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Dewatering sludge from primary and secondary clarifiers in Jabal Asfar wastewater treatment plants – case study

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ABSTRACT

Dewatering is an important step in sludge treatment process; it reduces the quantity and valorize the quality of the produced sludge. This paper aims to discuss the use of screw press machine for dewatering sludge mixture from primary and secondary clarifiers in Jabal Asfar wastewater treatment plant (JAWWTP). The study was conducted using a pilot scale with capacity of 52 m^3/h. Inlet and outlet samples were collected and transferred to the laboratory of JAWWTP for analysis. The speed of the screw press (rpm), the polymer dose (g) and the inlet TS% were monitored as operational parameters. Results showed that the screw press can dewater sewage sludge with lower total solids (TS) reached 0.5%. The optimum conditions for operating were regarded to the higher TS% in the outlet cake and the lower- energy and polymer consumption. Sewage sludge quantity entering the screw press fluctuated between 3.8 and 15.5 m^3/h. Inlet TS ranged from 0.5% to 0.9% and the polymer consumption ranged from 2.7 to 18.6 g for each kg of dewatered sludge. Cost of dewatering processes ranged from US$ 0.009 to 0.064 for each kg of dewatered sludge depending on the polymer and energy consumption. TS outlet fluctuated between 13.12% and 21.6% depending on the TS inlet, the speed of the conveyer rotation and the polymer dose. The produced sludge will be dried and used for various purposes. It can be concluded that mechanical dewatering systems are suitable alternatives for conventional drying beds especially in highly populated cites, and screw press can dewater sludge with low TS content reached 0.5%.

Keywords: Mechanical dewatering; Screw press; Wastewater sewage sludge; Total solids; Agglutination rate

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1. Literature review

Treatment activities carried out for municipal wastewater has resulted in a dramatic increase in sewage sludge. The produced sludge characterized by higher water content, colloidal and compressible nature [1–3]. Dewatering sludge is economically and technically feasible process; it facilitates the possible use of sludge as a fuel or as organic matter for composting and reduces transport and disposal costs [4–6].

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Screw press is a horizontal continuous mechanical dewatering system that is designed for separation of a wide range of sludge. It reduces the moisture content of the sludge for the following reasons: (1) reducing the area and time consumed to dry the sludge especially in case of using drying beds, (2) reducing the transportation costs to disposal sites, (3) increasing the calorific value of the sludge, (4) reducing the environmental effect of leachate production at the landfill site, and (5) improving the handling properties of the sludge [7–9]. Dewatering efficiency is expressed as percentage of total solids (TS%) present in the outlet cake after the loss of water molecules by squeezing [5].

The water present in the sludge is one of the forms; (1) free water that is not attached to particles and not affected by capillary action, (2) water inside particles, (3) water on particles surface that is retained on the surface of solid particles by adhesion (adsorbed and bounded water) and, (4) water linked between cells and chemical compounds (bound water) [2,8,9].

Most mechanical dewatering processes involve two stages; the filter cake formation stage, and the compression stage, where further water is squeezed from the cake by the application of a mechanical force [9]. Dewatering alternatives were conducted as an initial design step to select the dewatering technology that will be suitable as basis for design. Mechanical dewatering machines are assisted with physical means, such as centrifugal forces, shear and pressure, which used to dewater the sludge at a fast rate and up to relatively high solids content [4,5]. Three of the most commonly used wastewater biosolids mechanical dewatering technologies, belt press, centrifuge and screw press, the efficiency of these techniques depends on the particle size of the product being dewatered [6,8].

Wetlands treatment technology with or without earthworms was studied by Hu et al. [10] and Hu and Chen [11] in different countries as economical effective methods for sludge treatment. Conventional techniques like drying beds are improper solution for dewatering of colloidal and gelatinous sludge as it depends on hydraulic diffusion, where the particles mass decreases drastically [12]. Conventional drying beds require large foot print [3] and long time for dryness from 1.6 to 6 months before using as fertilizer in Egypt [8,13,14].

Wang et al. [8] stated that about 65% of the US-wastewater treatment plants utilize drying beds, and 50% of them dewater sludge by drying beds, especially the smaller wastewater plants located in warmer sunny regions. In Egypt, the sewage sludge produced from the primary and secondary stages are pumped to the gravity thickeners stage, where total solid can be concentrated from ≈ 0.8% to 4%–6% [14]. The thickened sludge is transferred to drying bed for dewatering. The degree of dryness depends on the period of exposure and environmental factors (temperature, sunny time, moisture, wind velocity etc.) [13].

The Jabal Asfar wastewater treatment plant (JAWWTP) is located in the north east of Cairo. It receives wastewater from Cairo City via culverts and pumping stations forming a wastewater conveyance system. The screw press system was placed in stage I (Contract 16), it is designed to treat wastewater by activated sludge for an average raw inflow of 1.5 million square meters per day. The aim of this study is to evaluate the screw press-dewatering machine in parallel with other mechanical systems as alternatives for conventional drying beds, especially in delta region and/or other cities where no land is available or unsuitable environmental conditions. Implementing the screw press in biosolid management taken as novelty idea in this research, because it was rarely detected in the sewage sludge-dewatering facilities in Egypt, also, proposing a parallel technology in this field will create a degree of balance between competitors. In addition, the screw press machine under investigation was able to dewater sewage sludge of low TS content reached 0.5%, besides its economic effectiveness. This machine was investigated in JAWWTP for dewatering sludge as a preliminary dewatering phase, which can be completed according to the intended purpose of the produced sludge in other complementary stages.

2. Materials and methods

2.1. Pilot plant scale

The pilot unit dimensions are 4.57 m long × 2.65 m wide × 2.16 m high, and the capacity of this machine is 52 m^3/h. The unit contains one screw with a diameter of 280 mm. The major elements of the screw press dewatering system are the sludge feed pump, polymer makeup and feed system.

The screw press is equipped with separate main drive and cone motors for independent control of speed and retention time within the press. This design with its unique screw action represents the latest refinement in screw press, which has served food processors successfully for many years. The unit can receive a discharge of 17.2 m^3/h at a solids content of 0.5%–0.9% currently measured in the inlets of JAWWTP.

The dewatering process can be optimized by adjusting the dose of the polymer and the equipment settings including the flows, the speed of the screw (rpm) and the feed pressure. Instrumentations like calibration of the pumps and observing the performance of the machine were adjusted before starting the real experiment. Operational financial needs like electricity power, polymer cost and manpower were calculated.

2.2. Sludge used in the pilot experiment

The experiment was carried out on sewage sludge pumped from primary and final clarifier in volume ratio of 1:2 (Fig. 1). The sludge entered the screw press machine via connection tube ended by pump to adjust the inlet flow. Primary sludge is very putrescible, foul smelling, grey, and 60%–70% of it consists of volatile solids, final clarifier sludge is brown and odorless, rich of volatile organic solids that reached about 75% and is mostly microbial biomass.

2.3. Operation cycle and polymer addition

- The mixed sludge from the wastewater plant (primary and secondary clarifier) enters the fine filters to dispose the large and inorganic solid residues present in the sewage sludge before entering the dewatering machine.

Fig. 1. Inlet point of liquid sewage sludge mixed in volume ratio of 1:2 from primary and secondary clarifier before pumping to the screw press machine.

