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Forensic veterinary examination of animal bodies injured by glass fragments

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Abstract. Pre-trial investigation of offences against animal health and life is impossible without the use of specialised knowledge by law enforcement agencies or the court, specifically veterinary and technical knowledge, the perfect form of which is a comprehensive forensic veterinary examination with the study of the instruments of injury: materials, substances, and products. In such cases, the subject of the forensic examination raises questions for the forensic experts to resolve regarding the nature, location, severity, and type of instrument that could have caused a certain injury to the animal's body. Considering the above, the purpose of the present study was to substantiate and develop an algorithm for forensic detection and identification of glass fragments removed from the bodies of injured animals. The study employed a set of modern research methods, including radiographic, ultrasonographic, visual, microscopic, physicochemical, X-ray fluorescence, and statistical analysis, which revealed new data on the informativeness of radiography, and

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ultrasonography as non-invasive methods of detecting foreign objects in the bodies of dead dogs, as well as the possibility of identifying the entire instrument of injury by individual fragments (glass fragments). Thanks to the findings obtained using an integrated approach to detect and identify foreign objects removed from the bodies of injured animals during forensic veterinary examinations, a series of significant issues were resolved: their presence in the body of animals, their attribution to inorganic silicate glass with a detailed description of its chemical composition, and identification of the instrument of injury by its individual parts were confirmed. This study will positively influence the efficiency and effectiveness of forensic examination of animals affected by severe injuries caused by foreign objects removed from their bodies. At the same time, this comprehensive approach allows increasing the degree of validity and objectivity of the expert's opinion as a means of proof in categorical proceedings and expands the evidentiary capabilities of pre-trial investigation bodies and the court

Keywords: comprehensive forensic examination; identification of materials; dogs; instrumental and microscopic examinations; puncture wound; piercing and cutting instruments; animal cruelty

Introduction

The relevance of the subject under study is that forensic veterinary examination (FVE) is actively developing in Ukraine, as well as in many countries of the world. Its problematic issues and ways of solving them have been analysed by many researchers, including the authors of the present study. A. Rebollada-Merino *et al*. (2020) and R. Munro (2022) emphasised that the principal task of the forensic science is to establish the facts and circumstances of the offence related to the determination by the forensic veterinary expert of the damage caused to the health and life of the animal. The forensic veterinary expert determines the nature of the damage caused to the animal based on the application of special veterinary knowledge, by conducting a comprehensive study of material and materialised objects as carriers of information, using relevant means (methods) to solve the identification, diagnostic, and situational tasks of the FVE. Considering the above, according to L. Reese *et al*. (2020) and M. Connor *et al*. (2021), law enforcement agencies and the court must use specialised knowledge to clarify the facts and circumstances of the case during the pre-trial investigation or judicial investigation of animal cruelty as a shameful phenomenon against public morality. D. Kolodin & A. Kolodina (2023) and O. Pirgo (2024) noted that in Ukraine, liability for this offence is prescribed by criminal and administrative Ukrainian legislation, specifically, Article 299 of the Criminal Code of Ukraine and Article 89 of the Code of Administrative Offences of Ukraine.

I. Yatsenko & O. Parilovskyi (2020) proved how animal cruelty is accompanied by the infliction of bodily harm and mutilation to animals. The researchers argued that the qualification of the offence of animal cruelty should factor in the opinion of a forensic veterinary expert on the nature and severity of bodily injuries, as well as the causal relationship between the injuries identified by the expert and the health disorder, injury, or death of the animal. J. Cooper & M. Cooper (2021) and Yu. Fedyk & I. Besaha (2023) proved that forensic examination is a scientifically based means of proof, while the opinion of a forensic expert is evidence in court. R. Rosa & R. Buckley (2024) found that it is essential to establish the type of instrument that caused the injury, specifically, sharp instruments, when investigating offences against animal health and life. Therewith, A. Davros *et al*. (2023) established the nature of injuries in animals caused by blunt objects. Foreign objects that can be found in the wound channel of an injured animal are also of substantial relevance (Lee *et al*., 2022).

Despite great strides in forensic veterinary examination, the information available in scientific sources on the algorithm for forensic detection and identification of foreign objects removed from the bodies of injured animals relates mainly to legal aspects and assessment of the nature of animal injuries. At the same time, the scientific literature has not yet described an algorithm for forensic veterinary examination of animals injured by sharp objects, nor has it tested the use of supplementary technical and instrumental examinations of injured animals (X-ray, ultrasonographic), nor methods of identifying foreign objects. Therefore, certain aspects of the substantiation and development of an algorithm for detecting and identifying foreign objects removed from the bodies of injured animals are quite problematic, understudied, and must be addressed. The purpose of the present study was to identify the principal factors for conducting a forensic veterinary examination, to describe the injuries inflicted on animals, and to identify foreign objects removed from their bodies.

