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EVALUATION OF LINEZOLID ANTIBIOTIC REMOVAL FROM PHARMACEUTICAL WASTEWATER USING MEMBRANE TECHNOLOGY

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ABSTRACT

Once pharmaceutical wastes are released into the sewage network, antibiotics can have several negative effects, such as promoting the development of antibiotic-resistant bacteria and disrupting natural microbial communities in water bodies. Linezolid is particularly concerning because it is a broad-spectrum antibiotic that targets a wide range of bacteria, including those resistant to other antibiotics. This means that linezolid may be more likely to contribute to the decreasing the huge number of strains of bacteria in the environment, that are used to decrease BOD values in wastewater streams. Linezolid is manufactured at many sites in Egypt, the study was started at the end of 2021, and it continued until the first quarter of 2022, in a pharmaceutical factory located in El Obour city. In this work, Reverse Osmosis (RO) is used to remove pharmaceutical pollutants such as linezolid antibiotics from waste that is drained of the pharmaceutical facility. The Results show that RO can remove significant amounts of linezolid from wastewater, with removal efficiencies ranging from 78% to 95%. The removal efficiency is affected by several factors. The factors under investigation are temperature, initial concentration of the pollutant (linezolid antibiotic), conductivity, and the total hardness of the influent of the wastewater. The maximum removal efficiency was discussed according to the optimum parameter, temperature 26 Cº, initial concentration 3 ppb, conductivity 500 µS/cm, and finally the optimum total hardness was obtained at 140 ppm. The study explained the results that Linezolid is a relatively small molecule, with a molecular weight of 337.35 g/mol, which makes it a good candidate for removal by RO.

Keywords: Antibiotics; Reverse Osmosis; Waste Removal; Environmental Impacts.

INTRODUCTION

The pharmaceutical manufacturing process has an impact on the wastewater stream's pollutant burden as well. For instance, the equipment-washing wastewater stream is distinguished by a lower effluent flow and lower pollution load (weak stream) (Yangali-Quintanilla *et al.,* 2010). The effluent produced by the formulation process, on the other hand, is more severely contaminated and is frequently referred to as a strong stream. This is owing to the formulation effluent's low biodegradability, which is caused by the high concentration of active ingredients (Verma *et al.,* 2021).

The high toxicity of pharmaceutical wastewater and the presence of refractory compounds that prevent biodegradation make it harmful in most cases (Monachan *et al.,* 2022). If not handled properly, wastewater treatment facilities and the ecosystem could suffer. Medicinal compound production often comprises several stages, including the fermentation, extraction, and primarily chemical synthesis of natural molecules into pharmaceutical components. Formulation and packaging of the finished product come after these first procedures (Rodriguez-Mozaz *et al.,* 2015).

It has been stated that 200 to 30,000 kg of waste can often be generated for every kilogram of active ingredient produced in the production of pharmaceuticals, which is a large increase above the amount of the actual completed product (Al-Rifai *et al.,* 2007). The type of drug manufacturing, the materials utilized in the production, and the actual processes involved all have an impact on the makeup of these pharmaceutical by-products (Liu *et al.,* 2022). They can consist of biological materials such as fermentation wastes, surplus extraction solvents left over after isolating and purifying active ingredients from natural sources, pharmacologically active substances such as anticoagulants and chemotherapeutic agents, as well as cleaning and disinfecting agents that are used to sterilize equipment (Beier *et al.,* 2010).

The increasing use of antibiotics in human and veterinary medicine has led to an increase in the number of antibiotics that end up in the environment. Pharmaceutical wastewater is one of the main sources of antibiotic residues in the environment (Dolar, *et al*., 2012). Antibiotic residues in the environment can lead to the development of antibiotic-resistant bacteria, which is a significant public health concern. Linezolid is a potent antibiotic that is commonly used in the treatment of infections caused by resistant bacteria, such as Methicillin-Resistant Staphylococcus Aureus (MRSA) and Vancomycin-Resistant Enterococci (VRE) (Dolar, *et al.,* 2012).

Reverse osmosis (RO) is one of the treatment methods that can effectively remove antibiotics like linezolid from wastewater. RO is a membrane-based process that uses pressure to force water through a semipermeable membrane, which selectively removes impurities and contaminants. The membrane has pore sizes that are small enough to trap bacteria, viruses, and other particles, including antibiotics (Reddy *et al.*, 2019).

Reverse osmosis (RO) membrane technology is a promising approach for the removal of antibiotic residues from pharmaceutical wastewater. RO technology uses a semi-permeable membrane to remove dissolved solids, organic compounds, and other contaminants from water. In recent years, RO technology has gained popularity in the treatment of pharmaceutical wastewater due to its high efficiency and low cost.

Reverse osmosis (RO) membrane technology is a promising approach for the removal of antibiotic residues from wastewater (de Ilurdoz *et al.*, 2022). RO technology uses a semi-permeable membrane to remove dissolved solids, organic compounds, and other contaminants from water. The principle behind RO is based on the natural phenomenon of osmosis, which occurs when two solutions of different concentrations are separated by a semi-permeable membrane. Water molecules move from the low-concentration solution to the high-concentration solution until the concentrations become equal. RO works by reversing the direction of osmosis using pressure. When pressure is applied to the high-concentration solution (Phoon *et al.*, 2020), water molecules are forced through the semi-permeable membrane to the low-concentration solution, leaving behind contaminants that are too large to pass through the membrane (Ishore, *et al.*, 2022).

