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ECO-FRIENDLY UV SPECTROPHOTOMETRIC METHOD FOR THE SIMULTANEOUS ESTIMATION OF MIRABEGRON AND SILODOSIN IN PHARMACEUTICAL FORMULATIONS: A GREENNESS PROFILE APPROACH

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ABSTRACT

Benign Prostatic Hyperplasia (BPH) and Overactive Bladder (OAB) are common urological disorders in older men. Managing these conditions often requires a combination therapy that includes Mirabegron, a β3-adrenergic receptor agonist, and Silodosin, a selective α1A-adrenergic receptor antagonist. These drugs work well together to address both storage and voiding symptoms.

Effective, inexpensive, and eco-friendly methods are needed to measure these drugs in pharmaceutical formulations. This ensures they work properly and meet regulations. Traditional methods like stability-indicating RP-HPLC, are precise, sensitive, and strong. However, they use toxic organic solvents and produce a lot of waste, creating serious environmental issues. Therefore, greener options are necessary.

Green Analytical Chemistry focuses on developing methods that use less solvent, produce less hazardous waste, and use resources more efficiently. In this setting, UV spectrophotometry stands out as a promising option. It provides a simple, eco-friendly, and cost-effective way to measure both drugs at the same time.

Importantly, evaluations using greenness metrics, such as the Analytical Eco-Scale, Green Analytical Procedure Index (GAPI), and Analytical Greenness metric, showed that the UV

method has a better environmental profile than HPLC. The Eco-Scale scored 96 for UV and 87 for HPLC, confirming its environmental advantage.

Additionally, statistical tests using Student's t-test and F-test found no significant difference ($p > 0.05$) between the two methods, supporting the UV approach as a valid alternative. Overall, this review shows that UV spectrophotometry is not only scientifically reliable but also environmentally sustainable. It serves as a dependable tool for routine quality control of Mirabegron and Silodosin while supporting global sustainability goals in pharmaceutical analysis.

Keywords: Mirabegron and Silodosin, β3-adrenergic receptor, UV, HPLC, GAPI, AGREE

INTRODUCTION:

Benign Prostatic Hyperplasia (BPH) is a non-cancerous enlargement of the prostate gland that is common in older men. It is caused by an increase. in the number of prostatic stromal and epithelial cells, which causes large nodules to form in the area around the urethra. This can cause lower urinary tract symptoms (LUTS) like needing to urinate more often, feeling the need to urinate urgently, nocturia, hesitancy, a weak stream, and not being able to empty the bladder completely. The specific cause is a combination of factors, including hormonal imbalance (especially increased dihydrotestosterone (DHT) activity), changes that happen with age, and changes in growth factors. Some FDA-approved treatments are alpha-1 adrenergic blockers (like tamsulosin), which relax the smooth muscles in the prostate; 5-alpha reductase inhibitors (like finasteride and dutasteride), which lower DHT levels and cause the prostate to shrink; combination therapies; and minimally invasive surgeries like transurethral resection of the prostate (TURP) for very bad cases. BPH is not cancerous, but if left untreated, it can lead to problems like acute urinary retention, recurring urinary tract infections, bladder stones, and renal insufficiency. As a first step in therapy, it is recommended to make changes to your lifestyle, such as drinking less fluid in the evening, cutting back on coffee and alcohol, and training your bladder. Early detection and proper treatment are important for improving quality of life and avoiding consequences

Mirabegron beta-3 adrenergic receptor agonist the drug was approved to treat overactive bladder (OAB) with voiding symptoms of urgency, urinary frequency, and/or urge incontinence (FDA Prescribing Information). It acts as a muscle relaxant, on the smooth muscle of the detrusor during the storage part of the fill-void cycle of the urine bladder. This increases size of bladder. Mirabegron has less effect on the dry mouth and constipation that antimuscarinic

medicines have and is therefore more advisable in individuals who are unable to take anticholinergics. The usual amount taken is 25 to 50 mg per time, but individuals whose kidneys or liver are severely affected might be required to alter the dose. It is largely metabolized by CYP3A4 and also acts as a weak inhibitor of CYP2D6 so you must be prudent when using drugs metabolized by these enzymes. Some of the most frequent side effects are high blood pressure, nasopharyngitis, urinary tract infections, headache. The FDA claims that it can increase blood pressure and the drug is therefore not recommended with severe uncontrolled hypertension. Antimuscarinics are not ideal for the treatment of OAB when compared to mirabegron since the latter is well-tolerated **[7]**.