Literature Review

Many researchers have addressed the problem of forensic detection and identification of foreign objects removed from animal bodies in case of injuries of various kinds. Thus, T. Saul *et al.* (2016) highlighted that the situations when sharps injuries occur may include social violence, accidents, hunting, veterinary care, religious rituals, etc. Accurate documentation and examination of these injuries, as emphasised by A. Van Neer *et al*. (2021), J. Rosa *et al*. (2022), may suggest the instrument of injury, the relative position of the animal and its offender, and the force with which the injury was inflicted. Thus, M. Skrypka *et al*. (2023) revealed the pathogenesis and detailed the pathomorphological signs of spinal cord injury with a sharp object in a domestic cat. J. Love (2019) proposed the use of light microscopy, microcomputer scanning, scanning electron microscope and epifluorescence microscopy, which together can help to identify the instrument that caused a particular injury. According to J. Voss *et al.* (2021), open injuries carry the risk of contamination by foreign bodies. Therefore, an accurate clinical examination is the first step in detecting foreign bodies in both human and animal bodies, but is not sufficient to identify their type, which requires further investigation. Therefore, the choice of a suitable imaging method that is a useful tool for finding foreign bodies is crucial for their detection and analysis.

Scientific research shows the capabilities of various imaging methods for detecting foreign bodies in soft tissues. A. Ayalon *et al.* (2021) and M. Blondel *et al.* (2021) substantiated the feasibility of using various research methods in the forensic examination of animals with injuries, including plain radiography, computed tomography, ultrasonography, magnetic resonance imaging, etc. R. Corzo & E. Steel (2020) and R. Corzo *et al.* (2021) argued the possibility of determining the nature of foreign objects by their different chemical composition, including glass fragments. In addition, A. Alfuraih *et al.* (2022) proposed using such research methods to detect plant particles in the pig's body, E. Palazzo *et al.* (2018) – signs of wound metallisation, etc.

Computed tomography is essential for determining the location of foreign bodies and the relationship with the surrounding structures, as well as the depth of the injury. However, magnetic resonance imaging is of little use for detecting foreign bodies. Furthermore, J. Del Cura *et al.* (2020) confirmed the effectiveness and efficiency of ultrasonography for the detection and removal of various foreign bodies (plant, metal, and glass objects, etc.), although the researchers emphasised that the signs of ultrasound examination depend on the type and shape of the foreign body. However, all foreign bodies are echogenic. F. Bosma *et al.* (2022) illustrated the possibility of visualising a foreign body with a woody structure in the soft paravertebral tissues and spinal canal of a dog using computed tomography. A. Kashani-Carver *et al.* (2023) reported the diagnosis of an intralenticular foreign body in a dog, and K. Hellbach *et al.* (2018) reported the successful intraoperative removal of a foreign body in a 4-month-old puppy from the cranial cavity under ultrasound guidance.

Undoubtedly, the scientific achievements of the above-mentioned scientists have contributed to solving some problems in the study of foreign objects removed from animal tissues, including glass fragments, which may originate from the instrument of animal injury in case of animal cruelty and may also become material evidence in criminal proceedings, but have not attracted the proper attention of forensic veterinarians. There are no theoretical developments or extensive empirical studies of the problem of detecting and identifying foreign objects of various origins from animal bodies. Therefore, to summarise, the issue of detection and identification of foreign objects and particles in animal wounds is quite problematic and therefore requires further investigation and testing in forensic practice.

Materials and Methods

The study was conducted in 2023-2024 at the Laboratory of Forensic and Military Research of the National Scientific Centre "Mykola Bokarius Institute of Forensic Expertise" of the Ministry of Justice of Ukraine (Kharkiv) in several stages. At the first stage, a forensic veterinary examination of injured animals was performed following the Methodology of forensic veterinary examination of a living animal (Yatsenko & Parilovskyi, 2023). Radiographic examinations were performed using a digital X-ray machine "Diagnostic X-RAY UNIT (model: PXM-408T PLUS)" (China). Ultrasonographic examinations were performed using a Chison CBit 9 device with a Chison linear transducer (China).

At the second stage, foreign objects found in the wounds of dogs were examined following the Forensic Examination of Glass and Glass Products (2016) and the Forensic Examination of the Material of Glass Products Installed on Vehicles (2016). For the purpose of laboratory research, the following were used: polymer scale ruler for photography (Ukraine); microscope MBS-9, magnification 4.5-63$^{\times}$ (Ukraine); microscope KERN OZP 558 with camera KERN ODC-82/ODC-83 (Ukraine); metal measuring ruler LRI 300 (Ukraine); caliper ШЦ-I-125-0.5 (Ukraine), measuring range 0-250 mm, $\Delta = \pm 0.1$ (Ukraine); energy X-ray spectrometer SER-01 (ElvaX Pro) (Ukraine); polarising microscope Ulab XP-501 LM 19095M013 (Ukraine); digital camera Canon Power Shot A3100IS (12.1 megapixels) (Ukraine). The external examination and study of glass fragments was performed visually in daylight and artificial light and in the field of view of the MBS-9 microscope (Ukraine) (magnification up to 63$^{\times}$, reflected light), KERN OZP 558 microscope with KERN ODC-82/ODC-83 camera (Ukraine) and Ulab *XP*-501 LM 19095M013 polarising microscope (Ukraine).

