

# The Use of Amalgam Electrodes for Monitoring of Organic Compounds.

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**Abstract.** This article provides an overview of the use of various types of amalgam electrodes for monitoring of organic compound described in papers published since 2011. Amalgam electrodes are a popular alternative to toxic liquid mercury electrodes in electroanalytical chemistry. These electrodes are made by forming an amalgam between metal and liquid mercury, and offer advantages such as a wide range of potential windows, low background currents, and high sensitivity. This article discusses the different types of amalgam electrodes, including metal solid amalgam electrodes, paste amalgam electrodes, and modifications of amalgam electrodes. The focus is on the use of these electrodes for the determination of organic compounds, which has various applications in environmental monitoring, pharmaceutical analysis, food and beverage analysis, and biomedical research. The studies demonstrated that Metal solid amalgam electrodes (MeSAEs) are promising alternatives to the hanging mercury drop electrode (HMDE) for electrochemical measurements.

**Keywords.** Voltammetry, electroanalysis, amalgam electrodes, silver amalgam, organic compounds.

## 1. Introduction

### 1.1 Voltammetry

Voltammetry is a powerful electroanalytical technique that has found numerous applications in chemical analysis. In voltammetry, a voltage is applied to an electrochemical cell containing an analyte of interest and the resulting current is measured as a function of the applied potential. The resulting current-potential curves (voltammograms) provide information about the redox properties, concentration, and reactivity of the analyte.

Voltammetry can be used for both qualitative and quantitative analysis of a wide range of analytes, including organic and inorganic compounds, metal ions, and biological molecules. The technique is particularly useful for the detection and quantification of trace amounts of analytes, and it has been widely used in environmental, clinical, and industrial samples.

Mercury electrodes are particularly useful in voltammetry, including the dropping mercury electrode (DME), hanging mercury drop electrode (HMDE), static mercury drop electrode (SMDE), streaming mercury electrode (SME), and mercury film electrode (MFE), due to its large potential window, ease of preparation, and a highly uniform and reproducible surface. Mercury electrodes have high overpotentials for hydrogen evolution, making them useful for reducing alkali metal cations in neutral or alkaline aqueous solutions. However, mercury electrodes have limitations at positive potentials [1].

Despite their usefulness, the highly toxic nature of mercury poses significant health and environmental risks, the use of mercury electrodes in voltammetry has become less common in recent years due to concerns about the toxicity and environmental impact of mercury.

### 1.2 Amalgam electrodes

Amalgam electrodes have been extensively studied

and utilized in electrochemical research and applications as an alternative to mercury electrodes.

Amalgam electrodes are made by forming an amalgam between metal and liquid mercury, which can be done by electrolytically depositing mercury film on the metal or by simply dipping the electrode directly in mercury [2].

Amalgam electrodes offer several advantages over other types of electrodes, including wide potential windows, low background currents, and high sensitivity. Additionally, they are relatively easy to prepare and can be used in various electrolytes, making them a popular choice in many electrochemical applications.

In this review is focused on papers published after 2011, including an overview of the properties and characteristics of amalgam electrodes, their preparation, and their applications in the determination of organic compounds. Recent advancements in the field and the future prospects of amalgam electrodes are also discussed.

## 2. Types of Amalgam Electrodes

There are many types of amalgam electrodes, liquid, paste, and solid, formed depending on the mercury to metal ratio, made by different transition metals and mercury (Ag/Hg, Pt/Hg, Au/Hg, Ir/Hg, and Cu/Hg) [3].

Metal solid amalgam **electrodes (MeSAEs)**, have on their surfaces a very small amount of mercury that cannot be released into the medium due to the strong adhesion to the solid amalgam support. The main advantages of MeSAEs include a broad range of working potentials, simple electrochemical regeneration of the electrode surface, long-lasting activity without significant changes, and applicability even in mobile laboratories and in countries prohibiting the use of liquid mercury. MeSAEs can be designed for selective applications and can be modified for specific experimental conditions. The mercury film-modified MeSAEs are the most sensitive analytically, but the preparation of these electrodes involves some challenges. The mercury meniscus-modified MeSAEs are the most appropriate for common analytical use [4].

