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EFFICIENCY OF A RADIAL PRIMARY CLARIFIER FOR MUNICIPAL WASTEWATER

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Abstract

The prime method to combat water pollution, and a means to improve the quality of wastewater, is the wastewater treatment process, which is now widely used. The common method of mechanical (primary) treatment is (conventional) sedimentation at rest. Decanters (also called sedimentation tanks or clarifiers) are an integral part of every wastewater treatment plant. The present work aims to determine the performance of a radial primary clarifier in an urban wastewater treatment plant in Romania for the year 2020. The determinations were carried out for one winter month (January) and one summer month (July), and for the other calendar months the average inlet and outlet concentrations of the clarifier were determined. For each day of January and July, the concentrations of impurities (mg/L) in the wastewater at the inlet of the decanter (ci) and in the clarified water at the outlet of the decanter were recorded, based on which the separation efficiency of decanter could be determined. To improve the primary settling efficiency, the use of coagulating agents (iron and aluminium solutions) is recommended.

***Key words**: efficiency, radial clarifier, sedimentation wastewater.*

INTRODUCTION

The biggest problem facing humankind right now is extreme environmental pollution. The natural environment is progressively getting worse and that ecological systems cannot respond to the pressure from anthropogenic factors, making the ecosphere's ability to regulate itself, impossible.

As infrastructure and regulatory development has been left behind by population expansion and urbanisation, urban wastewater management has become difficult in many countries (Saravanane et al., 2014).

Large cities started to realize they needed to decrease the number of pollutants found in the water that needed to be released into the environment in the 19th century, which is when wastewater treatment industries first emerged. Even though fresh water sources were abundant, and the water had an inherent ability to naturally purify itself over time, communities were so closely knit by 1850 that deadly disease outbreaks were blamed on bacteria in the contaminated water (Phumelele & Kallon, 2021). Since then, the most advanced biological, physical, chemical, and mechanical techniques have been used to establish and enhance wastewater collection and treatment practices. The public's health and the water's cleanliness are thus better safeguarded than ever.

Wherever people live, there is a continuous need for fresh drinking water and a constant production of waste. Thus, drinking water supply and wastewater management have been essential to the success of human society (Holger et al., 2006).

Advanced technologies and some conventional industrial facilities are used to satisfy food and basic human demands (physical, social, and psychological). Whether food factories or other industrial establishments, these entities emit waste into the environment, continuously discharging colossal quantities of wastewater, pumped straight into rivers and oceans. The consequences are dramatic - besides damaging the marine environment and fisheries, little is being done to conserve water at a moment when so many predict that global water scarcity is about to take its toll (Anjum et al., 2016). One of the biggest barriers to a sustainable future for the entire globe is the rising demand for clean water.

The best methods for environmental preservation are being sought after at the European level. Wastewater treatment, currently the most common technique, is the main way to stop water pollution.

A major strategy for protecting water sources is wastewater management, understood as the collection, treatment and reuse of wastewater. Perhaps the most important piece of infrastructure, the wastewater collection network, can face several problems due to unwanted behaviour. Since wastewater treatment is a procedure that depends on a multitude of physical and chemical aspects, it is imperative to predict the variables in wastewater treatment plants. Treated urban wastewater has some restrictions but is an appropriate resource for distribution to various industries and uses like agriculture (Roozbahani, 2021).

Figure 1 illustrates the various processes or operating components that make up a WWTP, including: pre-treatment, primary and secondary treatment, sludge and tertiary treatment.

Particulate pollutants like solids, grit, and greases are primarily targeted for elimination during pre-treatment and primary treatment. Through biological and chemical mechanisms, secondary treatment removes phosphorus, nitrogen, and organic matter from sewage (Rashid, 2023). In some WWTPs, tertiary treatment is used to get rid of any last-minute tiny particles and pathogens.