The presence of linezolid antibiotic residues in wastewater can pose a risk to the development of antibiotic-resistant bacteria (Monachan *et al.*, 2022). Therefore, the development of efficient and cost-effective technologies for the removal of linezolid from wastewater is of great importance.

The efficiency of RO membrane technology for the removal of linezolid from wastewater is dependent on several factors, including feed flow rate, feed concentration, pressure, and pH. The feed flow rate is the rate at which the wastewater is fed into the RO system. The feed concentration refers to the concentration of linezolid in the wastewater (Monachan *et al.*, 2022). The pressure is the force applied to the high-concentration solution to reverse the osmotic flow. The pH of the wastewater can also affect the removal efficiency of linezolid, as the charge of the linezolid molecule can change depending on the pH of the solution (Benner *et al.*, 2008).

The issue is presence of linezolid antibiotics in pharmaceutical wastewater is a significant scientific issue due to its potential impact on the environment and public health. Pharmaceuticals, including antibiotics like linezolid, are often excreted unchanged from the human body and can end up in wastewater treatment plants. While these plants are designed to remove organic and inorganic contaminants from wastewater, they may not be effective in removing all types of pharmaceuticals. In addition to its potential impact on public health, linezolid in pharmaceutical wastewater can also have ecological effects (Sui *et al.*, 2010). For example, it may accumulate in aquatic organisms, leading to potential toxic effects and disrupting food webs. Linezolid can also persist in the environment for a long time, meaning that even low levels of exposure over an extended period could have negative effects.

Probably water sampling and the method of Liquid chromatography (LC) is a powerful analytical technique used to separate, identify, and quantify the components of a complex mixture. It is commonly used in the pharmaceutical industry to identify and quantify drugs and their metabolites (Rodriguez-Mozaz *et al*., 2015).

The study aims to evaluate the efficiency of RO membrane technology in removing linezolid antibiotic residues from pharmaceutical wastewater. The study investigates the effects of various operational parameters, such as feed flow rate, feed concentration, and pressure, on the removal efficiency of linezolid antibiotics. Another study investigated the effect of pH on the removal efficiency of linezolid antibiotics (Urtiaga *et al.*, 2013).

The findings of this study contribute to the development of more efficient and cost-effective technologies for the removal of antibiotic residues from pharmaceutical wastewater. The results of this study may also provide insights into the mechanisms involved in the removal of antibiotic residues by RO membrane technology. Ultimately, this study may help to mitigate the environmental impact of antibiotic residues and reduce the risk of the development of antibiotic-resistant bacteria (Ghazal *et al.*, 2022).

Overall, the scientific issue of linezolid antibiotic pollutants in pharmaceutical wastewater highlights the need for effective treatment methods to remove pharmaceuticals from wastewater and prevent their release into the environment (Al-Rifai *et al.*, 2007). It also underscores the importance of promoting the responsible use and disposal of antibiotics to reduce the risk of environmental contamination and antibiotic resistance (Liu *et al.*, 2022).

MATERIAL AND METHODS

The following steps can be taken to identify linezolid antibiotics using liquid chromatography: The sample containing linezolid antibiotic needs to be extracted and purified before analysis. This involves the addition of a solvent to the sample, followed by centrifugation or filtration to remove any solid impurities. The resulting solution is then ready for analysis by LC (Yangali-Quintanilla *et al.*, 2010).

Selection of the chromatography column: A reverse-phase chromatography column is commonly used to separate linezolid from other components in the sample. The column’s stationary phase consists of a nonpolar material, while the mobile phase is a polar solvent. This difference in polarity enables the separation of linezolid from other components in the sample (Beier *et al.*, 2010).

Mobile phase preparation: The mobile phase is prepared by mixing a polar solvent, such as water, with a nonpolar solvent, such as acetonitrile, in a specific ratio. The ratio of the solvents is adjusted to optimize the separation of linezolid (Yangali-Quintanilla *et al.*, 2010).

Injection and separation: The sample containing linezolid is injected into the column, and the mobile phase is allowed to flow through the column. As the mobile phase flows through the column, the components in the sample are separated based on their polarity. Linezolid antibiotic is retained in the stationary phase, while other components in the sample elute first(Reddy *et al.,* 2019).

Detection: Once linezolid is separated from the other components in the sample, it needs to be detected. A common detection method is ultraviolet (UV) absorption. Linezolid has a characteristic absorption spectrum, which can be used to identify and quantify it in the sample. Other detection methods, such as mass spectrometry, can also be used for greater sensitivity and specificity (Verma *et al*., 2021).

a) **Stock standard solution:** The Linezolid working standard sample was weighed accurately at 73.3 mg in a 1000 ml volumetric flask and diluted to the volume with the solvent methanol.

b) **Standard solution:** The sample was diluted 1 ml of the stock standard solution into a 10 ml volumetric flask, complete the volume with the solvent methanol, and mix well.

c) **Stock test solution:** The sample weight is 73.3 mg of the linezolid working standard /500 ml, so the concentration will be 0.146 mg/ml, then take 5 ml from this solution (actually = 0.733 mg) and dilute it to 10 ml, so the concentration will be 0.0733 mg/ml) and spray all 10 ml on 5 cm X 5 cm = 25 cm² of a sheet of stainless steel, then leave it to dry.

- **Sampling Procedures and Precautions:**

When selecting sample locations for wastewater monitoring in a pharmaceutical factory, it is important to consider several factors to ensure representative and meaningful data is obtained.

