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Role of Forensic Science in Wildlife Crime Investigation in India: Challenges and Emerging Trends

Dr. Babita Negi

Independent Researcher, Himachal Pradesh, India

Abstract:
India, as a megadiverse country, faces increasing threats to its wildlife due to illegal poaching, trafficking, and habitat degradation. Wildlife crime has emerged as a significant environmental and economic concern, necessitating effective investigation and enforcement mechanisms. This paper analyses the role of forensic science in investigating wildlife crime in India, focusing on techniques such as DNA analysis, toxicology, isotope analysis, and morphological identification. It further analyses the challenges faced in the application of forensic science, including a lack of infrastructure, limited expertise, weak legal frameworks, and inadequate inter-agency coordination. The study also highlights recent developments, including the growing importance of forensic evidence in securing convictions, supported by contemporary case studies. It argues that the integration of scientific methods with legal processes is essential for strengthening wildlife law enforcement and ensuring biodiversity conservation. The paper concludes by emphasising the need for capacity building, technological advancement, and policy reforms to enhance the effectiveness of wildlife forensic investigations in India.

Keywords: Wildlife, Conservation, Forensic Science, DNA Analysis, Investigation, Wildlife Crime.

1. Introduction

India is recognised as a megadiverse nation with a wide variety of ecosystems and species, yet several species, such as the Asiatic lion and the Indian rhinoceros, are now facing serious threats to their survival. In earlier times, hunting was considered a royal pastime and was practised only by a limited section of society, as forests were extensive and wildlife was abundant. Large game reserves existed specifically for hunting, and the use of wildlife products was limited, ensuring a steady supply without much concern. Consequently, there was no perceived need for a dedicated legal framework for wildlife protection. However, by the late 1960s, increasing habitat destruction and human interference made it evident that effective management and regulation of wildlife were necessary. This led to the enactment of the Wildlife (Protection) Act, 1972, which prohibited hunting across the country and established a comprehensive legal framework for conservation. Following this, institutions such as the Wildlife Institute of India were established, and significant conservation programmes like Project Tiger and Project Elephant were launched. At the same time, global awareness regarding wildlife protection increased, as illegal trade and smuggling of wildlife products began to rise. These unlawful activities, collectively referred to as wildlife crime, include the illegal capture, possession, trade, transport, processing, or consumption of wild animals, plants, or their derivatives in violation of legal provisions, and may also involve cruelty towards both wild

and captive animals. Although wildlife species are the immediate victims, such crimes have far-reaching ecological consequences, disrupting ecosystems and biodiversity. In light of the constitutional mandate, wildlife is considered a national asset, and therefore, wildlife crime not only threatens biodiversity but also adversely affects the nation as a whole.

The common motivating factor behind these crimes is the presence of a trade network supported by demands and resources that perpetuate them. There is a global demand for wildlife and their products for consumption, traditional medicines, decorative purposes, and as pets, among other reasons. Indian wildlife species such as big cats, pangolins, elephants, and various birds fall prey to this cruel practice. Unfortunately, India has become a hotspot for wildlife crimes and illegal trade, as it is a biodiversity-rich country that serves as a source for criminals trafficking wildlife in both national and international markets. Awareness regarding the protected status of many lesser-known wildlife species, particularly marine life like sharks and corals, is lacking, leading to their sale to unsuspecting customers by illegal traders. Other lesser-known species, such as monitor lizards and many owl species, fall victim to the widespread illegal practices surrounding occult beliefs that seek their derivatives. Additionally, the porous borders that India shares with neighbouring countries like China, Bhutan, Bangladesh, and Nepal facilitate a high rate of wildlife crimes, as these countries are known transit and destination points for wildlife trade. The expanding presence of the internet and easily accessible resources has turned social media and online trade into significant players in wildlife crimes, as these platforms are used as covert trading venues for wildlife. All of these factors, combined with weaknesses in the enforcement, investigation, and application of wildlife laws, contribute to wildlife crime and illegal trade and require urgent attention to protect the future of the nation's wildlife. Wildlife trade involves substantial financial gains and should also be regarded as a serious economic offense.[1]