To establish the absence of the effect of double refraction of glass fragments removed from dog wounds, the latter were placed in the focus of a polarising microscope Ulab *XP*-501

LM 19095M013 (Ukraine). Examination in polarised light revealed the absence of the pleochroism effect, which indicated the amorphous structure of the fragments removed from the wounds of the dogs and the object seized at the scene of the offence. To determine the inorganic nature of the glass fragments, they were treated with solvents (dichloroethane, carbon tetrachloride) and sulphuric acid, including heating.

The elemental chemical composition of the shards provided for the study was determined using the X-ray fluorescence analysis (XRF) method. The XRF method is based on the dependence of X-ray fluorescence intensity on the concentration of an element in the sample. When a sample is irradiated with an X-ray flux, characteristic fluorescence radiation is generated, which is proportional to the concentration of the chemical element in the object. The radiation is decomposed into a spectrum using crystal analysers, and then its intensity is measured using detectors and counting electronics. Mathematical processing of the spectrum enables its quantitative and qualitative analysis. An energy X-ray spectrometer CEP-01 (ElvaX Pro) (China) was used to determine the quantitative and qualitative composition of the fragments (objects No. 1-4). The spectrometer is designed to measure the mass fraction of chemical elements in samples of various origins.

The following technical conditions were met during the measurements: range of detected elements from *Na* ($Z = 11$) to *U* ($Z = 92$); accelerating voltage of 60 kV; maximum current of the X-ray generator of 1000 μA; quantitative analysis algorithm – method of fundamental parameters and empirical calibrations; type and serial number of the X-ray tube Rh122594. To improve the measurement accuracy, brown layers were removed from the surface of the objects under study with an aqueous solution of ethyl alcohol only to the extent necessary for the study.

For X-ray fluorescence analysis, the fragments (objects No. 1-4) were placed in the working chamber of the spectrometer in the focus of the X-ray tube and subjected to analysis. All animal manipulations were performed following the principles regulated by the European Convention for the Protection of Vertebrate Animals used for Experimental and Other Scientific Purposes (1986) and the Law of Ukraine No. 3447-IV "On the Protection of Animals from Cruelty" (2006). Digital data were processed using the statistical method on a personal computer using Microsoft Excel. The assessment of statistical reliability was determined by the Student's coefficient at three levels of probability: $P < 0.05$, $P < 0.01$, $P < 0.001$.

This study was based on the conclusions of forensic examinations conducted in criminal proceedings for animal cruelty, when foreign objects, including glass fragments, were removed from the bodies of dead animals. In this case, the forensic veterinary examination included examination of the injured animals and the recovered foreign objects, which were glass fragments, and their identification by a set of features. To solve these problems, a comprehensive forensic veterinary examination of materials, substances, and products was performed.

Results and Discussion

Theoretical and methodologicalprinciples of forensic veterinary research

The expert tasks that can be solved by the forensic expert commission include identification (identification by individual parts, identifying object) of the entire object (identified), diagnostic (determination of the relation of foreign objects to inorganic silicate glass, determination of the chemical composition of glass fragments), and situational (mechanism of damage formation; the possibility of damage formation found in an animal under the established conditions and circumstances of the offence). The subjects of a comprehensive forensic veterinary and materials, substances and products examination are a commission of forensic experts in the expert specialities 18.1 "Veterinary research" and 8.5 "Research of glass, ceramics, and products made of them". The objects of forensic examination are injured animals and glass fragments.

It should be emphasised that during a comprehensive forensic veterinary examination with the study of materials, substances, and products, the subject of its appointment may raise the following issues for resolution by forensic experts, which are formulated for the first time in the author's version, specifically:

- What is the nature of the injuries and their location?
- What is the mechanism, sequence (order) of infliction of the injuries?
- What is the severity of each injury?
- Were the injuries caused to the animal life-threatening at the time of their infliction, and if so, what caused their danger?
- How old are the injuries?
- Is it possible to determine by the nature of the injury to the animal's body what type of tool could have caused the injury and whether the injury was caused by a tool analogous to the one provided for examination (knife, axe, pitchfork, etc.)? (This is decided by a comprehensive forensic veterinary and trace evidence examination).
- Are there any signs suggesting that the injury was caused by repeated exposure to a sharp object?
- What is the sequence in which the injuries were inflicted?
- Was the injury caused by one or more instruments?
- What is the direction of the wound channel and what foreign objects are found in it?
- Did the injuries cause crippling injuries to the animal and how did this affect the period of loss of general economic use of the injured animal due to the injury?
- Were there any defects in the veterinary care provided to the animal that caused the injury, and if so, what was the severity of the injury, was there a loss of general economic and special use of the animal and, if so, what was the duration of the loss?
- Is there a causal link between the bodily injuries caused to the animal under the circumstances and the disorder of its health due to death?
- Could the animal itself have caused the injury?
- Did the injuries that were found on the injured animal cause physical pain and suffering? What are the signs of infliction of pain?

Considering the above, it is proposed to amend the Scientific and Methodological Recommendations on the Preparation and Appointment of Forensic Examinations (Order of the Ministry of Justice of Ukraine No. 53/5, 1998) with a list of questions in the authors' version that can be solved by a comprehensive forensic veterinary examination with the study of materials, substances, and products during the examination of live animals or their cadavers injured by glass fragments. To solve the expert tasks set out in the procedural document (decision of the investigator or prosecutor) or court decision, the authors of the present study proposed an algorithm for forensic examination of animals for injuries caused by stabbed objects and glass fragments removed from their bodies (Fig. 1).

