغراض متعدده .