Regulatory requirements: First and foremost, it is important to review local and national regulations regarding wastewater monitoring in pharmaceutical factories. Regulations may dictate the number of sampling locations, frequency of monitoring, and specific parameters to be tested.

Wastewater generation points: It is important to identify all points in the pharmaceutical factory where wastewater is generated, such as process equipment, washrooms, and laboratories. Sampling points should be selected at key points in the wastewater network, such as before and after treatment processes, to capture changes in wastewater quality.

Flow rate: The flow rate of wastewater at each sampling point should be considered to ensure that an appropriate volume of wastewater is collected. If the flow rate is too low, collecting a representative sample cannot be collected (Dolar, *et al.*, 2012).

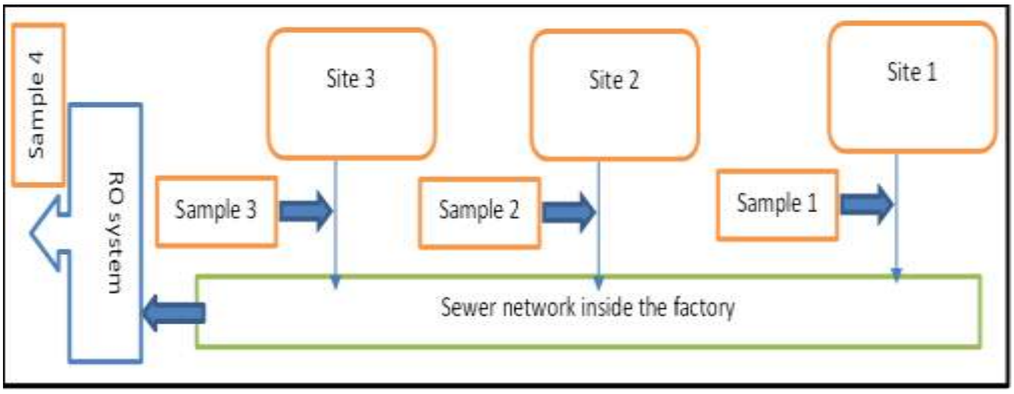


Fig. (1): The factory layout for manufacturing sites and sample locations.

Variability: Wastewater composition can vary significantly over time due to changes in production processes, cleaning procedures, and other factors. Sampling locations should be selected to capture this variability, such as sampling during peak production periods or after the use of certain chemicals.

Accessibility and safety, Sampling locations should be easily accessible to personnel and should be in areas that are safe to access. This may involve avoiding areas with hazardous chemicals, ensuring proper ventilation, and providing personal protective equipment (Dolar, *et al*., 2012).

Analysis requirements: The selection of sampling locations should consider the specific parameters that need to be analyzed. For example, if heavy metals are a concern, sampling locations should be selected in areas where these metals are likely to be present.

Record keeping: It is important to maintain accurate records of the location, date, time, and volume of each wastewater sample collected (Urtiaga *et al*., 2013). This information can be used to identify trends over time and to track changes in wastewater quality.

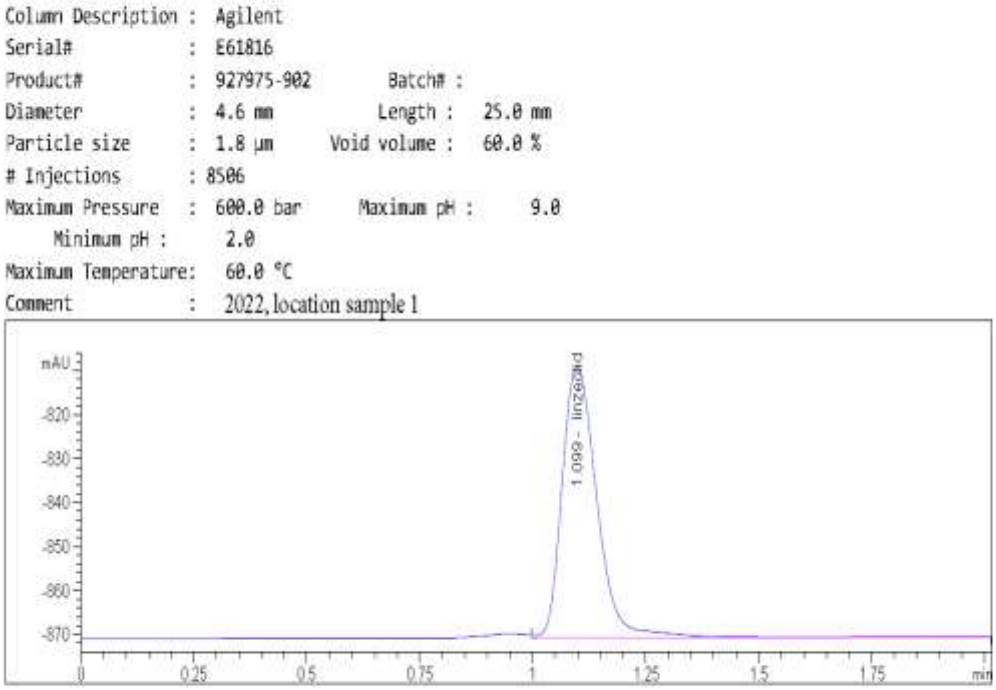
RESULTS AND DISCUSSION.