To resolve identification and diagnostic issues related to foreign objects removed from the wounds of a live animal or its cadaver (in this study – glass fragments), the subject of the forensic examination may ask the following clarifying questions in addition to the main list of questions:

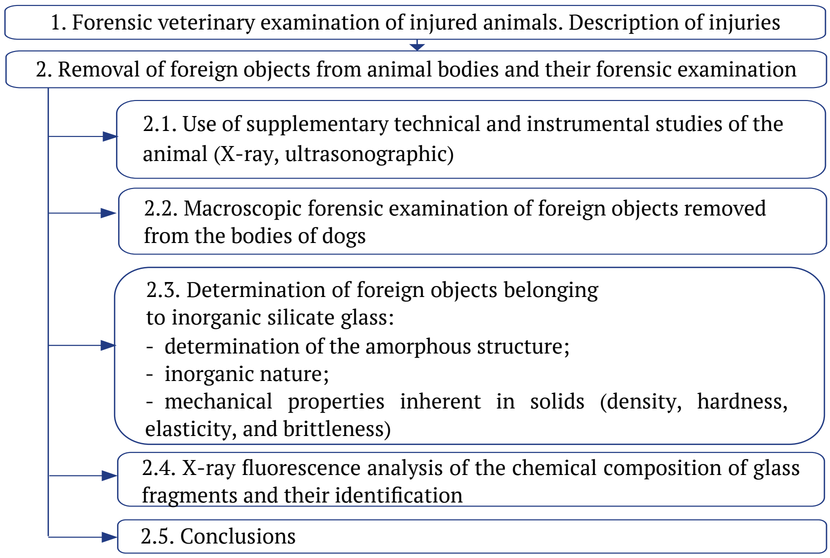


Figure 1. Algorithm for forensic examination of animals for injuries caused by stab wounds from objects removed from their bodies

***Sourse**: developed by the authors of this study*

♦ Are there any foreign objects in the animal's body? If so, what is their nature?

♦ What type of glass are the glass fragments removed from the soft tissues of the living animal (cadaver) and the fragments of the glass bottle (neck) removed during the examination of the crime scene?

♦ What is the chemical composition of the glass fragments recovered from the soft tissues of a living animal (cadaver) and fragments of a glass bottle (neck) found during the examination of the crime scene?

♦ Do the fragments of glass recovered from the soft tissues of the body of a living animal (cadaver) have a common genus (group) affiliation with the fragments of a glass bottle (neck) recovered during the inspection of the crime scene?

This list of questions is not exhaustive. The forensic veterinary expert may be asked other questions within the scope of the expert study.

Forensic veterinary examination of injured animals. Description of injuries

At the first stage of the forensic examination, it is necessary to conduct a clinical forensic veterinary examination of the injured animal or a pathological examination of the corpse. During a clinical forensic veterinary examination of a live animal or a pathological examination of a corpse, specific signs of damage caused by the action of piercing and cutting objects, including glass fragments, are revealed: the nature of the damage is a stab wound; its entrance opening is always linear in shape (Figs. 2a, 3a, 4a). The depth of the wound is much greater than the length, but it can be the same as the length of the glass fragment (if it is fixed in the skin and subcutaneous tissue and superficial layers of skeletal muscle) (Fig. 2a), or greater than its length (if it penetrates deep tissues or even into the body cavities of the animal with damage to internal organs) (Fig. 3a). The wound edges are smooth, even, intact, and slightly cyanotic, with abrasions, drying, abrasion border, deposition border, and absence of tissue bridges in the wound channel (Figs. 3a, 4a). The wound ends are acute-angled, sometimes with notches and incisions; the wound channel has smooth or bevelled edges. The expert summary of the morphology of stab wounds inflicted on animals was confirmed by the findings of M. Ghanbari *et al.* (2024). The radiographs of a dog named Reks, taken in the vertebral and lateral projections, revealed one foreign body in the form of a light X-ray shadow, which was close to triangular in shape, located in the right frontal region (Fig. 2b). The ultrasonogram revealed signs of a dense hyperechoic elongated object without a pronounced acoustic shadow (Fig. 2c).

a b c

Figure 2. Glass fragment in the soft tissues of the right frontal area of a dog named Reks (Object No. 1)

Note: *general view of the wound opening in the right frontal area of the dog and X-ray of the head and neck fragment with visualisation of a foreign body: a – external view of the puncture wound; b – view on the X-ray in the lateral projection (shown by an arrow); c – view on the ultrasonogram (1)*

Sourse: *developed by the authors of this study*

A lateral view radiograph of a dog named Baks (Object No. 2) revealed two foreign elongated objects in the form of light X-ray shadows, close to rectangles in shape, located in the soft tissues of the lower third of the right thigh (Fig. 3b). The ultrasonogram in the same area revealed signs of soft tissue prolapse and a 9.9 mm hyperechoic, elongated, tuberculated object without an acoustic shadow (Fig. 3c).