Furthermore, increasing pressures such as habitat destruction, poaching, and human-wildlife conflict, along with inadequate funding and weak enforcement mechanisms, have worsened the challenges of wildlife conservation. Moreover, ineffective implementation of laws, bureaucratic delays, and limited community participation continue to weaken conservation efforts. In India, conservation policies often face resistance due to conflicts between state authorities and local communities who depend on forests and wildlife for their livelihoods. Addressing these challenges requires a balanced and inclusive policy approach that integrates indigenous knowledge systems and ensures active community involvement in decision-making processes. Such an approach can promote a more sustainable and equitable model of conservation. Additionally, inadequate infrastructure and limited capacity among enforcement agencies further hinder effective action against wildlife crimes. Therefore, equipping authorities with modern technologies and tools is essential for strengthening wildlife protection and ensuring better enforcement outcomes.

Due to all these factors, the wildlife crime situation in the country has now assumed alarming proportions. To effectively try the offenders in the Court of law, different forensic knowledge has played a great role in wildlife management. The knowledge and technology used in forensics are not only important for detecting and trying wildlife offenders, but they are also important for wildlife managers to minimise conflict between men and wild animals. Forensic is a legal term related to the investigation of crime involving expertise like identification of fingerprints, analysis of viscera, postmortem and such other things.

[1]Wildlife crime scene management and forensic evidence collection, Training Manual I, *available at:* https://hpforest.gov.in/storage/files/4/aboutus/wildlifefile15-07-2023-1689416227.pdf. (last visited on April 21, 2026).

2. Wildlife Forensic

The Latin word *forensic* means *forum* public or marketplace. In the Roman Empire, the Senate used to conduct its meetings in a public place called the forum, where anyone could listen to the debates and watch the government's actions. The term forensic means *of the forum,* in the broadest sense and forensic science can be defined as the method of science applied to public matters. Forensic science encompasses more than just criminal activities; it has evolved to represent the integration of scientific methods in legal and criminal contexts. Wildlife forensics is a developing branch of forensic science that applies scientific principles to legal issues concerning wildlife. This discipline involves investigating crimes associated with wildlife, including the illegal trade of exotic pets, poaching, illegal hunting practices, and the impact of oil spills on ecosystems. One of the most significant offences addressed by Wildlife Forensic Scientists is poaching, which refers to the unlawful killing of protected species. Additional offences against wildlife involve the trade of endangered animals and their products, such as hides and bones. The goal of wildlife forensics is to utilise scientific techniques to analyse, identify, and compare evidence from crime scenes, thereby connecting this evidence to both suspects and the wildlife victims. The advancement of wildlife forensics is crucial for effectively managing the various social and ecological challenges related to illegal wildlife trade and enforcing wildlife laws.[2]

Forensic scientists worldwide follow a fundamental principle known as Locard's Exchange Principle, which states that "every contact leaves a trace." This means that the perpetrator of a crime will leave behind some sign or trace at the crime scene and will also take something away with them. These traces can serve as crucial evidence. Items collected by authorised officers from wildlife crime scenes, as well as contraband intercepted by agencies like Customs, are handed over to forensic scientists for analysis. They examine these items for evidence of human activity and protected animal parts. This thorough analysis can provide a substantial amount of proof "beyond a reasonable doubt," which courts worldwide rely on to make decisions in criminal cases.[3]

A New Delhi court has made a significant ruling in wildlife law enforcement by convicting Syed Shahid Ahmed Kashani, the owner of M/s Indian Art Gallery in Jaipur, for attempting to illegally export Shahtoosh shawls made from the hair of the critically endangered Tibetan Antelope. The judgment was delivered on March 12, 2026, concluding a case that began in December 2008. The Tibetan Antelope is listed in Schedule I of the Wildlife (Protection) Act, 1972, which prohibits its trade. Additionally, the global trade in Shahtoosh shawls has been banned since 1975 under CITES. This case is notable for the collaboration of four agencies—Wildlife Crime Control Bureau (WCCB), Central Bureau of Investigation (CBI), Customs, and Wildlife Institute of India (WII)—over nearly 17 years. In February 2009, WCCB identified 1,290 Shahtoosh shawls in an export consignment at Indira Gandhi International Airport and filed a complaint with the CBI. A forensic examination by WII confirmed the presence of Tibetan Antelope hair in 41 shawls. Despite the accused's claims of innocence and challenges to the evidence, the court upheld the findings from WII and sentenced him to three years of imprisonment, a ₹50,000 fine, and additional penalties. This case marks one of the earliest instances of a Shahtoosh smuggling offence being prosecuted by the CBI, showcasing the persistent efforts of multiple agencies in wildlife crime enforcement. The seized shawls will be confiscated as government property. It highlights that the

[2] Science Maps of Global and Indian Wildlife Forensics: A Comparative Analysis, *available at:* https://scholarworks.sjsu.edu/libphilprac/1403/ (last visited on October 29, 2024).