- Successful screw pressing mechanism requires thickening by chemical conditioning, typically, a polymer substance is used for this purpose (Zetag™ 7557, Solenis, SDS Number: R1200549).
- Equipment and operating tools that may affect the dewatering ability of the screw press include; speed of rotation (rpm), polymer dose (g) for dewatered sludge (kg) and inlet feed rate, where the polymer increase the rate of agglutination and capture.
- Conditioning the polymer includes a pump for metering the polymer, mixer, polymer storage and control. Polymer injection point feed directly with the upstream of the inlet sewage sludge.
- The sludge enters the flocculation tank in conjunction with the injection of the polymer and mixed properly, then, enters the screw press for dewatering.
- After entering the sludge and the polymer solution to the machine, where the main rotator connected to the other parts, the sludge is pushed from left to right, as it passes through two main stages; the first one is the stage of thickening of the sludge where large amount of water passes through the spaces between the fixed and moving parts. The clumped sludge passes to the pressing stage where the diameter of the main rotator increases to create the required pressure on the thickened sludge. The electric motor with a gearbox is responsible for the rotation of the combination that is connected to the main screw at its end. The distance between the fixed and moving rings is very precise to allow the passage of water only but not the clotted sludge.
- The self-cleaning process is carried out by spraying water along the combination to help the continuous movement of the moving parts to clean any residues of sludge that leak into the spaces between the fixed and moving rings. A liquid soap is added to the washing water to help the process of continuous cleaning.
- Upon completion of the operation of the equipment, it is recommended to clear it completely by running for a period of not less than 45 min without feeding with sludge, then it is filled with water (immersed) and liquid soap and not cleared from water until restarted for the next batch work.
- The polymer (g) required to dewater sewage sludge and produce sludge cake (kg) was prepared in the form of suspension in a concentration of 0.5%. The polymer suspension was continuously shaken to keep its homogeneity. It was injected in a rate of 30–80 L/h according to quantity of sewage sludge entering the screw press. It fluctuated between 3.8 and 15.5 m^3/h. The sewage sludge enters the flocculation tank in conjunction with the injection of the polymer suspension was mixed properly, then, enters the conveyer room of the screw press. The pumps used for dosing the volumes were calibrated in each batch.

2.4. Sampling and analysis

In this research, samples were collected from the inlet and outlet of the screw press machine to measure the total solids (TS) according to APHA [15]. Fifty-eight samples were collected in clean containers and transferred to the lab for investigation within 10 min after collection. Sludge samples were distributed in evaporation watch glasses and heated in an oven at 103°C–105°C for 1 h.

Dishes cooled, the dried sludge were stored in a desiccator. Watch glasses weighed prior to use and after desiccation to calculate the difference represented the total solids, which was calculated from the equation $TS\% = (W_1–W_2)/(W_3–W_2) \times 100$, where W_1 is the weight of crucible, W_2 is the weight of wet sample and W_3 is the total weight of substrate and crucible. Tools required for this work are Crucible, Laboratory oven, Desiccator, Electronic precision balance, Dish tongs, Magnetic stirrer, Wash bottles and Muffle furnace. Analyses were carried out in the laboratory of JAWWTP.

TS% as the quantity of the material residue left in the crucible after evaporation of the sample and its subsequent drying in a laboratory oven at 105°C for a period of 1 h [16] were calculated from the equations $TS\% = (W_1–W_2)/(W_3–W_2) \times 100$ [5].

3. Statistical analysis

Statistical Product and Service Solutions SPSS version 10.0 was used to carry out descriptive statistics for the obtained results and calculate the mean, standard deviation, standard error, one sample t-test, correlation coefficient between operational parameters and significance of correlation.

4. Results and discussion

The excess of sludge produced from municipals represent a challenge toward achieving the sustainable hygienic safe situation for drinking water and sanitation sector in Egypt [17]. The illegal use of non-stabilized sludge resulting in a serious environmental pollution [18]. In Egypt, sewage sludge produced from activated sludge based-technologies represent 45% of the total wastewater treatment technologies, it produces about 2.1 million tons of dry solids annually [19]. Dewatering sludge is one

Fig. 2. Sludge cake delivered from the screw press machine.

of the suitable steps should be taken before reuse. It helps to concentrate biological content of sludge thus increase its calorific value and proof handling properties of the sludge [20,21].

In Egypt, many WWTPs using conventional drying beds facilities for dewatering sewage sludge [14,19,20]. It is a concrete tank typically rectangular in shape contain draining medium of roughly 0.50 m in height made of sand or gravel allows the drainage process to occur in the drying beds. Because drying beds require only basic operation, they are considered a low cost method [21,22]. Wetlands as an efficient and economical technology [10,11] are used in sludge dewatering at non-central governorates like Al-Fayum and El-Menia, but its large footprint still the most important limiting factor against using this technology in Delta region. The primary and secondary sewage sludge produced from the WWTPs is pumped to thickening facilities, mainly gravity thickeners. Hence, the solids are concentrated to 4%–6% TS, the thickened sludge is pumped to drying bed facilities, where it is dried to concentrations of 40%–60% TS. The dewatering time is usually 25 d in summer and 40 d in winter [20].

The merit of dewatering sludge in drying beds in Egypt is the daily exposure for solar energy as renewable source, which get the benefit of low operational costs. To the other side, the large foot print especially in highly populated cities in Delta Governorates, where the prices of lands in Nile valley and Delta ranged from 10 to 15 US$/m^2, which may be duplicated for 100–200 US$/m^2 in the segment allowed for residential buildings or within the frame of cities [20,21]. The cost of land for drying beds is assumed at 15 US$/m^2 as a reference value. The accelerated increase of population in Egypt requiring extensions in the wastewater facilities and this is one of the reasons behind changing the conventional drying beds to mechanical dewatering systems [13,14]. Combined with this approach, the hygienic conditions of the drying beds, climate changes especially rainy season, environmental impact like insects, polluting subaquifer water and/or soil caused from leaching and unacceptable odors, sand bed cloggage [6], all these challenges are strongly standing against using conventional drying beds in the highly populated area in Nile valley and Delta region of Egypt. It may be compatible with cities with desert extensions that will offer suitable area and safe hygienic use in governorates of Sinai, Matrouh and South Egypt, where extensions of area can be used with relatively lower costs. To the other hand, Ghazy et al. [20,21] found that the drying beds will be more cost effective when used for WWTP serving peoples less than 9×10^4 for Egyptian climate.

The second alternative for dealing with sewage sludge is the long-distance transportation via pumping in pipelines or tubes for miles or carrying in trucks. Pumping sludge in pipelines is risky [5], it is issue of energy consumption, risk of bursting the pipelines or stop pumping may cause clogging of the tubes and some other precautions should be taken to keep steady work of this pathway. Also transporting by trucks need some environmental and hygienic restrictions and is not compatible with the available cost.

On site mechanical dewatering of sludge is one of the alternative solution to reduce the water content of sludge, avoid expense of transportation, reduce hygienic effects of drying, control odors and keep environmental hygiene. Researchers [5,23] have proved the suitability of a mechanical dewatering technology depending on studies considered more than ten factors for comparing between the different dewatering technologies. Evaluating factors included; inlet and outlet TS content (dewatering efficiency), operation time, required space or footprint, the purpose of dewatering, process automation, capital expenditure, operating costs, energy efficiency and emissions and process waste [6,22,23].