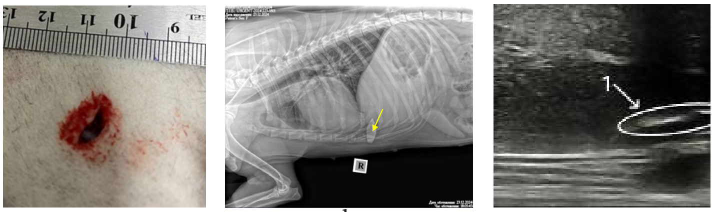
a b c

Figure 3. Glass fragment in the soft tissue of the left thigh of a dog named Baks (Object No. 2)

Note: *general view of the wound opening in the left thigh of the dog and X-ray of a fragment of the animal's pelvic limbs with visualisation of a foreign body: a – external view of the puncture wound with a foreign body in the wound channel; b – view on the X-ray in the lateral projection (shown by an arrow); c – view on the ultrasonogram (1)*

Sourse: *developed by the authors of this study*

The radiograph of a dog named Archi (Object No. 3), taken in the lateral and spinal projections, revealed one foreign elongated object in the form of a light radiopaque shadow, close to a pentagon in shape, located in the soft tissues of the lower third of the right thigh (Fig. 4b). In the same area, ultrasonographic signs of soft tissue prolapse up to 9.5 mm in size and two hyperechoic objects 9.2 mm and 3.9 mm in size, elongated, with a tuberous surface, without an acoustic shadow were visualised (Fig. 4c).



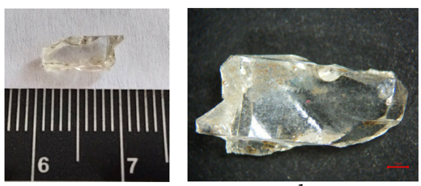
a b c

Figure 4. Glass fragment in the liver of a dog named Archi (Object No. 3)
Note: *general view of the wound opening in the left rib wall and a lateral view of the animal's body with visualisation of a foreign body: a – external view of the stab wound in the right rib wall; b – view on the lateral projection X-ray (shown by an arrow); c – view on the ultrasonogram (1)*
Sourse: *developed by the authors of this study*

The authors of the present study emphasise that the sensitivity for detecting vitreous foreign bodies by radiography and ultrasonography was 100% for all sensors. Foreign bodies detected in wounds using imaging methods were removed, documented, attached to the case files, and handed over to investigators in criminal proceedings for forensic examination. E. Bartelnik *et al*. (2022) pointed out the relevance of the identification, collection, and preservation of forensic veterinary evidence at the scene and during pathological examination. Ensuring high accuracy in forensic veterinary examinations of injured animals is an essential component of modern forensics, as such studies provide key information to establish the mechanism of injury, the time of their formation, and the possible tool used.

Forensic examination of foreign objects removed from the bodies of dogs

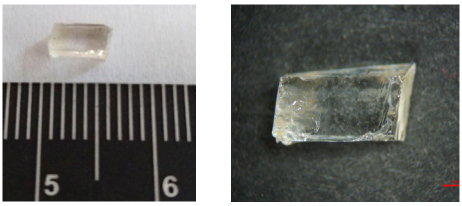
In the structure of a comprehensive forensic veterinary examination of materials, substances, and products, a separate determination of glass fragments removed from the bodies of injured dogs is performed by a forensic expert in the study of materials, substances, and products, including glass. Thus, during the examination of a transparent foreign object removed from the corpse of a dog named Reks (Object No. 1), it was found that it was a single transparent vitreous fragment with dimensions of 4 mm wide, 10 mm long, and 2.7 mm thick. It was polygonal in shape, with two flat-parallel surfaces of technological origin. On the surface of Object No. 1, there were layers of a brown substance that looked like blood (Fig. 5).



a b

Figure 5. A view of an object removed from a dog's wound (Object No. 1)
Note: *a view of the object removed from the body of a dog named Reks: a – general view, b – detailed view*
Sourse: *developed by the authors of this study*

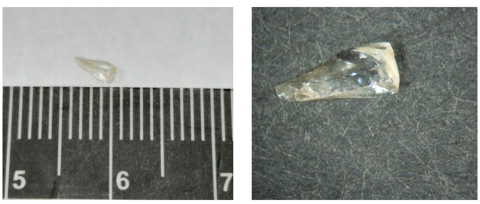
During the examination of the foreign object recovered from the cadaver of a dog named Baks (Object No. 2), it was found that it was a transparent object of a vitreous structure, with dimensions of 3 mm wide, 5.4 mm long, and 2.8 mm thick. The fragment was polygonal in shape with two flat-parallel surfaces of technological origin. On the surface of this object there were layers of a brown substance that looked like blood (Fig. 6).



a b

Figure 6. A view of an object removed from a dog's wound (Object No. 2)
Note: *a view of the object removed from the body of the dog named Baks: a – general view, b – detailed view*
Sourse: *developed by the authors of this study*

The examination of the foreign object recovered from the corpse of the dog named Archi (Object No. 3) revealed that it was a transparent glassy object with dimensions of 1.9 mm wide, 4.3 mm long, and 2.9 mm thick. The object had a complex pointed shape. The surface of this object had layers of a brown substance that looked like blood (Fig. 7).