Paste amalgam electrodes are a type of amalgam electrode that is made by mixing mercury with a relatively low content of powdered metal to form a paste. It can be done with a pasting liquid, similar to classical carbon paste electrodes (CPE), or without. Paste amalgam electrodes have high rate of electrode processes, like metal electrodes, as well as simple mechanical exchange of working surface, like that of CPE, and a potential window comparable with other amalgam electrodes [5, 6].

Liquid electrodes offer advantages such as the formation of a new and reproducible surface without

interference from previous measurements or contaminants, and the ability to modify the electrode with different reagents. However, handling drop systems can be more technically complicated compared to using solid electrodes. The liquid amalgam has mechanical properties and toxicity that are almost identical to those of liquid mercury due to its high degree of dilution, as such, it is not yet considered an alternative electrode material to liquid mercury electrode [2].

## 3. Electrochemical Techniques

Some electrochemical techniques are commonly used with amalgam electrodes for monitoring organic compounds. These electrochemical techniques provide a range of analytical information about the organic compounds being monitored, such as their redox behaviour, concentration, and oxidation/reduction potentials. However, the choice of technique used depends on the specific application and the analytical requirements of the experiment. The different electrochemical techniques used with amalgam electrodes for monitoring organic compounds include:

Cyclic Voltammetry (CV), a technique that measures the current response of the electrode as the potential ramps linearly versus time in cyclical phases [7]. The current response is plotted against the applied potential to produce a cyclic voltammogram. CV is often used to study the redox behaviour of organic compounds [8].

Differential Pulse Voltammetry (DPV), a technique that measures the current response of the electrode after applying a series of superimposed small amplitude, short, regular voltage pulses. The current is measured immediately before each potential pulse and at the end of each pulse [9]. The current response is plotted against the potential to produce a differential pulse voltammogram. DPV is often used for the detection of trace amounts of organic compounds [10].

Square Wave Voltammetry (SWV), a technique that measures the current response of the electrode while the potential between the working electrode and a reference electrode is pulsed forward and backward at a constant frequency, while ramped in one direction [11]. The current response is plotted against the potential to produce a square wave voltammogram.

Stripping Voltammetry (SV), is a technique that measures the current response of the electrode after a preconcentration step, which involves applying a constant potential to the electrode for a set period of time to accumulate the analyte of interest. After the preconcentration step, the potential is scanned in the opposite direction, during which the analyte is stripped back to the solution, and the current response is measured to produce a stripping

voltammogram [12, 13]. SV is often used for the determination of trace amounts of organic compounds after adsorptive accumulation [14].

Variations, modifications and combinations of those techniques are also applied. Like Differential Cyclic Voltammetry (DCV), Adsorptive stripping voltammetry (AdSV), Square-Wave Adsorptive Stripping Voltammetry (SWAdSV), Square Wave Stripping Voltammetry (SWSV), Adsorptive Stripping Differential Pulse Voltammetry (AdSDPV), Transfer Stripping Voltammetry (TSV), etc.

## 4. Determination of organic compounds

Amalgam electrodes are widely used in electroanalytical chemistry to detect and measure trace amounts of organic compounds in different matrices. In environmental monitoring, to measure trace amounts of organic pollutants in water, soil, and air. In pharmaceutical analysis, amalgam electrodes are used to monitor the purity of pharmaceuticals and detect trace amounts of impurities. In food and beverage analysis, amalgam electrodes are used to monitor the quality and safety of food and beverages. In biomedical research, they are used to measure the levels of neurotransmitters and other organic compounds in biological fluids such as blood, urine, and cerebrospinal fluid. Moreover, there are many other applications.