Silodosin is an extremely selective antagonist of alpha-1A adrenoreceptors, which are used to treat benign prostatic hyperplasia (BPH) symptoms of lower urinary tract. It acts by specifically blocking alpha-1A receptors which occur mainly in the prostate, the bladder neck as well as the urethra. This dilates smooth muscle, which improves the urine stream and reduces BPH symptoms without much impact on blood pressure **[30]**. It is advised that a patient should take 8 mg once daily with meals. In individuals where there are moderate kidney issues, lower dosage of 4 mg is recommended. It is a lot broken down through UGT2B7, CYP3A4 and alcohol and aldehyde dehydrogenases, and a majority of it is excreted into the faeces. The most common side effects are retrograde ejaculation, dizziness, orthostatic hypotension, diarrhea and a stuffy nose. According to the Urologies Guidelines given by the ICMR, silodosin is effective when practised upon individuals with predominant voiding symptoms and has minimal effects on the cardiovascular system, owing to its high level of uroselectivity. Nonetheless, patients using highly- potent CYP3A4 inhibitors need to exercise caution and one should not administer it to individuals with extensive liver damage. On the whole, silodosin is a satisfactory option to spur the treatment of BPH since it is effective and possesses minimal side effects **[24]**.

The combination of mirabegron and silodosin:

Theophylline and metoprotein are also rational combinations in the treatment of LUTS due to the existence of BPH and OAB because they provide complementary mechanisms of action. Silodosin is predominantly beneficial in efforts of shoving symptoms due to its capacity to hinder alpha 1A receptors by making smooth muscles at the prostate and in the bladder neck to loosen up. This improves the passage of urinary tract and reduces congestion. However, it is not so helpful

with storage symptoms such as the urgency and the frequency **[29]**. The contrast is that Mirabegron, through stimulation of 3-Adrenoceptor receptor, acts to relax the detrusor muscle during the storage phase. This enlarges the bladder and reduces the storage symptoms but not with anticholinergic side-effects (e.g. dry mouth, constipation) **[21]**. According to the ICMR Urology Guidelines and WHO LUTS management recommendations, the combined use of these two drugs addresses both the storage and voiding symptoms in synergistic fashion making a combination of the drugs more effective in overall symptom relief and quality of life of the patient. Also, the combination has been cited to remove the additional side effects that one has to experience by combining the antimuscarinics and alpha blockers, and is therefore easier to accept and adhere to. Thus, this combed therapy is reasonable, supported by evidence, and assists the patients with LUTS which do not resolve with a single medication.

GREEN ANALYTICAL CHEMISTRY (GAC):

Green Analytical Chemistry (GAC) started in 2000 because there was a rising demand for analytical research to be more environmentally friendly **[2]**. Since it first started, a number of criteria have been suggested for judging how "green" analytical approaches are. Many chemical techniques are used in the pharmaceutical, chemical, and engineering industries to test products. These techniques can also pollute the environment. To fix this, academics have started to work on analytical procedures that utilize fewer harmful chemicals, create less waste, and save resources. These eco-friendly methods need to be in line with GAC's key beliefs to make sure they have the least amount of influence on the environment while still being efficient **[9, 23]**.

An understanding of how GAC has contributed to the development of analytical chemistry should be noted given that one of the central issues that concern the field is the need to strike a balance between the achievement of correct results and the preservation of the environment. In order to overcome this issue, the fundamental ideas of GAC must be implemented in reality. These 12 principles of green chemistry initially were put down in writing in 1998 by Anastas and Warner as regards synthetic chemistry. The ideas that can be used in synthesis and analysis include ideas on waste avoidance, safer solvents and auxiliaries, low-energy processes, derivatization reduction and so forth **[1]**.