a b

Figure 7. A view of an object removed from a dog's wound (Object No. 3)
Note: *a view of the object removed from the body of the dog named Archi: a – general view, b – detailed view*
Sourse: *developed by the authors of this study*

Examination of the object found at the scene (Object No. 4) revealed that it was a fragment of a glass bottle (neck) made of pure glass. The length of the neck fragment was 110 mm. Due to its design features the neck of the bottle had a variable outer diameter: the smallest (at the base of the neck) was 29 mm, the largest was 43 mm. The inner surface of the upper part of the neck contained a dispenser made of polymeric material. The upper part of the bottle neck was covered with a black polymer film tightly adjacent to the outer walls of the bottle with the printed inscription "JACK DANIEL'S", "Old No. 7 BRAND" in white. There were convex inscriptions on the surface of the neck, which were part of the glass neck. Due to the limited size of the neck fragment, the content of the inscription could not be determined. On the surface of the black polymer film, there were two fragments of an excise stamp and stickers marked "6" and "9". On the outer surface of the neck there was a sticker with the marking "5". On the inner surface of the neck there was a sticker with the markings "7" and "8" (Fig. 8).

Figure 8. General view of a fragment of a glass bottle (neck) recovered during the inspection of the scene
Sourse: *developed by the authors of this study*

Thus, the analysis of the interim results of the study showed that during the forensic veterinary examination of the injured dogs, they were diagnosed with stab wounds, in the wound channels of which foreign objects resembling glass were found. Therefore, at the next stage of the forensic examination, it was necessary to establish whether these foreign objects belonged to inorganic silicate glass.

Determination of the belonging of foreign objects removed from the bodies of dogs to inorganic silicate glass

According to the ideas about the structure and properties of glass, based on the concept of the glassy state, it is necessary and sufficient to identify three features to classify foreign objects removed from animal wounds as inorganic silicate glass: amorphous structure, inorganic nature, and mechanical properties of solids. Thus, the amorphous nature of the glassy state is manifested in the anisotropy of glasses due to the lack of directional orientation of structural formations. This orientation and, consequently, anisotropy are characteristic of crystals, in contrast to which glass microparticles do not exhibit the effect of pleochroism (double refraction) in polarised light. The results of the microscopic examination revealed that the fragments of objects Nos. 1-4 did not exhibit the pleochroism effect in polarised light. Accordingly, the absence of this effect indicated the amorphous structure of the substance.

The inorganic nature of the foreign objects removed from the dogs' wounds was established. The authors of the present study point out that all substances of organic origin, unlike inorganic ones, dissolve in organic solvents and/or interact with sulphuric acid and are subject to destruction at temperatures of 200-400°C. According to the results of the study of objects Nos. 1-4, during their treatment with solvents (dichloroethane, carbon tetrachloride) and sulphuric acid, including during heating, there were no noticeable changes in their shape and appearance, which confirmed the inorganic nature of the objects of study.

The mechanical properties of the foreign objects removed from the wounds of the dogs (Objects Nos. 1-3) and the object at the crime scene were also determined. According to G. Kaur *et al.* (2019), the mechanical properties of glass include density, hardness, elasticity, and brittleness. To determine the mechanical properties of objects recovered from dog wounds, specifically those inherent in glass, it is sufficient that the value of one of these properties is within the range of inorganic glasses. The appearance of the fragments is a qualitative characteristic of the fragility (brittle fracture) of the material. Therefore, microscopic examination of objects Nos. 1-4 recovered from animal bodies revealed signs characteristic of brittle fracture: chips, cracks, sharp shaped fragments with cutting edges, and a shell-shaped fracture surface (Figs. 5-8). Thus, the above studies of glass fragments recovered from the bodies of dogs proved that they belong to inorganic silicate glass in terms of their amorphous structure, inorganic nature, and mechanical properties.

X-ray fluorescence analysis of the chemical composition of glass fragments and their identification

According to V. Sharma *et al*. (2023), the identifying feature of glass fragments recovered from animal bodies to attribute them to a single object is their chemical composition. Notably, the elemental composition of glass is formed from the main components, additives specially introduced into the glass to give it the specified properties, and random impurities that enter the glass mass with raw materials or refractory of the furnace in which the glass is smelted. In this regard, XRF allows differentiating glass fragments recovered from dog wounds by their qualitative and quantitative elemental composition, as well as to determine the main and impurity elements in this composition. Thus, the elemental chemical composition (in the range from atomic number 11, which belongs to sodium (Na), to atomic number 92, which belongs to uranium (U), of the objects of study is presented in Table 1.