[3] Forensics in Wildlife Crime Investigation, *available at:* https://www.wildlifeconservationtrust.org/forensics-in-wildlife-crime-investigation/ (last visited on November 1, 2024).

enforcement of wildlife law in India needs a coordinated approach of detection, investigation, forensics, and prosecution with the ability to sustain the proceedings for over a decade.[4]

3. Role of Forensic Techniques in Wildlife Investigation

Forensic science employs a range of specialised techniques to identify species, determine origin, and establish links between evidence and offenders in wildlife crime cases. Various investigative tools and techniques assist scientists in connecting with the perpetrator, the victim, and the specific crime committed against wildlife, such as poaching, illegal hunting, and trafficking. When materials are seized, they must be sent to forensic laboratories that specialise in wildlife crimes or to wildlife-related research institutions for identification. Forensic laboratories use specific characteristics of seized materials to identify wildlife species. Different areas of forensics, including anthropology, toxicological analysis, DNA and serology testing, ballistics, hair examination, and microscopic analysis, are employed to investigate various aspects of the animals involved, including their species, age, geographical origin, and whether they are prey or predator. The following are some major investigative techniques that are commonly used worldwide to uncover the truth behind crimes against wildlife.

3.1 DNA Analysis: Genetic analysis is one of the most widely used tools in wildlife DNA forensics, primarily for identifying the species from which an evidence sample originates. This technique is particularly useful in cases of illegal poaching, where it helps in examining trace evidence collected from crime scenes or recovered from suspects. It is also extensively applied in identifying wildlife products that have lost their physical characteristics, such as processed wood, traditional medicines, or shark fins. While DNA profiling has long transformed human forensic investigations by enabling individual identification, its application in wildlife protection has been comparatively limited. However, it becomes crucial in certain cases, especially poaching, where it is necessary to establish that a horn, tusk, bone, or skin belongs to a specific animal. DNA profiling achieves this by analysing highly variable genetic markers that differ among individuals of the same species. Overall, wildlife DNA forensics focuses on identifying evidence to determine the species, population origin, genetic relationships, or even the individual identity of a biological sample.[5]

On January 2, 2012, a leopard attacked and killed a child in the Bharari area of the Bilaspur Forest Division in Himachal Pradesh. The victim's body, partially consumed with injuries to the face and neck, was found on January 9, 2012, in a small grotto within a ravine. Authorities discovered two leopard droppings approximately 400 meters away from where the body was located. To prevent further incidents, a search operation was launched, and the suspected man-eater leopard was shot and killed on January 15, 2012, roughly 4 to 5 kilometres from the site of the attack. The authorities sent the droppings along with a tissue sample from the deceased leopard to the Wildlife Institute of India in Dehradun to verify whether all the samples belonged to the same individual or not.[6] This case highlights the significant role of forensic science in wildlife investigations. Through DNA analysis and scientific comparison, forensic techniques help in accurately identifying the animal involved in the attack, thereby avoiding the wrongful killing of

[4]Shahtoosh Trader Convicted in Landmark Wildlife Crime Case spanning 17 years, *available at:* https://www.pib.gov.in/PressReleaseDetail.aspx?PRID=2252139&utm_source=chatgpt.com&reg=3&lang=2 (last visited on April 22, 2026).

[5] Rob Ogden, Nick Dawnay, *et.al.,* "Wildlife DNA forensics—bridging the gap between conservation genetics and law Enforcement" 9 *Endangered Species Research* 6-7 (2009).

[6] Puneet Pandey, Vipin Sharma *et.al., "*Curtailing Human-Leopard Conflict Using Wildlife Forensics: A Case Study from Himachal Pradesh, India" 7 *Journal of Forensic Research* 1 (2016).

non-offending wildlife. It ensures objectivity and reliability in investigation, strengthens evidentiary value in legal proceedings, and supports informed decision-making by authorities. Additionally, the use of forensic science enhances transparency, promotes scientific wildlife management, and contributes to both conservation efforts and public safety.