Various classes of organic compounds are determined with the application of amalgam electrodes. Some examples are listed in table 1. The most commonly used electrodes for the determination of organic compounds are the mercury meniscus-modified and polished silver-amalgam electrode, m-AgSAE and p-AgSAE, respectively, mostly due to its high sensitivity, low background current, and excellent reproducibility. Additionally, the AgSAE is relatively easy to prepare and use compared to other electrodes, and it can be used in a wide range of pH and ionic strength conditions. As such they were used in combination with various techniques such as DPV, CV, and AdSV.

### 4.1 Silver solid amalgam electrodes

Danhel et al. used m-AgSAE as a promising alternative to the hanging mercury drop electrode to study the electrochemical behaviour of labelled dsDNA using different electrochemical techniques such as CV, AdSV, and TSV [16]. They studied the electrochemical behaviour of NBF and dCNBFMP at m-AgSAE using CV within different potential windows and with different scan rates, which provided information about the mechanisms of respective electrode processes. The study found that the AdSV method was the most sensitive for both studied compounds, but required a relatively high sample volume. The TSV method was more convenient and efficient, requiring less than 0.3  $\mu\text{L}$ , or about 2.0  $\mu\text{L}$ , of the sample and providing

comparable sensitivity. Incorporation of the dCNBFMP into the dsDNA may increase sensitivity of the DNA detection together with an increase in signal response diversity, typically useful in DNA sequence analysis.

Dejlová et al. developed and compared DCV and DPV methods for the detection of trace amounts of genotoxic compounds 4-NP and 5-NBIA using different types of silver solid amalgam electrodes (SAEs) including p-AgSAE, m-AgSAE, and MF-AgSAE [17]. The authors found that MF-AgSAE gives the highest peaks with the highest sensitivity of determinations for both 4-NP and 5-NBIA, although its repeatability at lower concentrations was worse than p-AgSAE or m-AgSAE. This resulted in higher LOQs obtained for MF-AgSAE. The sensitivity slightly differs between individual concentration orders, which is usually caused by the passivation of the electrode surface by the electrode reaction products or by analyte adsorption. Nevertheless, within the individual concentration orders, the concentration dependences obtained are linear. Lowest LOQs can be achieved using m-AgSAE. The developed methods are verified through direct determination of the studied compounds in drinking water. All tested electrodes show potential for the determination of micromolar concentrations of substances under investigation in drinking water.

Šelešovská et al. investigated the voltammetric behaviour of leucovorin (LV), using two types of AgSAEs, m-AgSAE and p-AgSAE [18]. They compared the results obtained using these AgSAEs with those achieved using HMDE. The optimal parameters for using DPV to measure LV in a model solution, were found. These parameters include the initial potential, potential of accumulation, time of accumulation, and regeneration parameters of the electrode surfaces. It was found that changes in the initial potential do not significantly affect the peak height of LV on either AgSAE, and that a potential of accumulation of 200 mV is the most suitable. The time of accumulation depends on the concentration of LV in the solution, and the authors provide linear equations describing the dependence of peak height on time of accumulation for each electrode. The insertion of one negative potential for 30 seconds is the most suitable for m-AgSAE surface regeneration, while the insertion of 30 cleaning cycles in the form of potential jumps between -1000 mV and 0 mV is the most suitable for p-AgSAE. Overall, the study demonstrates the usefulness of AgSAEs for investigation of voltammetric behaviour of drugs and the optimization of DPV parameters for drug determination.

Table I. List of organic compounds determined by different voltammetric techniques at different types of silver amalgam electrodes in the years 2011-2023.