Table 1. Chemical composition of objects Nos. 1-4, M ± m, n = 3

Chemical elements		Concentration of chemical elements (wt%)			
Atomic number	Name	Object No. 1	Object No. 2	Object No. 3	Object No. 4
14	Silicon (Si)	60.007 ± 0.302	60.205 ± 0.354	62.381 ± 0.671	60.036 ± 0.237
11	Sodium (Na)	33.958 ± 0.501	33.929 ± 0.655	31.580 ± 2.045	34.184 ± 0.365
20	Calcium (Ca)	2.585 ± 0.016	2.597 ± 0.018*	2.756 ± 0.036***	2.534 ± 0.012
12	Magnesium (Mg)	1.609 ± 0.058	1.586 ± 0.072	1.727 ± 0.186	1.623 ± 0.044
13	Aluminium (Al)	1.404 ± 0.043	1.444 ± 0.052	1.401 ± 0.113	1.409 ± 0.032
16	Sulphur (S)	0.099 ± 0.008	0.127 ± 0.010*	0.023 ± 0.034	0.085 ± 0.005
15	Phosphoros (P)	0.061 ± 0.024	0.022 ± 0.029	–	0.035 ± 0.002
26	Iron (Fe)	0.031 ± 0.001	0.032 ± 0.001***	0.035 ± 0.003**	0.025 ± 0.001
22	Titanium (Ti)	0.027 ± 0.005	0.029 ± 0.006	0.031 ± 0.012	0.022 ± 0.017
19	Potassium (K)	0.025 ± 0.004	–	–	0.022 ± 0.004
38	Strontium (Sr)	0.012 ± 0.000	0.011 ± 0.000	0.009 ± 0.001	0.011 ± 0.000
40	Zirconium (Zr)	0.007 ± 0.000	0.007 ± 0.000	0.006 ± 0.001	0.008 ± 0.000
23	Vanadium (V)	0.003 ± 0.002	0.002 ± 0.003	0.005 ± 0.006	0.003 ± 0.002
25	Manganese (Mn)	0.003 ± 0.001	0.004 ± 0.001	0.015 ± 0.003	0.002 ± 0.000
30	Zinc (Zn)	0.003 ± 0.000	0.003 ± 0.000	0.003 ± 0.004	0.001 ± 0.001
24	Chromium (Cr	–	0.002 ± 0.002	0.003 ± 0.001	–
46	Palladium (Pd)	–	–	0.023 ± 0.003	–

Note: **P < 0.05; **P < 0.01; ***P < 0.001 compared to the indicator of Object No. 4*
Source: *developed by the authors of this study*

According to the XRF results, it was established that the chemical elements listed in Table 1 are markers for establishing the generic characteristics of the investigated objects in the composition of objects Nos. 1-4, recovered from animal soft tissues. Objects Nos. 1-3, recovered from the bodies of dogs by nicknames: Reks, Baks, Archi, and a fragment of a glass bottle (neck) seized at the scene of the offence (Object No. 4) did not have the property of luminescence and fluorescence in ultraviolet rays with a wavelength of λ_{max} = 256 nm and with λ_{max} = 325 nm, as well as phosphorescence after the cessation of irradiation with ultraviolet rays. These coincident features are common to the material from which they are made, which indicated that they belonged to inorganic silicate glass.

The established chemical composition of Objects Nos. 1-4 suggested that the glass fragments recovered from the cadavers of dogs named: Reks (Object No. 1), Baks (Object No. 2), Archi (Object No. 3), and a fragment of a glass bottle (neck) seized during the inspection of the crime scene (Object No. 4) belonged to inorganic sodium aluminosilicate glass. Subsequently, the genus of the objects was established, i.e., their assignment to a specific set, following the classification accepted in science and technology. Therefore, based on the XRF results, the glass fragment (Object No. 1) recovered from the body of the dog named Reks and the fragment of the glass bottle (neck) (Object No. 4) recovered during the inspection of the crime scene were identical in terms of the qualitative composition of chemical elements and had no significant difference. Thus, the glass fragment (Object No. 1) and the bottle neck (Object No. 4) had a common origin.

Comparative studies of the chemical composition of Object No. 2, recovered from the body of a dog named Baks, with a fragment of a glass bottle (neck) (Object No. 4) revealed that Object No. 2 differed from the fragment of the glass bottle (neck) in the qualitative composition of chemical elements by the absence of potassium (K) and the presence of chromium (Cr). Differences in the quantitative composition of chemical elements were also revealed, specifically, the elemental composition of Object No. 2 significantly differed from the same Object No. 4 in the content of the following chemical elements: calcium ($P < 0.05$), sulphur ($P < 0.05$), and iron ($P < 0.001$), which indicated their different generic affiliation, i.e., the glass fragment (Object No. 2) and the bottle neck (Object No. 4) had different origins.

Comparative studies of the chemical composition of the glass shard (Object No. 3) and the fragment of the glass bottle (neck) (Object No. 4) revealed that Object No. 3 differed from the fragment of the glass bottle (neck) (Object No. 4) in the qualitative composition of chemical elements by the absence of potassium (K) and phosphorus (P) in Object No. 3 and the presence of chromium (Cr) and palladium (Pd). Furthermore, Object No. 3 did not differ significantly from Object No. 4 in terms of the quantitative composition of chemical elements, specifically, sodium, magnesium, aluminium, sulphur, titanium, strontium, zirconium, vanadium, manganese, and zinc. However, a quantitative significant difference in the content of chemical elements in Object No. 3 versus Object No. 4 was found, specifically: silicon ($P < 0.05$), calcium ($P < 0.01$), and iron ($P < 0.01$), which indicated that they were of different generic origin, with the glass fragment (Object No. 3) and the bottle neck (Object No. 4) were of different origin.

