Al-Nahrain Journal of Science
ANJS, Vol.26 (1), March, 2023, pp. 15-20

Study of Drugs: Antibiotic and Study Mechanism and Adverse Effects

Haider K. Hussein[1], Ban A. Abdel Jabbar[1], Seenaa S. Amin[2], Asmaa A. Jawad[1,*], Ruqaya K. Abbas[3] and Shaymaa A. Jawad[4]

[1]Forensic DNA Research and Training Center, Al-Nahrain University, Jadriya, Baghdad, Iraq
[2]Department of Clinical Laboratory Sciences, College of Pharmacy, University of Baghdad, Baghdad, Iraq
[3]Ministry of Health, Central Children Hospital, Baghdad, Iraq
[4]Ministry of Health, Alshahid Mohammad Bagir Al-Hakeem Hospital. Baghdad. Iraq

Article's Information

Received:
31.10.2022
Accepted:
22.03.2023
Published:
31.03.2023

Keywords:
Drugs
Antibacterial
Bacteria
Antibiotic

DOI: 10.22401/ANJS.26.1.03

*Corresponding author: asmaa85ali@gmail.com

Abstract

A drug is any chemical substance that causes a change in an organism's physiology or psychology when consumed. Antibiotics are medicines that fight bacterial infections in people and animals. They work by killing the bacteria or by making it hard for the bacteria to grow and multiply. The antibiotic can class according to structure or action or basic. Every drug have side effects on body if use If taken incorrectly.

1. Introduction

Drugs are any chemicals that have an impact on how organisms and the microbes that infect them (such as bacteria, fungi, and viruses) function. The study of pharmaceuticals, or pharmacology, covers all aspects of a drug's use in medicine, such as its mechanism of action, physical and chemical characteristics, metabolism, treatments, and toxicity. In addition to providing a general review of the many medication types used in the treatment and prevention of human illnesses, this article concentrates on the principles of pharmacological action [1,2].

The approach to drug treatments was purely empirical up until the middle of the 19th century. This perspective evolved as the physiological analysis of the drug action mechanism and the first chemical investigations of naturally occurring medications were carried out. The development of the pharmaceutical sector and the creation of the first synthetic medications were heralded at the end of the 19th century. The most significant source of medicinal medications is now chemical synthesis. Through genetic engineering, a number of therapeutic proteins, including specific antibodies, have been created [3].

2. Mechanism of Drug Action

With only a few instances, a medicine must contact at the molecular level with a target component of the cell in order to impact the cell functions. The majority of the time, the interaction involves a weak, reversible binding of the drug molecule, while other medications have the ability to make strong chemical bonds with their target locations, producing effects that linger for a long time. Target molecules can be divided into three categories: receptors, macromolecules with particular physiological roles, such as enzymes, transporters, and nucleic acids, and membrane lipids [4,5].

In order to identify and react to the body's own (endogenous) chemical messengers, such as hormones or neurotransmitters, receptors are protein molecules. Drug molecules and sites may interact to start a chain of biochemical and physiological changes. The development of the drug-receptor complex, known as binding, and the effect's moderating process, known as receptor activation, are the two different processes involved in receptor-mediated pharmacological effects. A drug's propensity to bind to a receptor is described by the word affinity, but its effectiveness (also known as intrinsic activity) refers to its capacity to trigger a physiological response. A medication's potency is determined by both its affinity and its effectiveness [6].

Drugs that bind to receptors can either be agonists or antagonists depending on how well they work. An agonist is a medication that has effectiveness and affinity high enough to attach to a receptor and modify cell activity. An antagonist is a medication that has the affinity to bind to a receptor but lacks the effectiveness to cause a reaction. An

antagonist can counteract the effects of an agonist after it binds to a receptor [7].