CAS#	Compound	Working electrode	Technique	Medium	LOD ( $\mu\text{M}$ )	LOQ ( $\mu\text{M}$ )	Concentration Range ( $\mu\text{M}$ )	Ref.
100-02-7	4-NP	AgSA-PE	DPV	0.2 M acetate buffer, pH 4.8	1	Not specified	1 to 100	[15]
214147-22-5	NBF; dCNBFMP; dsDNA-NBF	m-AgSAE	CV; AdSV; TSV	0.3 M AFP buffer, pH 6.95	NBF: CV: 3; AdSV: 0.02; TSV: 0.04 Dcnbfmp: CV: 2; AdSV: 0.03; TSV: 0.02 dsDNA-NBF: TSV: 0.5	Not specified	TSV: NBF: 0.02–0.10 dCNBFMP: 0.02–0.10 dsDNA-NBF: 0.47–3.4	[16]
100-02-7 94-52-0	4-NP; 5-NBIA	p-AgSAE; m-AgSAE; MF-AgSAE	DCV; DPV	BR buffer 4-NP: pH 6.0 5-NBIA: pH 8.0	Not specified	LOQ: 4-NP: p-AgSAE: DCV: 0.77; DPV: 0.47 m-AgSAE: DCV: 0.32; DPV: 0.16 MF-AgSAE: DCV: 0.97; DPV: 0.70 5-nitrobenzimidazole: p-AgSAE: DCV: 0.37; DPV: 0.32 m-AgSAE:	0.2-1.0	[17]

CAS#	Compound	Working electrode	Technique	Medium	LOD ( $\mu\text{M}$ )	LOQ ( $\mu\text{M}$ )	Concentration Range ( $\mu\text{M}$ )	Ref.
1492-18-8	LV	p-AgSAE; m-AgSAE	DPV	m-AgSAE: BR buffer, pH 4 p-AgSAE: acetate buffer, pH 5	p-AgSAE: 0.050 m-AgSAE: 0.022	DCV: 0.14; DPV: 0.1 MF-AgSAE: DCV: 0.87; DPV: 0.37 p-AgSAE: 0.075 m-AgSAE: 0.033	p-AgSAE: 0.05 – 5.0 m-AgSAE: 0.1 – 6.0	[18]
6285-57-0	ANBT	BiF-AgSAE	DCV; DPV	BR buffer-methanol (9:1), pH 10	Not specified	DCV: 0.16; DPV: 0.22	0.2 to 100	[19]
6285-57-0	ANBT	p-AgSAE; m-AgSAE	DCV; DPV	BR buffer-methanol (9:1), pH 10	Not specified	p-AgSAE: DCV: 0.10; DPV: 0.19 m-AgSAE: DCV: 0.17; DPV: 0.12	0.2–100	[20]
20624-25-3	Na-DDC	AgNP-SAE	SWAdSV	BR buffer, pH 5.5	0.0726	0.242	0.283 to 0.689	[21]
100-02-7	4-NP; ODN; GFP	bPGE-AgAP	4-NP: CV ODN: AdTS CV GFP: AdTS CP	ODN: AFP buffer, pH 6.9	4-nitrophenol: 1.5	Not specified	4-nitrophenol: 1-100	[22]

CAS#	Compound	Working electrode	Technique	Medium	LOD ( $\mu\text{M}$ )	LOQ ( $\mu\text{M}$ )	Concentration Range ( $\mu\text{M}$ )	Ref.
7261-97-4	DAN	p-AgSAE; m-AgSAE	DPV	BR buffer, pH 6.0	m-AgSAE: 0.00075 p-AgSAE: 0.02	m-AgSAE: 0.0025 p-AgSAE: 0.07	m-AgSAE: 0.003 - 30 p-AgSAE: 0.1 - 50	[23]
3513-03-9	BS	Hg(Ag)FE	SWV; SWSV	BR buffer, pH 7.0	SWV: 0.0213 SWSV: 0.00265	SWV: 0.071 SWSV: 0.00885	SWV: 0.1 – 1.0 SWSV: 0.01 – 0.2	[24]
607-57-8 88-89-1 443-48-1	2-NF; TNP; MTZ	p-AgSA-CE	DCV; DPV	2-NF: BR buffer-methanol (1:1), pH 5.0 TNP Acid and MTZ: BR buffer, pH 2.0 and 4.0	Not specified	2-Nitrofluorene: DCV: 4; DPV: 3 Picric Acid: DCV: 0.1; DPV: 1 Metronidazole: DCV: 2; DPV: 4	2-Nitrofluorene: DCV: 4-10 DPV: 3-10 Picric Acid: DCV: 0.1-1 DPV: 1-10 Metronidazole: DCV: 2- 10 DPV: 4-10	[25]