3.2 Morphological Analysis: The identification of wildlife through morphological or physical characteristics is one of the simplest and most cost-effective forensic methods. This process relies on the external features of various species, providing vital clues for identification. Each species typically has unique physical traits such as fur colour, patterns, eye shape, ear structure, tails, and ivory characteristics. Ivory, often illegally traded from elephants in Africa or Asia, displays a distinctive pattern known as Schreger, which helps differentiate between species. When an entire skin or skeleton is available as evidence, both morphological and anatomical analyses, including microscopic examination, aid in species identification. Having expert knowledge and a database of reference samples is essential for accurate morphological identification. For instance, when animal skin is collected, analysing hair and comparing it to reference samples is critical for determining the species. Morphological testing evaluates the form and structure of various evidence types, including hairs, feathers, skeletal remains, and parts of plants and animals. These samples are analysed against taxonomic keys and species monographs for accurate identification. However, a significant challenge in morphological identification is the often-limited availability of whole or intact animal specimens, which usually restricts the analysis to the genus or higher taxonomic classifications.[7]

3.3 Footprint Analysis: Wildlife footprints serve as crucial evidence in the forensic identification of species. These impressions are created by an animal's foot on the surfaces they traverse or within their captivity. Identifying the species and its age relies on the size and patterns of these footprints. However, a significant challenge in using footprint impressions for species identification is that they can be difficult to detect on hard surfaces, and footprint sites are often compromised by the presence of other animals.[8]

3.4 Age and Sex Determination: In certain wildlife crime investigations, determining the age of a biological sample becomes essential. For instance, if a rhinoceros horn is proven to have been obtained before 1947, it may fall outside the scope of laws prohibiting its trade. To verify such claims, scientific techniques like stable isotope analysis, particularly radiocarbon dating, are employed to estimate the age of the sample. This method works by analysing natural variations in chemical elements present in biological materials. Additionally, the age of animals can be assessed through physical examination, such as studying teeth in animals like goats, sheep, and cattle, or analysing scales in fish. Similarly, identifying the sex of an animal is important in cases where hunting regulations differ for males and females, as seen in species like deer. However, when animal remains are processed or put up for sale, distinguishing physical features such as antlers or external genitalia may no longer be visible. In such situations, sex determination can be carried out through examination of skeletal features like the skull, vertebral column, and lumbar region. Moreover, DNA analysis provides a reliable scientific method for accurately identifying the sex of the specimen in wildlife investigations.[9]

3.5 Toxicology: Toxicological analysis plays a crucial role in wildlife crime investigations, particularly when poisoning is suspected. It focuses on detecting harmful substances such as pesticides, heavy metals,

[7] Nishant K, Vrijesh KY, *et.al.,* "Wildlife Forensic: Current Techniques and their Limitations" 5 *Journal of Forensic Science & Criminology* 3 (2017).
[8] *Ibid.*
[9] Sweta Singh, Mamta Aruna Barmase, *et al.,* "Wildlife Forensics: Investigation Techniques & Laws in India" 9 *Legal Desire International Journal on Law* 12-13 (2022).

and pharmaceuticals. Various advanced techniques are used for this purpose, including High-Performance Liquid Chromatography (HPLC), Atomic Absorption Spectroscopy (AAS), and gas Chromatography–Mass Spectrometry (GC-MS). The choice of method depends on the nature of the case and preliminary findings in the laboratory. A wide range of biological samples can be examined during toxicological investigations. Blood or serum is useful for detecting certain metals and assessing medical conditions, while the liver is particularly effective for identifying heavy metals, chemicals, and drugs. The kidneys also help in detecting metals and pharmaceuticals, whereas the brain is valuable in cases of organophosphate poisoning by assessing enzyme activity. The lungs can reveal inhaled toxins, and hair or feathers may provide insights into the duration of exposure to toxic substances. Additionally, stomach or crop contents in birds, as well as vomitus, are helpful in identifying ingested poisons, especially in cases of acute toxicity. Other materials such as suspected bait can indicate deliberate poisoning, and even insects found on decomposed carcasses may help determine the presence of toxins, as these substances can sometimes be detected in their developmental stages, such as eggs, larvae, or pupae.[10]