It is supposed that the screw press is one of the suitable solutions for the Nile Vally and Delta Region of Egypt because of the limited footprint for this machine [21,22], when compared with the drying beds [14]. In addition, the low operation energy and capital expenditure as it is locally designed and manufactured. The machine spare parts are manufactured and provided locally and the maintenance is well understood [22]. Also, its internal parts moving slowly that helps continuous dewatering with low energy consumption and least maintenance, also low emission of odors and aerosol [6].

Screw press is simply mechanized to use an agglutination substance (polymer) that combined with sludge molecules and building large floccules, where the screw press enhances releasing the sludge's water [4,22]. At the inlet of the screw press, sludge dewatered by gravity then by squeezing and the conveyer continue pressing to compress the sludge and reducing the available cross-sectional area between macro floccules. The liberated water was allowed to release through the perforated screen surrounding the screw and the sludge floccules retain inside the press [2,5,7].

One of the sizing and pricing dewatering criteria is the inlet (throughput) and outlet TS as a key consideration, the machine under investigation has the privilege to dewater inlet sewage sludge with TS content ≤0.5%, which is a mixture in ratio of 1:2 from primary and secondary sedimentation reactor, consequently there is no need for thickened sludge, and the system can be used for wastewater treatment plant without thickening stage [4,22].

During the study period, raw wastewater of JAWWTP showed characteristic values of average concentrations for total suspended solids reached 181 mg/L, with min. and max. values 140 and 262 mg/L. The BOD average conc. was 147 mg/L, with min. and max. values 120 and 199 mg/L. The COD average conc. was 276 mg/L, with min. and max. values 202 and 461 mg/L, respectively. VSS measurements showed an average conc. of 130 mg/L, with min. and max. values ranged from 107 to 188 mg/L.

TS% of the inlet changed from 0.5% to 0.9% according to the day time and peak water consumption in the served region. The screw press was operated on different speeds (rpm) to detect the optimum dose for agglutination and achieve the highest TS% outlet. Results are categorized in Table 1 for inlets TS% 0.5, 0.6, 0.7, 0.8 and 0.9 and represented in 5 figures showing the variations of average total cost US$/kg, polymer dose g/kg and outlet TS% vs. screw press speeds as 0.55, 1, 1.5, 2 and 2.5 rpm. Generally, the main operating factors affecting the dewatering ability of the screw press were the polymer dose, the speed of the machine and the TS% of the inlet and this agree with many researchers [1,4,7]. The polymer dose and TS% of the inlet proportionally affects the agglutination of the sludge, to the other side, the speed (rpm) of the machine affects inversely the agglutination of the dewatered sludge. The higher the dose of introduced polymer, the more agglutination was recorded.

The cost of performing the dewatering process is really subject to the goals of dewatering sewage sludge. Table 1 shows the cost values for the dewatered sewage sludge ranged from US$ 0.009 to 0.064/kg. The polymer dose is inversely related to the inlet TS%, as the inlet TS% increases, the consumed polymer dose will be decreased. The speed of the machine conveyer, where the lower speeds (0.55 and 1 rpm) increased the polymer consumption (Figs 3–9). The following paragraphs will go thoroughly for each inlet TS% and explain the interference of the effecting factors together.

4.1. Dewatering ability of the screw press for inlet TS 0.5% (Table 1 and Fig. 3)

The lowest inlet TS% content reached the screw was 0.5, Table 1 shows the measured outlet TS% and the polymer doses. In this case, the TS% outlet ranged from average 13.32 to 21.26, depending on the speed (rpm) and the polymer dose (g/kg). The highest outlet TS% reached

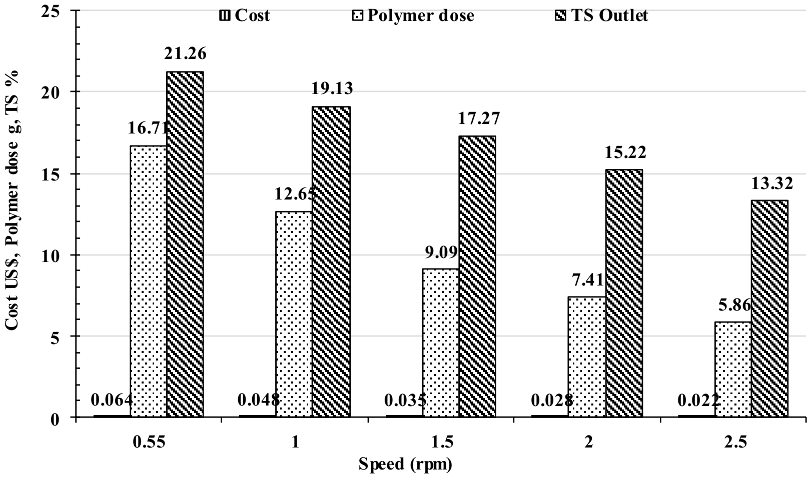

Fig. 3. TS% and costs of dewatered sludge from sewage with TS 0.5% at different speeds and polymer doses.

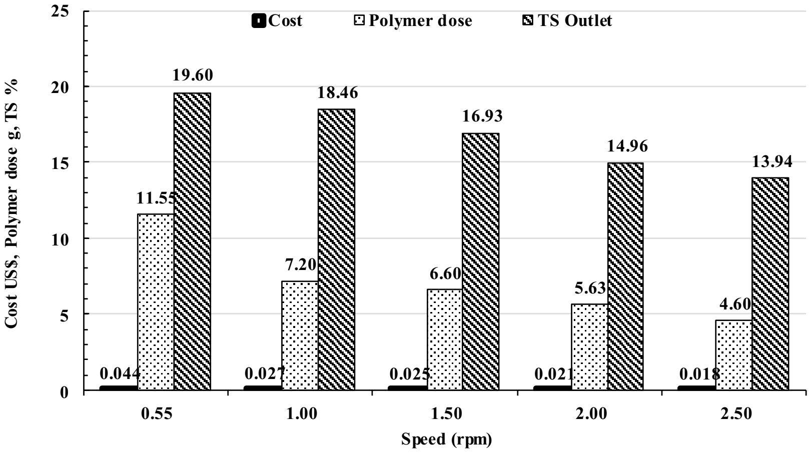

Fig. 4. TS% and costs of dewatered sludge from sewage with TS 0.6% at different speeds and polymer doses.

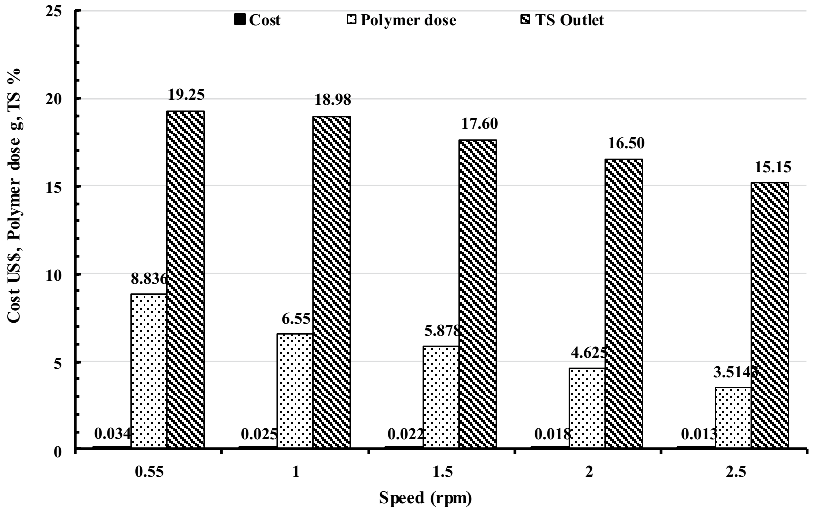

Fig. 5. TS% and costs of dewatered sludge from sewage with TS 0.7% at different speeds and polymer doses.