Lucca and co-authors, discussed the electrochemical study and voltammetric determination of Na-DDC using a solid amalgam electrode manufactured with silver nanoparticles (AgNP-SAE) [21], the advantages of using nanoparticles for amalgam electrode fabrication, the parameters related to the electrochemical and electroanalytical experiments and optimization of the experimental parameters for SWAdSV. The pH of the buffer had a significant effect on the electrochemical reaction and peak current heights, with the maximum response obtained at pH 5.5. The authors propose a mechanism for the reduction of Na-DDC based on the cleavage of the bond involving one of the sulphur atoms of the molecule after a protonation step in acid media, generating the cathodic signal observed. The intermediate formed in this reduction step reacts with the mercury of the electrode and provides an oxidation peak. The authors also optimize the SWAdSV parameters, including the accumulation potential, accumulation time, frequency of the pulses, amplitude of the pulses, and scan increment, in order to achieve the maximum electrochemical response for the reduction of Na-DDC at the surface of the AgNP-SAE, resulting in a LOD and LOQ of 0.073 and 0.24  $\mu\text{M}$ , respectively.

Sebest et al. optimized the process of AgAP electrodeposition on a basal-plane pyrolytic graphite electrode (bPGE) to investigate its use in voltammetric and spectroelectrochemical analysis [22], using a model organic nitrocompound, 4-nitrophenol, and the redox center of a prospective DNA redox label to demonstrate the potential applications of the bPGE-AgAP electrode. The electrode's potential was optimized by registering cyclic voltammograms of 4-NP on bare bPGE and on bPGE-AgAPs electrodeposited from different Ag(I) and Hg(II) content solutions. They found that a low bPGE surface coverage by the AgAP resulted in cathodic peaks corresponding to the reduction of 4-NP on the AgAPs and the underlying bPGE, respectively. Increasing the surface coverage, resulted in suppressing one peak and increasing others, providing a well-developed and separated cathodic peak. The electrochemical reduction of 4-NP on the bPGE-AgAP was found to be diffusion-controlled, and the linear relationship between the peak current and 4-NP concentration was used to obtain LOD of 1.5  $\mu\text{M}$ . The authors suggest that their approach could be used to detect nucleic acids and proteins using cyclic voltammetry and highly sensitive constant current stripping chronopotentiometry, respectively.

Skrzypek and co-authors, used a renewable silver amalgam film electrodes (Hg(Ag)FE) in the determination of blasticidin S (BS) using SWV [24]. The applied electrode uses silver amalgam to preserve the properties of the mercury electrode and consume very small amounts of mercury, being able to last several months in a stable manner. The pH of the supporting electrolyte was found to have a strong effect on the peak's currents and potentials. The best response was obtained at pH 6.5-7.5, with BR buffer

at pH 7 being chosen for further experiments. The study also investigated the influence of deposition potential and time on the sensitivity and LOD of the method. The BS signal was found to be highly sensitive to the accumulation factor, with the maximum response obtained at a deposition potential of 0.9 V and a deposition time of 30 s. the authors achieved a LOD and LOQ of 0.0027 and 0.0089  $\mu\text{M}$ , respectively, on SWSV, and found that BS plays the role of a catalyst in the electrode mechanism, and the results were consistent with theoretical assumptions for other guanidine compounds.