3.6 Isotope Analyses: Stable isotope analysis is a relatively modern scientific technique used to measure variations in the ratios of stable elements present in biological tissues such as bones, teeth, skin, and feathers. Since different geographical regions and dietary patterns produce distinct isotopic signatures, these variations can reveal where an animal lived at the time the tissue was formed and what it consumed. Consequently, this method is highly useful in determining the origin and migration patterns of animals. It has wide applications across disciplines such as archaeology, ecology, and geology.The most commonly analysed elements in isotope studies include carbon, hydrogen, oxygen, and nitrogen. Biological tissues contain these elements in specific isotopic proportions—for example, carbon may exist predominantly as 12C with a smaller proportion of 13C. In forensic science, analysing stable isotope ratios in materials like hair, bones, and tooth enamel helps in identifying the geographical origin of animals, humans, and their products, as well as plant-based substances such as pharmaceuticals. The process is carried out using mass spectrometry, and the results require careful analysis and interpretation in specialised laboratories.[11]

3.7 Microscopic Analyses: Microscopy encompasses the study of hair morphology, elemental composition, and cuticular scale patterns. Hair is significant for species identification, making it a valuable form of physical evidence in criminal investigations. The morphological features and keratin structure of hair can aid in determining the species, and hair also contains both nuclear and mitochondrial DNA from an individual. Consequently, hair can be utilised for precise species identification through morphometric analysis and DNA techniques. Microscopic characteristics of hair have been employed for species differentiation. A scanning electron microscope (SEM) is effective for identifying animals through hair analysis, offering high magnification and the capability of Energy Dispersive Spectroscopy (EDS), which aids in pinpointing geographical origins by analysing elements like Sodium, Potassium, Calcium, and Sulphur.[12]

3.8 Other techniques: Serological techniques are based on the specific interaction between antigens and their corresponding antibodies, similar to a lock-and-key mechanism. In wildlife forensics, species-specific antibodies are employed to identify the species of origin of biological samples. Another important approach involves infrared-based techniques. Recent advancements show that spectroscopic methods such

[10] *Ibid.*
[11] *Id* at 14.
[12] Vivek Sehajpal, S.P.Goyal, *et.al.,* "Dealing Wildlife Offences in India: Role of The Hair as Physical Evidence" 1 *International Journal of Trichology* 19-20 (2009).

as mid-infrared (mid-IR), near-infrared (NIR), and Raman spectroscopy, when combined with chemometric analysis, are highly effective in distinguishing species and determining the geographical origin of herbal and biological materials. Among these, NIR spectroscopy is widely preferred due to its reliability, cost-effectiveness, and ease of analysing samples like soil, food, and beverages, making it useful in wildlife identification. In addition, molecular techniques play a significant role in determining species origin. These include the analysis of nuclear DNA, mitochondrial DNA (mt DNA), and DNA fingerprinting, all of which support wildlife law enforcement efforts. Genetic approaches are also used to trace geographical origin, with methods such as assignment tests and microsatellite analysis providing valuable insights into population structure and provenance.[13]

Wildlife forensics plays a critical role in conservation efforts by providing scientific evidence supporting endangered species protection. For instance, forensic investigations can help track the source of illegal wildlife products, disrupting trafficking networks. This intersection of science and conservation highlights the importance of wildlife forensics in global efforts to preserve biodiversity. Students entering this field have the opportunity to contribute directly to these efforts, making wildlife forensics a rewarding and impactful career path.

4. Challenges in Forensic Investigation

Wildlife forensics faces several unique challenges, including the often-decomposed state of wildlife specimens and the wide range of species that may be involved in a single case. Wildlife crimes often occur in remote areas, making evidence collection and preservation difficult. Forensic scientists must be adept at working with limited or degraded samples, and they must be able to apply their expertise across a broad spectrum of species.[14] Wildlife crime is a pressing global issue, impacting biodiversity, ecosystems, and local communities. As illegal poaching, trafficking, and habitat destruction continue to escalate, the need for effective investigative techniques becomes paramount. Forensic science offers powerful tools for wildlife crime investigations, yet numerous challenges remain. This article delves into the complexities faced by investigators in this field.