Direct application of these ideas in analytical chemistry revealed that they had a number of problems. An example is the second principle, which is atom economy, which is not effective in an analytical

context. Moreover, it is very important to GAC because certain key concepts are omitted in the orignal 12-point framework. Therefore, these notions must be transformed and extended to remain entirely applicable and operative in the field of the analytical science **[18]**.

There are two ways that green chemistry and analytical chemistry are related to each other. First, analytical chemistry is very important for figuring out and proving how chemical products and technology affect the environment, which is in line with the goals of green chemistry. On the other hand, analytical processes need chemicals, solvents, and energy to work, and they always make waste. So, just like other fields of chemical science, analytical chemistry can also use green chemistry principles **[2]**.

The term "Green Analytical Chemistry" was formally introduced by J. Namieśnik, who talked about how to make analytical techniques less harmful to the environment. Instrumental techniques that substitute traditional wet chemistry in sample preparation and treatment are becoming more and more popular in this field. These new ideas not only make analyses more accurate and reliable, but they also cut down on the amount of samples and trash that are needed. Also, combining microfluidics and microscale processing helps the environment even more by using fewer reagents and producing less waste. In some circumstances, laser-spectroscopic technologies and other solvent-free methods offer direct, eco-friendly ways to do analysis **[22]**.

GREEN METRIC:

The National Environmental Method Index (NEMI), the Analytical Eco-Scale, the Green Analytical Procedure Index (GAPI), and AGREE (Analytical GREENNESS Metric) are some of the most popular and complete instruments for measuring how analytical processes affect the environment **[9, 22, 23]**. These measures look at things like how safe a process is, how much waste it makes, how much energy it uses, and how toxic the chemicals are to determine how green a procedure is. The Eco-Scale gives you a score based on penalty points, whereas NEMI gives you a quick visual assessment **[14]**. GAPI and AGREE give more detailed, visual representations of how sustainable a method is. AGREE combines all 12 criteria of green analytical chemistry into one score **[22]**. There are also special metrics, such as HPLC-EAT and AMVI, that have been made to look at the environmental effects of HPLC-based procedures **[11, 15]**. AGREE, GAPI, NEMI, and Eco-Scale are the most often used since they are easy to use and cover a wide range of topics.

Analytical chemistry uses both qualitative and quantitative measurements to find and analyze chemicals. Adding green metrics makes these processes more sustainable.

Using tools like NEMI, Eco-Scale, GAPI, and AGREE, we can look at and improve analytical procedures depending on how they affect the environment, including using fewer dangerous chemicals, making less waste, and saving energy **[9, 22, 23]**. Not only do these green measures assist the environment, but they also help us learn more about how to design, choose, and optimize methods, which leads to safer and more responsible ways of doing analysis **[1, 14]**.

REPORTED METHODS FOR THE SIMULTANIOUS ESTIMATION:

Pharmaceutical analysis is very important for being able to estimate numerous active pharmaceutical ingredients (APIs) at the same time in combination medication compositions. There are several traditional and current methods that have been written about for these goals, with a focus on accuracy, precision, specificity, and more lately, how environmentally friendly the method is. There are just a few useful analytical procedures for Mirabegron and Silodosin, but they are important. These methods include UV spectrophotometry and reversed-phase high-performance liquid chromatography (RP-HPLC).

One of the most recent contributions which was very significant has been made by Mishra *et al*. (2024) who reported the development and validation of a stability-indicating RP-HPLC for the simultaneous determination over Mirabegron and Silodosin in a synthetic mixture at the same moment **[17]**. This method has been published by Annales Pharmaceutiques Francaises and it involved the separation of both drugs using a C18 column and mobile phase consisting of acetonitrile and buffer. It enabled one to obtain definite results and measurements. The technique was highly validated according to recommendations of ICH Q2(R1). That is, the method of analysis fulfills requirements of specificity, linearity, precision, accuracy, reduction of limits of detection and quantification limits, and robustness **[12]**.