3. Antibiotics

Antibiotics, a drug is a substance created by a living thing, often a microbe, that is toxic to other microorganisms. Typically, soil microorganisms produce antibiotics, which are probably used by living things to control the development of rival bacteria in complicated settings like soil. Penicillin, a substance that looked to be able to prevent bacterial development brought on by fungus, was discovered by Alexander Fleming in 1926. In 1939, Edward Chain and Howard Florey conducted human penicillin experiments after continuing their research on penicillin (with what were considered fatal bacterial infections). Fleming, Florey, and Chain shared the 1945 Nobel Prize for their role in establishing the antibiotic era [8, 9].

4. Class of Antibiotics

Antibacterial antibiotics are often categorized according to their mode of action, chemical makeup, or range of activity. Most attack bacterial mechanisms of growth or function. The penicillin's and cephalosporins effect on bacterial cell wall and the polymyxins that act on cell membrane. The lipiarmycins, rifamycins, quinolones, and sulfonamides have been activities of bactericidal interfere with essential bacterial enzymes. Those that target protein synthesis (macrolides, lincosamides and tetracyclines) are usually bacteriostatic (with the exception of bactericidal aminoglycosides) [9].

Depending on action mechanism, the antibiotics can be separated into two groups. Antibiotics plays a big role in inhibition of growth bacteria or reproduction to kill bacteria. Once of antibiotic types that contain Beta-lactam group in his structure can kill the bacteria by inhibiting of cell wall synthesis, such as penicillin derivatives (penams), cephalosporins (cephems), monobactams, and carbapenems) and vancomycin. Other type can inhibition of translation for enzymes or protein [10].

Daptomycin, fluoroquinolones, metronidazole, nitrofurantoin, co-trimoxazole [10], and telithromycin are additional batericidal medications. Antibiotics that include aminoglycosidic acids are often thought of being bactericidal, while they may also be bacteriostatic for particular species. The MBC, or minimum bactericidal concentration, is the lowest medication concentration at which 99.99% of the population may be killed alive.

4.1 Antibiotic classification based on chemical composition [11,12]:

1. Antibiotics that include carbohydrates.
2. Antibiotics made of pure saccharides, such as streptozotocin.
3. Streptomycin is an example of an aminoglycoside.
4. N/O glycosides, such as chloromycin.
5. Other, such as Lincomycin.
6. Antibiotics with macrocyclic lactones, such as erythromycin.
7. Antibiotics called quinolones, such as fluroquinolone.
8. Antibiotics that include N, such as beta-lactum.
9. Heterocyclic antibiotics containing O, such as cycloserine.
10. Antibiotics that are alicyclic, such cycloheximide.
11. Nitrobenzene-based aromatic antibiotics, such as chloramphenicol.
12. Antibiotics using aliphatic amines, such as spermidine.
13. Antibiotic peptides, such as Polymyxin, Bacitracin, and Gramicidin.

4.2 Classification of antibiotics based on place of manufacture [12,13]:

1. Polymyxin, Bacillus polymyxa.
2. Bacitracin for Chromobacter violaceum.
3. Gentamycin for Micromonospora species.
4. The antibiotic Penicillium notatum.
5. Cephalosporin species: Cephalosporin.
6. Streptomycin for Streptomyces griseus.
7. Chloramphenicol for S. venezuelue.
8. Erythromycin for S. erythreus.
9. Rifampicin for S. mediterranea.

4.3 Antibiotic classification based on range of action (spectrum of activity) [14]:

1. Narrow spectrum: Active against a smaller variety of bacteria. Macrolides and Polymyxin, for instance.
2. Moderate spectrum: Active against various systemic and UTI-causing Gram negative bacteria as well as Gram positive bacteria. Example: Sulfonamide with aminoglycosides.
3. Broad-narrow spectrum: Effective against both gram-positive and gram-negative bacteria. For instance, beta-lactum.
4. Broad spectrum: Effective against all bacteria except Pseudomonas and Mycobacteria, both Gram positive and Gram negative. examples: Tetracycline, chloramphenicol.
5. Antibiotics that fight mycobacteria, such as ethambutol, rifampin, isoniazid, and pyrazinamide.