4.1 Shortage of Resources: There is a need to set up wildlife laboratories in every state near forested areas to conserve wildlife and detect wildlife crimes. There is also a shortage of manpower in existing laboratories, such as state forensic laboratories, wildlife laboratories, and laboratories of the Zoological/Botanical Surveys of India. While advancements in forensic technology have improved wildlife crime investigations, several limitations persist, i.e. High-quality forensic analysis can be prohibitively expensive, especially for conservation organisations and smaller enforcement agencies. Many regions lack trained personnel in forensic techniques specific to wildlife, limiting the effectiveness of investigations. Besides routine detection of wildlife species or their products, the laboratories should also carry out research work to develop indigenous wildlife kits. Therefore, there is a need for proper research-oriented training of the existing workforce with sensitive and specific molecular technologies. The budget for the Ministry of Environment, Forests and Climate Change (MoEFCC) has increased to a value of Rs 3030 crore in the last financial year (2022–2023) from its previous year's budget of Rs 2520 crore (2021–2022), more of which needs to be channelized to wildlife projects since rampant poaching remains a big challenge that may have an impact on the extra burden of wildlife management on police

[13] *Supra* note 7.
[14] Wildlife Forensics: Crimes Involving Animals, *available at:* https://edinbox.com/council/forensic-sciences-gfsec/2241-wildlife-forensics-crimes-involving-animals (last visited on October 29, 2024).

organizations. The role of today's forensic scientists is increasingly important in the efforts being made around the world to uncover the secrets of wildlife crime and its perpetrators. Thus, forensic laboratories must be recognised as important stakeholders, and governments must invest human and financial resources in the development of dedicated, high-throughput wildlife forensic laboratories. Financial institutions and specialised units such as the state-level Anti-Corruption bureaus must be roped in on investigations regularly to bolster scientific evidence of wildlife crime with financial evidence. On their part, forensic scientists must dedicate time for research, development, and standardisation of robust tools for rapid and real-time identification of wildlife contraband when it is intercepted by enforcement agencies.

4.2 Legal Framework: Most nations currently lack the legal framework necessary to create databases for personal information related to humans, such as DNA and fingerprints. These databases are essential for statistically validating findings from forensic analyses. While a few databases exist in countries like India, which can be used to address cross-border wildlife trade cases, there is a significant lack of coordination between nations in this area. This gap complicates the effective linking of criminals to the global network of wildlife crime. Wildlife crime often involves complex legal frameworks that differ from one country to another. The challenges include the fact that wildlife trafficking frequently crosses international borders, making investigations and prosecutions more difficult due to varying laws and enforcement practices. In some regions, inadequate laws or weak enforcement mechanisms can further undermine efforts to investigate and prosecute wildlife crimes effectively.[15]

4.3 Public Awareness: A critical aspect of wildlife crime investigation is the role of local communities and the public. Building trust and cooperation with local communities is essential for effective wildlife protection, yet scepticism and fear can hinder collaboration. Limited public awareness about wildlife crimes and their consequences can reduce support for conservation efforts and enforcement actions.

5. Conclusion

As previously stated, wildlife forensics is a branch of forensic science that assists in crime detection by scientifically collecting evidence from the scene of the crime and analysing it to identify the perpetrators involved in hunting, poaching, or unlawfully selling flora and fauna or products obtained from them. Wildlife forensics has emerged as a vital component of modern wildlife crime investigation, enabling the scientific identification of species and strengthening evidentiary standards in legal proceedings. Techniques such as DNA analysis and isotopic fingerprinting enhance the ability to prosecute offenders effectively and understand the ecological impacts of illegal activities. However, challenges relating to infrastructure, training, legal coordination, and public awareness continue to limit its full potential. Ultimately, the integration of forensic science into wildlife protection not only helps combat wildlife crime but also contributes to the preservation of our planet's biodiversity for future generations. By fostering collaboration among law enforcement, scientists, and local communities, forensic methods can significantly improve conservation efforts. Strengthening forensic capabilities and promoting inter-agency coordination will not only improve conviction rates but also contribute to the long-term conservation of biodiversity. We need to effectively use forensics to fight wildlife crime. If we don't take this seriously, it will show that we're not really committed to stopping wildlife crime.

[15] *Supra* note 7.

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