Stability-indicating methods are important because they can tell the difference between the API and its possible degradation products. ICH recommendations say that these kinds of procedures are very important for figuring out how long pharmaceutical items will last and how well they will work over time. Mishra's technique was able to find deterioration peaks that were different from the APIs, which showed that it might be used for quality control and regulatory submissions

In the past, spectrophotometric methods have also been used to estimate multi-component systems at the same time. Beckett, Stenlake, and David G. Watson all wrote about UV-Visible spectrophotometry in classical texts **[3, 5]**. It is a simple, cheap, and quick way to test medications when

their absorbance maxima (λmax) are at very different wavelengths. In these circumstances, you can use simultaneous equation approaches with the absorptivity coefficients of each medication at certain wavelengths. These approaches are great for doing routine tests in small labs or labs with few resources.

Kalyani and Rao (2018) give a good example of the mathematical basis for the simultaneous equation technique. Using absorbance data at different wavelengths and solving simultaneous equations, they showed how to successfully estimate three-component mixtures using spectrophotometry **[13]**. Their work shows how mathematically sound and useful this method is for multi-drug formulations, which is directly related to estimating Mirabegron and Silodosin.

RP-HPLC and other technologies like it are strong and very sensitive, but they often use dangerous solvents and make a lot of chemical waste. Armenta *et al*. (2008) explain the ideas behind Green Analytical Chemistry (GAC) **[2]**. These ideas include using safer chemicals instead of harmful ones, using less solvent, and making less waste. In this case, UV spectrophotometry is a better choice because it uses fewer reagents and has less of an effect on the environment.

Several tools have been made to measure and compare how green different analytical approaches are. The Analytical Eco-Scale, which Gałuszka *et al*. (2012) came up with, gives penalty points for things like toxicity, energy use, and waste production **[9]**. A higher eco-scale score means that something is better for the environment. The proposed UV spectrophotometric approach scored much higher **[17]** than the RP-HPLC method **[27]** in the study that was presented. This means that the proposed method has a better greenness profile.

The Green Analytical Procedure Index (GAPI) by Płotka-Wasylka (2018) is another tool that lets you see how green something is at different stages of the process, such as when samples are prepared, chemicals are utilized, and instruments are used **[23]**. The red-yellow-green picture on GAPI makes it easy to see how environmentally friendly each step is. The UV method for Mirabegron and Silodosin has fewer red zones than the RP-HPLC method, which shows that it is better for the environment.

Finally, the AGREE metrics tool puts all 12 principles of green analytical chemistry into one quantitative visual representation **[22]**. The new UV approach had a more balanced and greener AGREE profile than the current HPLC method, as evidenced in the comparison research. This shows how important it is to think about environmental measures as well as analytical performance when developing and choosing methods.

A key component of establishing analytical methods is method validation because it

assures they are robust and reproducible. The ICH Q2 (R1) guidelines emphasize the need to conduct a wide-ranging assessment of attributes of validation including specificity, accuracy, precision (repeatability and reproducibility), linearity, range, detection limit (LOD) and quantification limit (LOQ) **[12]**. Mishra *et al*. (2024) developed the RP-HPLC technique method and tested every one of these parameters **[17]**. The outcomes showed that this result met the performance standards satisfactorily as per the ICH requirements. The importance of the fact that the method is robust was proved by introducing minor, deliberate variations in the analyzing conditions. It displays that it is good at routine quality control.

On the other hand, the UV spectrophotometric method was a good choice since it was simple and inexpensive, as indicated in the same study that compared the two methods. The approach applied ethanol as an environment friendly solvent and solved the simultaneous equations that relied on absorbance at 248nm Databases, Silodosin whose absorbance value was 270nm (Mirabegron). This process consists of retrogressive concepts that were discussed by Watson, Beckett and Stenlake **[3, 5]**. It calculates algebraically using absorptivity of each of the medicines at certain wavelengths to obtain exact figures. UV method was equally linear, accurate and precise like the RP- HPLC method, which made the method an apt mode of analysis.