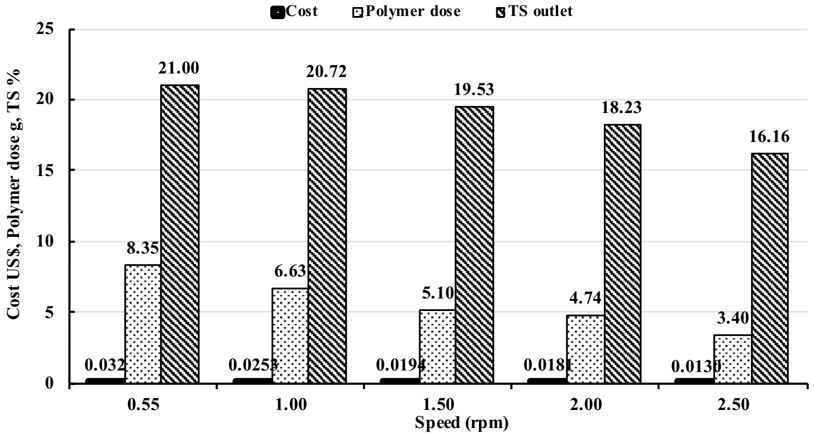

Fig. 6. TS% and costs of dewatered sludge from sewage with TS 0.8% at different speeds and polymer doses.

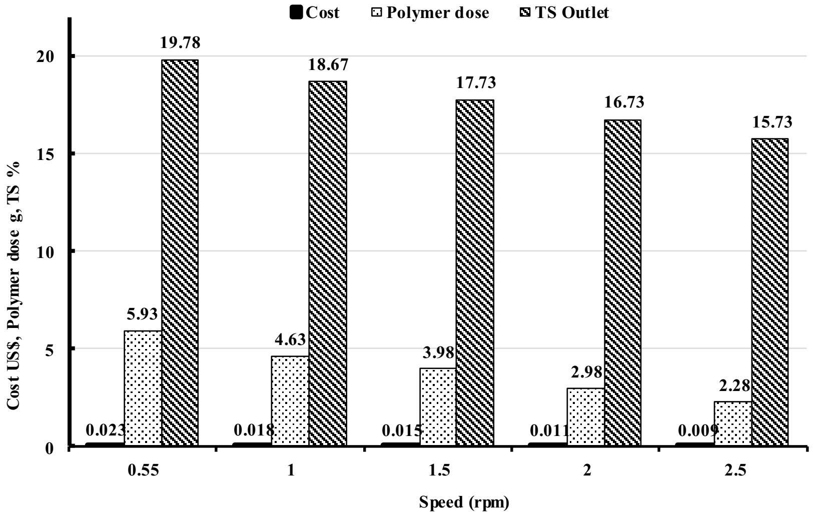

Fig. 7. TS% and costs of dewatered sludge from sewage with TS 0.9% at different speeds and polymer doses.

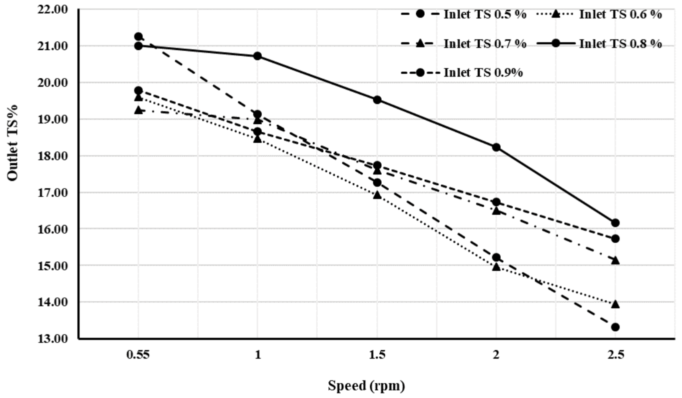

Fig. 8. Relation between the outlet TS% and the rotation speed of the screw press.

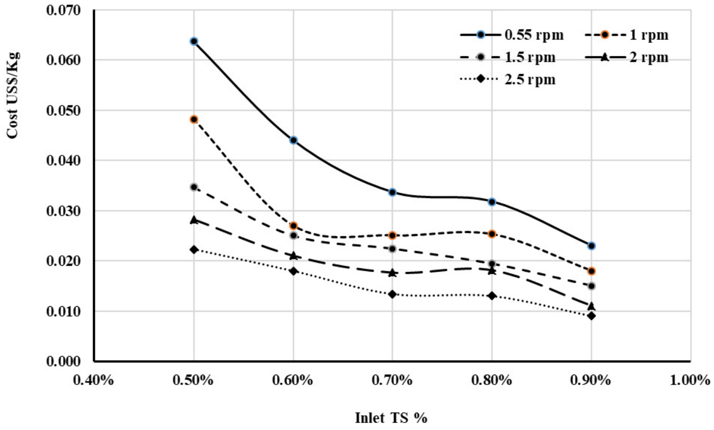

Fig. 9. Relation between the costs of dewatering the sludge and the inlet TS%.

Table 1
Operating parameters[a] inlet TS%, the speed of the screw press (rpm) and the costs (US$) for outlet dewatered sludge

Speed (rpm)	Inlet TS 0.5%			Inlet TS 0.6%			Inlet TS 0.7%			Inlet TS 0.8%			Inlet TS 0.9%		
	Polymer dose (g)[b]	Outlet (TS%)	Cost (US$)[c]	Polymer dose (g)	Outlet (TS%)	Cost (US$)	Polymer dose (g)	Outlet (TS%)	Cost (US$)	Polymer dose (g)	Outlet (TS%)	Cost (US$)	Polymer dose (g)	Outlet (TS%)	Cost (US$)
0.55	16.71	21.26	0.064	11.55	19.60	0.044	8.85	19.25	0.034	8.35	21.00	0.032	5.93	19.78	0.023
NoM[d]		5			19			15			9			6	
1	12.65	19.13	0.048	7.20	18.46	0.027	6.55	18.98	0.025	6.63	20.72	0.025	4.63	18.66	0.018
NoM		20			21			8			3			6	
1.5	9.09	17.27	0.035	6.60	16.93	0.025	5.88	17.60	0.022	5.10	19.53	0.019	3.98	17.73	0.015
NoM		14			8			4			2			6	
2	7.41	15.22	0.028	5.63	14.96	0.021	4.64	16.50	0.018	4.74	18.23	0.018	2.98	16.73	0.011
NoM		7			3			18			18			6	
2.5	5.86	13.32	0.022	4.60	13.94	0.018	3.51	15.15	0.013	3.40	16.16	0.013	2.28	15.73	0.009
NoM		3			5			35			10			3	

[a] Values of polymer dose (g) and outlet (TS%) are calculated as an average from the total number of measurements.
[b] Polymer dose expressed as g for each kg of dewatered sludge.
[c] The cost was expressed as US$ for each kg of dewatered sludge, the average retail price of electricity in 2021 is US$ 0.089 (1.4 EGP)/kWh in Egypt, the exchange rate used in 2021 was US$ = 15.7 EGP, polymer price is US$ 3,810 (60,000 EGP) for one ton (1,000 kg) and the cost is a combination of polymer and energy consumption.
[d] NoM = Number of measurements for each speed.