Notably, these qualitative and quantitative differences in the chemical composition of the elements are substantial features of forensic significance. This helped to state that objects Nos. 2 and 3, recovered from the bodies of dogs named Baks and Archi, respectively, did not have a common origin with the material of a fragment of a glass bottle (neck) (object No. 4) recovered during the examination of the scene. To summarise, the proposed algorithm for forensic detection and identification of glass fragments recovered from the wounds of injured animals will enable forensic experts to state the mechanism of formation of stab wounds under the circumstances and at the time specified in the criminal proceedings.

Conclusions

For the first time, an integrated approach to the detection and identification of glass fragments removed from animal bodies in the form of a comprehensive forensic veterinary examination with the study of materials, substances, and products was introduced into forensic science. During this examination of glass fragments removed from animal bodies, the expert commission can solve identification, diagnostic, and situational tasks. The algorithm of forensic examination of animals injured by glass fragments removed from their bodies comprises the following stages: visual forensic veterinary examination of injured animals and description of injuries; application of additional technical and instrumental studies of the animal (X-ray, ultrasonographic), removal of foreign objects from animal bodies and their forensic examination, which includes description of macroscopic parameters, determination of the foreign object's affiliation with inorganic silicate glass by determining its amorphous structure, inorganic nature, mechanical properties inherent in solids (density, hardness, elasticity, and fragility); X-ray fluorescence analysis of the chemical composition of glass fragments and their identification; formulation of forensic expert opinions. X-ray and ultrasonographic methods of examining injured animals enabled an accurate visualisation of the presence of foreign objects in the body, establishing their number, shape, size, and location. However, they do not provide information on the type of foreign object.

The elemental composition of glass fragments removed from the bodies of injured animals and fragments found at the scene of the offence, determined by X-ray fluorescence analysis, is reliable, accurate, reliable for qualitative and quantitative analysis, and suitable for identifying glass fragments during a comprehensive forensic veterinary examination of materials, substances, and products. Glass fragments recovered from the bodies of dogs named Reks, Baks, Archi, respectively (Objects Nos. 1-3) and a fragment of a glass bottle (neck) (Object No. 4) recovered during the examination of the scene belonged to inorganic sodium aluminosilicate glass. The glass fragment (Object No. 1) recovered from the body of the dog named Reks and the fragment of the glass bottle (neck) (Object No. 4) recovered during the examination of the scene of the crime had a common generic affiliation by the material from which they were made. However, the glass fragments recovered from the bodies of dogs named Baks and Archi, respectively (Objects Nos. 2 and 3) did not have a common generic affiliation with the chemical composition of the glass bottle fragment (neck) (Object No. 4) recovered during the examination of the scene. The application of the algorithm for forensic examination of animals damaged by glass fragments removed from their bodies, developed and tested by the authors of the present study, will enable forensic experts to formulate categorical opinions. Further research will be aimed at resolving issues related to the detection and identification of substances of soil origin removed from animal wounds.

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Conflict of Interest

None.

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Судово-ветеринарна експертиза тіл тварин, травмованих осколками скла

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Анотація. Досудове розслідування правопорушень проти здоров'я і життя тварин неможливе без застосування правоохоронними органами або судом спеціальних знань, зокрема ветеринарних і технічних, довершеною формою яких є комплексна судова ветеринарна експертиза з дослідженням знарядь їх травмування: матеріалів, речовин та виробів. У таких випадках суб'єкт призначення судової експертизи ставить на вирішення судового експерта питання, які стосуються характеру, локалізації, ступеня тяжкості, виду знаряддя, яким могло бути заподіяне певне ушкодження тіла тварини. З огляду на зазначене, мета дослідження полягала в обґрунтуванні та розробці алгоритму судово-експертного виявлення та ідентифікації уламків скла, вилучених із тіл травмованих тварин. У роботі використовували комплекс сучасних методів дослідження, що включав рентгенографічний, ультрасонографічний, візуальний, мікроскопічний, фізико-хімічний, рентгенофлюоресцентний та статистичний аналіз, завдяки яким встановлено нові дані щодо інформативності рентгенографії та ультрасонографії як неінвазивних методів виявлення сторонніх предметів в тілах загиблих собак, а також можливості ідентифікації цілого знаряддя травми за окремими фрагментами (уламками скла). Завдяки отриманим результатам із застосуванням комплексного підходу для виявлення та ідентифікації сторонніх предметів, вилучених із тіл травмованих тварин, під час проведення судово-ветеринарних досліджень, вирішено низку важливих питань: підтверджено їх наявність у тілі тварин, приналежність до неорганічного силікатного скла з детальним описом його хімічного складу, а також ідентифіковано знаряддя травми за окремими його частинами. Напрацювання авторів статті позитивно вплинуть на ефективність проведення і результативність судової експертизи тварин, постраждалих внаслідок нанесення важких травм сторонніми предметами, вилученими з їхніх тіл. Водночас цей комплексний підхід дає змогу підвищити ступінь обґрунтованості й об'єктивності висновку експерта як засобу доказування у судочинстві в категоричній формі та розширює доказові можливості органів досудового розслідування та суду

Ключові слова: комплексна судова експертиза; ідентифікація матеріалів; собаки; інструментальні та мікроскопічні дослідження; колото-різана рана; колюче-ріжуче знаряддя; жорстоке поводження з тваринами