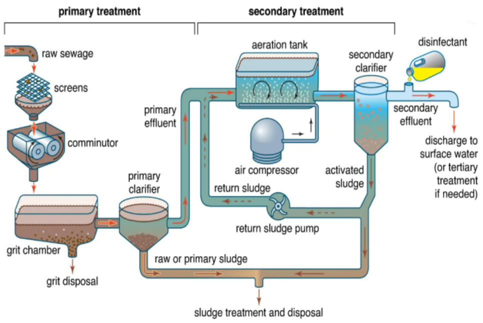

Figure 1. Flow diagram of the wastewater treatment process (https://www.britannica.com/technology/wastewater-treatment/Primary-treatment#/media/1/666611/19281)

Because most industries rely on water and having restricted access to clean water resources can affect both production capacity and profits, water management is a crucial component of any economy. The circular economy (CE), which implies sustainable management of raw materials (including water) and waste, emphasizes the importance of water problems (also wastewater) (Smol, 2002; Sandu et al., 2021).

Every strategy must now be created with consideration for the environment's global influence; if this factor is overlooked, environmental loads will change or have an effect, and no reduction will be made. Due to the integration of energy production and resource recovery during the production of clean water, urban wastewater treatment facilities can be a significant component of circular sustainability. Facilities for wastewater treatment will soon need to use "environmentally sustainable" technical solutions. Global nutrient requirements as well as water and energy recovery from wastewater are currently the primary forces driving the development of the wastewater industry (Neczaj & Grosser, 2018).

Particle separation plays a significant role in wastewater purification. This is because most pollutants in wastewater are particulate or colloidal in nature or change to these forms during the cleaning process. This has caused the wastewater treatment approach to first remove particulate and colloidal matter, and then deal with soluble compounds that need to be converted to particulate and colloidal matter. Traditionally, settling is used to perform particle separation in the first stage (Ødegaard, 1998).

The first experimental studies concentrated on the overall separation performance and efficiency of decanters. Therefore, the effectiveness of removing suspended solids relies on both the flow regime in the decanter and the physical characteristics of the solids (type and nature, particle size, density, and sedimentation velocity).

The separation of the liquid-solid mixture is dependent on many parameters linked to the solid component, the liquid component, and the design parameters of the decanter.

Andral et al. (1999) and Roger et al. (1998), show in their studies that particles with a diameter smaller than 50 μm made up 70-80% of the total amount of solid suspensions, and in 2002, Furumai and colleagues showed that particles with a diameter smaller than 20 μm made up more than 50% of the total amount of solid suspensions for experiments with total solid suspension concentrations lower than 100 mg/L. Wakeman (2011) noted that particles with a diameter of order a few microns decant very slowly and advised that they be coagulated for a while to increase effective dimension and, consequently, a while increase sedimentation rate (Wakeman, 2011). McNown et al. (1952) carried out one of the first studies to ascertain the impact of solid particle concentration on sedimentation velocity. Despite being qualitatively incompatible, their findings demonstrate that a decrease in particle settling velocity is caused by a rise in particle concentration (McNown & Lin, 1952).

Following research, Kinnear discovered that excess suspended solids in effluents rise as air temperature falls in 2004 (Kinnear, 2004).

According to Goula et al. (2008), a temperature differential of just 1°C is enough to reduce settling efficiency.

Throughout the settling process, a particle's sedimentation velocity increases until its own weight, which acts as a settling force, matches the opposing pressures. Due to the balance of the forces acting on the particle in this instance, (dvp/dt) = 0. Sedimentation velocity, an essential hydrodynamic quantity, plays an important role in both the technical design of the equipment used for the separation of heterogeneous systems by sedimentation and the characterization of particle motion (Gavrilă, 2001).

Sewage contains polluting substance in a variety of forms, which is complicated. The mixture also contains a heterogeneous dispersion of various substances (organic and inorganic), in colloidal, pseudo colloidal, and basic suspension forms, in addition to the dissolved impurities.

Most of the insoluble inorganic matter and the gross solid material are removed during the initial screening and grit removal processes, but the suspended matter, which is primarily organic and heavily polluting, continues to flow through the liquid. Processes for removing pollutants from wastewater frequently employ physical settling methods.

The first stage of wastewater purification traditionally uses primary settling to separate particles. According to Stokes law, particles down to about 30-50 μm will settle out at the usual velocity rates (around 2 m/h) and typical wastewater particle densities.