4.4 Based on the mechanism of action classification:

1. Restrictors of protein synthesis [15]:

Tetracyclines, aminoglycosides, and macrolides are some of the major groups. Fundamental action mechanism; The bacterial ribosome (70 S), which is made up of a tiny 30 S and a big 50 S component, is the target of most antibiotics that stop protein synthesis. The complex, important molecule known as a ribosome, which is formed of RNA and proteins, is in charge of protein synthesis. Aminoglycosides, macrolides, and other protein synthesis inhibitors target and halt certain phases of protein synthesis at specific places on 70 S ribosomes. Bacteria perish

because the cell is unable to create the proteins required for essential biological processes [16].

Nucleic acid synthesis inhibitors:
Major categories: topoisomerase inhibitors and antifolates (floroquinolones)

Basic action mechanism: These antibiotics target several stages and routes involved in the production of nucleic acids (DNA, RNA, etc.). In conclusion, antifolates (including sulfonamides) prevent the production of folate/folic acid (vitamin B9) by inhibiting the enzymes involved. For the creation of pyrimidine and purines, two chemicals that are present in nucleotides, the building blocks of DNA and other nucleic acids, folate is a necessary component. Topoisomerase activity is suppressed by topoisomerase inhibitors, which stop DNA replication. Enzymes called toposiomerases reduce DNA supercoil stress during DNA replication. DNA replication is severely hampered and cell division is slowed down by suppressing topoisomerase activity [17].

Humans get folate via dietary; they lack a mechanism for its production and are not impacted via antifolates in the same manner that bacteria are. Human cells include topoisomerases, although they are different from bacterial topoisomerases in terms of their molecular structure (There may be more negative effects).

2. Inhibitors of cell wall production:
Big Beta-lactam groups, such as (cephalosporins, penicillins).

As their name implies, this class of antibiotics works by stopping specific processes that are necessary for the development of the bacterial cell wall. The bacterial cell wall contains an essential polymer known as peptidoglycan, which is especially critical in Gram-positive bacteria. Penicillin-binding proteins, also known as beta-lactam antibiotics, are important in the final stages of peptidoglycan production. When PBP activity is suppressed, peptididoglycan formation is inadequate and the cell lyses as a consequence.

Humans are not vulnerable to beta-lactam antibiotics because human cells do not utilize or produce peptidoglycan. (There may be more negative effects) [18].

5. Antibiotics of Drug

1. Penicillin: An antibiotic from the penicillin family known as penicillin V is used to treat bacterial infections in the body. One of the many bacterial diseases that penicillin is used to treat is an ear infection. When bacteria are in the active replication stage and sensitive to penicillin, penicillin G is bactericidal. It works by inhibiting the synthesis of mucopeptides on the cell wall. It is useless against staphylococcal strains and other bacteria that make penicillinase.
2. Mechanism of penicillin group: The bacterial plasma membrane is often surrounded by a peptidoglycan cell wall, which prevents osmotic lysis and provides structural stability. During replication and development, the peptidoglycan wall is constantly changing. The cell wall's peptidoglycan does not cross-link when penicillin is present. This procedure is sped up by penicillin-binding proteins like the DD-transpeptidase enzyme. The DD-transpeptidase may attach to the four-membered-lactam ring of penicillin, rendering it permanently inert. While a result, even as other proteins continue to degrade the wall, the bacteria are unable to form their cell walls [19,20].
3. 3. Adverse effects: If you have a sensitivity to penicillin V or any other penicillin antibiotic, including ampicillin (Omnipen, Principen), carbenicillin (Geocillin), dicloxacillin (Dycill, Dynapen), or oxacillin, do not use this drug (Bactocill).