21.26 when the polymer dose was 16.71 g/kg at speed of 0.55 rpm and total average operating cost reached US$ 0.064. When the speed increased to 1 rpm, the polymer dose and TS% decreased to 12.65 and 19.13 consequently. Table 1 shows that the increase of machine speed resulted in the decrease in the polymer dose and the TS% outlet. At the same inlet content, when the speed increased to 1.5 rpm, the polymer dose decreased to 9.09 g/kg and the TS% outlet decreased to 17.27 and cost was 0.035 US$. For speed 2 rpm, polymer dose and outlet TS% decreased to 7.41 g/kg and 15.22 consequently. The lowest polymer dose was 5.86 that was recorded at speed of 2.5 rpm and costed 0.022 US$/kg of dewatered sludge, this agree with studies by Goss et al. [6]. Statistical analysis for the data showed that the polymer dose has a significant inverse relation (-0.64) with the TS inlet and a significant direct relation (0.755) with TS outlet (Fig. 8).

In our point of view, the optimum operation conditions and effective cost can be reached at speeds 1.5 and 2 rpm and polymer consumption from 7.1 to 8.3 that produced TS from 19.2% to 19.8% for cost of US$ 0.030 and 0.031.

4.2. Dewatering ability of the screw press for inlet TS 0.6% (Table 1 and Fig. 4)

When the inlet TS was 0.6%, TS outlet of the dewatered sludge ranged from average 13.94% to 19.6%, depending on the polymer dose and the speed (rpm) of the screw press, the cost ranged from US$ 0.018 to 0.044. The lowest TS% was recorded at speed of 2.5 rpm and the polymer dose 4.6 g/kg. The highest outlet TS contents were 19.6% and 18.46% that were recorded at speeds of 0.55 and 1 rpm, and polymer doses 11.55 and 7.2 g/kg, and cost were US$ 0.044 and 0.027 respectively. At speed 1 rpm, statistical analysis showed a significant inverse relation of –0.475 between the polymer dose and the TS inlet, at the same speed, a significant direct relation of 0.633 between the polymer dose and TS outlet. At speed 2 rpm, TS inlet has shown a significant inverse relation with both TS outlet of –0.347 and polymer dose of –0.353.

4.3. Dewatering ability of the screw press for inlet TS 0.7% (Table 1 and Fig. 5)

When the inlet TS was 0.7%, the outlet TS of the sludge cake ranged from 15.15% to 19.25% according to the speed of the screw press and the polymer dose. The highest TS outlet was 19.25% that recorded at speed of 0.55 rpm and polymer dose of 8.84 g/kg and cost of US$ 0.034. The lowest TS content was 15.15% that recorded at speed of 2.5 rpm for polymer dose of 3.51 g/kg and cost of US$ 0.013 (Table 1), similar results were recorded by Goss et al. [6] and Shaum and Lux [23]. At speed of 2.5 rpm, TS inlet has shown a significant inverse relation of –0.59 with the polymer dose.

4.4. Dewatering ability of the screw press for inlet TS 0.8% (Table 1 and Fig. 6)

When the inlet TS was 0.8%, the highest outlet TS was 21.0%, it was recorded at speed of 0.55 rpm and consumed polymer dose of 8.35 g/kg for cost of US$ 0.032. At speed 1 rpm, the recorded TS outlet was 20.72% for polymer dose of 6.63 g/kg and cost of US$ 0.025. For the current case, the lowest cost was US$ 0.0135 recorded at speed of 2.5 rpm and produced sludge cake of TS% 16.16.

4.5. Dewatering ability of the screw press for inlet TS 0.9% (Table 1 and Fig. 7)

For the inlet TS 0.9%, results were repeatedly recorded during the experiment, the screw press produced a high TS% reached 19.78 when the polymer dose was 5.93 g/kg and the speed was 0.55. For speeds of 2 and 2.5 rpm, the polymer doses were 2.98 and 2.28 g/kg and the outlet TS were 16.73% and 15.73%, respectively.

The highest outlet TS% contents were recorded during the slow rotation speeds of the screw press (Fig. 8), regardless the inlet TS content, that is, the polymer dose is the effecting factor [6,22]. In addition, the cost of dewatering was the highest for the slower speeds of rotation (Fig. 9), and decreased gradually with the increase of rotation, to the other hand, the outlets TS content inversely related to the speed (Fig. 9).

The highest TS% recorded during the current study was 20% ± 1%. The previous reported outlet TS%s of mechanical dewatering systems for sludge from activated sludge wastewater plants ranged from 18% to 27% distributed as follow; solid bowl centrifuge 18%–20%, belt filter press 21%–22%, press centrifuge 21%–23%, Diaphragm filter press 25%–27%, drying beds has shown TS% from 19 to 25 [8,9,13,24,25]. A comparative study between centrifuge, belt press and screw press as mechanical dewatering system was carried out by Kabouris et al. [22] and Goss et al., [6], they assigned the screw press as a favorable technology considering its operational simplicity as a priority.

Statistical analysis showed that inlet TS% has a direct non-significant relation (0.104) with the machine speed and inverse significant relation (–0.484) with the polymer dose. Outlet TS% showed a direct significant relation (0.626) with polymer dose, to the other side, the machine speeds (rpm) has shown an inverse relation with both (–0.578) the polymer dose g/kg of sludge cake and (–0.455) outlet TS%, respectively. Outlet TS% has shown a direct significant relation with polymer dose (0.626).

5. Conclusion

- Screw press is one of the mechanical alternative solution to reduce the water content of sludge, avoid expense of transportation, reduce hygienic effects of drying beds, control odors and keep environmental hygiene.
- The volume of the sludge entered the screw press machine ranged between 3.8–15.5 m^3/h with solids content 0.5%–0.9%, the amount of polymer used 2.7–18.6 g/kg, the solid cake produced from the screw press with total solids 13.12% and 21.6% and the total cost ranged from US$ 0.009–0.064/kg depending on the polymer and energy consumption.
- Conventional drying beds may be compatible with cities with desert extensions that will offer suitable area and safe hygienic use like governorates of Sinai, Matrouh and South Egypt governorates.

6. Recommendations

The screw press is one of the suitable alternative dewatering systems for sewage sludge with low solid content up of 0.5%, it needs a suitable earth footprint compared with drying beds, which mostly occupy 75%–80% of the WWTP area. Therefore, it is suitable for WWTPs in the delta region in Egypt in parallel with other mechanical dewatering systems, due to the unavailability of land, in addition, it can be manufactured locally, operated and maintained economically.