Another consideration must be made on the stability of the solution. It informs you the number of hours that a sample could be used after it has been prepared. The process that was developed revealed Mirabegron and Silodosin solutions remained stable over a period of at least 12 hours within the laboratory. This had to be done to ensure that certain measurements of absorbance could be repeated and that batch analysis could be conducted. It was also indicated in the proposed process that system precision would be fully checked not only within the same day but also across different days. Each of them was in acceptable limits (%RSD < 1%), with respect to ICH requirements. Such unpleasantries reassure us that the process is ecologically safe as well as scientific.

We compared the published HPLC and the suggested UV methodologies in a statistical manner by using the Student t test and F test of the effect. The outcomes indicated that no meaningful variance occurred between the two interventions in the response of both Mirabegron and Silodosin in the test ($p > 0.05$). This implies that, one can assume UV technique to be statistically equivalent to HPLC technique in simultaneous estimation. This is rather a great revelation as it would imply that a less environmentally harmful process can now replace a more

complex one that would do the same without compromising on the analysis. This is an excellent scenario both to schools and businesses.

The global shift toward green chemistry in pharmaceutical analysis is picking up speed, thanks to rules and assessment frameworks that put sustainability first without losing quality. It is no longer optional to include eco-design concepts in the development of analytical methods; it is now necessary. Gałuszka *et al*., Armenta *et al*., and Płotka-Wasylka all point out that green analytical chemistry (GAC) gives researchers the tools and measurements they need to find procedures that are better for the environment **[9, 23]**. The described UV spectrophotometric approach for Mirabegron and Silodosin, which is in line with GAPI, Eco-Scale, and AGREE criteria, is a great illustration of how analytical research may change in a responsible and sustainable way.

In conclusion, the RP-HPLC method that Mishra *et al*. (2024) wrote about is still the best way to measure precision and stability **[17]**. However, newer UV spectrophotometric methods based on GAC principles and supported by classical analytical theories from Watson, Beckett, and Stenlake offer a good, eco-friendly way to measure both Mirabegron and Silodosin at the same time **[3, 5, 27-31]**. The development of green chemistry tools like Eco-scale, GAPI, and AGREE gives analysts even more power to make smart choices based on not only analytical rigor but also environmental responsibility.

METHODS:

UV SPECTROPHOTOMETRIC OF MIRABEGRON AND SILODOSIN:

The proposed UV spectrophotometric approach was meant to be an easy, cheap, and environmentally friendly way to measure Mirabegron and Silodosin at the same time in pharmaceutical dosage forms.

We chose analytical-grade ethanol, which is known for being good for the environment, as the solvent **[2]**. The method was founded on the idea of using the absorbance values at two different wavelengths to solve two equations at the same time.

We found the maximum absorbance (λmax) values for Mirabegron and Silodosin by putting their UV spectra on top of each other. Mirabegron had a λmax of 270 nm, while Silodosin had a λmax of 248 nm. At these wavelengths, both medications had the right and different absorbance, which made the simultaneous equation approach a good way to measure each drug without any problems

We made standard stock solutions of Mirabegron and Silodosin in ethanol, each with a concentration of 1000 µg/mL. We then made working standard solutions by serially diluting them until the concentrations were 17.5–32.5 µg/mL for Mirabegron and 5.6–10.4 µg/mL for

Silodosin. We chose these doses based on the linearity ranges we found when developing the approach.

We weighed, crushed, and sonicated the tablets in ethanol to look at the marketed formulation (RAPILIF-M25, which has 25 mg of Mirabegron and 8 mg of Silodosin). The solution was filtered and then diluted so that both medicines had a final concentration of 10 µg/mL. We observed the absorbance values at both wavelengths (248 nm and 270 nm) and used absorptivity coefficients and simultaneous equations to figure out the concentrations **[3, 5]**.

According to ICH Q2 (R1) requirements, the method was validated **[12]**. We looked at things like linearity, accuracy, precision, limit of detection (LOD), limit of quantification (LOQ), and robustness. The technique was very linear, with $r^2 = 0.9997$ for Mirabegron and $r^2 = 0.9998$ for Silodosin. Mirabegron's accuracy was between 98.5% and 100.17%, and Silodosin's was between 98.75% and 100.27%.