Penicillin V and G side effects include rash, stomach discomfort, urticaria, nausea, vomiting, and diarrhoea. Along with these side effects, Penicillin G may also cause muscular cramps, fever, chills, muscle discomfort, headache, tachycardia, flushing, tachypnea, and hypotension. Hypersensitivity Reactions: Hypersensitivity, either with rapid or delayed onset, is a typical adverse medication response to penicillin [21].

- 20 minutes after administration, this kind of response starts to manifest itself. Urticaria, pruritis, edoema, laryngospasm, bronchospasm, hypotension, vascular collapse, and mortality are its defining symptoms.
- Delayed onset: This response happens 1-2 weeks after the start of therapy. Fever, malaise, urticaria, myalgia, arthralgia, stomach discomfort, and skin rashes are some of its unusual symptoms.
- Gastrointestinal System: GI problems were the most common and were reported in more than 1% of patients. GI difficulties are often encountered with oral treatment. These signs included stomatitis, vomiting, and nausea. Additionally, during or after the treatment, pseudomembranous colitis is seen.
- Hematologic Reactions: Patients who receive doses more than 10 million units per day or who have previously received larger doses may have neutropenia and hemolytic anaemia with Coombs positive results, which improve when medication is discontinued.
- Metabolic Reactions: When administered IV at a high dosage, the salt form of penicillin G may result in electrolyte abnormalities, such as hyperkalemia.
- Nervous System: Patients with compromised renal function are more prone to have neurological symptoms such as hyperreflexia, myoclonic twitches, seizures, and coma following IV dosages.
- Urogenital System: Renal tubular injury from high IV dosages is a urological symptom. Acute interstitial nephritis, a condition marked by inflammation of the kidneys' tubules and interstitium, may also be brought on by penicillins. Additionally, hematuria, fever, and rash might be symptoms of acute interstitial nephritis. Removing the medication is advised since, in this case, the condition may result in renal failure.

- Other: Giving penicillin to syphilis patients causes them to have a Jarisch-Herxheimer response.

Drug-drug interactions:
Because of their antagonistic effects, concurrent use of sulfonamides, erythromycin, and chloramphenicol should be avoided. Probenecid may prevent the tubular secretion of penicillin G, resulting in greater and longer plasma concentrations. By inhibiting tubular secretion, aspirin, phenylbutazone, sulfonamides, indomethacin, thiazide, furosemide, and ethacrynic acid prolong the half-life of penicillin. Additionally, probenecid lessens the amount of penicillin that is distributed [22].

5.2 Cephalosporins:

1. Cephalosporin antibiotics have long been a significant component of hospital antibiotic regimens in developed nations. They are advised daily for a wide variety of illnesses. Their undeniable success is based on a broad range of sports, as well as decreased allergy and toxicity hazards. Microorganisms that are resistant to these compounds may be selected, nonetheless, thanks to the aforementioned characteristic [23].
2. Mechanism of cephalosporins: Penicillin-binding proteins help bacteria create a stronger cell wall by cross-linking peptidoglycan units (PBP, peptidoglycan transpeptidase). A large family of bactericidal antimicrobials known as cephalosporins was first created from the fungus Cephalosporium sp. Their beta-lactam rings are what allow them to operate. The beta-lactam rings attach to the penicillin-binding protein, preventing it from performing its intended function. Those bacteria that cannot build a cell wall die [23,24].
3. Adverse effects: A wide variety of adverse effects, including nausea, vomiting, diarrhoea, yeast infection or oral thrush, dizziness, and stomach distress, may be brought on by cephalosporins.

A C. difficile infection is one of the most dangerous potential side effects. This infection generally develops after a lengthy treatment of antibiotics and has the potential to be fatal [24].