Studies have shown that removal efficiency can depend on several factors, such as the characteristics of the wastewater and the operating conditions of the RO system (Hashemian *et al*., 2018).

It's worth noting that while RO can effectively remove linezolid from wastewater, it may not be the most sustainable or cost-effective treatment method (Ahmed et al., 2015). RO can be energy-intensive and produce concentrated brine waste, which can be challenging to dispose of properly. Therefore, a combination of treatment methods may be necessary to achieve the desired level of linezolid removal while minimizing environmental impact.

The following layout is for the pharmaceutical factory located in El Obour city that is under investigation.

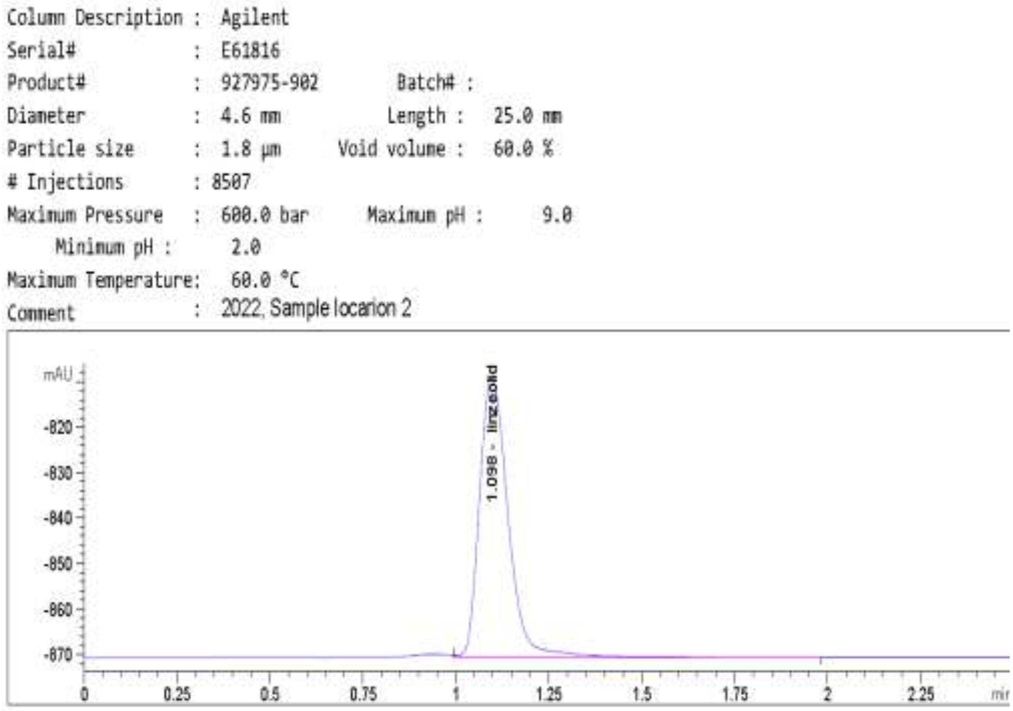
- **Measuring the Concentration of linezolid in sample locations.**
- **<u>Location 1:</u>**



Column Description : Agilent
Serial# : E61816
Product# : 927975-902 Batch# :
Diameter : 4.6 mm Length : 25.0 mm
Particle size : 1.8 µm Void volume : 60.0 %
Injections : 8506
Maximum Pressure : 600.0 bar Maximum pH : 9.0
Minimum pH : 2.0
Maximum Temperature: 60.0 °C
Comment : 2022, location sample 1

Fig. (2): The result of sample location (1) at the site (1), printed from HPLC Agilent E61816**.**

- **Location 2:**



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Column Description :  Agilent
Serial#            :  E61816
Product#           :  927975-902       Batch# :
Diameter           :  4.6 mm          Length :   25.0 mm
Particle size      :  1.8 µm     Void volume :   60.0 %
# Injections       : 8507
Maximum Pressure   :  600.0 bar     Maximum pH :      9.0
     Minimum pH :      2.0
Maximum Temperature:   60.0 °C
Comment            :  2022, Sample locarion 2
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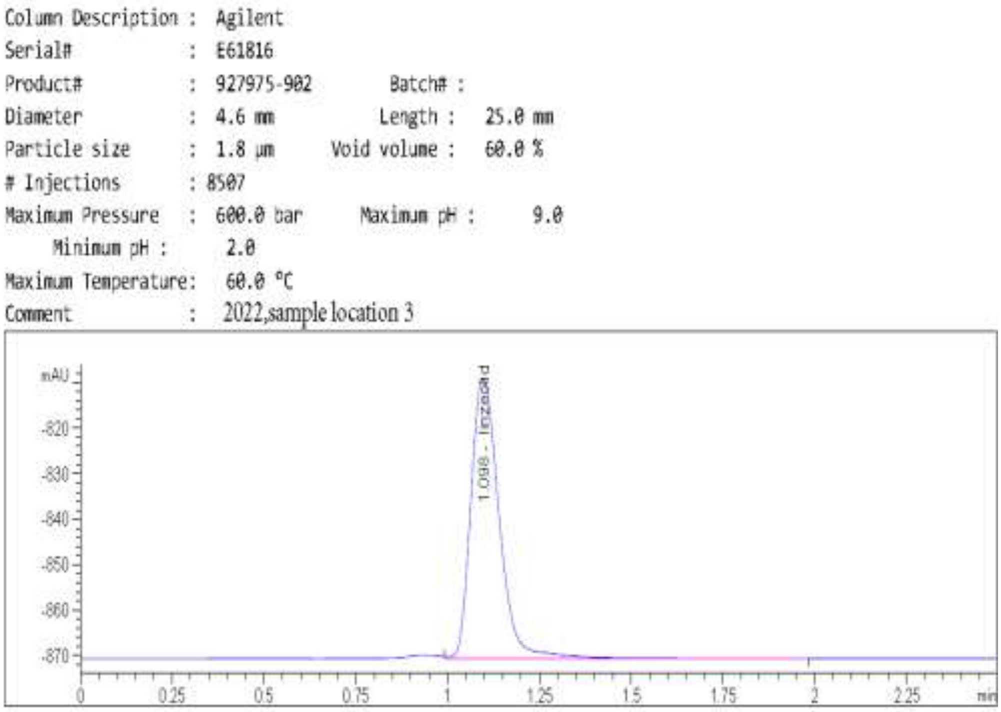
Fig. (3): The result of sample location (2) at the site (2), printed from HPLC Agilent E61816