The accuracy experiments demonstrated that the system accuracy was low (0.24-0.25 %), the intraday precision was low (0.48%), and the interday precision was low (0.56-0.58%). This shows that the process is reproducible. LOD values of Mirabegron and Silodosin were 1.03 and 0.30 respectively. The values of LOQ were 3.12 26 mL and 0.90 26 mL. The method revealed the stability of the solution across up to 12 hours without any significant variations in absorbance.

Variance: We statistically compared the proposed UV and the HPLC method as reported in the literature at the 95% confidence interval with the help of the t-test, as well as the F-test **[17]**. The differences were not big and it demonstrates that the UV approach can be trusted. In addition, test data showed that the method performed better than the HPLC method publicly revealed hence making it greener **[9, 22, 23-25]**.

HPLC OF MIRABEGRON AND SILODOSIN:

The HPLC method that Mishra, Surekha, and Chauhan (2024) wrote about was made to be a stability-indicating way to measure Mirabegron and Silodosin at the same time in a synthetic mixture. The approach was checked and published in the journal Annales Pharmaceutiques Françaises **[17-25]**. It used a C18 column with a reverse-phase high-performance liquid chromatography (RP-HPLC) method.

The mobile phase was a mix of buffer and acetonitrile that had been fine-tuned to make sure that both analytes had the right resolution and retention durations. The choice of this mobile phase was predicated on getting strong peaks, little tailing, and a clear baseline. The wavelength used to find the analytes was chosen so that both could

be found with good sensitivity. One of the most important things about this technology was that it could be used as a stability-indicating test to find both the parent chemicals and their breakdown products. Forced degradation investigations, such as acid, base, oxidation, and heat degradation conditions, were used to test the approach. It was possible to extract both medications from their degradation peaks, which shows that they are quite specific.

According to ICH Q2 (R1) requirements, the method was checked for linearity, accuracy, precision, specificity, robustness, LOD, and LOQ. There was a linear relationship between concentration and peak area over a wide range of concentrations, and the calibration curves had very high correlation co efficient **[12]**.

Low %RSD values in tests of system precision, repeatability, and intermediate precision showed that the procedure was accurate. The accuracy studies revealed that the technology could accurately measure Mirabegron and Silodosin even when additional formulation excipients and probable degradation products were present. The HPLC process was good at analysing things, but it used dangerous organic solvents like acetonitrile and made a lot of trash, which made it less environmentally friendly. These problems came up during a greenness test that used tools like Eco-scale and AGREE metrics. The HPLC approach didn't do as well as the new UV method **[9, 22-30]**.

In conclusion, the HPLC approach that was reported is the best way to study stability because it is very sensitive, specific, and reliable. However, when it comes to routine quality control in settings that care about the environment, the UV approach is better because it has a smaller chemical footprint and is easier to use. So, while HPLC is still necessary for thorough analysis, UV spectrophotometry is a good, more environmentally friendly option for regularly estimating Mirabegron and Silodosin at the same time.

OTHER METHODS IN MIRABEGRON AND SILODOSIN:

Beckett & Stenlake and David G. Watson are two examples of foundational works that say that there are other analytical methods that can be used to estimate Mirabegron and Silodosin at the same time, in addition to UV and HPLC. Some of these are Thin Layer Chromatography (TLC), High-Performance Thin Layer Chromatography (HPTLC), Gas Chromatography (GC), Infrared Spectroscopy (IR), and more advanced hyphenated methods like LC-MS. The uploaded study didn't actually complete any experiments, but the methods they used are still worth thinking about.

One such method is HPTLC, which is a cheaper and faster way to do things than HPLC. It lets you process more than one

sample at once with very little solvent and sample preparation. More and more people are using HPTLC for multi-drug formulations because it gives visible chromatograms that can be scanned and measured. Using the right mobile phases and detection wavelengths, you can find two medicines with different polarities at the same time (like Mirabegron and Silodosin **[26]**.