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Descriptive

Descriptive statistics

S_RPM	TS_in		N	Minimum	Maximum	Mean	Std. deviation
0.55	0.5	Poly_G_K	5	9.97	19.60	16.7140	3.95638
		TS_out	5	19.60	23.60	21.2600	1.48257
		Valid N (listwise)	5				
	0.6	Poly_G_K	19	5.12	16.40	11.5537	3.10224
		TS_out	19	16.20	21.70	19.6211	1.40380
		Valid N (listwise)	19				
	0.7	Poly_G_K	15	4.46	10.50	8.8360	1.93654
		TS_out	15	15.80	21.10	19.2467	1.59636
		Valid N (listwise)	15				
	0.8	Poly_G_K	9	4.58	12.30	8.3533	2.68870
		TS_out	9	19.00	22.00	20.7222	0.99596
		Valid N (listwise)	9				
	0.9	Poly_G_K	6	3.43	5.50		0.79588
		TS_out	6	15.90	21.00	18.6667	2.53272
		Valid N (listwise)	6				
	1.0	Poly_G_K	3	3.33	4.50	4.1100	0.67550
		TS_out	3	17.90	20.50	19.3000	1.31149
		Valid N (listwise)	3				
1.00	0.4	Poly_G_K	6	11.80	11.80	11.8000	0.00000
		TS_out	6	20.00	21.50	20.8667	0.53541
		Valid N (listwise)	6				
	0.5	Poly_G_K	20	3.70	11.80	6.9650	2.71512
		TS_out	20	13.90	21.50	17.2150	2.63744
		Valid N (listwise)	20				
	0.6	Poly_G_K	21	2.80	9.80	7.2048	1.53345
		TS_out	21	15.10	20.60	18.4667	1.68117
		Valid N (listwise)	21				
	0.7	Poly_G_K	8	1.80	5.30	4.6250	1.18412
		TS_out	8	14.00	19.00	16.5000	2.03470
		Valid N (listwise)	8				
	0.8	Poly_G_K	3	4.60	4.70	4.6333	0.05774
		TS_out	3	19.00	20.00	19.5333	0.50332
		Valid N (listwise)	3				
	0.9	Poly_G_K	6	5.70	6.40	5.9333	0.36148
		TS_out	6	18.00	20.60	19.7833	0.93256
		Valid N (listwise)	6				
	1.0	Poly_G_K	5	4.10	7.40	5.5600	1.70382
		TS_out	5	19.60	20.80	20.2200	0.46043
		Valid N (listwise)	5				

S_RPM	TS_in		N	Minimum	Maximum	Mean	Std. deviation
1.50	0.4	Poly_G_K	11	10.20	14.00	11.8909	1.58900
		TS_out	11	19.20	21.50	20.3727	0.77083
		Valid N (listwise)	11				
	0.5	Poly_G_K	14	4.10	9.30	6.0929	2.32063
		TS_out	14	13.10	22.00	17.2714	3.30860
		Valid N (listwise)	14				
	0.6	Poly_G_K	8	2.90	9.70	6.6625	2.74171
		TS_out	8	16.50	21.60	18.9375	1.93090
		Valid N (listwise)	8				
	0.7	Poly_G_K	4	5.10	7.70	7.0500	1.30000
		TS_out	4	17.00	18.80	17.9750	0.76757
		Valid N (listwise)	4				
	0.8	Poly_G_K	2	5.10	5.10	5.1000	0.00000
		TS_out	2	20.90	21.10	21.0000	0.14142
		Valid N (listwise)	2				
	0.9	Poly_G_K	6	2.00	6.00	2.9833	1.55360
		TS_out	6	15.00	19.10	16.7333	1.43062
		Valid N (listwise)	6				
2.00	0.5	Poly_G_K	7	3.80	6.90	5.8571	0.98295
		TS_out	7	17.90	21.00	19.1286	1.08891
		Valid N (listwise)	7				
	0.6	Poly_G_K	3	5.50	5.90	5.6333	0.23094
		TS_out	3	19.30	20.60	19.9667	0.65064
		Valid N (listwise)	3				
	0.7	Poly_G_K	18	3.70	6.80	4.8778	0.92645
		TS_out	18	15.80	21.00	18.6000	1.27879
		Valid N (listwise)	18				
	0.8	Poly_G_K	18	1.40	5.90	4.7444	1.24769
		TS_out	18	17.00	20.00	18.2333	0.76312
		Valid N (listwise)	18				
	0.9	Poly_G_K	6	2.00	5.00	2.2833	1.55360
		TS_out	6	15.00	18.10	15.7333	1.43062
		Valid N (listwise)	6				
2.50	0.6	Poly_G_K	5	3.30	5.20	4.6000	0.83964
		TS_out	5	12.50	15.60	13.9400	1.31072
		Valid N (listwise)	5				
	0.7	Poly_G_K	35	3.20	4.30	3.5143	0.29119
		TS_out	35	12.50	20.50	16.1457	1.94956
		Valid N (listwise)	35				
	0.8	Poly_G_K	10	3.20	3.90	3.4000	0.24037
		TS_out	10	14.10	18.80	16.1600	1.43542
		Valid N (listwise)	10				
	0.9	Poly_G_K	2	2.60	3.00	2.8000	0.28284
		TS_out	2	14.00	15.80	14.9000	1.27279
		Valid N (listwise)	2				

T-Test

One-sample statistics

S_RPM	TS_in		N	Mean	Std. deviation	Std. error mean
0.55	0.5	TS_out	5	21.2600	1.48257	0.66302
	0.6	TS_out	19	19.6211	1.40380	0.32205
	0.7	TS_out	15	19.2467	1.59636	0.41218
	0.8	TS_out	9	20.7222	0.99596	0.33199
	0.9	TS_out	6	18.6667	2.53272	1.03398
	1.0	TS_out	3	19.3000	1.31149	0.75719
1.00	0.4	TS_out	6	20.8667	0.53541	0.21858
	0.5	TS_out	20	17.2150	2.63744	0.58975
	0.6	TS_out	21	18.4667	1.68117	0.36686
	0.7	TS_out	8	16.5000	2.03470	0.71937
	0.8	TS_out	3	19.5333	0.50332	0.29059
	0.9	TS_out	6	19.7833	0.93256	0.38072
	1.0	TS_out	5	20.2200	0.46043	0.20591
1.50	0.4	TS_out	11	20.3727	0.77083	0.23241
	0.5	TS_out	14	17.2714	3.30860	0.88426
	0.6	TS_out	8	18.9375	1.93090	0.68268
	0.7	TS_out	4	17.9750	0.76757	0.38379
	0.9	TS_out	6	16.7333	1.43062	0.58405
	1.0	TS_out	2	21.0000	0.14142	0.10000
2.00	0.5	TS_out	7	19.1286	1.08891	0.41157
	0.6	TS_out	3	19.9667	0.65064	0.37565
	0.7	TS_out	18	18.6000	1.27879	0.30141
	0.8	TS_out	18	18.2333	0.76312	0.17987
2.50	0.6	TS_out	5	13.9400	1.31072	0.58617
	0.7	TS_out	35	16.1457	1.94956	0.32954
	0.8	TS_out	10	16.1600	1.43542	0.45392
	0.9	TS_out	2	14.9000	1.27279	0.90000