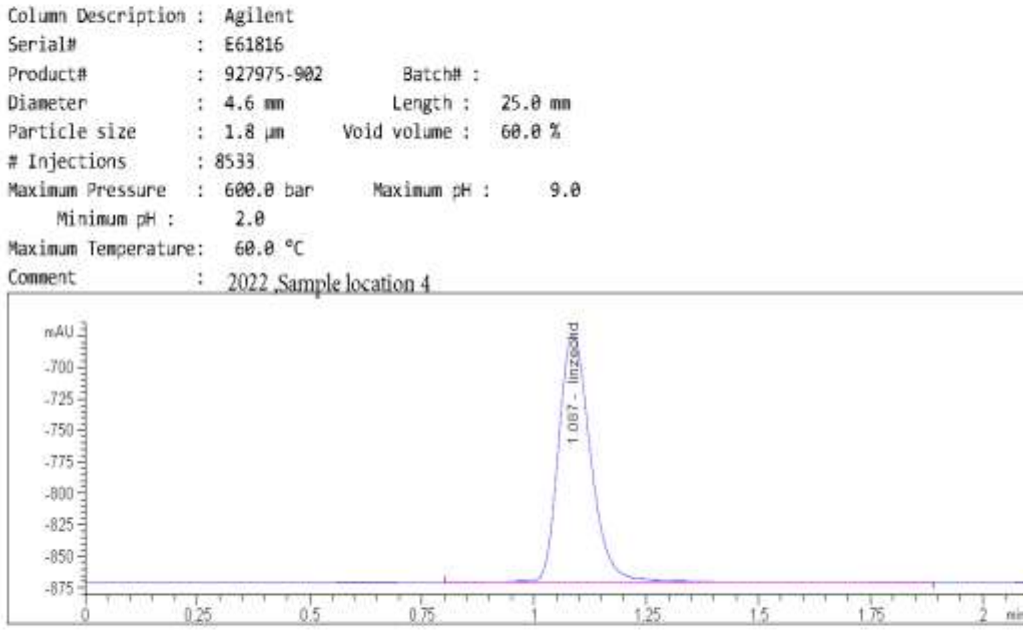
.**Location 3:**



Column Description : Agilent
Serial# : E61816
Product# : 927975-902 Batch# :
Diameter : 4.6 mm Length : 25.0 mm
Particle size : 1.8 µm Void volume : 60.0 %
Injections : 8507
Maximum Pressure : 600.0 bar Maximum pH : 9.0
Minimum pH : 2.0
Maximum Temperature: 60.0 °C
Comment : 2022,sample location 3

Fig. (4): The result of sample location (3) at the site (3), printed from HPLC Agilent E61816.

- **Location 4:**



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Column Description :  Agilent
Serial#            :  E61816
Product#           :  927975-902        Batch# :
Diameter           :  4.6 mm           Length :   25.0 mm
Particle size      :  1.8 µm      Void volume :   60.0 %
# Injections       : 8533
Maximum Pressure   :  600.0 bar      Maximum pH :      9.0
     Minimum pH :      2.0
Maximum Temperature:   60.0 °C
Comment            :  2022 Sample location 4
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Fig. (5): The result of sample location (4) at the site 4, printed from HPLC Agilent E61816.

- **<u>Effect of temperature.</u>**

Temperature can have a significant impact on the removal efficiency of linezolid antibiotics from pharmaceutical wastewater using reverse osmosis (RO) membrane technology (Ahmed et al., 2105). At lower temperatures, the viscosity of water increases, which can lead to decreased water flux through the RO membrane (Rivera-Utrilla et al., 2013). This decrease in water flux can result in lower removal efficiencies of linezolid. On the other hand, higher temperatures can increase the solubility of linezolid, which can increase the concentration of the antibiotic in the wastewater, making it more challenging to remove. Therefore, an optimum temperature needs to be maintained to achieve the maximum removal efficiency of linezolid (Kulkarni *et al*., 2014).

The efficiency of the reverse osmosis system (RO) is shown in Fig. (6) to be at its highest point at 26 C° and to gradually decline as the temperature of the feed stream is raised. Reverse osmosis (RO) is a membrane technology that separates solutes from a solvent by applying pressure to force water through a semi-permeable membrane. This process is widely used for the desalination and purification of water (Hashemian *et al*., 2018).

