Research Proposal for PhD

Title : Detection of pesticides at different concentrations using silica embedded silver nano-particles and constructing rapid field detection kits of the same for pesticide poisoning cases

Submitted by:
Kola Rajani Priya
MSc Forensic Science
Osmania University
Hyderabad

Submitted to:
Kalasalingam Academy of Research and Education(Deemed to be university),
Chennai,
December, 2025.

INDEX

1. Introduction:

Nanotechnology involves manipulating materials at the nanoscale—typically between 1 and 100 nanometre—where substances exhibit unique physical, chemical, optical, and biological properties not seen at larger scales. These novel characteristics make nanomaterials highly valuable in forensic science, where precision, sensitivity, and rapid detection are critical. In crime investigation, nanotechnology enhances the visualization of latent fingerprints using metal and semiconductor nanoparticles, improves the detection of trace evidence like explosives, drugs, and toxins through nanosensors, and aids DNA analysis with nanoparticle-based extraction and amplification methods. Nano-enabled materials also strengthen forensic imaging, document examination, and gunshot residue analysis by increasing accuracy at the microscopic level. As forensic challenges grow more complex, nanotechnology offers powerful tools for evidence detection, preservation, and interpretation, making it an evolving and indispensable component of modern forensic practice.

This nanotechnology can also be utilized as a revolutionary, for toxicological analysis. Our present system does not have, advanced rapid detection techniques for the preliminary testing of drugs and pesticide poisoning cases. The traditional chemical methods may not give better results, but the nanoparticles may give better detection and identification of a particular pesticide.

Due to modified and improved properties of the nanoparticles from their bulk states , the nanoparticles have a better optical properties and enhanced surface area which enables in better reactivity and sensitivity towards the questioned compounds or components. These nanoparticles also have enhanced capacity of adsorbing the questioned compounds onto their surface, thus enables the detection of the compound even in trace quantities.

Hence, usage of nanoparticles and nanotechnology would lead to positive change in the field of forensic toxicology, helping in rapid analysis with better sensitivity and efficiency. These, can be very efficiently used in the forensic mobile vans for easy detection, and when improved can also be used along with other instrumental techniques like LC-MS, GC-MS etc.

2. Statement of problem:

The widespread use of pesticides in agriculture has raised serious environmental and public health concerns due to their persistence, bio-accumulation, and potential toxicity even at trace levels. Along with the extensive use of pesticides in farming, the suicidal and potential homicidal poisoning cases include the use of pesticides. Conventional pesticide detection methods—such as chromatography and mass spectrometry—while accurate, are often expensive, time-consuming, require sophisticated instrumentation, and are unsuitable for rapid on-site analysis. This creates a significant gap in monitoring and investigating the poisoning cases. As the detection itself takes time, the processing of the case and the investigation of the case also gets delayed. Nanotechnology-based sensing approaches have emerged as promising alternatives, particularly due to their high sensitivity and tunable surface properties. Among these, silver nanoparticles exhibit strong surface plasmon resonance (SPR) and excellent optical properties that allow for the detection of small molecules, including pesticides. The problem of instability of the silver nano particles in their aqueous state can be overcome by, embedding silica in silver nanoparticles. This offers a potential solution by improving their stability, dispersion, and surface functionalization capacity. Silica shells also enhance bio-compatibility and enable a controlled interaction between the analyte and the nanoparticle surface.

Since there is no much research performed on these reactions, there is a pressing need to develop and evaluate a sensitive, stable, and cost-effective detection system using silica-embedded silver nanoparticles. The problem lies in understanding how these nano-composites interact with different pesticides across a wide concentration range and determining their detection limits, selectivity, sensitivity, and suitability for field applications. Working on this gap can lead to reliable detecting means for case investigation as well as the accidental poisoning through the vegetables etc on which the pesticides have been used

.

3. Objectives:

The main of this research proposal are :

a) To synthesize nanocomposites by embedding silica in silver nanoparticles.

b) To characterize the nano composites using UV-Vis spectroscopy, FTIR, XRD.

c) To test their reactivity with various pesticides containing carbamates, organophosphates, carbaryls, endosulfans etc.

d) To test their sensitivity with the pesticides at various concentrations and determining the minimum concentration of the pesticide that can be detected.

e) To see the reactivity with the raw direct pesticide and the extracted pesticide from the toxicological sample.

f) To construct a rapid detection kit, using the above used principles and testing it’s practical applicability in the real time cases.

4. Scope and limitations :

Scope:

The proposed investigation into the detection of pesticides using nanocomposites offers a promising avenue for rapid, on-site chemical analysis. By integrating such technology into mobile forensic laboratories, this approach could markedly accelerate the identification of toxic agents encountered in field investigations. The incorporation of silica-embedded silver nanoparticles provides a platform that combines sensitivity and portability, allowing forensic personnel to obtain preliminary findings swiftly without reliance on conventional laboratory infrastructure.

Once optimized, this methodology has the potential to extend beyond known pesticide compounds and assist in the detection of emerging or unconventional poisoning agents. In its advanced stages of development, the underlying principles may also be adapted or integrated into instrumental analytical techniques, thereby enhancing their sensitivity, selectivity, and efficiency. Ultimately, this work could serve as a foundational contribution toward the creation of versatile nano-enabled detection systems in forensic toxicology.