Šelešovská et al. studied on the voltammetric behaviour of DAN on various electrodes [23], including HMDE, p-AgSAE, m-AgSAE, and BiFE, and the development of methods for its precise determination. The study compared the electrochemical properties of amalgam and bismuth electrodes as alternatives to mercury electrodes. Through the electrochemical study of the behaviour of  $5.0 \times 10^{-6}$  M DAN in BRB of pH 6.0, it was found that HMDE had the widest cathodic potential window, followed by m-AgSAE and p-AgSAE, and BiFE had a narrower potential window. Electrodes with liquid mercury surface, HMDE and m-AgSAE, had comparable peak potentials and electrochemical properties. The application of -1200 mV for 20 s was the most appropriate for the surface regeneration of p-AgSAE and m-AgSAE. The authors reached LODs of 0.00075 and 0.02  $\mu\text{M}$  for m-AgSAE and p-AgSAE, respectively. It was proved that both modified AgSAEs and BiFE can detect DAN, and using AdSV improves the LODs achieved. All electrodes were successful in detecting DAN in model solutions of spiked drinking water.

## 4.2 Silver amalgam paste electrodes

Danhel et al. described a new type of silver amalgam paste electrode (AgSA-PE) [15], made of silver solid amalgam fine powder and paraffin oil, which combines the advantages of solid amalgam electrodes and paste electrodes. The electrode was tested using DPV to determine 4-NP in drinking and river water samples using FIA and HPLC methods with amperometric detection. The calibration curve obtained from the DP voltammograms showed a linear dynamic range of 1-100  $\mu\text{M}$ , and LOD 1  $\mu\text{M}$ . The authors concluded that AgSA-PE is a suitable non-toxic electrode material for voltammetric determination of organic compounds, providing good mechanical stability, simple handling and preparation, and easily renewable electrode surface, solving problems associated with passivation.

## 4.3 Modified silver solid electrodes

Deýlová and Vyskočil described the development of an electroanalytical method for the determination of ANBT [19], a compound used in the dye industry known for its genotoxic and mutagenic properties, in water. The method involved the use of a bismuth film on an amalgamated silver solid electrode (BiF-AgSAE) and DCP and DPV techniques. The results

indicate that ANBT undergoes a four-electron reduction at the BiF-AgSAE, and the voltammetric peak shifts to more negative potentials with increasing pH. The highest sensitivity was achieved in BR buffer pH 10.0-methanol (9:1) medium, and the calibration curves were linear in the concentration range of 0.2 to 100  $\mu\text{M}$  of ANBT. The BiF-AgSAE was found to have sensitivity approximately two times higher than that of the bare p-AgSAE for the concentration range of 2 to 100  $\mu\text{M}$  of ANBT and approximately 1.6 to 1.7 times higher for the concentration range of 0.2 to 1.0  $\mu\text{M}$  of ANBT. Overall, the developed electroanalytical method using the BiF-AgSAE and DCP/DPV techniques has shown good potential for the determination of ANBT in water samples, providing a sensitive and inexpensive alternative to existing methods.

Vyskočil et al. described the development of DCV, DPV and AdSV methods for detecting trace amounts of three biologically active organic nitro compounds, 2-NF, TNP and MTZ [25]. In this study, the authors used a AgSAE modified with a monolayer of p-mercaptobenzoic acid for their voltammetric determinations and compared the results with UV-vis spectrophotometry. They investigated the effect of pH on the voltammetric behaviour of the test substances and found that all three compounds yielded only one well-developed cathodic peak over the whole pH range. One interesting finding was the observation of a new voltammetric peak (pIV) for 2-NF, which had not been observed using other types of electrodes. The researchers proposed that this peak was due to the reversible two-electron reduction of a nitroso group that was formed beforehand. LOQs for all three tested compounds were similar to those attained using UV-vis spectrophotometric determination.