When the temperature of feed water to an RO system increases, several negative impacts can occur. The water flux, or rate of water flowing through the membrane, is also affected by temperature. Increasing the temperature of the feed water can cause an increase in the osmotic pressure of the feed water, which can lead to a reduction in water flux through the membrane. This can result in reduced efficiency of the RO process (Ghazal *et al*., 2022).

Effect of temperature of influent on removal percentage

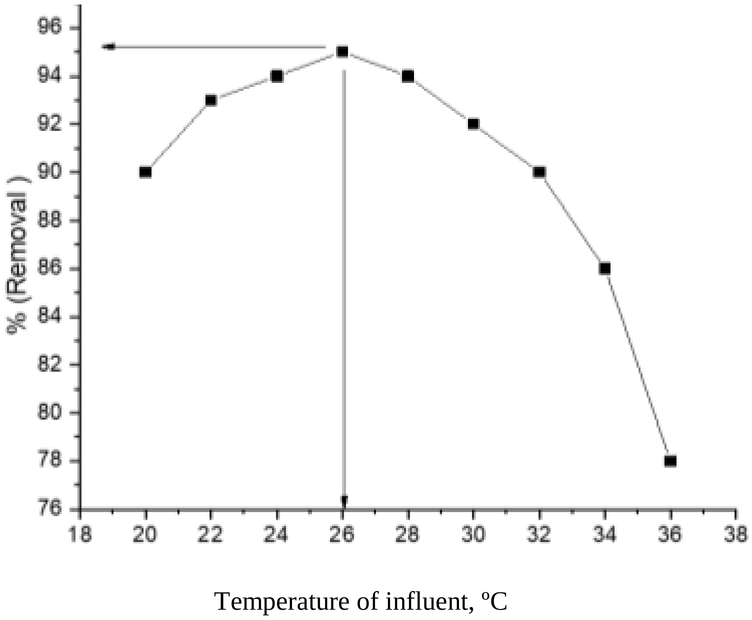


Fig. (6): The effect of temperature of the influent stream on the removal efficiency.

Accelerated membrane degradation: High temperatures can accelerate the rate of membrane degradation due to thermal oxidation, which can cause the membrane to become brittle and more prone to cracking (Ishore, et al., 2022). This can lead to reduced membrane life and increased maintenance costs (de Ilurdoz *et al.*, 2022).

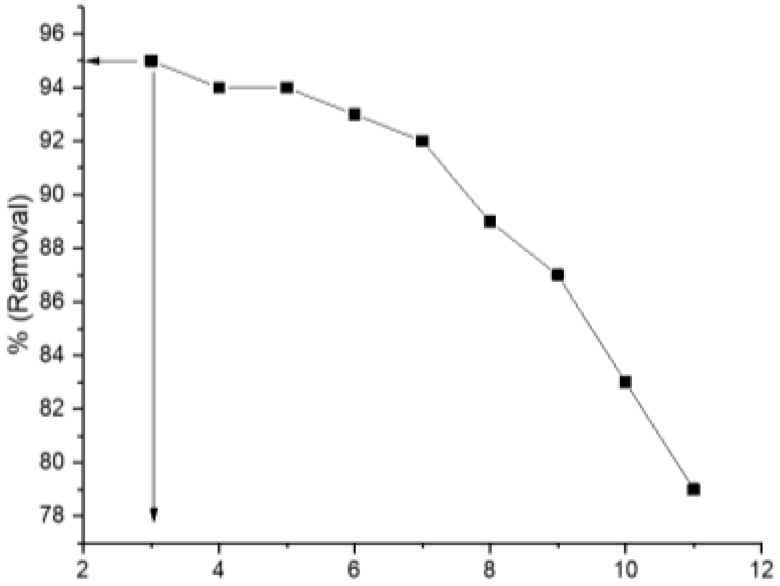
The results in fig.(6) show that the higher temperatures can promote biological and organic growth on the membrane surface, leading to biofouling and scaling that can decrease the efficiency of the RO system. Therefore, it is recommended to operate RO systems at lower feed water temperatures to optimize performance and extend membrane life (Monachan *et al.*, 2022).

- **<u>Effect of initial concentration.</u>**

The initial concentration of linezolid in pharmaceutical wastewater is one of the critical parameters that affect the removal efficiency of linezolid using RO membrane technology. The higher the concentration of linezolid in the wastewater, the more difficult it is to remove the antibiotic using RO (de Ilurdoz *et al.,* 2022). When the initial concentration of linezolid is low, the removal efficiency is high. Therefore, it is essential to optimize the feed concentration of the wastewater to achieve the maximum removal efficiency of linezolid (Ishore, *et al.,* 2022) .

The results in figure (7) illustrates that the removal efficiency of linezolid antibiotic is inversely proportional to increasing in the initial concentration. The highest removal efficiency of value 95% was obtained at the lowers tinction concentration of 3 ppb.

Effect of Initial concentration of influent on removal percentage.



Initial concentration of influent, ppb.

Fig. (7): The effect of temperature of the influent stream on the removal efficiency.

Increasing the initial concentration of a linezolid antibiotic pollutant in RO feed water can have several negative impacts on membrane technology (Monachan *et al.,* 2022).