Limitations:

Despite its potential, this research presents several inherent challenges. The scientific literature on the use of silica-based silver nanocomposites for pesticide detection is relatively limited, which may pose conceptual, experimental, and methodological difficulties during the initial stages. This lack of precedent necessitates extensive prototyping, validation, and optimization before reproducible outcomes can be achieved.

A significant limitation lies in the evaluation of the nanocomposite's performance under real-world conditions. Further, the analytical effectiveness of silica-embedded silver nanoparticles must be firmly established to ensure reliability in forensic applications.

Another constraint pertains to the stability and shelf life of silver nanoparticles. Factors such as aggregation, oxidation, and degradation over time may influence their functional lifespan, thereby affecting the feasibility of their deployment in practical scenarios. Until issues of durability, storage, and reproducibility are adequately addressed, wide-scale implementation limited.

5. Prospected Methodology :

This study employs both biological and chemical synthesis routes to develop nanomaterials suitable for pesticide detection, followed by nanocomposite fabrication, characterization, and analytical evaluation.

1. Synthesis of Silver Nanoparticles (AgNPs):

Silver nanoparticles will be synthesized via a green biosynthetic approach using selected plant extracts as reducing and stabilizing agents. Aqueous solutions of silver salts will be subjected to reduction at varying concentrations of the plant extract to optimize nanoparticle yield, morphology, and stability. Parameters such as pH, temperature, and incubation time will be monitored to ensure controlled synthesis.

2. Synthesis of Silica Nanoparticles (SiNPs):

Silica nanoparticles will be produced using a chemical precipitation method. A suitable silica precursor (silica salt) will be treated with an appropriate reducing or condensing agent under controlled conditions. Multiple concentrations will be prepared to determine the optimal formulation for subsequent composite development. Reaction conditions, including solvent system, temperature, and stirring rate, will be standardized.

3. Characterization of Individual Nanoparticles:

Both silver and silica nanoparticles will undergo comprehensive characterization using the:

UV–Visible Spectroscopy to confirm nanoparticle formation and assess optical properties.

Fourier Transform Infrared Spectroscopy (FTIR) to identify functional groups involved in reduction and stabilization.

X-Ray Diffraction (XRD) to determine crystallinity and particle structure.

Based on the characterization outcomes, the most suitable nanoparticle sets—with respect to size, stability, and surface properties—will be selected for composite production.

4. Fabrication of Silica–Silver Nanocomposites:

Nanocomposites will be developed by depositing silver nanoparticles onto the surface of silica nanoparticles using reduction-based methods. The process will be optimized to ensure uniform coating, appropriate particle dispersion, and structural integrity. The resulting nanocomposites will again be characterized using UV–Vis spectroscopy, FTIR, and XRD to verify successful integration and assess morphology and stability.

5. Preliminary Pesticide Detection Studies:

The synthesized nanocomposites will first be evaluated using standard pesticide samples prepared at varying concentrations. Preliminary trials will focus on identifying concentration-dependent responses, detection thresholds, and interaction mechanisms. All observations, including visual, spectral, or colorimetric changes, will be systematically recorded.

6. Application to Biological Matrices:

To simulate real forensic conditions, the same detection protocol will be applied to pesticides extracted from meat samples. Extracts will be prepared at different concentrations to assess matrix effects, selectivity, and sensitivity. Data from these trials will be compared with the results of standard pesticide testing to validate performance.

Upon obtaining consistent and desirable detection outcomes, the optimized nanocomposites will be translated into a rapid, field-usable detection kit. The design will concentrate on portability, ease of use, stability, and rapid response time, with potential integration into mobile forensic platforms.

6. **Chapter plan** :

Chapter 1 – Introduction

a) Background of the study
b) Significance in forensic science
c) Problem statement
d) Research gap
e) Aim, objectives, and research questions
f) Scope and expected contributions
g) Overview of methodology
h) Structure of the thesis

Chapter 2 – Review of Literature

a) Overview of pesticide poisoning and forensic relevance
b) Conventional methods of pesticide detection
c) Introduction to nanotechnology in toxicological analysis
d) Silver nanoparticles: synthesis, properties, and applications
e) Silica nanoparticles: advantages and uses
f) Nanocomposites in analytical and forensic sciences
g) Identified research gaps and justification of the study

Chapter 3 – Research Methodology

a) Research design and approach
b) Materials, chemicals, and instrumentation
c) Synthesis of silver and silica nanoparticles
d) Characterization techniques (UV–Vis, FTIR, XRD, etc.)
e) Fabrication of silica–silver nanocomposites
f) Testing on raw pesticides and pesticide spiked biological samples (e.g., meat extracts)

Chapter 5 – Observations and Inferences

a) Anticipated analytical efficiency of the nanocomposites
b) Improvement over existing forensic detection methods
c) Potential for on-site/mobile forensic application
d) Contribution to forensic toxicology and nanomaterial science

Chapter 6 – Scope and Limitations

a) Research scope in forensic toxicology
b) Applicability to field investigations
c) Technological and methodological limitations
d) Practical constraints (stability, reproducibility, shelf life, field validation)

Chapter 7 – Conclusion

a) Summary of proposed research
b) Long-term applications (instrumental techniques, portable kits)
c) Future research directions
d) Possible interdisciplinary extensions

Chapter 8 – References / Bibliography