## 5. Conclusion

Amalgam electrodes have gained a lot of attention in electrochemical research and applications as a non-toxic alternative to liquid mercury electrodes in last decades. They offer several advantages over other types of electrodes, including wide potential windows, low background currents and high sensitivity. The different types of amalgam electrodes include liquid, paste, and solid amalgam electrodes, each with unique properties and characteristics. Amalgam electrodes are widely used in electroanalytical chemistry to detect and measure trace amounts of organic compounds in different matrices, including environmental monitoring, pharmaceutical analysis, food and beverage analysis, and biomedical research.

The use of silver solid amalgam electrodes for the determination of organic compounds has been extensively studied by several researchers. The studies discussed in the review have demonstrated that m-AgSAE, MF-AgSAE, and AgNP-SAE are promising alternatives to the hanging mercury drop electrode for electrochemical determinations. The AdSV and TSV methods have been shown to be

sensitive and efficient for the detection of compounds such as NBF, dCNBFMP, 4-NP, and 5-NBIA. The optimization of parameters such as initial potential, potential of accumulation, time of accumulation, and regeneration parameters of electrode surfaces has been found to be crucial for accurate determinations. The use of bPGE-AgAP electrodes has also been explored for voltammetric and spectroelectrochemical analysis. Overall, the studies have demonstrated the potential of silver solid amalgam electrodes for the determination of micromolar concentrations of substances in drinking water, drugs, and DNA redox labels. The findings suggest that silver solid amalgam electrodes can serve as a viable and greener alternative to the HMDE for electrochemical determinations.

## 6. List of abbreviations

2,7-DNF	2,7-Dinitrofluorene
2,7-DNFN	2,7-Dinitro-9-fluorenone
2-NF	2-Nitrofluorene
2-NFN	2-Nitro-9-fluorenone
4-NP	4-Nitrophenol
5-NBIA	5-Nitrobenzimidazole
AdSV	Adsorptive Stripping
AFPB	Ammonium Formate/Phosphate Buffer
AgNP-SAE	Silver Nanoparticles Solid Amalgam Electrode
AgSA-PE	Silver Solid Amalgam Paste Electrode
ANBT	2-Amino-6-nitrobenzothiazole
BiF-AgSAE	Bismuth Film on a Silver Solid Amalgam Substrate
BPGE-AgAP	Basal-Plane Pyrolytic Graphite Electrode - Silver Amalgam Particles
BRB	Britton-Robinson Buffer
BS	Blasticidin S
CAS#	Chemical Abstracts Service Number
CFE	Carbon Film Electrode
CSV	Cathodic Stripping Voltammetry
CV	Cyclic Voltammetry
DAN	Dantrolene Sodium
DCNBFMP	Deoxycytidine Monophosphate Conjugate With NBF



DPV	Differential Pulse Voltammetry
dsDNA-NBF	NBF Labelled Model Short Double Stranded DNA
GFP	Green Fluorescent Protein
HCADE	Hanging Copper Amalgam Drop Electrode
Hg(Ag)FE	Mercury Film Silver-Based Electrode
LOD	Limit of Detection
LOQ	Limit of Quantification
LV	Leucovorin
M	Molar concentration (mol/L)
m-AgSAE	Meniscus-Modified Silver Solid Amalgam Electrode
MF-AgSAE	Mercury Film Modified Silver Solid Amalgam Electrode
MTZ	Metronidazole
Na-DDC	Sodium diethyldithiocarbamate
NBF;	N-Methyl-4-hydrazino-7-nitrobenzofurazan
ODN	Oligodeoxyribonucleotide
p-AgSA-CE	Polished Silver Solid Amalgam Composite Electrode
p-AgSAE	Polished Silver Solid Amalgam Electrode
SCV	Staircase Cyclic Voltammetry
TNP	2,4,6-Trinitrophenol (Picric acid)
TSV	Transfer Stripping Voltammetry

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