5.3 Fluoroquinolone:

1. Fluoroquinolone antibiotic: Certified antibiotics for severe, perhaps fatal bacterial infections are fluoroquinolones. As with other antibiotic medications, it is important to follow official recommendations for using antibacterial agents [26].
2. Mechanism of action: Because they block the activity of two DNA topoisomerases that are necessary for bacterial DNA replication but lacking in human cells, fluoroquinolones are both selective and bactericidal. These enzymes contribute to the production of bacterial DNA. The DNA topoisomerases are in charge of dividing the duplex strands of bacterial DNA, putting another strand of DNA through the break, and then re-sealing the first split strands [27].
3. Adverse effects: Significant dips in blood sugar levels, burst tendons, discomfort, "pins and needles" feelings, sadness, anxiety, suicidal thoughts, and other mental health difficulties are among the serious side effects that have been reported to the FDA. The aorta is the body's primary artery. Fluoroquinolones may cause major adverse effects, and around half of the patients who had them reported that they started after the first or second dosage. chronic pain, weakness, numbness, burning, tingling, and pain tendons, muscles, and joints might experience swelling, discomfort, and tendon rupture as symptoms. more than a year's worth of symptoms, depression, anxiety, or other mental health changes, Modifications in sensation or nerve injury in the hands, feet, arms, or legs dramatic reduction in quality of life, including marital conflict, financial difficulties, and job loss [26, 28].

5.4 Tetracycline:

1. In addition to being often used to treat respiratory tract infections, acne, and other skin diseases, tetracycline is also well recognized for its efficacy in treating urinary infections. Tetracyclines have been used to treat a wide range of gram-positive and gram-negative bacterial illnesses since the 1950s. Tetracyclines and a variety of non-infectious disorders have been used to treat infections brought on by intracellular chlamydiae, mycoplasmas, rickettsiae, and protozoan parasites in addition to being effective against common bacteria [29, 30].
2. Mechanism of action: Tetracyclines likely enter bacterial cells by passive diffusion and stop the development of the bacteria by preventing protein synthesis or by rupturing the membrane. A rising number of different bacterial species develop resistance to tetracycline's bacteriostatic effects [31].
3. Adverse effects: It's possible to have nausea, vomiting, diarrhoea, loss of appetite, mouth sores, a tongue covered in black hair, a sore throat, headache, dizziness, or rectal pain [29, 31].

5.5 Macrolides:

1. Due to their effectiveness against a variety of causing organisms, macrolides are often recommended for treating community acquired bacterial pneumonia. But the prevalence of microbial resistance is rising. Macrolides have furthermore been used in the treatment of Chlamydia trachomatis-related STDs. Macrolides are also used to treat staphylococcal and propionobacter acnes-related skin and soft tissue infections [32].
2. Mechanism of action: By attacking the bacterial ribosome, macrolide antibiotics prevent the production of proteins. They cling to and partly block the developing peptide escape tube. As a result, macrolides are thought of as "tunnel plugs" that prevent the creation of all proteins [32].

3. Adverse effects: Anorexia, abdominal discomfort, nausea, vomiting, and diarrhoea are among the most common adverse effects. Antibiotics called macrolides may lessen gastrointestinal problems if taken with meals [33].

Along with abnormal liver function, deafness, tinnitus, and cardiac arrhythmias (irregular heart rhythm, particularly in persons at risk of cardiac events or who have a cardiac history).

6. Conclusions

Antibiotics are medicinal chemicals that treat the human body after conducting a clinical examination by the doctor and prescribing them to the patient. Where some of the drugs are similar in the way they work and the other differs from each other. If the medicine is taken incorrectly, it will have harmful effects and complications. The medicines differ in terms of composition, efficacy, basic and mechanical, as each medicine can be used against a specific disease. Some drugs are among the most common adverse effects.

References

[1] Kobow, K.; Baulac, S.; Von Deimling, A.; Lee, J. H.; "Molecular diagnostics in drug-resistant focal epilepsy define new disease entities". Brain pathology, 31(4), e12963, 2021.

[2] Vinks, A. A.; Barrett, J. S.; "Model-informed pediatric drug development: application of Pharmacometrics to define the right dose for children". The Journal of Clinical Pharmacology, 61: S52-S59, 2021.