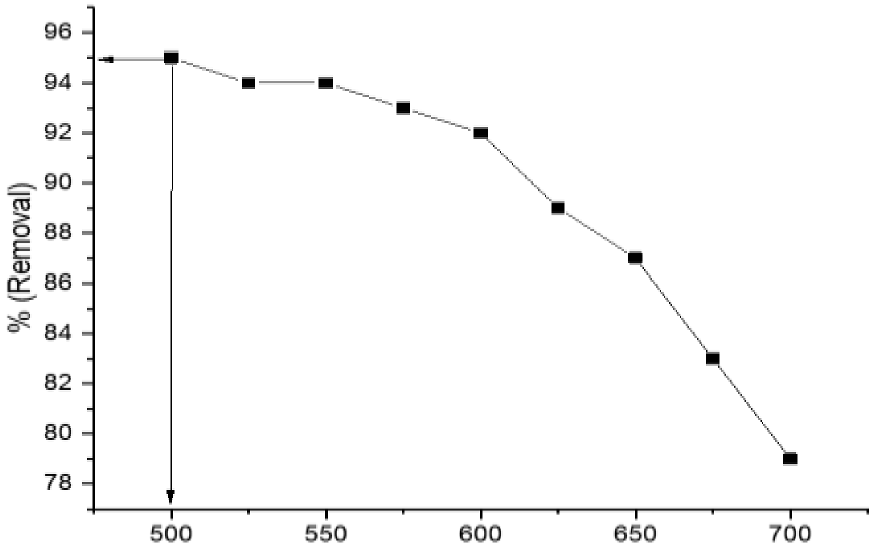
Membrane fouling: Linezolid is a large molecule that can easily adsorb onto the surface of the RO membrane, leading to membrane fouling. As the concentration of the linezolid pollutant increases, the fouling rate of the membrane also increases. This can result in reduced water flux and membrane performance, and increased energy consumption (Benner *et al.*, 2008).

Membrane scaling: Linezolid is also known to cause membrane scaling due to its tendency to form crystalline deposits on the membrane surface. As the concentration of the linezolid pollutant increases, the scaling rate of the membrane also increases. This can lead to a reduction in water flux and membrane life.

- **Effect of conductivity.**

The electrical conductivity of water is a measure of the ability of water to conduct an electric current. The conductivity of incoming water can affect the removal efficiency of linezolid from pharmaceutical wastewater (Dolar et al., 2009). Higher conductivity of incoming water can cause fouling and scaling of the RO membrane, which can reduce the water flux through the membrane and, in turn, the removal efficiency of linezolid (Sui et al., 2010). Therefore, incoming water must be treated to remove the dissolved salts and other contaminants that contribute to high conductivity.

Effect of conductivity of influent on removal percentage.



Conductivity of influent, µS/cm.

Fig. (8): Effect of the conductivities on the removal efficiency.

Fig. (8) shows that the removal effectiveness of the antibiotic linezolid decreases as the conductivity of the feed wastewater increases. The lowest influent conductivity of 500 µS/cm yielded a maximum removal efficiency of 95 percent.

- **<u>Effect of Total Hardness :</u>**Hardness in water is caused by the presence of minerals such as calcium and magnesium. The hardness of the incoming water can affect the removal efficiency of linezolid antibiotics from pharmaceutical wastewater (Ahmed *et al.*, 2015). High levels of hardness in the incoming water can cause scaling and fouling of the RO membrane, which can lead to a decrease in the removal efficiency of linezolid. The water must be treated to remove the hardness-causing minerals to achieve the maximum removal efficiency of linezolid (Rivera-Utrilla *et al.*, 2013).

The results in fig.(9) illustrate how the amount of total hardness in the feed wastewater decreases the effectiveness of the linezolid antibiotic's removal. At a lower influent total hardness of 140 ppm, the greatest removal effectiveness of about 93 percent was achieved.

Effect of total hardness on removal percentage.

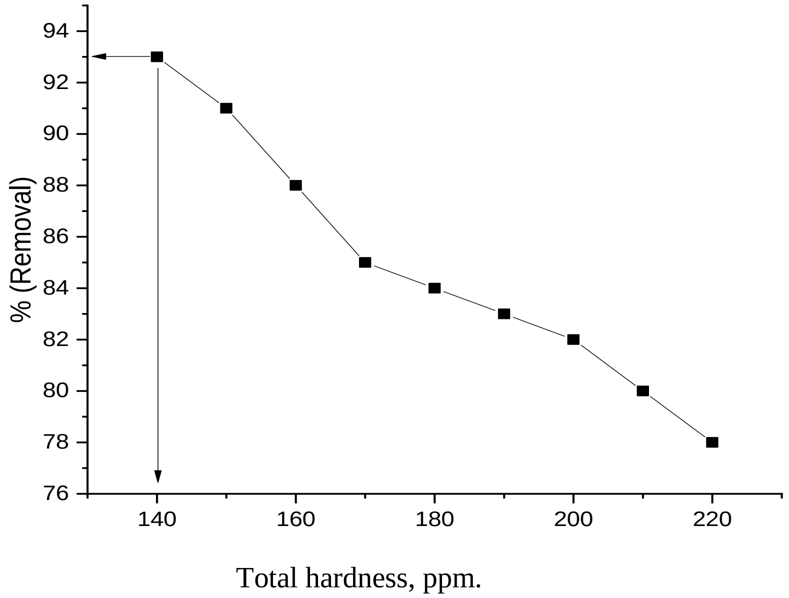


Fig. (9): Effect of the total hardness on the removal efficiency.