Primary settling removes about 50% of the suspended solids and 30% of the organic debris. A significant increase would be made if particles smaller than one micron could be removed (Ødegaard, 1998).

Primary settling tanks are an essential component of the biological wastewater and sludge treatment process (Patziger, 2016) and have been used widely to remove suspended solids (SS) by gravitational settling that are not removed by preliminary treatment (Christoulas, et al., 1998). The need for primary settling tanks, which are now required for both wastewater treatment and the production of renewable energy in the wastewater treatment plant in the form of biogas and electrical energy, is one of the factors affecting the overall construction costs of wastewater treatment facilities (WWTP).

The main objective of sedimentation is to separate sewage into the two components of settled sewage and sludge so that each can be treated separately, usually more successfully and affordably. Most of the time, sedimentation reduces the sewage's total polluting load by up to 50% (The Institute of Water Pollution Control, 1980).

In many unit processes in wastewater treatment plants, settling is a crucial process (WWTPs). Primary settling tanks (PSTs), which are treatment units before the biological reactor, and secondary settling tanks (SSTs), which are a clarification stage before discharge into a receiving water, are the two most well-known of these unit processes.

Additionally, settling is crucial in the development of novel technologies like granular sludge reactors (Torfs, 2016). The current study seeks to estimate the 2020 efficiency of a radial primary clarifier in a Romanian urban wastewater treatment facility.

The typical inlet and outlet concentrations of the clarifier were calculated for the remaining calendar months, and the measurements were made for one winter month (January) and one summer month (July).

MATERIALS AND METHODS

To assess the primary clarifier's efficiency in the winter (January) and the summer (July) of 2020, measurements were taken at one of the radial main clarifiers in the wastewater treatment facility.

The determinations were carried out for one winter month (January) and one summer month (July), and for the other calendar months the average inlet and outlet concentrations of the clarifier were determined. For each day of January and July, the concentrations of impurities (mg/L) in the wastewater at the inlet of the decanter (c_i) and in the clarified water at the outlet of the decanter were recorded, based on which the separation efficiency of decanter could be determined.

The radial clarifier has a structure comparable to that in Figure 2 and measures 55 meters in diameter, 8000 m^3, 7% invert slope, 0.8 meters in width, and 29 meters in length. Its peripheral velocity is 1.8 meters per minute.

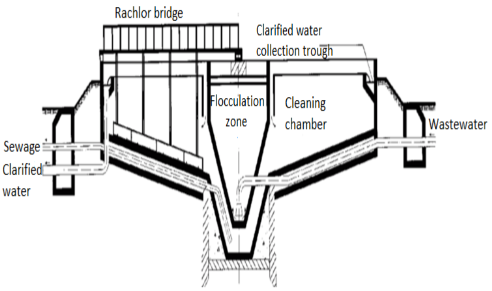

Figure 2. Radial clarifier

The separation efficiency of decanter E (%) was determined using the relation:

$$E = \frac{c_i - c_f}{c_i} \cdot 100$$

where:
- E is the separation efficiency (%);
- c_i - initial concentration (%);
- c_f - final concentration (%).

RESULTS AND DISCUSSIONS

Table 1 displays the values obtained from the measurements and includes the accompanying notations: T - wastewater temperature (ºC); c_i - concentration of the suspension at the inlet to the decanter (mg/L); c_f - suspension concentration decanter outlet (mg/L); E -separation efficiency (%).

For both January and July, M. Excel was used to process the data and show the efficiency variation over 31 days (Figure 3).