One-sample test								
S_RPM	TS_in		Test value = 18					
			t	*df*	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
							Lower	Upper
0.55	0.5	TS_out	4.917	4	0.008	3.26000	1.4192	5.1008
	0.6	TS_out	5.033	18	0.000	1.62105	0.9444	2.2977
	0.7	TS_out	3.025	14	0.009	1.24667	0.3626	2.1307
	0.8	TS_out	8.200	8	0.000	2.72222	1.9567	3.4878
	0.9	TS_out	0.645	5	0.547	0.66667	–1.9913	3.3246
	1.0	TS_out	1.717	2	0.228	1.30000	–1.9579	4.5579
1.00	0.4	TS_out	13.115	5	0.000	2.86667	2.3048	3.4285
	0.5	TS_out	–1.331	19	0.199	–0.78500	–2.0194	0.4494
	0.6	TS_out	1.272	20	0.218	0.46667	–0.2986	1.2319
	0.7	TS_out	–2.085	7	0.076	–1.50000	–3.2011	0.2011
	0.8	TS_out	5.277	2	0.034	1.53333	0.2830	2.7837
	0.9	TS_out	4.684	5	0.005	1.78333	0.8047	2.7620
	1.0	TS_out	10.781	4	0.000	2.22000	1.6483	2.7917
1.50	0.4	TS_out	10.209	10	0.000	2.37273	1.8549	2.8906
	0.5	TS_out	–0.824	13	0.425	–0.72857	–2.6389	1.1818
	0.6	TS_out	1.373	7	0.212	0.93750	–0.6768	2.5518
	0.7	TS_out	–0.065	3	0.952	–0.02500	–1.2464	1.1964
	0.9	TS_out	–2.169	5	0.082	–1.26667	–2.7680	0.2347
	1.0	TS_out	30.000	1	0.021	3.00000	1.7294	4.2706
2.00	0.5	TS_out	2.742	6	0.034	1.12857	0.1215	2.1356
	0.6	TS_out	5.235	2	0.035	1.96667	0.3504	3.5829
	0.7	TS_out	1.991	17	0.063	0.60000	–0.0359	1.2359
	0.8	TS_out	1.297	17	0.212	0.23333	–0.1462	0.6128
2.50	0.6	TS_out	–6.926	4	0.002	–4.06000	–5.6875	–2.4325
	0.7	TS_out	–5.627	34	0.000	–1.85429	–2.5240	–1.1846
	0.8	TS_out	–4.054	9	0.003	–1.84000	–2.8668	–0.8132
	0.9	TS_out	–3.444	1	0.180	–3.10000	–14.5356	8.3356

T-Test

One-sample test								
S_RPM	TS_in		Test value = 19					
			t	*df*	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
							Lower	Upper
0.55	0.5	TS_out	3.409	4	0.027	2.26000	0.4192	4.1008
	0.6	TS_out	1.928	18	0.070	0.62105	–0.0556	1.2977
	0.7	TS_out	0.598	14	0.559	0.24667	–0.6374	1.1307
	0.8	TS_out	5.188	8	0.001	1.72222	0.9567	2.4878
	0.9	TS_out	–0.322	5	0.760	–0.33333	–2.9913	2.3246
	1.0	TS_out	0.396	2	0.730	0.30000	–2.9579	3.5579
1.00	0.4	TS_out	8.540	5	0.000	1.86667	1.3048	2.4285
	0.5	TS_out	–3.027	19	0.007	–1.78500	–3.0194	–0.5506
	0.6	TS_out	–1.454	20	0.162	–0.53333	–1.2986	0.2319
	0.7	TS_out	–3.475	7	0.010	–2.50000	–4.2011	–0.7989
	0.8	TS_out	1.835	2	0.208	0.53333	–0.7170	1.7837
	0.9	TS_out	2.058	5	0.095	0.78333	–0.1953	1.7620
	1.0	TS_out	5.925	4	0.004	1.22000	0.6483	1.7917
1.50	0.4	TS_out	5.906	10	0.000	1.37273	0.8549	1.8906
	0.5	TS_out	–1.955	13	0.072	–1.72857	–3.6389	0.1818
	0.6	TS_out	–0.092	7	0.930	–0.06250	–1.6768	1.5518
	0.7	TS_out	–2.671	3	0.076	–1.02500	–2.2464	0.1964
	0.9	TS_out	–3.881	5	0.012	–2.26667	–3.7680	–0.7653
	1.0	TS_out	20.000	1	0.032	2.00000	0.7294	3.2706
2.00	0.5	TS_out	0.312	6	0.765	0.12857	–0.8785	1.1356
	0.6	TS_out	2.573	2	0.124	0.96667	–0.6496	2.5829
	0.7	TS_out	–1.327	17	0.202	–0.40000	–1.0359	0.2359
	0.8	TS_out	–4.262	17	0.001	–0.76667	–1.1462	–0.3872
2.50	0.6	TS_out	–8.632	4	0.001	–5.06000	–6.6875	–3.4325
	0.7	TS_out	–8.662	34	0.000	–2.85429	–3.5240	–2.1846
	0.8	TS_out	–6.257	9	0.000	–2.84000	–3.8668	–1.8132
	0.9	TS_out	–4.556	1	0.138	–4.10000	–15.5356	7.3356

One-sample test

S_RPM	TS_in		Test value = 20					
			t	*df*	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
							Lower	Upper
0.55	0.5	TS_out	1.900	4	0.130	1.26000	–0.5808	3.1008
	0.6	TS_out	–1.177	18	0.255	–0.37895	–1.0556	0.2977
	0.7	TS_out	–1.828	14	0.089	–0.75333	–1.6374	0.1307
	0.8	TS_out	2.175	8	0.061	0.72222	–0.0433	1.4878
	0.9	TS_out	–1.290	5	0.254	–1.33333	–3.9913	1.3246
	1.0	TS_out	–0.924	2	0.453	–0.70000	–3.9579	2.5579
1.00	0.4	TS_out	3.965	5	0.011	0.86667	0.3048	1.4285
	0.5	TS_out	–4.722	19	0.000	–2.78500	–4.0194	–1.5506
	0.6	TS_out	–4.180	20	0.000	–1.53333	–2.2986	–0.7681
	0.7	TS_out	–4.865	7	0.002	–3.50000	–5.2011	–1.7989
	0.8	TS_out	–1.606	2	0.250	–0.46667	–1.7170	0.7837
	0.9	TS_out	–0.569	5	0.594	–0.21667	–1.1953	0.7620
	1.0	TS_out	1.068	4	0.346	0.22000	–0.3517	0.7917
1.50	0.4	TS_out	1.604	10	0.140	0.37273	–0.1451	0.8906
	0.5	TS_out	–3.086	13	0.009	–2.72857	–4.6389	–0.8182
	0.6	TS_out	–1.556	7	0.164	–1.06250	–2.6768	0.5518
	0.7	TS_out	–5.276	3	0.013	–2.02500	–3.2464	–0.8036
	0.9	TS_out	–5.593	5	0.003	–3.26667	–4.7680	–1.7653
	1.0	TS_out	10.000	1	0.063	1.00000	–0.2706	2.2706
2.00	0.5	TS_out	–2.117	6	0.079	–0.87143	–1.8785	0.1356
	0.6	TS_out	–0.089	2	0.937	–0.03333	–1.6496	1.5829
	0.7	TS_out	–4.645	17	0.000	–1.40000	–2.0359	–0.7641
	0.8	TS_out	–9.822	17	0.000	–1.76667	–2.1462	–1.3872
2.50	0.6	TS_out	–10.338	4	0.000	–6.06000	–7.6875	–4.4325
	0.7	TS_out	–11.696	34	0.000	–3.85429	–4.5240	–3.1846
	0.8	TS_out	–8.460	9	0.000	–3.84000	–4.8668	–2.8132
	0.9	TS_out	–5.667	1	0.111	–5.10000	–16.5356	6.3356

Correlations

Correlations

S_RPM			TS_in	Poly_G_K	TS_out
0.55	TS_in	Pearson correlation	1	–0.751**	–0.169
		Sig. (2-tailed)		0.000	0.209
		N	57	57	57
	Poly_G_K	Pearson correlation	–0.751**	1	0.507**
		Sig. (2-tailed)	0.000		0.000
		N	57	57	57
	TS_out	Pearson correlation	–0.169	0.507**	1
		Sig. (2-tailed)	0.209	0.000	
		N	57	57	57

At speed 0.55 rpm, polymer dose has shown a significant inverse relation with TS inlet (–0.751) and a significant direct relation with TS outlet (0.507).