Figure 9 illustrates how the amount of total hardness of influent water containing linezolid antibiotic pollutants can have several negative impacts on membrane technology in reverse osmosis (RO) system: Membrane scaling: Hard water contains high levels of calcium and magnesium ions, which can combine with other ions to form insoluble salts that can precipitate onto the surface of the RO membrane (Hashemian *et al.*, 2018). This can lead to membrane scaling, which can reduce the effectiveness of the membrane and increase the pressure drop across the system (Hashemian et al., 2018). As the scaling on the membrane surface increases, the RO system will require more frequent cleaning, which can lead to increased downtime and reduced system efficiency (Košutić *et al.,* 2007).

Reduced water flux: Membrane scaling can also lead to a reduction in water flux, or the rate of water flow through the membrane(Košutić *et al.*, 2007). This is because the scaling can create a physical barrier that restricts the flow of water through the membrane. As a result, the RO system will require more energy to maintain the desired water production rate, which can increase operating costs(Košutić *et al.*, 2007).

Reduced membrane life: Membrane scaling can cause mechanical stress on the membrane surface, which can lead to damage and reduce membrane life. This can result in increased maintenance costs and downtime for replacement (Phoon *et al*., 2020).

Reduced effectiveness of membrane cleaning: High levels of total hardness can make it more difficult to effectively clean the RO membrane (Ghazal *et al.,* 2022). This is because the scaling can become embedded in the membrane material and resist removal by cleaning agents. Over time, the residual scaling can accumulate and decrease membrane performance. Therefore, it is recommended to remove the total hardness from influent water before it reaches the RO system (de Ilurdoz et al., 2022).

CONCLUSION

In summary, temperature, the concentration of the pollutant linezolid antibiotic, the conductivity of the incoming water, and the total hardness can all affect the percentage of linezolid antibiotic that is removed from pharmaceutical wastewater using reverse osmosis membrane technology. Optimizing these parameters is essential to achieve the maximum removal efficiency of linezolid from wastewater. Liquid chromatography is a powerful technique that can be used to identify and quantify linezolid antibiotics in a complex mixture. The process involves sample preparation, selection of the chromatography column, mobile phase preparation, injection and separation of the sample, and detection of linezolid using UV absorption or other detection methods. The selectivity of an RO membrane depends on its pore size and charge.

To mitigate the negative impacts of linezolid antibiotic pollutants on membrane workability and efficiency, it is recommended to treat the feed water with suitable pretreatment processes like activated carbon adsorption, or ultrafiltration. The potential environmental impact of the treatment method should be evaluated, including the generation of by-products and the impact on other pollutants present in the wastewater. This can be achieved by conducting toxicity tests on the treated effluent and assessing the impact of the treatment method on the ecosystem. The limitations of the study suggest areas for future research, which can include the development of new treatment methods, optimization of existing methods, or evaluation of the performance of the treatment method at a larger scale.

Finally, appropriate cleaning procedures should be implemented to prevent fouling and scaling of the RO membranes. Regular monitoring of the feed water and RO system performance is also necessary to identify any potential issues and take corrective action as required.

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تقييم إزالة المضاد الحيوى Linezolid من مياه الصرف الدوائية باستخدام تقنية الأغشية

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المستخلص

بمجرد إطلاق النفايات الصيدلانية في شبكة الصرف الصحي ، يمكن أن يكون للمضادات الحيوية العديد من الآثار السلبية ، مثل تعزيز تطوير البكتيريا المقاومة للمضادات الحيوية وتعطيل المجتمعات الميكروبية الطبيعية المفيدة في المسطحات المائية. يعتبر Linezolid مثيرًا للقلق بشكل خاص لأنه مضاد حيوي واسع الطيف يستهدف مجموعة واسعة من البكتيريا، بما في ذلك تلك المقاومة للمضادات الحيوية الأخرى. هذا يعني أنه من المرجح أن يساهم linezolid في تقليل العدد الهائل من سلالات البكتيريا في البيئة ، والتي تُستخدم لتقليل قيم BOD في تيارات مياه الصرف الصحي. في هذا العمل ، يتم استخدام التناضح العكسي (RO) لإزالة الملوثات الصيدلانية مثل المضادات الحيوية linezolid من النفايات التي يتم تصريفها من المنشأة الصيدلانية. تظهر النتائج أن التناضح العكسي يمكن أن يزيل كميات كبيرة من المخلفات الصلبة من مياه الصرف ، مع كفاءة إزالة تتراوح من ٧٨٪ إلى ٩٥٪. تتأثر كفاءة الإزالة بعدة عوامل. العوامل قيد البحث هي درجة الحرارة ، والتركيز الأولي للملوث (المضاد الحيوي linezolid) ، و التوصيلية الكهربائية ، و العسر الكلي لمياه الصرف الصحي. حيث تمت مناقشة كفاءة الإزالة القصوى وفقًا للمعامل الأمثل ، درجة الحرارة ٢٦ درجة مئوية ، التركيز المبدئي ٣ جزء في البليون ، التوصلية ٥٠٠الكهربائية ميكروسيمنز / سم، وأخيراً تم تحديد العسر الكلي الامثلى عند ١٤٠ جزء في المليون. أوضحت الدراسة النتائج أن Linezolid هو جزيء صغير نسبيًا ، بوزن جزيئي يبلغ ٣٣٧,٣٥ جم / مول، مما يجعله مرشحًا جيدًا للإزالة بواسطة RO.

الكلمات الرئيسية: المضادات الحيوية. التناضح العكسي؛ إزالة النفايات التأثيرات البيئية.