[3] Mohammadinejad, R.; Shavandi, A.; Raie, D. S.; Sangeetha, J.; Soleimani, M.; Hajibehzad, S. S.; Varma, R. S.; "Plant molecular farming: production of metallic nanoparticles and therapeutic proteins using green factories". Green chemistry, 21(8): 1845-1865, 2019.

[4] Boopathi, S.; Poma, A. B.; Kolandaivel, P.; "Novel 2019 coronavirus structure, mechanism of action, antiviral drug promises and rule out against its treatment". Journal of Biomolecular Structure and Dynamics, 39(9): 3409-3418, 2021.

[5] Du Preez, I.; Loots, D. T.; "Novel insights into the pharmacometabonomics of first-line tuberculosis drugs relating to metabolism, mechanism of action and drug-resistance". Drug metabolism reviews, 50(4): 466-481, 2018.

[6] Nguyen, D. D.; Gao, K.; Chen, J.; Wang, R.; Wei, G. W.; "Potentially highly potent drugs for 2019-nCoV". BioRxiv, 2020-02, 2020.

[7] Gupta, M.; Sharma, R.; Kumar, A.; "Docking techniques in pharmacology: How much promising?". Computational biology and chemistry, 76: 210-217, 2018.

[8] Hutchings, M. I.; Truman, A. W.; Wilkinson, B.; "Antibiotics: past, present and future". Current opinion in microbiology, 51: 72-80, 2019.

[9] Kovalakova, P.; Cizmas, L.; McDonald, T. J.; Marsalek, B.; Feng, M.; Sharma, V. K.; "Occurrence and toxicity of antibiotics in the aquatic environment: A review". Chemosphere, 251, 126351, 2020.

[10] Chatzopoulou, M.; Reynolds, L.; "Role of antimicrobial restrictions in bacterial resistance control: a systematic literature review". Journal of Hospital Infection, 104(2): 125-136, 2020.

[11] O'Rourke, A.; Beyhan, S.; Choi, Y.; Morales, P.; Chan, A. P.; Espinoza, J. L.; Nelson, K. E.; "Mechanism-of-action classification of antibiotics by global transcriptome profiling". Antimicrobial agents and chemotherapy, 64(3): e01207-19, 2020.

[12] Abramova, A. A.; Isakov, V. G.; Nepogodin, A. M.; Grakhova, E. V.; Dyagelev, M. Y.; "Classification of antibiotics contained in urban wastewater". In IOP Conference Series: Earth and Environmental Science, IOP Publishing, 548(5): 052078, August, 2020.

[13] Douafer, H.;rieu, V.; Phanstiel IV, O.; Brunel, J. M.; "Antibiotic adjuvants: make antibiotics great again!". Journal of medicinal chemistry, 62(19): 8665-8681, 2019.

[14] Jardón-Romero, E. A.; Lara-Carrillo, E.; González-Pedroza, M. G.; Sánchez-Mendieta, V.; Salmerón-Valdés, E. N.; Toral-Rizo, V. H.; Morales-Luckie, R. A.; "Antimicrobial Activity of Biogenic Silver Nanoparticles from Syzygium aromaticum against the Five Most Common Microorganisms in the Oral Cavity". Antibiotics, 11(7): 834, 2022.

[15] Eldek, A.; "Antibiotic-Regulated Plasmid Copy Number Variation". A Driver of Antibiotic Resistance, 2019.

[16] Dmitriev, S. E.; Vladimirov, D. O.; Lashkevich, K. A.; "A quick guide to small-molecule inhibitors of eukaryotic protein synthesis". Biochemistry (Moscow), 85: 1389-1421, 2020.

[17] Yilancioglu, K.; "Antimicrobial drug interactions: systematic evaluation of protein and nucleic acid synthesis inhibitors". Antibiotics, 8(3): 114, 2019.