S_RPM			TS_in	Poly_G_K	TS_out
1.00	TS_in	Pearson correlation	1	–0.475**	0.183
		Sig. (2-tailed)		0.000	0.132
		N	69	69	69
	Poly_G_K	Pearson correlation	–0.475**	1	0.633**
		Sig. (2-tailed)	0.000		0.000
		N	69	69	69
	TS_out	Pearson correlation	0.183	0.633**	1
		Sig. (2-tailed)	0.132	0.000	
		N	69	69	69

At speed 1 rpm, polymer dose has shown a significant inverse relation with TS inlet (–0.475) and a significant direct relation with TS outlet (0.633).

S_RPM			TS_in	Poly_G_K	TS_out
1.50	TS_in	Pearson correlation	1	–0.640**	–0.187
		Sig. (2-tailed)		0.000	0.218
		N	45	45	45
	Poly_G_K	Pearson correlation	–0.640**	1	0.755**
		Sig. (2-tailed)	0.000		0.000
		N	45	45	45
	TS_out	Pearson correlation	–0.187	0.755**	1
		Sig. (2-tailed)	0.218	0.000	
		N	45	45	45

At speed 1.5 rpm, polymer dose has shown a significant inverse relation with TS inlet (–0.64) and a significant direct relation with TS outlet (0.755).

S_RPM			TS_in	Poly_G_K	TS_out
2.00	TS_in	Pearson correlation	1	–0.358*	–0.347*
		Sig. (2-tailed)		0.015	0.018
		N	46	46	46
	Poly_G_K	Pearson correlation	–0.358*	1	–0.084
		Sig. (2-tailed)	0.015		0.580
		N	46	46	46
	TS_out	Pearson correlation	–0.347*	–0.084	1
		Sig. (2-tailed)	0.018	0.580	
		N	46	46	46

At speed 2 rpm, TS inlet has shown a significant inverse relation with both TS outlet (–0.347) and polymer dose (–0.353).

S_RPM			TS_in	Poly_G_K	TS_out
2.50	TS_in	Pearson correlation	1	–0.590**	0.137
		Sig. (2-tailed)		0.000	0.334
		N	52	52	52
	Poly_G_K	Pearson correlation	–0.590**	1	–0.177
		Sig. (2-tailed)	0.000		0.209
		N	52	52	52
	TS_out	Pearson correlation	0.137	–0.177	1
		Sig. (2-tailed)	0.334	0.209	
		N	52	52	52

At speed 2.5 rpm, TS inlet has shown a significant inverse relation with the polymer dose (–0.59).

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

At speed 0.55 rpm, polymer dose has shown a significant inverse relation with TS inlet (–0.751) and a significant direct relation with TS outlet (0.507). At speed 1 rpm, polymer dose has shown a significant inverse relation with TS inlet (–0.475) and a significant direct relation with TS outlet (0.633). At speed 1.5 rpm, polymer dose has shown a significant inverse relation with TS inlet (–0.64) and a significant direct relation with TS outlet (0.755). At speed 2 rpm, TS inlet has shown a significant inverse relation with both TS outlet (–0.347) and polymer dose (–0.353). At speed 2.5 rpm, TS inlet has shown a significant inverse relation with the polymer dose (–0.59).

Correlations

Correlations

		TS_in	Poly_G_K	TS_out	S_RPM
TS_in	Pearson correlation	1	–0.484**	–0.065	0.104
	Sig. (2-tailed)		0.000	0.288	0.089
	N	269	269	269	269
Poly_G_K	Pearson correlation	–0.484**	1	0.626**	–0.578**
	Sig. (2-tailed)	0.000		0.000	0.000
	N	269	269	269	269
TS_out	Pearson correlation	–0.065	0.626**	1	–0.455**
	Sig. (2-tailed)	0.288	0.000		0.000
	N	269	269	269	269
S_RPM	Pearson correlation	0.104	–0.578**	–0.455**	1
	Sig. (2-tailed)	0.089	0.000	0.000	
	N	269	269	269	269

**Correlation is significant at the 0.01 level (2-tailed).

Statistical analysis has shown a TS inlet has shown a direct non-significant relation with the machine speed (0.104) and inverse significant relation with the polymer dose (–0.484). TS outlet has shown a direct significant relation with polymer dose (0.626). The machine speeds (rpm) has shown an inverse relation with the polymer dose concentration and TS outlet calculated as –0.578 and –0.455, respectively.

The polymer concentrations have shown a direct significant relation with TS outlet (0.626) and an inverse significant relation with the machine speed (–0.455) and an inverse significant relation with the machine speed (–0.455).

T-Test

One-sample statistics

TS_in		N	Mean	Std. deviation	Std. error mean
0.4	TS_out	17	20.5471	0.72121	0.17492
0.5	TS_out	46	17.9630	2.87567	0.42399
0.6	TS_out	56	18.6018	2.17878	0.29115
0.7	TS_out	80	17.4063	2.14472	0.23979
0.8	TS_out	40	18.3725	1.89412	0.29949
0.9	TS_out	20	18.0450	2.28069	0.50998
1.0	TS_out	10	20.1000	0.93808	0.29665

One-sample test

TS_in		Test value = 18					
		t	*df*	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
						Lower	Upper
0.4	TS_out	14.561	16	0.000	2.54706	2.1762	2.9179
0.5	TS_out	–0.087	45	0.931	–0.03696	–0.8909	0.8170
0.6	TS_out	2.067	55	0.043	0.60179	0.0183	1.1853
0.7	TS_out	–2.476	79	0.015	–0.59375	–1.0710	–0.1165
0.8	TS_out	1.244	39	0.221	0.37250	–0.2333	0.9783
0.9	TS_out	0.088	19	0.931	0.04500	–1.0224	1.1124
1.0	TS_out	7.079	9	0.000	2.10000	1.4289	2.7711

T-Test

One-sample test							
TS_in		Test value = 19					
		t	*df*	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
						Lower	Upper
0.4	TS_out	8.844	16	0.000	1.54706	1.1762	10.9179
.5	TS_out	–2.446	45	0.018	–1.03696	–1.8909	–0.1830
0.6	TS_out	–1.368	55	0.177	–0.39821	–0.9817	0.1853
0.7	TS_out	–6.647	79	0.000	–1.59375	–2.0710	–1.1165
0.8	TS_out	–2.095	39	0.043	–0.62750	–1.2333	–0.0217
0.9	TS_out	–1.873	19	0.077	–0.95500	–2.0224	0.1124
1.0	TS_out	3.708	9	0.005	1.10000	0.4289	1.7711

T-Test

One-sample test							
TS_in		Test value = 20					
		t	*df*	Sig. (2-tailed)	Mean difference	95% confidence interval of the difference	
						Lower	Upper
0.4	TS_out	3.127	16	0.006	0.54706	0.1762	0.9179
0.5	TS_out	–4.804	45	0.000	–2.03696	–2.8909	–1.1830
0.6	TS_out	–4.802	55	0.000	–1.39821	–1.9817	–0.8147
0.7	TS_out	–10.817	79	0.000	–2.59375	–3.0710	–2.1165
0.8	TS_out	–5.434	39	0.000	–1.62750	–2.2333	–1.0217
0.9	TS_out	–3.833	19	0.001	–1.95500	–3.0224	–0.8876
1.0	TS_out	0.337	9	0.744	0.10000	–0.5711	0.7711