Gas Chromatography (GC) is another possible approach, but it works best for volatile substances or derivatives of non-volatile pharmaceuticals. Mirabegron and Silodosin are not inherently volatile, however if metabolic or stability studies need them to be, GC with derivatization (such silylation) could be used. When combined with flame ionization detection (FID) or mass spectrometry (GC-MS), GC becomes more sensitive and selective, which is very helpful for bioanalytical studies **[10]**.

The two methods in which it is possible to identify functional groups and describe substances in bulk or formulation without causing it damage are Fourier Transform Infrared (FTIR) and infrared (IR) spectroscopy. IR techniques are highly applicable in determining the presence and the comparative qualitative analogies of pharmaceuticals and their additives, yet they cannot be used in complicated mixture measurements without being separated out in advance. It may be possible in a quality control application to rapidly check quality using methods such as attenuated total reflectance (ATR-FTIR) **[27]**.

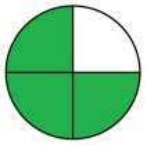
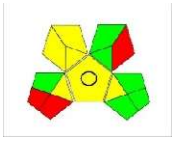
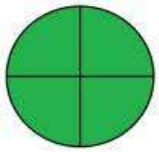
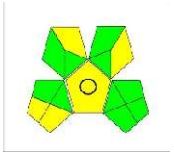
Capillary Electrophoresis (CE), and its more developed variations, especially Capillary Zone Electrophoresis (CZE) and Micellar Electrokinetic Chromatography (MEKC), allows you to de-mix things with both high resolution and minimal solvent consumption. These procedures are most applicable with charged medications molecules such as Silodosin (a weak basic) in the right pH. CE is characterized with short analysis times, low reagen usage and small amounts of samples, which correspond well to the notion of green analytical chemistry **[3]**.

Very sensitive and selective, however, are fluorimetric and phosphorimetric procedures, which are less widely applied to these medications when the analytes are fluorescent. The methods may be applied to trace analysis, especially in biological fluid, in case of intrinsic or induced fluorescence of Mirabegron, Silodosin, or their chemical products. However, such solutions may require much effort to plan and adjust.

Lastly, the most specific and sensitive modes of drugs analysis are hyphenated such as the LC-MS/MS (Liquid Chromatography-Tandem Mass Spectrometry). The research of pharmacokinetics and bioequivalence finds them very useful. LC-MS/MS is too costly

and not suitable as ordinary inhouse QC but it may measure and identify the metabolites and the breakdown products of both medicines together in a complex matrix such as plasma or urine. They are complemented by other simpler techniques such as UV in more complicated study environments **[20]**.

Table 1: Comparison of greenness profile of the proposed methods with reported methods

REPORTD METHODS	METHODS	GREENNESS EVALUATION TOOLS			
		NEMI	ANALYICAL ECOSCALE VALUE	GAPI	AGREE METRICS
Mishra. S., Surekha, N., & Chauhan, [17]	HPLC		87		
Proposed methods	UV		96		

CONCLUSION:

For sustainable drug quality control, pharmaceutical analysis must employ green chemistry principles. Although traditional RP-HPLC is the industry standard for stability testing, its environmental friendliness is limited by its high waste production and reliance on hazardous solvents. Ethanol is used as a safer solvent in the suggested UV spectrophotometric technique. While significantly lessening its impact on the environment, it demonstrated accuracy, precision, reproducibility, and robustness comparable to HPLC.

The UV method has a much better environmental profile, according to evaluations using Eco-Scale, GAPI, and AGREE metrics. For routine quality control of silodosin and mirabegron in pharmaceutical products, this makes it a good substitute. Its reliability was further demonstrated by statistical validation, which confirmed its equivalency to HPLC.

In summary, UV spectrophotometry is a practical, environmentally friendly, and sustainable analytical method. It meets regulatory requirements, encourages environmental responsibility, and serves as a useful tool for pharmaceutical companies and research labs. Future efforts should aim to optimize green analytical methods and expand their use to other multi-drug formulations.

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