[18] Xia, Q.; Zhang, Y.; Li, Z.; Hou, X.; Feng, N.; "Red blood cell membrane-camouflaged nanoparticles: a novel drug delivery system for antitumor application". Acta Pharmaceutica Sinica B, 9(4): 675-689, 2019.

[19] Shenoy, E. S.; Macy, E.; Rowe, T.; Blumenthal, K. G.; "Evaluation and management of penicillin allergy: a review". Jama, 321(2), 188-199, 2019.

[20] Wei, X.; Huang, S.; Wu, Y.; Wu, S.; Yang, J.; "A comprehensive study on torrefaction of penicillin mycelial residues: Analysis of product characteristics and conversion mechanisms of N". Fuel, 330, 125703, 2022.

[21] Stone Jr, C. A.; Trubiano, J.; Coleman, D. T.; Rukasin, C. R.; Phillips, E. J.; "The challenge of de-labeling penicillin allergy". Allergy, 75(2): 273-288, 2020.

[22] Yu, X.; Chu, Z.; Li, J.; He, R.; Wang, Y.; Cheng, C.; "Pharmacokinetic drug-drug interaction of antibiotics

used in sepsis Care in China". Current Drug Metabolism, 22(1): 5-23, 2021.
[23] Toai; P.; Charles, V.; "Cephalosporins". In: Stat Pearls; Stat Pearls Publishing, 2021.
[24] Arumugham, V. B.; Gujarathi, R.; Cascella, M.; "Third generation cephalosporins". 2019.
[25] Ribeiro, A. R.; Sures, B.; Schmidt, T. C.; "Cephalosporin antibiotics in the aquatic environment: A critical review of occurrence, fate, ecotoxicity and removal technologies". Environmental pollution, 241: 1153-1166, 2018.
[26] Brar, R. K.; Jyoti, U.; Patil, R. K.; Patil, H. C.; "Fluoroquinolone antibiotics: An overview". Adesh University Journal of Medical Sciences and Research, 2(1): 26-30, 2020.
[27] Yang, Z.; Li, X.; Huang, Y.; Chen, Y.; Wang, A.; Wang, Y.; Yan, K.; "Facile synthesis of cobalt-iron layered double hydroxides nanosheets for direct activation of peroxymonosulfate (PMS) during degradation of fluoroquinolones antibiotics". Journal of Cleaner Production, 310: 127584, 2021.
[28] US Food and Drug Administration, "Drug safety communication: FDA warns about increased risk of ruptures or tears in the aorta blood vessel with fluoroquinolone antibiotics in certain patients 2018". 2022.
[29] Xu, L.; Zhang, H.; Xiong, P.; Zhu, Q.; Liao, C.; Jiang, G.; "Occurrence, fate, and risk assessment of typical tetracycline antibiotics in the aquatic environment: A review". Science of the total Environment, 753, 141975, 2021.
[30] Zhang, Q.; Jiang, L.; Wang, J.; Zhu, Y.; Pu, Y.; Dai, W.; "Photocatalytic degradation of tetracycline antibiotics using three-dimensional network structure perylene diimide supramolecular organic photocatalyst under visible-light irradiation". Applied Catalysis B: Environmental, 277, 119122, 2020.
[31] Cheng, D.; Ngo, H. H.; Guo, W.; Chang, S. W.; Nguyen, D. D.; Zhang, X.; Liu, Y.; "Feasibility study on a new pomelo peel derived biochar for tetracycline antibiotics removal in swine wastewater". Science of the Total Environment, 720: 137662, 2020.
[32] Svetlov, M. S.; Koller, T. O.; Meydan, S.; Shankar, V.; Klepacki, D.; Polacek, N.; Mankin, A. S.; "Context-specific action of macrolide antibiotics on the eukaryotic ribosome". Nature Communications, 12(1), 2803, 2021.
[33] Qin, Y.; Ma, S.; "Recent advances in the development of macrolide antibiotics as antimicrobial agents". Mini Reviews in Medicinal Chemistry, 20(7): 601-625, 2020.