Table 1. Decanter inlet and outlet concentration values for January and July 2020

January				July			
T, ºC	c_i, mg/L	c_f, mg/L	E, %	T, ºC	c_i, mg/L	c_f, mg/L	E, %
≈ 10	159	79	50.31	≈ 23	179	85	52.51
	128	69	46.09		147	76	48.29
	227	87	61.67		161	83	48.44
	261	105	59.77		167	67	59.88
	209	101	51.67		182	87	52.19
	175	87	50.86		266	92	65.41
	145	85	41.38		167	98	41.31
	179	86	51.96		255	78	69.41
	228	108	52.63		187	56	70.05
	192	79	58.85		218	59	72.93
	201	86	57.21		153	77	49.67
	377	115	69.49		137	79	42.33
	289	93	67.82		208	95	54.32
	187	87	53.47		157	87	44.58
	195	91	53.33		145	83	42.75
	176	94	46.59		239	87	63.59
	209	87	58.37		185	105	43.24
	287	85	70.38		175	85	51.42
	199	76	61.80		173	93	46.24
	197	89	54.82		276	94	65.94
	346	98	71.67		138	82	40.57
	222	104	53.15		195	87	55.38
	227	107	52.86		195	73	62.56
	182	115	36.81		202	72	64.35
	261	102	60.91		157	79	49.68
	189	89	52.91		279	81	70.96
	168	75	55.35		167	86	48.50
	209	97	53.58		186	71	61.82
	189	106	43.91		185	69	62.70
	227	119	47.57		279	65	76.70
	194	108	44.32		199	77	61.30

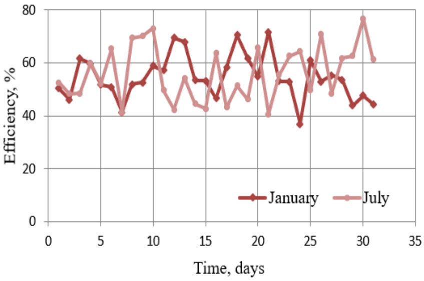

Figure 3. Efficiency variation for January and July, 2020

As can be seen, the higher the value of the solid particle concentration, the more efficient the settling process is (> 60%). The accumulation of particulate could be the cause of this. Uncontrolled discharges and abundant rains both contribute to higher settler inlet concentration levels. In January, efficiency was 54.56%, and in July, output was 56.10%.

The monthly decanter efficiency was determined based on the monthly average of the inlet and outlet concentrations for 2020. Table 2 displays the values that were found.

Table 2. Monthly average values for inlet concentration, outlet concentration and decanter efficiency

Month	Monthly average concentration c_i, mg/L	Monthly average concentration c_f, mg/L	Monthly decanter efficiency E, %
January	209.74	95.28	54.57
February	198.65	115.50	41.86
March	217.55	117.50	45.99
April	250.14	129.40	48.27
May	240.22	118.95	50.48
June	215.74	108.52	49.70
July	199.94	81.49	59.24
August	194.28	97.35	49.89
September	195.87	105.45	46.16
October	222.25	118.75	46.57
November	205.25	109.78	46.51
December	235.40	127.45	45.86

Figure 4 illustrates the decanter efficiency forecast for 2020, which is predicted to be 48.75%.

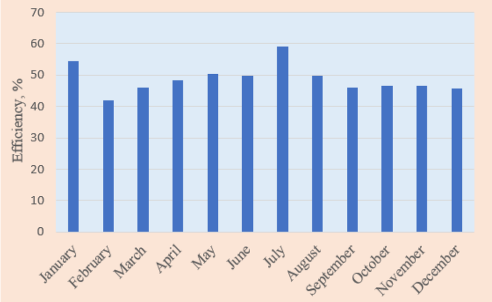

Figure 4. Efficiency of the decanting process for year 2020

Coagulating agents (solutions of iron and aluminium) are suggested to increase the effectiveness of the main settling process.

From the foregoing, decanter efficiency does not inherently correlate with atmospheric temperature, although mean efficiency in summer months is marginally greater than in lower temperature months.

CONCLUSIONS

One of the biggest barriers to a sustainable future for the entire globe is the rising demand for clean water. Wastewater treatment, currently the most common technique, is the main way to stop water pollution.

The main objective of sedimentation is to separate sewage into the two components of settled sewage and sludge so that each can be treated separately, usually more successfully and affordably. Most of the time, sedimentation reduces the sewage's total polluting load by up to 50%.

The higher the value of the solid particle concentration, the more efficient the settling process is (> 60%). In January, efficiency was 54.56%, and in July, output was 56.10%.

To improve the efficiency of the primary settling procedure, coagulating agents (solutions of iron and aluminium) are advised.

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